Smart Innovation, Systems and Technologies 241

G. Jezic · J. Chen-Burger · M. Kusek · R. Sperka · R. J. Howlett · Lakhmi C. Jain *Editors*

Agents and Multi-Agent Systems: Technologies and Applications 2021

Proceedings of 15th KES International Conference, KES-AMSTA 2021, June 2021

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Preface

This volume contains the proceedings of the 15th KES Conference on Agent and Multi-Agent Systems—Technologies and Applications (KES-AMSTA 2021) held as a virtual conference between June 14 and 16, 2021. The conference was organized by KES International, its focus group on agent and multi-agent systems and University of Zagreb, Faculty of Electrical Engineering and Computing. The KES-AMSTA conference is a subseries of the KES conference series.

Following the success of previous KES Conferences on Agent and Multi-Agent Systems—Technologies and Applications, held in St. Julians, Gold Coast, Vilamoura, Puerto de la Cruz, Sorrento, Chania, Hue, Dubrovnik, Manchester, Gdynia, Uppsala, Incheon, and Wroclaw, the conference featured the usual keynote talks, presentations, and invited sessions closely aligned to its established themes.

KES-AMSTA is an international scientific conference for discussing and publishing innovative research in the field of agent and multi-agent systems and technologies applicable in the Digital and Knowledge Economy. The aim of the conference is to provide an internationally respected forum for both the research and industrial communities on their latest work on innovative technologies and applications that is potentially disruptive to industries. Current topics of research in the field include technologies in the area of decision making, big data analysis, cloud computing, Internet of Things (IoT), business informatics, artificial intelligence, social systems, health, transportation systems, smart environments, etc. Special attention is paid on the feature topics: multi-agent systems and architectures, modeling and simulation of agents, business process management, agent negotiation and optimization, business informatics, and intelligent agents applied to health and medicine.

The conference attracted a substantial number of researchers and practitioners from all over the world who submitted their papers for main track covering the methodologies of agent and multi-agent systems applicable in the smart environments and knowledge economy, and five invited sessions on specific topics within the field. Submissions came from 17 countries. Each paper was peer reviewed by at least two members of the International Programme Committee and International Reviewer Board. 43 papers were selected for presentation and publication in the volume of the KES-AMSTA 2021 proceedings.

The Programme Committee defined the following main tracks: Intelligent Software Agents and Optimisation, and Multi-Agent and Smart Systems. In addition to the main tracks of the conference there were the following invited sessions: Agent-based Modeling and Simulation, Business Process Management, Intelligent Agents in health, wellness, and human development environments applied to health and medicine, Business Informatics and Agent-based Modeling, and Multi-Agent Systems in Transportation Systems.

Accepted and presented papers highlight new trends and challenges in agent and multi-agent research. We hope that these results will be of value to the research community working in the fields of artificial intelligence, collective computational intelligence, health, robotics, smart systems and, in particular, agent and multi-agent systems, technologies, tools, and applications.

The Chairs' special thanks go to the following special session organizers: Prof. Rosario Baltazar Flores, Tecnologico Nacional de Mexico—Campus Leon, Mexico, Prof. Arnulfo Alanis Garza, Tecnologico Nacional de Mexico—Campus Tijuana, Mexico, Prof. Hiroshi Takahashi, Keio University, Japan, Prof. Setsuya Kurahashi, University of Tsukuba, Japan, Prof. Takao Terano, Tokyo Institute of Technology, Japan, and Dr. Mahdi Zargayouna, Université Gustave Eiffel, France, for their excellent work.

Thanks are due to the Programme Co-chairs, all Programme and Reviewer Committee members and all the additional reviewers for their valuable efforts in the review process, which helped us to guarantee the highest quality of selected papers for the conference.

We cordially thank all authors for their valuable contributions and all of the other participants in this conference. The conference would not be possible without their support.

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Shoreham-by-sea, UK	R. J. Howlett
Shoreham-by-sea, UK	Lakhmi C. Jain
April 2021	

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Dr. Lakhmi C. Jain, Ph.D., M.E., B.E. (Hons) Fellow (Engineers Australia), is with the University of Technology Sydney, Australia, and Liverpool Hope University, UK. Professor Jain serves the KES International for providing a professional community the opportunities for publications, knowledge exchange, cooperation, and teaming. Involving around 5,000 researchers drawn from universities and companies worldwide, KES facilitates international cooperation and generates synergy in teaching and research. KES regularly provides networking opportunities for professional community through one of the largest conferences of its kind in the area of KES.

Part I
Intelligent Software Agents and Optimisation

Chapter 1
An Agent-Oriented, Blockchain-Based Design of the Interbank Money Market Trading System

Morteza Alaeddini, Julie Dugdale, Paul Reaidy, Philippe Madiès, and Önder Gürcan

Abstract When studying the interbank money market (IMM), it is common to model banks as agents interacting through loans to tackle its complexity. However, the use of agent abstraction in the IMM is mostly limited to some specific cases. Besides, recent advancements show that it is promising to use blockchain technology to improve its security in a decentralized way. Based on this observation, this paper proposes an agent-oriented, blockchain-based design of the IMM trading systems, where the main objective is to decide on the times and methods of liquidity supply and demand by various market players based on what has been learned from the information available. The models in this paper are suitable for use by both academics and practitioners in this field.

1.1 Introduction

The interbank money market (IMM) reallocates liquidity from banks with excess to banks with a deficit via borrowing and lending money at interbank rates. Therefore, the IMM plays a fundamental role in the proper functioning of the banking system and

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the economy as a whole. The following facts about IMM explain the complexity of decisions in this environment: (i) the secured (collateral-based) and unsecured (trust-based) methods of liquidity provisioning are varied [1, 2]; (ii) the overall demand for short-term liquidity is stochastic [3, 4]; (iii) there is always the likelihood of domino failures of tightly connected competitors (banks) who lend themselves vast amounts of liquidity [5, 6]; (iv) it is difficult to access sufficient information from market members [7, 8]. Moreover, when the central bank intervenes in the market by buying or selling government securities to expand or contract liquidity in the banking system, the decision-making process becomes much more complicated. This complexity affects the decisions of both the central bank as the regulator and banks as active competitors in the market.

Besides, for sending the funds between the banks, the centralized SWIFT[1] protocol that simply sends the payment orders is used, and also loan agreements between banks ultimately lead to binding contracts for the parties. A promising approach to tackle these issues is to use blockchain technology where an immutable, append-only, and decentralized ledger of transactions is maintained without a trusted third party (e.g., a central bank). Regarding IMM, blockchain technology has already been started to be adopted. In 2018, the first live securities lending took place with a \$30.5 M transaction between Credit Suisse and ING.[2] In 2020, in Italy, thirty-two banks had gone live with one of the first real-world deployments of enterprise blockchain technology in interbank financial markets.[3]

To model such complex systems, a well-known approach is to use multiagent systems [9]. The field of agents and multiagent systems (MAS) dates back to the late 1980s and the shift in artificial intelligence (AI) to distributed AI [10, 11]. However, since the late 1990s, MAS has developed a new method of analyzing, designing, modeling, and implementing complex, large-scale software systems [12, 13]. Agents are software entities that are autonomous within their environment and are able to achieve social ability by exhibiting flexible, reactive, or proactive behavior [13]. These abilities are facilitated by an agent architecture, known as belief-desire-intention (BDI) [14], that can model cognitive reasoning.

Standing on these observations, in this study, two issues are addressed to improve the quality of decision-making in IMM. Firstly, since in a static model, the market configuration cannot quickly adapt to (un)intentional changes because the market design is predetermined [15, 16], we propose a MAS model where the market can be dynamically rebuilt at runtime, resulting in a more nimble, flexible and stable system. Secondly, since recording loan transactions in a distributed ledger can lead to greater transparency, security, traceability, and efficiency and reduce costs arising

[1]Society for Worldwide Interbank Financial Telecommunication, https://en.wikipedia.org/wiki/Society_for_Worldwide_Interbank_Financial_Telecommunication, last access on 21/02/2021.

[2]How Blockchain Could Disrupt Banking, https://www.cbinsights.com/research/blockchain-disrupting-banking/, last access on 21/02/2021.

[3]Interbank Market Sees Live Deployment of Blockchain Technology in Reconciliation Process, https://financialit.net/news/blockchain/interbank-market-sees-live-deployment-blockchain-technology-reconciliation-process, last access on 21/02/2021.

from information asymmetry [17, 18], we propose blockchain technology and its features for better designing the proposed system.

Concretely, the contributions of this paper are threefold: (i) an agent-based software architecture that supports all the functions and concerns associated with liquidity supply and demand; (ii) use of learning agents in system design; and (iii) use of blockchain as part of the architecture of the target system. To this aim, Sect. 1.2 gives background information about the IMM as a complex system and MAS applications in IMM. In Sect. 1.3, an agent-oriented, blockchain-based model of an IMM trading system is proposed. It also gives more details about the proposed architecture by providing an example covering both blockchain and learning. The main success scenarios based on this model are given in Sect. 1.4. Finally, Sect. 1.5 concludes the paper and gives future works.

1.2 Background

1.2.1 IMM as a Complex, Large-Scale System

In an extensive financial market network, where each node represents several market operations, many entities interact non-linearly with each other, making it a complex system. The centralized IMM is where banks exchange funds with each other using centralized software solutions (central depository system (CDS), centralized trading systems (TS) of third parties, etc.) to balance their books. In such a market, when the liabilities side of banks' books (e.g., deposits) is lower than the assets side (e.g., loans), they are forced to make up for their lack of liquidity by borrowing from those banks in the market whose liabilities exceeds their assets. This loan might be granted based on prior trust and the preferential relationship between the parties or by using an intermediary platform to connect lenders and borrowers.

Figure 1.1 shows the three most common lending processes in a centralized IMM: preferential (bilateral) short-term lending, central bank's long-term refinancing, and short- or long-term lending using third party trading platforms. The first often includes unsecured overnight loans, and the last contains both unsecured short-term loans and secured long-term ones, as well as repurchase agreements (repo). Furthermore, central bank intervention is generally made in the form of long-term refinancing of banks against securities with them and through auctions.

In a centralized model, banks record their position loan data and related accounts in their own core banking systems (CBS), all payments are integrated with banks' CBSs and made by a central real-time gross settlement (RTGS) system, and securities and auctions are handled in the CDS. Also, banks require special workstations being used by their trading operators to connect to TS and CDS. It is worth noting that banks assess many counterparty risks and make their lending decisions using data provided by rating agencies and financial news providers, which are not shown in Fig. 1.1 for simplification.

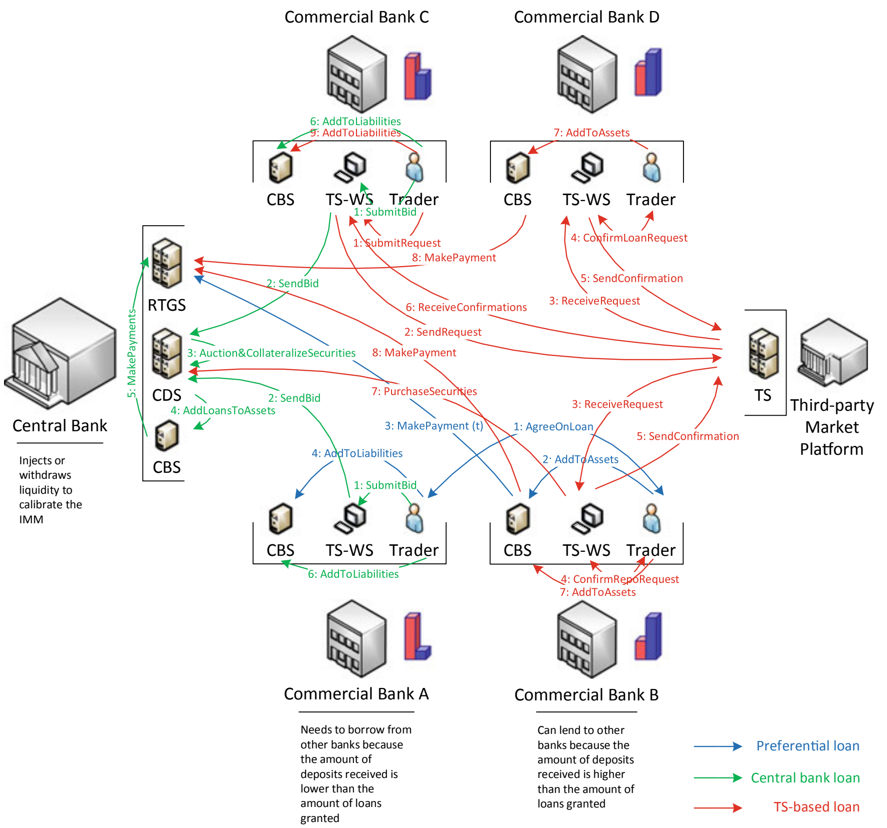


Fig. 1.1 The centralized approach of IMM lending

Another aspect of complexity emerges in supporting the market participants' main concerns and their impact on banks' goals and decisions to supply and demand liquidity. In detail, the central bank seeks to reduce systemic risk and prevent financial contagion [2, 5, 19], as well as managing the network [1, 4, 7] in a way that makes the IMM more stable and resilient to shocks [1, 2, 6] to conserve confidence. At the same time, banks attempt to maintain their lending relationships [3, 8] and reduce the risk of failure to meet the legal obligations [5, 19].

1.2.2 MAS Applications in IMM

An approach to reduce the complexity of a system with such specifications could be to use a self-organizing multiagent system [20]. In recent years, much partial research has been conducted using agent-based simulation on various concerns of IMM, i.e., systemic risk [19, 21–24], stability [21, 25], market structure [21, 26], trust [27], and default [19, 28]. To the best of our knowledge, except for a few studies on interbank payment and settlement systems [29–31], a serious complete work may rarely be found on designing an agent-based architecture that can cover all the IMM functions and help to make decisions. Also, the number of studies in which banks have been modeled as intelligent agents is very limited [7, 15, 19, 25, 32].

Indeed, a BDI approach, which is able to model each bank's individual concerns, coupled with machine learning, could be useful to improve banks' ability to predict and achieve a competitive equilibrium among market participants. Because the IMM consists of different banks with different and sometimes conflicting goals and proprietary information, a BDI MAS is an excellent option to model their interactions. From a problem perspective, the IMM is a dynamic, complex, and technically open environment in which interaction takes the form of both negotiation and deliberation. From a solution perspective, all three facets of data, resources, and tasks are distributed in the IMM. These features determine that this approach is appropriate for IMM [33].

Also, because loan agreements between banks ultimately lead to binding contracts for the parties, a smart contract that is non-repudiation and transparent [34] could lead to a more reliable and trustworthy market. This explains a case where private data needs to be adequately protected in a distributed manner; thus, blockchain could be a potential solution.

1.3 The Proposed Model

1.3.1 Agent-Based Model

The open architecture components of the proposed system are shown in the UML class diagram in Fig. 1.2. The architecture is designed to support emergent behaviors and performance of agents in a volatile environment so that they can provide a higher level of adaptability, discovery, and intelligence. In this approach, each bank has its intelligent agents, i.e., their learning mechanisms that learn their preferences. For instance, in the presence of many banks with different preferences, their agents could negotiate the optimal interest rates. Also, the central bank agents could enforce the regulations that must be considered by the bank agents as influential factors in the negotiations between them.

As shown in Fig. 1.2, the agents *B_DataCollector* and *L_DataCollector* at borrower and lender banks, respectively, collect information from data sources inside and outside the banks (e.g., news and ratings). Agents *B_LoanPlanner* at borrower banks and *L_LoanPlanner* at lender banks use this information to calculate the deficit or excess of liquidity and target loans. The central bank's similar agent *C_LoanPlanner* directly uses the data recorded in the bank's blockchain node to plan the total market liquidity needs and refinance it. Banks also use their collected information to assess their own and the counterparty's risks. This is performed at borrower

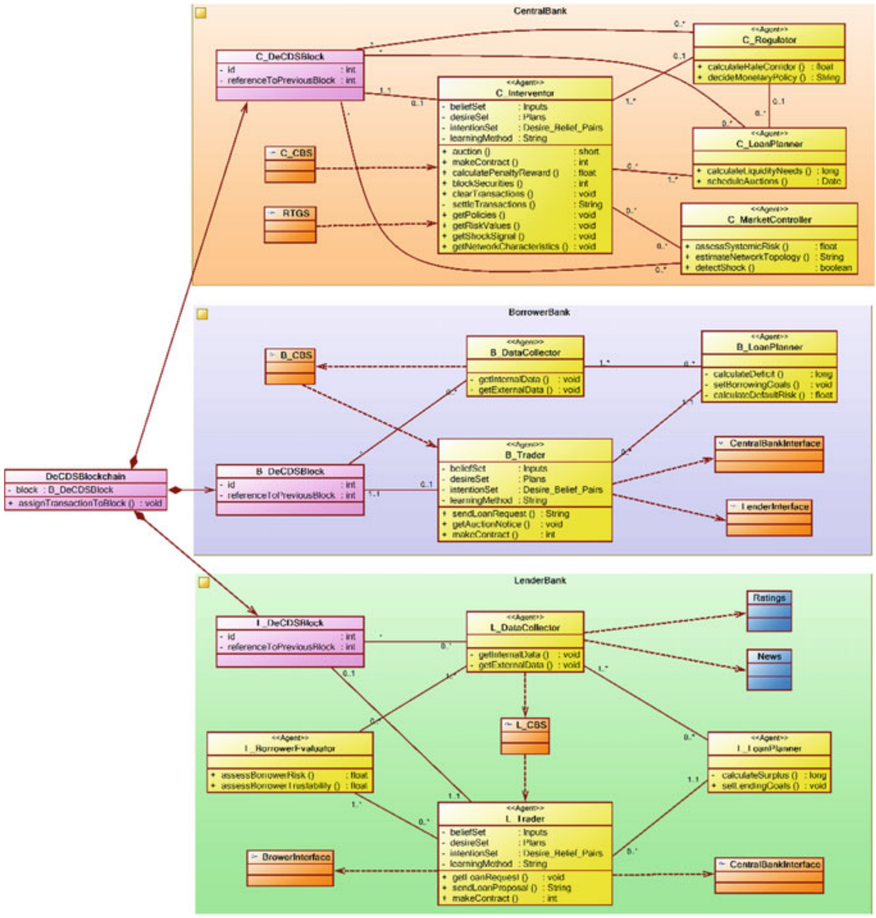


Fig. 1.2 The decentralized agent-based approach of IMM

banks via *B_LoanPlanner*'s operation *calculateDefaultRisk*, while at lender banks, agent *L_BorrowerEvaluator* is responsible for that.

The proposed architecture mainly focuses on negotiation behavior among a group of autonomous agents, e.g., how distributed agents negotiate their goals, achieve their goals through planning, etc. Therefore, an intelligent agent at each bank is responsible for negotiating with other banks' agents, meaning several exchanges of requests and proposals, and finally making a loan contract. This function is the responsibility of agents *B_Trader* and *L_Trader* at borrower and lender banks, respectively, and agent *C_Interventor* at the central bank.

As considered in agents *B_Trader* and *L_Trader*, each bank-specific learning method alongside the BDI model would ensure better predictions based on its past preferences and future goals because there is no need to learn all the preferences of all banks. It also means that the bank spends less learning time when faced with a new goal because it uses fewer data over fewer epochs.

The rationale for choosing BDI is that it allows us to model each bank's different beliefs, desires, and intentions, which may even be contradictory. Moreover, it has advantages for the implementation of agents with the characteristics of reasoning, communication, and planning [35, 36]. It is also suitable for prediction and performance purposes [36]. The clear functional decomposition of the agent subsystem and the formal logic properties of BDI are the advantages of this agent architecture over other existing ones, such as traditional logic-based and reactive architectures [37]. In the proposed model, the BDI agent model's weakness of its inability to support the learning and decision-making characteristics of agents [36, 38] is compensated through machine learning.

In this way, the bank agents present in this smart market take over the negotiation process according to their individual learning mechanisms and by calling each other's interfaces. If some banks have different preferences regarding, for example, interest rates, their agents would first calculate their preferences and then start the negotiation process with other agents, where they must consider the extent of the differences between their preferences. The learning methods that can be applied by each bank are not specified at this level but can include a range of machine learning methods such as supervised, unsupervised, and reinforcement learning [39–41]. Combining these learning methods with the BDI architecture would lead to better decisions by market members [42].

As mentioned earlier, a similar learner agent (*C_Interventor*) at the central bank is responsible for market intervention. It uses information produced by other agents (i.e., open market operation objectives set by *C_LoanPlanner*, market variables monitored by *C_MarketController*, and regulations set by *C_Regulator*) to carry out auctions, lending against securities, clearance, and settlement. All data related to loan agreements in the market would be recorded in a distributed general ledger realized by blockchain technology. This means that each bank, as a node in a consortium blockchain network, can participate in the consensus needed to record loan transaction data in blocks. Each bank's agents would also use these data as part of their input, playing a role in making their plans and decisions.

1.3.2 Blockchain and Learning

A blockchain is an append-only immutable data structure of transactions organized as a list of blocks linked using cryptography. It is maintained across several nodes that are linked in a peer-to-peer network (Fig. 1.3). A blockchain can manage a self-enforcing agreement embedded in computer code, which is called a smart contract. The smart contract code contains a set of rules under which the smart contract parties agree to interact with each other.

In our study, we consider a blockchain consisting of $N = \{n_1, n_2, \ldots, n_m\}$ nodes (banks), of which $P \subseteq A$ are endorsing peers classified into p levels. Each bank

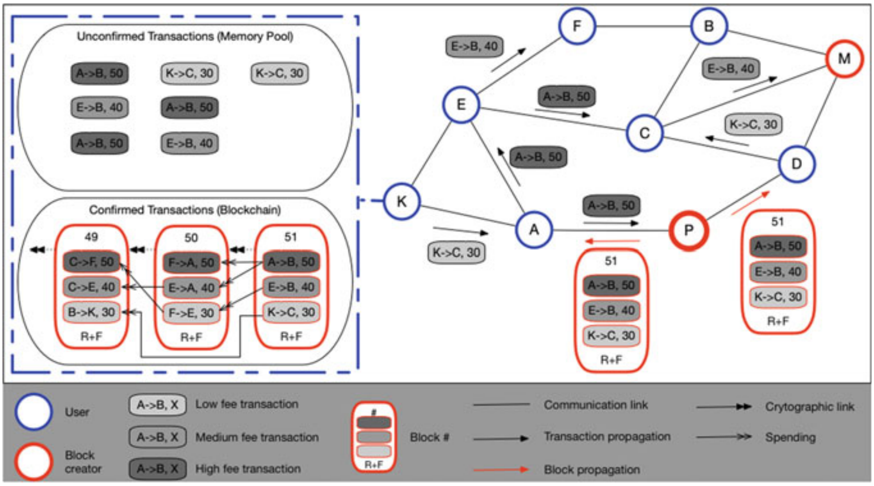


Fig. 1.3 Multi-agent representation of a blockchain system [43]

uses blockchain for various data categories, e.g., submitting its smart contracts (loan transactions) or sharing common interest information, such as counterparty defaults. The endorsing peers examine these data before being written in the distributed ledger. The block could be written as $B = \{t_{i,j}\}$, where $t_{i,j}$ refers to the transaction j of data category i (corresponding to p levels).

Endorsers calculate each transaction's score by tracking the number, volume, riskiness, and impact of transactions. When two banks, which agree upon a smart contract and sign it with their private keys, want to add this new transaction to the blockchain, they must collect a minimum prerequisite score from endorsing peers (i.e., consensus). This score is obtained based on recommendations from other related nodes at the moment of submitting the transaction. It means that other nodes check the state of the blockchain, including the exact contract code, and validate that those parties are who they say they are and the transaction is unique in the network. Also, a state transition function checks the behavior and the results of that code when it is executed.

Once a new block is created, all claimed transactions to be included in it are checked for legality and uniqueness by the consensus protocol, and transactions that fail to collect the required score for the selected level are discarded. To reach higher levels, the bank must increase its contributions to the blockchain and make high-impact, trusted transactions. To this aim, the bank uses intelligent mechanisms to make the optimized decision at the right time, based on the available network data as well as its own data. Adapted from Mbarek et al. [44], the score of a given transaction could be calculated according to formula 1.1:

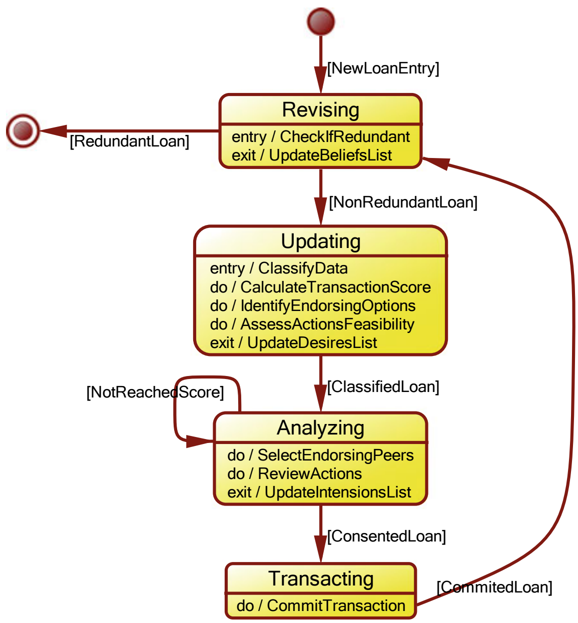
$$S_l = \sum_{i=1}^{p} \left(\sum_{j=1}^{q} s_{l,j} \right) w_i \tag{1.1}$$

where, w_i denotes the weight of the endorsers of level i; $s_{l,j}$ is the score given to the loan transaction l by the endorsing bank j at the same level that accepts the transaction scoring request. Also, q is the number of required endorsers at that level.

In this mechanism, each member bank in the blockchain network has to establish trust with its peers, especially the endorsing ones. Trust relationships would be particularly helpful in gaining recommendations from higher level endorsers. In the proposed system, the bank can intelligently identify its current options, plan its actions, and reflect on the results to establish and maintain trust and identify appropriate endorsing partners. As proposed in Fig. 1.2, learning is the responsibility of intelligent agents *B_Trader* and *L_Trader* at borrower and lender banks, respectively, and agent *C_Interventor* at the central bank.

Figure 1.4 shows the UML statechart diagram of the loan registration in the system's blockchain, borrowed from its detailed design model. Based on the BDI architecture, 'beliefs' include information that the intelligent agent has about itself (e.g., its current liquidity, market strategies, default risk, etc.) and its surroundings (e.g., network structure, potential/actual banks for a relationship, and events of interest, such as other banks' defaults and announced auctions). The beliefs also include a copy of the blockchain containing data belonging to the categories to which the agent has access (state *Transacting*). Beliefs can be right or wrong and

Fig. 1.4 States of a loan transaction registered in the blockchain



change over time as the market operates (state *Revising*). In this system, 'desires' reflect the objectives that the agent wishes to achieve and include such things as receiving/granting loans, sharing information, or accepting/refusing other agents' endorsement. Based on the new beliefs, the agent's desires must also be updated (state *Updating*). Finally, 'intentions' refer to the actions that the agent chooses to execute. For each possible action, the agent calculates the reward, cost, priority, etc. Once a set of possible actions is identified, the agent analyzes the calculated results to prepare and execute an action plan (state *Analyzing*). The output of the actions is assessed, and the intentions of the agent are updated accordingly.

1.4 Main Scenarios

In this section, UML sequence diagrams are used to describe how and in what order a group of agents work together in the proposed system to execute the most common IMM scenarios according to Liu et al. [15], Barroso et al. [19], and Gurgone et al. [21]. We model two scenarios: one for overnight lending based on trust among banks and another for long-term refinancing by the central bank against banks' securities.

For the first scenario, as shown in Fig. 1.5, the borrower bank's agent *B_Trader* uses *need* data generated by agent *B_LoanPlanner* and sends its request to the lender bank's agent *L_Trader*. To decide on the loan terms and conditions, *L_Trader* inquires the liquidity *surplus* as well as the borrower bank's credit *risk* and trust *score* from agents *L_LoanPlanner* and *L_BorrowerEvaluator*. According to the results of these inquiries, *L_Trader* suggests loan terms (e.g., interest rate) to *B_Trader*. This offer is based on all that *L_Trader* has learned so far about the overnight loan in the smart IMM.

After receiving a *proposal* from *L_Trader*, based on what *B_Trader* has learned, it may immediately accept or reject the offer or enter into a negotiation process with *L_Trader*. As mentioned earlier, the negotiation is based on the learnings of the two agents from their past, market conditions, and other players' behavior and progresses in the form of changing goals and preferences. In any case, if no agreement is reached, the process ends here; otherwise, if the negotiation between the two agents succeeds, a smart contract would be made, which would be recorded in a *DeCDSBlockchain block* of each of these two banks as well as other market members.

Finally, the agent *C_Interventor* at the central bank would perform clearance and settlement of the banks' *transactionList* at the end-of-day based on the information recorded on the smart contracts. Also, the systemic effects of banks in the IMM network could be evaluated by this agent based on these smart contracts, and if one bank's transaction is accordingly subject to a reward or penalty by the central bank, the amount is calculated and deducted from that bank's account with the central bank.

The second scenario, in Fig. 1.6, starts from the central bank. First, *transactionList* stored in the central bank's *DeCDSBlockchain* blocks is used to determine *policyList* by agent *C_Regulator* as well as calculating systemic *risk*, estimating network

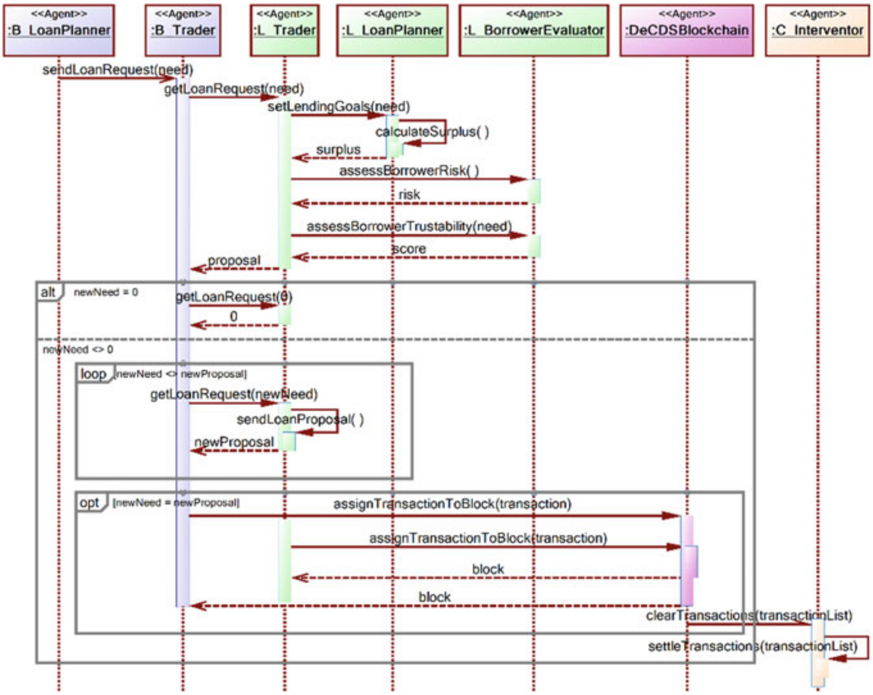


Fig. 1.5 Agent-based scenario for overnight loans

topology, and detecting possible shock *signal* by agent *C_MarketController*. Similarly, agent *C_LoanPlanner* determines market *need* using *transactionList* and specifies *time* for auctions. *C_Interventor* then receives the results of calculations by these three agents as well as *B_Trader*'s *bid* for the central bank's loan. After auctioning and determining the winners, if a loan is granted to the bank, *C_Interventor* notifies *B_Trader* of *bidResult*.

Like the first scenario, a smart contract would be made between *C_Interventor* and *B_Trader* and stored in a *DeCDSBlockchain block* of the central bank and the borrower bank, as well as other market participants. The central bank would employ the information stored in the form of these smart contracts to clear and settle the borrower banks' *transactionList*. Also, the central bank and the other banks use the information recorded in these smart contracts in their future forecasts and plans.

1.5 Conclusion and Future Works

This paper describes a software architecture that uses intelligent agents to execute the interbank market functions and make decisions on behalf of the market actors. In this proposed solution, the BDI architecture is employed to model the cognitive

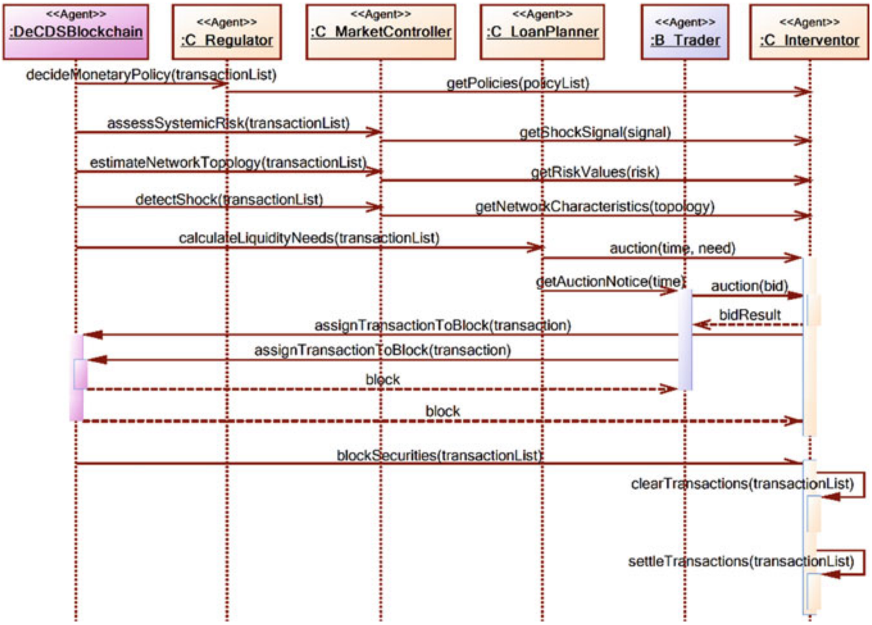


Fig. 1.6 Agent-based scenario for central bank refinancing

part of the agents and execute goal-based scenarios. Also, data obtained from the interbank lending transactions are recorded and stored in a consortium blockchain platform, of which the banks and the central bank are nodes. To better understand the designed agents and the mechanisms of using information and learning, some of the most widely used IMM scenarios have been modeled using the UML diagrams.

The main limitation of the work is that only a high-level design is presented, and no part of it has yet been implemented and tested to validate the proposed architecture and ensure performance. Therefore, the next step is the detailed design and implementation of the proposed system prototype. In addition to the full realization and testing of the system, further studies could also be directed at improving the system's machine learning aspect, alongside the greater use of blockchain in designing the new processes required for trading the new financial instruments such as crypto-securities. Agent-based modeling and simulation of the desired system in which agents can learn from each other and their past data when loan transactions are stored in a blockchain network is another topic for future work.

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Chapter 2
A Conceptual Model for Human-Agent Teams

S. Noorunnisa, D. Jarvis, J. Jarvis, and R. Rönnquist

Abstract In this paper, a novel conceptual framework for human/agent teams employing assistant agents is presented, together with its mapping to the GORITE BDI framework. The framework enables goal achievement by a human/agent team to be consistently modelled in terms of goal hierarchies known as process models. Furthermore, from the perspective of the process model execution, an individual goal execution proceeds in a consistent manner regardless of how the actual goal is realized. A proof of concept system based on an automated medication dispensing system is used to demonstrate the feasibility of the framework.

2.1 Introduction

The Belief-Desire-Intention (BDI) model of agency has been a popular choice for the modelling of goal-based behaviour for both individual agents and more recently, teams of agents [1]. Numerous frameworks have been developed since the model was first proposed in the early 1980s. However, while the more recent frameworks support a delegative model of agent/agent and human/agent collaboration, no frameworks support a general model of collaboration. To redress this shortcoming, the GORITE BDI framework [1] has been extended to enable a human operator to inspect and

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modify an agent's beliefs and intentions and for an agent to request operator assistance. The extensions were validated through the implementation of a simple war gaming scenario [2, 3].

While the work described in [2, 3] enables a human to interact and collaborate with a team of agents that are pursuing a particular goal, goal achievement is ultimately an agent responsibility. However, both war gaming and agent-based simulation in general would benefit from the flexibility that goal achievement by both humans and agents collaborating in a team would provide. Likewise, Bardram has noted that real-world activity involving human collaboration mediated by a shared computational workspace, as in patient care, would benefit from a reformulation of activity in terms of goals [4]. If the work described in [2, 3] is to be extended to accommodate human-agent teams, then an extended conceptual framework and a mapping of these extensions to an underlying agent framework (in this case GORITE) is required. While the Janus methodology, introduced in [5] is presented as a prospective starting point for such a methodology, the focus of this paper is the construction of a conceptual framework and its mapping to GORITE. The conceptual framework and its mapping to GORITE is validated through a proof of concept system concerned with a simulation of an automated medication dispensing system. The conceptual model, together with its mapping to GORITE, is presented in Sect. 2.2, which is followed by a description and discussion of the proof of concept system in Sect. 2.3. Concluding remarks are provided in Sect. 2.4.

2.2 The Conceptual Model

The conceptual model is grounded in the BDI model of agency, which has its origins in Bratman's theory of human practical reasoning [6]. The BDI model is concerned with how an agent makes rational decisions about the actions that it performs through the employment of

- Beliefs about its environment, other agents and itself,
- Desires (often referred to as goals) that it wishes to satisfy and
- Intentions to act towards the fulfilment of selected desires.

Operationally, a BDI agent

> … performs a continuous loop in which it updates its beliefs to reflect the current state of the world, deliberates about what to achieve next (reacting to changes in the environment or pursuing its own goals, finds an applicable plan from a predefined plan library and executes the next step in that plan [7].

In this execution model (which we refer to as the traditional BDI execution model), goals are not represented as explicit, persistent entities, but rather as transitory events that are triggered either as a plan step or in response to a belief update. The execution model is well suited to the realization of situated autonomous behaviour—in response to both internal and external goal events, an agent selects and commits to a course

Table 2.1 Human/agent interaction requirements [3]

Requirement	Description
I0	Initiate goal execution (user)
I1	Pause and resume a particular goal execution (user initiated)
I2	Inspect current beliefs relevant to a particular goal execution. If appropriate, make modifications
I3	Inspect historical beliefs associated with a particular goal execution
I4	Inspect the goals that an agent has committed to pursue. If necessary, add new goals, delete existing goals or modify the execution order
I5	Pause goal execution (agent initiated)

of action (plan) on the basis of its current beliefs. If that course of action fails, then the current goal can be reconsidered or pursuit of the goal can be terminated. As a consequence, the traditional execution model has underpinned many successful agent applications [1] and has provided the conceptual basis for all major research and commercial BDI frameworks, in particular PRS, dMARS and JACK [1]. The execution model has also been adapted in JACK Teams [8] to accommodate teams of agents (such as military platoons and manufacturing cells) as distinct entities with their own beliefs, desires and intentions.

If BDI agents are to support semi-autonomous behaviour, then the functional requirements provided in Table 2.1 need to be supported:

As discussed in [3], achieving these requirements using frameworks that employ the traditional execution model is problematic. Rather, the GORITE BDI framework was used as it employs an alternative execution model which operates on explicitly represented (and persistent) goals that share an explicit data context. Consequently, a human is able to pause some (or all of) the agent's current intentions (plans) prior to inspection or modification of intentions and/or beliefs and to resume paused intentions on completion of inspection or modification. Additionally, the agent is able to pause some (or all) of its own intentions if it determines that assistance from a human is required.

In terms of human-agent teams, the requirements of Table 2.1 represent a significant first step. However, if humans are to be part of a team that includes agents rather than supervisors of agent teams, then goals need to be allocated to both human and agent team members.[1]

Furthermore, the underlying execution model will need to accommodate both types of team members. In this regard, the requirements of Table 2.1, which specify how agents and humans interact are complemented by the new requirements of Table 2.2, which are concerned with how goals are allocated, specified and executed in human-agent teams.

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[1] Allocation is used here in the Systems Engineering sense. As such, it is a design activity where the requirements that form the logical architecture of a system are allocated to the elements of the physical architecture. In this case, requirements equate to goals and there is a 1–1 correspondence between the human-agent team and the elements of the physical architecture.

Table 2.2 Human/agent team requirements

Requirement	Description
T0	Allocate goals to both humans and agents
T1	Provide a common framework for the representation of both agent and human goals
T2	Provide a common execution model to support the execution of both agent and human goals

2.2.1 Goal Allocation

When goals are to be achieved using BDI agent frameworks such as JACK Teams or GORITE, a task team is formed from the available team members. A task team may be created to perform a single goal, or the task team may persist for the performance of multiple goal achievements. Also, a task team can change dynamically during goal achievement, for example, when a cyber-physical agent (such as a sensor) fails [1]. Task team formation pre-supposes that agents have been allocated goals that they can perform and that a particular agent may be able to perform a particular goal in multiple ways and that multiple agents may be able to perform the same goal.

The actual allocation of goals to team members is a design activity, as in Janus, which is a methodology for the design of industrial cyber-physical systems where the cyber element is implemented using GORITE agents [5]. Janus embodies a Systems Engineering approach in which the logical and physical architectures of traditional Systems Engineering [9] are augmented with an agent architecture that is aligned with the physical architecture. In contrast to traditional Systems Engineering

1. Functional decomposition and analysis is reformulated as goal decomposition and analysis
2. Agents and teams of agents are mapped to the systems, subsystems and leaf nodes of the physical architecture
3. Functional allocation is reformulated as goal allocation to the agent/teams of agents identified in 2.

In terms of systems to be realized through the deployment of human-agent teams, we note that the agent architecture that underpins Janus can be extended without any loss of generality to accommodate humans through the use of what we call assistant agents. The processes described in [9] can then be employed to determine whether a particular goal is allocated to a human (via an assistant agent) or an automated agent. Task team formation then proceeds as normal [1], with assistant agents acting on behalf of (but interacting as required with) their human embodiments.

As one would expect, systems engineers have employed a wide range of techniques and methodologies to assist in the analysis and allocation of requirements in semi-automated systems [9, 10]. While these techniques are transferable to multi-agent systems (in particular, BDI systems, as demonstrated by the use of Cognitive

Work Analysis and Cognitive Task Analysis in [11, 12]), they have not yet been incorporated into Janus, as the complexity of human behaviours involved in applications have thus far not warranted their use.

2.2.2 Goal Representation and Execution

As noted in the previous section, in Janus, goals (which are analogous to the functional requirements of Systems Engineering) are allocated to agents. In [5, 13, 14], these agents are local in the sense that their cyber elements all execute within a single local process, although their embodiments (physical or virtual) may be realized via separate processes—for example, industrial automation environments, such as nxtSTUDIO. However, there is no reason why a goal must be achieved by an agent or if it is to be achieved by an agent, why its cyber component must be local. The former admits the possibility of goals being achieved by humans or software applications; the latter of heterogeneity in terms of agent frameworks. To support all of these possibilities, we introduce the concept of a remote goal to GORITE. A remote goal is modelled as a goal in a GORITE process model and appears as such to the GORITE executor. However, as we shall see in the proof of concept system, actual goal achievement is delegated to a remote entity, which may be an assistant agent/human, an application or an agent (either GORITE or non-GORITE). In the latter case, the remote agent will contain both cyber and embodiment components.

As described in [1], GORITE process models are executable, and as such, an alternative execution model to that employed by traditional BDI frameworks (where an agent initiates plan execution in response to the arrival of goal events) is required. Rather than explicitly managing its own behaviour, a GORITE agent delegates that responsibility to an executor object, which then initiates goal execution on behalf of the agent. This execution involves the traversal of the process model and the invocation of the `action()` and/or `execute()` methods of each of the component goals. During this traversal, the executor makes available to the participants in the execution (i.e. the team members) a shared data context. If a remote goal is encountered, the elements of the data context that are relevant to the remote goal execution are extracted and the remote goal execution is initiated with the extracted data elements. As with a local goal execution [1], the executor either polls the remote goal for the status of the remote execution or it blocks until a condition flag is unset. On completion of the remote execution, the remote goal merges the remote data elements with the local data context. The net result is that the remote process, regardless of how it is actually realized, appears to the executor as a local goal.

In terms of infrastructure, a `RemoteGoal` class that extends GORITE's `Goal` class is provided. On construction, a remote goal is provided with access to objects that manage the interaction with the remote process (via the `Monitor` interface) and the extraction and merging of remote data elements (via the `RemoteData` interface).

2.3 The Proof of Concept System

In [13, 14], the utility of a team of agents to physically control a Pick and Place Manipulator (PnP) was demonstrated. The purpose of the manipulator is to move workpieces from input trays to the output tray. The manipulator consists of three vertical and three horizontal cylinders and one gripper, as illustrated in Fig. 2.1. Horizontal cylinder 3 and vertical cylinder 3 have lengths of 2 units. All the remaining cylinders have lengths of 1 unit. A workpiece can be placed in one of 20 positions that are organized into 4 rows and 5 columns. Each of the cylinders is individually controllable, as indicated in Fig. 2.1 and together with the gripper, which was modelled as an agent team. The embodiment for each agent was realized using task goals and not remote goals. For a detailed discussion of the implementation, refer to [13, 14].

In the proof of concept system, we incorporate the PnP team as a remote agent with virtual embodiments and rather than embedding the team in a simulated manufacturing scenario, it is embedded in a simulation of a pharmacy-based automated dispensing system (ADS). As described in [15], with such systems, medications are stored on designated shelves. When a dispensing order is received, a robotic arm or picking device selects medication on the appropriate shelf and transfers it to the delivery station. The medication is then checked and labelled by pharmacy staff. While this scenario is straightforward, it (like the wargaming vignettes) validates the key requirements of the conceptual model outlined in Sect. 2.2 and its realization in an industrial strength BDI agent framework. Note that while the case study could be realized using traditional software development techniques, the use of agents and goals provides an alternative modelling framework for developing the intention aware computational support for human activities that were envisaged by Bardram [4].

Dispensing is modelled with the following process model:

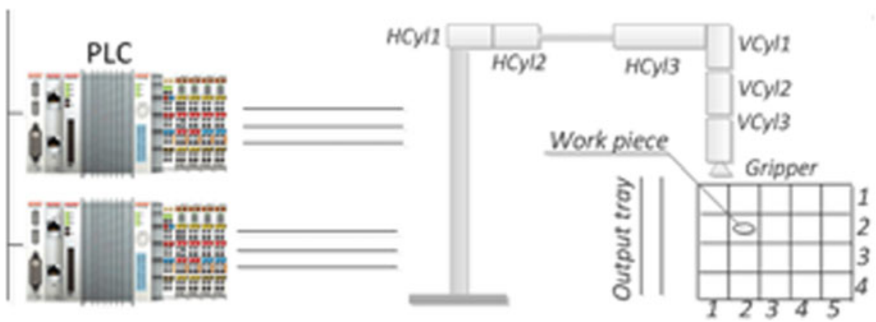

Fig. 2.1 The Pick and Place (PnP) Manipulator

```
Goal dispense() {
  return plan( DISPENSE_MEDICATION,
    subgoals(
      // Determine target location and cylinder actuations
      remote( PREPARE_ADS ),
      // Retrieve medication
      remote( PICK_MEDICATION ),
      // Performed by humans
      remote( LABEL_MEDICATION ),
      remote( CHECK_PRESCRIPTION ),
      remote( DELIVER_MEDICATION )
    )
  );
}
```

The data context for the process model execution contains the information required to fill the prescription. In addition, it contains additional data elements (such as the location of the medication) that will be populated by a particular sub-goal and used by a subsequent sub-goal. Note that the above process model differs from those presented in [1], in that a simple DSL (Domain Specific Language) is employed, where, for example, `remote()` is defined as

```
BDIGoal remote( String n ) {
  return new BDIGoal( n );
}
```

In the process model above, `remote()` returns a BDI goal and not a remote goal as might have been expected. What happens is that when the process model is executed and a BDI goal is encountered, the executor looks through all of the agent's capabilities to find goal instances with the same name and forming what is called the applicable set. One of these is then selected for execution—if there is more than one, the decision will be made on priority/context. In this case, there will be only one goal in the set and it will be a remote goal.

In GORITE, the executor object processes a goal by invoking its `instantiate()` method, which creates the `Instance` object that represents an actual intention to achieve the goal. If particular execution semantics are required (as for the GORITE control goals and also for `RemoteGoal`), `Instance.action()` can be overridden. In the case of a remote goal, its behaviour is specified in the `Instance.action()` method via `Monitor` and `RemoteData` interface methods, as shown below.

```
public Goal.States action(String head, Data d) {
  if (monitoring == false) {
    // extract data context elements (inputs + outputs) for the
    //remote goal execution.
    remoteData.prepare(d);
    // initiate goal execution
     monitor.initiate(head, getGoalName(),
       remoteData.inputs(), remoteData.outputs());
     monitoring = true;
     return Goal.States.STOPPED;
   }
   // monitor progress
   try {
     States s = monitor.check();
     // if execution has completed, merge remote data elements
     // with the data context
     if (s == Goal.States.PASSED)
       remoteData.passed(monitor.results());
     if (s == Goal.States.FAILED)
       remoteData.failed(monitor.results());
     // execution has not completed
     return s;
   } catch (Throwable t) {
       t.printStackTrace();
       cancel();
       return Goal.States.CANCEL;
   }
}
```

Companion objects that implemented the `RemoteData` interface were provided for each remote goal. As indicated above, the purpose of these objects was to manage the extraction from the data context that are required for the remote goal execution and their subsequent merging on remote goal completion. Interaction with the remote processes was realized using a client/server architecture, where client objects implement the `Monitor` interface. Messages consisted of serialized objects that were sent over TCP/IP connections—JSON was used for its generality.

On the remote side, separate server processes were provided for each remote goal. In the case of the `PREPARE_ADS` goal, the server executes a method that determines the location of the desired medication and determines the sequence of cylinder actuations required for its retrieval. In [13, 14], these functions were modelled as goals which were achieved by members of a PnP task team. That task team also contained members controlling each of the physical elements of the manipulator. The reason for this design decision was purely illustrative—namely, to demonstrate that a remote goal can be realized as an external process/web service/function. In this case, the server constructs a response message which contains the output data elements that have been populated by the preparation method.

The remaining goals were implemented as GORITE goals. `PICK_MEDICATION` was achieved by a team of agents (PnP), as described in [13, 14]. `LABEL_MEDICATION`, `CHECK_PRESCRIPTION` and `DELIVER_MEDICATION` were realized by humans, but with goal achievement mediated by assistant agents. The assistance goals were modelled as GORITE task goals, which initiate human activity via the addition of a task to a job list stored in a database. The job status is then updated by the human team member and is conveyed on request by the assistant agent. When the job is completed, any outputs associated with the job are set in the database and are conveyed by the assistant agent to the remote goal. Other means of interaction, such as email or SMS could be employed, but a shared job list represents a simple and illustrative approach.

2.4 Conclusion

In this paper, we have extended the conceptual model for human/agent teams that was presented in [4] to accommodate humans in the actual team structure and not just as supervisors of agent teams. This has been achieved through the introduction of the concept of a remote goal, which enables remote activities, regardless of whether they are performed by applications, web services, humans or software agents to be modelled as goals. Thus, both human and agent behaviour can be modelled uniformly in terms of beliefs, desires and intentions. As observed by Norling [16], the BDI paradigm is grounded in folk psychology. That is, the core concepts of the BDI model map readily to the language people use to describe their reasoning and actions in everyday conversation. Consequently, one of the key reasons for the success of the BDI model of agency is that supports the generation of readily understandable agent behaviours. We would expect that if humans are to work with agents, then having a common representational framework based on the concepts of BDI would facilitate interaction.

Evaluating the effectiveness of the BDI model as the basis for modelling the behaviour of human/agent teams will require a more complex case study than the proof of concept system presented in this paper. However, note that the dispensing system discussed in this paper could be readily incorporated into a larger patient care scenario.

In this paper, framework extensions have focused on the realization of the remote goal concept. Extending the remote goal concept to accommodate the human/agent interactions identified in Table 2.1 is straightforward—it is simply a case of providing an additional messaging layer between the client and the server. Of more interest is the issue of task team formation. In the proof of concept system, the task team is not explicitly created before the process model begins execution in contrast to the examples provided in [1]. Rather, the task team member for a particular remote goal is determined when remote goal execution is initiated. It may well be useful in some situations to either partially or completely construct the task team prior to process model execution. To support this, an additional messaging layer would be required and potentially the provision of proxy agents on the local side.

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Chapter 3
Learned Dynamics Models and Online Planning for Model-Based Animation Agents

Vihanga Gamage, Cathy Ennis, and Robert Ross

Abstract Deep Reinforcement Learning (RL) has resulted in impressive results when applied in creating virtual character animation control agents capable of responsive behaviour. However, current state-of-the-art methods are heavily dependant on physics-driven feedback to learn character behaviours and are not transferable to portraying behaviour such as social interactions and gestures. In this paper, we present a novel approach to data-driven character animation; we introduce model-based RL animation control agents that learn character dynamics models that are applicable to a range of behaviours. Animation tasks are expressed as meta-objectives, and online planning is used to generate animation within a beta-distribution parameterised space that substantially improves agent efficiency. Purely through self-exploration and learned dynamics, agents created within our framework are able to output animations to successfully complete gaze and pointing tasks robustly while maintaining smoothness of motion, using minimal training epochs.

3.1 Introduction

The use of interactive virtual characters has been researched extensively, investigating how the appearance and animation of such characters can affect human perception [1]. Findings from previous studies demonstrate that the plausibility of animation can positively affect how a character is perceived and that this creates potential for character-based applications to be more engaging and effective [2, 3]. However, developing character control methods to consistently animate a variety of behaviours in real time is a challenging task. Motion-capture clip-based systems require the capture of reference motions that cover the entire range of character behaviours and are difficult to modify. As a result, these systems have a propensity to be time-consuming and expensive to construct.

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In recent years, neural network-based approaches have been a popular choice for researchers seeking to explore novel approaches to data-driven animation control. Treating animation control as a supervised learning task has lead to several implementations that output robust, varied animation, learning from a limited set of reference motions [4, 5]. However, such methods depend heavily on the training dataset used, and outputs can be unpredictable when attempting to output animation in conditions not covered in the training set.

Given these limitations, the reformulation of the character control problem as a Reinforcement Learning (RL) task has been attracting a great deal of interest. Recent work has lead to promising implementations where RL has been utilised alongside physics-based simulations for the creation of character animation agents, such as DeepMimic [6]. While these physics-simulation based methods have resulted in impressive implementations of character animation control, they are heavily reliant on interaction with physical surfaces and objects. Many applications using virtual characters require socially interactive behaviours, such as gestures, nods, exclamations or pointing, which are not appropriate for a physics-based simulation paradigm. Therefore, data-driven approaches to generate robust social behaviours thus far have required supervised.

Given these challenges, the contributions of the work presented in this paper involve a novel model-based agent for generating animation, and a framework for expressing animation tasks in a way that allows for models to be learnt in a task-agnostic manner. Agents operate using information applicable to character animation regardless of the behaviour portrayed, and can be trained without the need for an extensive dataset, instead generating data via self-exploration. The ensuing approach allows for RL to be used to train agents capable of animating multiple behaviours in real time in an efficient manner.

3.2 Related Work

Existing work on animation control is varied; here we briefly review key topics, namely: Inverse Kinematics, data-driven animation methods and RL-based animation control approaches.

A practice used as an alternative to, or to augment motion-capture clip-based methods for animation generation, has been the use of solvers for the Inverse Kinematics (IK) problem. The IK problem can be defined as one where a set of joint rotation parameters need to be obtained such that a specified end effector goal is reached. Some of the most efficient current forms of IK solvers are heuristic methods such as Forward and Backward Reaching Inverse Kinematics (FABRIK) [7]. However, given the nature of IK solvers, in that they focus on finding a solution for the IK problem driven by only the end effector goals, there is not much flexibility or capacity to address characteristics of behaviour such as realism, and when the skeletal structure involved becomes more complex and hierarchical, the solutions themselves can be difficult to work out [8].

More recently, researchers have sought to leverage the ability of deep neural networks to learn high-level features from data. An example of this is the Phase-Functioned Neural Network (PFNN) architecture introduced by Holden et al. where a Convolutional Neural Network was supplemented with a cyclical phase function [4]. By allowing for the cyclical nature of the behaviour portrayed through the animation to be explicitly accounted for, animation datasets with increasing dimensionality were used as training data in a supervised learning paradigm with the PFNN used to output a wider range of motions smoothly.

However, similar to data-driven IK solvers, supervised learning methods rely significantly on the training data used. Thus, limitations reported included poor performance in response to input parameters such as those representing overly steep terrain. This observation by the authors can be considered demonstrative of the case for the use of RL for character animation. The authors also noted that their system at times behaves unpredictably.

An example of deep learning methods being used to create controllers able to output social behaviours is the work carried out by Klein et al. where gaze animations were generated using Recurrent Neural Networks (RNNs) [5]. While this method can be used to generate gaze animation in real time, the authors observed that it struggles to perform when presented with targets not present in the training data, and that owing to limitations posed by the equipment used to capture the data, eye animation was sometimes inadequate.

In work where animation controllers were based on RL, two prevalent approaches for optimisation have been physics-based simulations and the imitation of motion sequences. The work carried out by Peng et al. on DeepMimic is one of the earliest works that seeks to utilise RL and motion clips as well as physics-based simulation to create data-driven character controllers capable of realistic behaviour [6]. In their work, a motion-imitation objective is combined with a task-objective where the agents are trained to follow the trajectories of the motion clips and are optimised via rewards associated with the physics simulations to create flexible and generic behaviour while retaining realism.

RL is by nature more unstable than supervised learning; hence, these concerns are more present when using RL so stability of the trained model is a factor to which careful attention should be paid. DeepMimic addresses these concerns through the use of robust, consistent signals derived via a physics engine, to train agents. However, this approach is limited in the range of behaviours that agents can be trained to portray. For instance, social interactive behaviours, such as gestures and pointing, do not elicit adequate physics feedback. In our work, we investigate the feasibility of the RL paradigm for real-time character control where animation generation is done in a flexible and dynamic manner, that can be applicable for a wider range of behaviours.

3.3 Model-Based RL for Character Animation

A key aspect of RL tends to be that the problem an agent is tasked with solving is constructed as a Markov Decision Process (MDP). This leads to the assumption of a state transition function which represents the core dynamics of the environment within which an agent operates. By definition, the state transition is considered to be partly dependant on the actions and partly random. Model-free RL seeks to leverage this to avoid learning a model of the environment, with the aim of the resulting policy being more adaptable to unseen states when operating, which allows it to potentially function in real-world settings where learning an accurate ground truth model of the environment is not an option.

However, for an animation agent, the goal is to output desirable animations for previously known tasks, as agents would not be expected to learn plausible animation for unseen tasks. Furthermore, MDPs also assume that a state or an action at any given time step is independent of all previous states and actions. While it is possible to assume that this applies to animation tasks, we believe that it may be imprudent to do so, since for an output animation sequence to be realistic, an animation pose represented by an action a_t at any given time step would be dependant upon the previous pose a_{t-1}. These considerations lead us to believe model-based RL provides the apt underpinning for real-time animation control agents capable of a wide range of behaviours.

Computational efficiency is also of importance; in addition to agents being able to perform in real time, agents should be lightweight, to allow for future modification to perform more complex behaviours. We determine that agents would also be required to display a high degree of versatility with regards to both the behaviour portrayed and the events driving the behaviour. We achieve this versatility by using a meta-character objective and state pair to ensure agent operation within our framework is task agnostic.

Within our framework, agents can be created to output optimal animation sequences portraying behaviours successfully completing three tasks: gaze, point and a combination of the two. The framework infrastructure uses the Panda3D game engine [9], and we use a realistic human character obtained from Adobe Mixamo [10]. To allow for exploratory character behaviours, we configured our experiment infrastructure to support target-driven tasks in one of three behaviour modes: gaze, point or combined. Figure 3.1 provides details regarding the targets used, and joints animated. Targets can be created within any point in a possible space of 112.5 m^3 as displayed. When the gaze component is active, the agent can rotate left and right eyes, head, neck and spine joints (highlighted in red). The collar, shoulder, elbow and wrist joints are available for rotation within the relevant left (purple) or right (blue) components. Based on Euler angles, we create a representational animation action space where valid rotations within each free axis are parameterized in a range [0, 1].

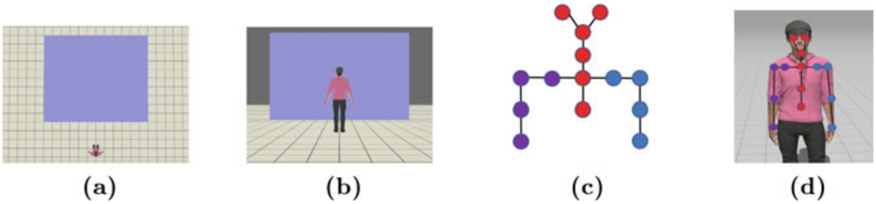

Fig. 3.1 Target and character joint configurations used. **a** and **b** illustrate the area within which targets can be created, and **c** and **d** visualise the relevant joints

3.4 Character Animation Framework

A summary of the how the agent is trained and operates is depicted in Fig. 3.2. An objective state (O) and character state (C) pair is used to represent the objective and character state within the same domain. The agent animates the character via an online planning module and the learned dynamics model $p(C_{t+1}|C_t, a_t)$ to generate candidates, as well as evaluate and select the optimal animation A. We use an iterative training process, where the model is initialised with random parameters θ, and the sample buffer S is initialised with sample task episodes with random animation sequences, and then updated to minimise the loss as denoted by L. After each model update, the agent explores the episode further and S is expanded by the [A, C] pairs representing fresh agent experiences.

In this section, we discuss the three elements that make up our framework, allowing agents to learn a character dynamics model that is used to make predictions as a means of evaluating candidate animation sequences through a planning process.

3.4.1 Meta-character Objectives and States

We aim to leverage the requirement for smooth motion, known task dynamics, and the structured nature of character animation, to learn a model of the behaviour portrayed which is used by an agent to generate task-agnostic animation. To facilitate this,

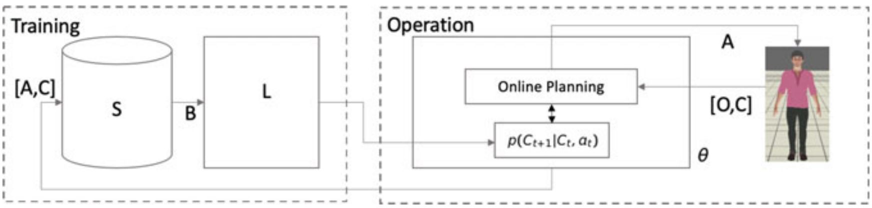

Fig. 3.2 Overview of our approach (A—animation, C—meta-character state, O—meta-objective state, S—sample buffer, B—training batches, L—loss function (Eq. (3.3)), Θ—model parameters)

we define a character state and objective state pair, which, given the context of the exploratory tasks for gaze and point motions, is as follows:

$$O_t = \left[\overrightarrow{I_L T}, \overrightarrow{I_R T}, \overrightarrow{E_L T}, \overrightarrow{E_R T}\right] \quad C_t = \left[\overrightarrow{I_L T'}, \overrightarrow{I_R T'}, \overrightarrow{E_L T'}, \overrightarrow{E_R T'}\right] \tag{3.1}$$

where I_L, I_R, E_L, E_R are the positions of the left index finger, right index finger, left eye, right eye, respectively. T is the target position and T' is a point generated by the Euclidean distances of the O_t vectors in the current direction of the index fingers and eyes. As a result, the character state consists essentially of information on where the character is looking and pointing at a given time. Meanwhile, the goal is defined as the objective state O_t which can be interpreted as the optimal character state at the termination of a task episode.

3.4.2 Character Dynamics Model

Given our definition of the character state space, the agent learns a dynamics model for (3.2), where C_t and a_t are the character state and action at time t and C_{t+1} is the forward predicted character state at the next time step.

$$p(C_{t+1}|C_t, a_t) \tag{3.2}$$

This dynamics model is used to predict forward character states and sequences. Accurately learning the optimal parameters for this model allows the agent to predict forward how possible animation sequences would change where it is looking or pointing at. This allows the agent to ascertain during planning when the objective O_t is reached successfully according to $|C_i - O_t|$ where i is the termination step, by predicting future character states of the current trajectory. During training, agent optimisation entails learning a model that allows this prediction to be made accurately.

This dynamics model is parameterized using a feedforward network comprised of 3 layers, where, with the exception of the output layer, rectified linear unit (ReLU) activation functions are included after each layer [11]. The learning objective for agents comprises of minimising the error when making predictions regarding the animation trajectory, per Eq. (3.3).

$$\frac{1}{N}\sum_{i=0}^{N}(c_{t+1} - p(c_{t+1}|c_t, a_t))^2 \tag{3.3}$$

3.4.3 Planning Animations

The agent generates thousands of candidate animations at each time step. The dynamics model learnt allows the agent to obtain a probability distribution for the next character state given an animation action and the current character state. The mean of this distribution is used to predict forward to evaluate candidate trajectories to obtain and maintain an ideal animation sequence. In this section, we present a novel method that uses a beta distribution to maintain a representation of this optimal animation sequence.

Beta Distribution A beta distribution is a class of continuous probability distributions that is defined within a bounded interval [0, 1], parameterised by two shape parameters α and β, and is a popular choice to represent probabilities of probabilities. We consider it well suited to fit candidate joint sequences as the values in the distribution are bounded, due to joint rotation limits. The manner by which the mean is parameterized allows the maintenance of a current value for animation actions without hindering exploration.

Behaviour Trajectory Within the context of our exploratory tasks, we define ideal character animation as portraying behaviour that successfully looks at, and/or points at the target within an episode of preset length, as well as requiring the motion output to be smooth. To ensure that these component requirements are addressed, the agent must maintain and evaluate candidate actions over the remaining duration of an episode. However, maintaining animation states for each step until termination of the episode can lead to untenable memory and time requirements. Hence, in our planning method, we approximate an animation trajectory by maintaining $\Delta\alpha_j$, and $\Delta\beta_j$. The planning mechanism is used to optimise and update just these transitional values $\Delta\alpha_j$ $\Delta\beta_j$.

To evaluate candidate animation trajectories expressed in this manner, assuming sequences of f timesteps, at each timestep t, candidate animations for the final timestep a_f are obtained by

$$a_f = \frac{\alpha + r\Delta\alpha}{\alpha + r\Delta\alpha + \beta + r\Delta\beta} \tag{3.4}$$

where r is the remaining number of steps until termination $f - t$.

After the planning mechanism is completed at each step, the animation to be applied to the character, A, is obtained as follows:

$$A = \frac{\alpha + \Delta\alpha}{\alpha + \Delta\alpha + \beta + \Delta\beta} \tag{3.5}$$

The algorithm by which the agent operates at each step is as follows:

1. Generate $\Delta\alpha$, $\Delta\beta$ candidates by adding noise to current $\Delta\alpha$, $\Delta\beta$.
2. Obtain a_f candidates per Eq. 3.4.

3. Use the dynamics model to predict the character states for each candidate and compare to objective state.
4. Update $\Delta\alpha$ and $\Delta\beta$ to reflect the most ideal candidates generated in Step 1.
5. Repeat Steps 1–4 for i iterations.
6. Obtain joint rotations to be applied to character per Eq. 3.5.

3.5 Model Training and Results

When evaluating agents trained using our framework, we use the cosine similarity between the actual and optimal vector states at the end of the episode as a metric for accuracy, and throughput time for the agent to complete the candidate generation and evaluation process at each step as a measure of computational efficiency. During training and evaluation, sample task episodes were generated with random targets selected, within the parameters set out in Sect. 3.3, configured to portray behaviours of 3 categories: gaze, point and combined. Examples sequences of animation generated using our agent can be viewed at https://virtualcharacters.github.io/links/AMSTA2021, where a link to an open-source implementation of our agent is also available. All our experiments were carried out using a machine with an Intel Core i7-8750H 2.2GHz CPU and a Nvidia GeForce FTX 1070 GPU. We use an iterative procedure for training our agent, which simulates our agent exploring the task, gathering new experiences regarding its behaviours, and refining the dynamics model according to the feedback provided. During training, we use a sample buffer S where rollouts collected are stored and sampled during training. The procedure can be summarised as follows:

1. Initialise dynamics model with random parameters.
2. Initialise S with n rollouts with actions sampled from a random motion policy.
3. Update model parameters drawing samples from S.
4. Using the current model, generate a rollout and add to S.
5. Repeat Steps 2 and 3 for a total of P epochs.

Using this iterative training procedure, we train each agent over 100 epochs. For the final agent trained, 256 was the hidden layer size for the character dynamics model across each task, allowing for agents to complete the animation tasks robustly and consistently. We saved the model parameters at the end of each epoch and sampled 100 episodes from each control model. The results from this evaluation are presented in Fig. 3.3, which show that as the agent explores the tasks, it is able to gather experiences and refine the dynamics model accordingly, increasing the accuracy of the behaviours with regards to completing the pointing objective, and, over time, allowing it to learn to consistently output successful animations across all three tasks. Even though the neural network we use is relatively shallow and the agent is only trained for 100 epochs, it is able to consistently portray desired behaviours even though the targets are positioned within a large candidate area.

Fig. 3.3 Final agent evaluation over 100 training epochs

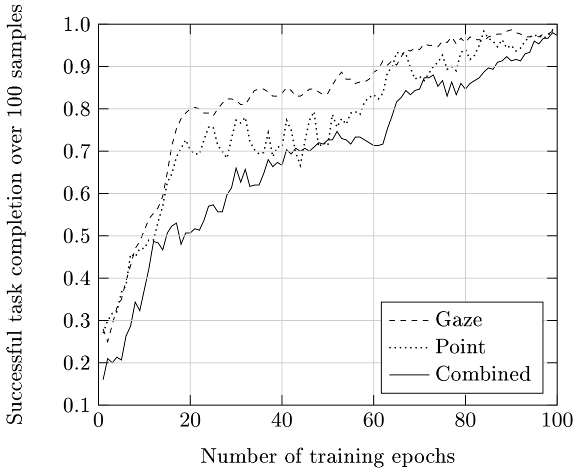

Table 3.1 Agent performance evaluated over 100 episodes

Task	Hidden size	Accuracy			Time (μs)		
		Average	Min	Max	Average	Min	Max
Gaze	64	0.982	0.932	0.996	39.8	29.8	57.2
	128	0.990	0.990	0.991	35.3	30.4	69.0
	256	0.991	0.990	0.998	41.8	29.9	61.1
Point	64	0.921	0.699	0.991	35.5	29.8	75.7
	128	0.976	0.898	0.994	36.8	29.6	46.5
	256	0.979	0.896	0.994	37.2	29.7	66.4
Gaze and point	64	0.864	0.145	0.991	31.1	29.4	38.3
	128	0.880	0.319	0.991	30.3	29.6	31.0
	256	0.983	0.949	0.995	30.1	29.8	30.5

We ascertained that 256 was the optimal hidden layer size for the dynamics model, by comparing trained agent variants that included dynamics models of hidden layer sizes 64, 128 and 256. For each task, we generated 100 episodes of the designated behaviour being performed using a fully trained agent. For the pointing tasks, we sampled 50 episodes each from agents trained to point using the left and right arm. These results are presented in Table 3.1.

We compared the performance of this neural network-based approach to a method based on IK, a more direct computation alternative that does not require learning a model. We used a Python implementation of FABRIK (described in Sect. 3.2) to create a control agent for the pointing task [12]. The time taken to calculate the joint rotations to successfully point at a target was approximately 0.2 s. Considering an average 100 step episode, our method outperforms the IK control version as the total time to compute animations was 0.005 s.

We believe that our framework is significantly more computationally efficient when compared to IK-based methods as a result of the dynamicism and versatility afforded by the way in which neural networks are leveraged within our framework to learn the dynamics in a task-agnostic manner. The use of a RL paradigm also allows agents to respond to changes in target position without any change to computational time. While additional time is required for training, it only needs to be performed once for agents to learn to portray dynamic behaviour.

3.6 Conclusion

We presented a model-based agent that learns a character dynamics model and generates animation via planning within a framework where tasks are expressed as meta-objectives. Our agent successfully learns to portray behaviour for tasks with objectives concerned with gaze, pointing and combination of the two, purely via self-exploration. Additionally, we also present a novel method for planning animations that makes use of a beta distribution for fitting candidates and allows agents to capture and update rotations in real time by means of a transitional matrix. We have demonstrated the possibility of creating and training in a task-agnostic manner an agent within a RL styled paradigm for portraying non-physics based behaviours. Our results also show that the use of neural networks to capture underlying dynamics to character animation can yield significant gains in performance over methods such as IK solvers. Agents created within our framework were able to generate animations portraying gaze, pointing or combined behaviours robustly responding to real-time changes to target position. In future work, we plan to examine ways in which the realism of animation generated can be enhanced, and explore augmenting our framework to allow for a higher range of social behaviours. Additionally, we believe our findings also demonstrate that model-based agents can be useful approaches in other real-world tasks where dynamics can be learnt effectively [13, 14].

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Chapter 4
Swarm Intelligence Optimisation Algorithms and Their Applications in a Complex Layer-Egg Supply Chain

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Abstract Optimising processes in a supply chain can benefit enormously all participating companies and the entire supply chain, e.g. for cost-cutting or profit raising. Traditionally, simulation-based technologies are used for such purposes. However, such methods can be expensive and under-performing when the solution space is too large to be adequately explored. Biologically inspired computing approaches such as swarm intelligence algorithms are uniquely suited to solve complex, exponential, vectorial problems, such as those posed by multi-product supply chains connected with a large and diverse customer base and transportation methods. Although swarm intelligence algorithms have been used to optimise supply chains before, there has been little work on formalising and optimising the layer-egg supply chain, or the supply chain of a perishable product—where same/similar products can be packaged to form different product offerings to seek optimised configurations for different buyers based on different pricing and cost structures. In this paper, we introduce two new Swarm Intelligence algorithms and use them to optimise the profits of participating suppliers in a real-world layer-egg supply chain using its operational data, trade network, and demand & supply models. Several swarm intelligence algorithms were discussed and their performance was compared. Through this, we aim to understand how the complex domain of real-life layer-egg supply chain may be suitably formalised and optimised in a bid to help improve and sustain layer-egg supply chain's financial well-beings.

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4.1 Introduction

A supply chain (SC) can be understood in terms of inter-connected activities that together produce and deliver products and services from the suppliers to the end-consumers [1]. Supply Chain Management (SCM) is about strategic coordination of businesses in the supply chain with the purpose of improving the long-term performance of individual companies and the supply chain as a whole [2]. According to a 2014 study by Deloitte, almost 80% of companies that are leaders in SCM have higher revenue growth on average and almost 70% of those leaders have a higher than average profit margin [3]. This study further states that leaders in SCM were 75% more likely to use some kinds of optimisation software. We can conclude from this study that the better the SCM of a company the more likely they are to obtain higher revenues and profits. However, to obtain a highly performed supply chain, optimisation software can play a vital role in it. Traditionally, simulation techniques are widely used. However, such techniques are more useful to explore specific business scenarios and not suitable for optimisation purposes, esp. when the solution space is very large. To overcome such limitations, we apply our new AI algorithms, including an improved Particle Swarm Optimisation (CPSO+) algorithm and an improved Swarm Intelligence Based (SIBv) algorithm and compare their performance with a standard SIB algorithm using real-world supply chain business data.

4.1.1 A Supply Chain Case Study: Taiwanese Layer-Egg Industry

The supply chain case study consists of Taiwanese egg farmers, dealers and customers and the transportation links that connect each of them. The number of eggs produced per day is determined by the number of laying hens an egg farmer owns. These farms can be of varying sizes and are located all over Taiwan. Egg farms can also be categorised on quality, e.g. organic, semi-organic or those that have gained certifications from the government on the ethical treatment of animals.

A dealer is an individual or a company that may or may not own their own egg farms but collects eggs from farms and supplies eggs to customers. A dealer's customers may be supermarkets, hypermarkets, grocery stores, cooperative buyers, restaurants and bakeries. The dealer can either collect the eggs from the farms and processes the eggs in their facilities before selling the eggs, or they can broker a sale between a farmer and a customer. The dealer almost always is responsible for the transportation of the eggs either from the farm to their own facilities or from the farm directly to the customer. Once the eggs arrive in the dealer's warehouse it is either washed or cleaned and then packed. If the eggs are washed they need to be kept refrigerated. After the eggs are washed or cleaned, they are packed using different packaging materials that may be of different sizes to form different products.

A large or medium sized truck is usually used to transport the eggs from the farms to the dealer's warehouse. These third party operated trucks can be used to transport other commodities as well or could be used only for eggs. Similarly, large, medium or small sized trucks are used to transport the processed eggs from the dealer's warehouse to the customer's warehouse. Smaller orders and last-mile deliveries are sometimes done through taxi-services like Uber. Washed eggs that need to be kept refrigerated are transported using a refrigerated truck. Each truck has a limited capacity and different running costs.

A consumer is someone who will buy eggs from a supermarket, hypermarket, grocery-store or via a cooperative (bulk) buying with other consumers. They may also be someone who buys directly from the dealer to produce other products, e.g. a bakery or restaurant. Because the consumers may access products through different sales channels, this selling method is called the multi-channel sales model. This supply chain is therefore a multi-product, multi-channel sales supply chain with differential pricing and costing structure that is attached with the volume of sales and supplier's contracts. Further, certain constraints are in place, e.g. a farm may only produce a certain amount of eggs of a particular quality, a customer may only buy a maximum number of eggs in several different packaging, trucks have a maximum capacity and costs.

When there is only a few products, farms, customers and a single dealer, the most profitable combination can be found by enumerating all possible sales models, subtracting their associate costs and selecting the most profitable combinations. However, as the number of variables increases, the size of the problem/solution space may increase to such a degree that it is no longer computationally feasible to identify and compare each and every combination. Such problems are regarded as hard problems.

Instead of finding the absolute optimal solutions, optimisation algorithms are often used to find as optimal a solution as possible for hard problems [4]. This means the solution found through optimisation might not necessarily be the best solution, but a good enough one given a limited time. Swarm Intelligence algorithms are one of such successful optimisation algorithms [5]. In this paper, we therefore exploit three of such algorithms and discuss their performance.

4.2 Literature Review

For hard problems, a brute-force or enumeration type of approach is unfeasible given the possible combinations of values or the size of the search space. In such cases, an alternative approach to finding solutions is needed.

Particle Swarm Optimisation (PSO) Algorithm: The PSO algorithm came about as an attempt to simulate the social behaviours of animals in the natural world—where each animal is formulated as a particle with cognitive ability. [6] created an optimisation algorithm that was efficient in terms of computational memory and speed. They encoded each particle as a possible solution to a problem, and the search space being the domain of all possible solutions in which the particles conduct a search. Each particle's *position* is a matrix which stores the values of dimensions of the search space. In order for each particle to move in the search space, a *velocity* function produces a speed and direction, at which it moves through the search space. After each iteration, the particle's *position* is adjusted based on its *velocity*. While the PSO is designed for continuous search spaces, position values can be rounded up and suitable stochastic strategies can be used for error recovery to suit discrete domains.

Furthermore, the PSO algorithm can use a "social-network", or a neighbourhood of informants, as a way to delay the spread of information among the swarm, resulting in a more complete search [7]. As informants act like an additional source of information, they enhance the ability of other particles so that they can "see" beyond their own cognitive ability. The information that is spread through the swarm pertains to the best position that each particle has been. Of the many neighbourhood configurations, one of them is the Ring Neighbourhood topology, where each particle is connected to two other particles [7]. In this configuration, each particle acts as an informant and shares its position with its two neighbours. This information sharing enables the identification of the "Global Best" position for all particles, leading to the converging to this position over time. A *constriction coefficient* was later added to PSO for high dimensional search spaces [8] and a modified Constrained Particle Swarm Optimisation (CPSO) was used to optimise engineering design problems [9].

PSO for Supply Chain Optimisation: [10] applied the PSO algorithm in a single-vendor-single-buyer inventory problem, with the objective function to minimise the total cost of the supply chain. It has also been used in the strategic planning of a biomass supply chain with the objective function being the optimal amount of biomass to be harvested and the best technology to produce energy [11]. Another study used a modified PSO algorithm to optimise a petroleum supply chain with the objective function to reduce costs [12]. The PSO algorithm was also applied to a multi-echelon automotive supply chain with the objective function of minimising operating costs [13]. We found PSO algorithms suitable to solve supply chain types of problems, because they do not require gradient information for the objective functions, but only their values. Furthermore, we couldn't find previous case studies on the PSO being used on discrete search spaces of a supply chain that will be an interesting exploration.

Swarm Intelligence Based (SIB) Algorithm: Like the PSO algorithm, the SIB algorithm has a swarm consisting of particles that are potential solutions, but unlike the PSO there is no velocity update function, instead it uses the *MIX* and *MOVE* operations [14]. In the *MIX* operation, every particle produces two new particles that contain selected elements from the Global Best and Informant's Best positions—these are produced using the particle's position and are called *mixwGB* and *mixwLB*, respectively, [14]. In the *MOVE* operation, the *mixwGB* and *mixwLB* are evaluated using the objective function and the particle assumes the best position out of the *mixwGB* and *mixwLB* [14]. However, if the particle is evaluated to be better than the *mixwGB* and *mixwLB*, then some elements of the particle are randomly changed in a process called 'random jump' [14]. While PSO algorithms are designed for optimising continuous search spaces, SIB algorithms are suited for discrete domains without needing modifications [14] and has been used in designing computer experiments [15], optimising super saturated designs of Hadamard matrices [16], target localisation of radio frequencies [17] and minimising energy demands [18].

4.3 Methodology

The Taiwanese layer-egg supply chain consists of multiple product offerings, diverse customer bases, product-dependent transport modes, differential pricing and costing structure that are governed by supply and demand constraints. Given the enormous amount of factors for consideration, an enumeration-based approach for finding the most profitable combinations of products to supply is not feasible. Although the PSO algorithm has been used to optimise supply chains before, there has been no work on formalising and optimising the layer-egg supply chain or supply chains with similar input variables and constraints. Furthermore, the SIB algorithm while applied to other problems has never been used to optimise a supply chain. As a result, in this paper we will attempt to optimise the Taiwanese layer-egg supply chain from the dealer to customer using our newly devised CPSO+, a previous SIB, and our newly modified SIBv algorithms. We will use the supply chain's profitability as the objective function. We aim to determine whether it is possible to model and optimise this supply chain given its complex nature and its many inter-related variables and constraints. We will then compare the performance of these three algorithms. Via this research, we hope to shed some lights on egg suppliers in improving their financial well-being by allocating the best combinations of products to customers while meeting supply and demand constraints.

4.3.1 Formalising Problem Domain and Algorithms

We examined a Taiwanese layer-egg supply chain of 30 farms, 78 product offerings, 82 customers of different types and 4 modes of transport. This data was provided by the National University of Taiwan under the "Intelligent agriculture for layer industry" programm funded by Ministry of Science and Technology, Taiwan (MOST 108-2321-B-001-016-). This data was formalised in a problem domain below: D = (Customer, Customer-type, Region-of-customer, Product, Product-type, Core-cost-per-product, Order-per-product-customer, Price-per-product, Discount-per-order, Price-per-product-customer, Transport-type, Cost-transport-per-product-customer).

The *Customer* is an individual buyer. *Customer-type* refers to the types of customers, e.g. hypermarket, supermarket, bakery, etc. *Product* denotes the total number of *Product-types* sold, where a *Product-type* may be a box of 6 eggs that have been pre-washed. *Core-cost-per-product* represents the core cost including the costs of producing, packing and processing the eggs at the farmers' and dealers'. *Price-per-product* is the standard price that a *Customer* pays for a *Product-type*. This does not include any volume-based/negotiated discounts—which is denoted by *Discount-per-order*. *Price-per-product-customer* is the price paid by a *Customer* for the *Product-type* after the discount, if any. *Region-of-customer* is the geographical location of the *Customer* that is used to calculate the *Cost-transport-per-product-customer* which is the cost to transport a *Product* to a *Customer*. *Transport-type* is the type of transport, e.g. the size of the truck and whether it is refrigerated or not. It is also used to calculate the *Cost-transport-per-product-customer* along with the *Order-per-product-customer*. The *Order-per-product-customer* is the quantity sold for a *Product-type* to a *Customer*. Equation 4.1 therefore denotes the total revenue of all product offerings to all customers.

$$\begin{aligned} Sales = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{o}\sum_{l=1}^{p} & Customer_i * Product\text{-}type_j * \\ & (Order\text{-}per\text{-}product\text{-}customer_k \\ & * Price\text{-}per\text{-}product\text{-}customer_l) \end{aligned} \tag{4.1}$$

where $Customer_i$ denotes a particular customer i; $Product\text{-}type_j$ denotes a *Product-type* j, and $Order\text{-}per\text{-}product\text{-}customer_k$ denotes the amount of $Product\text{-}type_j$ purchased by $Customer_i$ at the $Price\text{-}per\text{-}product\text{-}customer_l$. This indicates that each customer (e.g. a supermarket) may purchase a number of different product types, e.g. 5,000 boxes of eggs of six, and 1,000 boxes of boxes of 12. The summation of all customers' total purchase makes the total sales of the company.

$$\begin{aligned} Cost = \sum_{c=1}^{m}\sum_{o=1}^{n}\sum_{t=1}^{k} & (Customer_c * Core\text{-}cost\text{-}per\text{-}product_o \\ & * Order\text{-}per\text{-}product\text{-}customer_o) \\ & + (Customer_c * Order\text{-}per\text{-}product\text{-}customer_o \\ & * Transport\text{-}per\text{-}product\text{-}customer_t) \end{aligned} \tag{4.2}$$

We define the total costs for the supply chain to be the sum of the core production cost and the transportation cost. The total core cost is the summation of all of the cost to generate products bought by all customers; whereas the total transportation cost is the summation of all of the transportation cost of all products for all customers. The total profit of the supply chain is therefore the difference between the sales from Eq. 4.1 and the costs from Eq. 4.2, as denoted in Eq. 4.3.

$$Profit = Sales - Costs \tag{4.3}$$

The total profit is the objective function that we will maximise through the optimisation process. The *Order-per-product-customer* is the quantity of a *Product-type* supplied to a *Customer*—which needs to be within the upper limit of the demand for that customer and for that product type. It also needs to stay within the limits of total product types available, for the solution to be valid. Each particle is a matrix of *Order-per-product-customer* to indicate the different configurations of supply for all *Product-types* and for all *Customers*, together they make the entire swarm. Each optimisation algorithm initialises each particle with random but valid values. By optimising the quantities supplied, the algorithms find an optimal combination that reduces the core and transportation cost, and also the optimal combination of product sales, thus yielding the highest profit while keeping within the product supply and customer demand boundaries.

Constrained Particle Swarm Optimisation+ (CPSO+): We modified the original CPSO algorithm as proposed by [9] by enhancing the cognitive abilities of particles by accessing information through their informants. Instead of using Global Best as a guide in [9], we have chosen to use informants as a way of conveying information about the best *positions* seen by the swarm. This allows a gradual information spread, thereby reducing the chances of converging to a local optimum prematurely. The new *velocity* function of CPSO+ is given below.

$$v_i^{t+1} \leftarrow \chi \left[v_i^t + c_1 * rand(x_i^{*,t} - x_i^t) + c_2 * rand(x_i^{+,t} - x_i^t) \right] \tag{4.4}$$

$$\chi = \frac{2}{|2 - \varphi - \sqrt{\varphi^2 - 4\varphi}|} \tag{4.5}$$

where v_i^{t+1} is the new *velocity*, v_i^t is the previous *velocity*, *rand* is a random number between 0 and 1, $x_i^{*,t}$ is the best position seen by a particle, x_i^t is the particle's current position and $x_i^{+,t}$ is the best position seen by the particle and its informants. χ is the constriction coefficient that was added to the original PSO algorithm to help it converge in multi-dimensional search spaces and it was proposed that $\varphi := c_1 + c_2 > 4$ [8]. For this project, we found setting c_1 and c_2 to 2.05 produce successful results similar to [9]. After each iteration, each particle would move through the search space by adding the *velocity* matrix to the current *position* matrix as seen in Eq. 4.6.

$$x_i^{t+1} \leftarrow v_i^{t+1} + x_i^t \tag{4.6}$$

x_i^{t+1} is the new *position* obtained after adding the *velocity* v_i^{t+1} to the previous *position* x_i^t. As PSO are used for continuous numbers, we need to modify the algorithm and round up position values to their nearest integers. Furthermore, if this new position returns an unfeasible solution, we would replace it with a random value that obeys the constraints. Once a valid new x_i^{t+1} is found, we calculate its profitability by applying the objective functions as described in Eqs. 4.1, 4.2 and 4.3 and this process repeats for all particles in each iteration.

The SIB Algorithm: [14] describes SIB as where particles are enhanced by comparing itself with the informants (*lbest*) and global best (*gbest*) particles to identify target cells to be exchanged. Once they are found, a partial swap of cells are executed, resulting in two new particles *mixwLB* and *mixwGB*, respectively. However, if the swap results in a *position* that would break demand or supply constraints, then the swap does not take place. The profitability and the objective functions are defined in Eqs. 4.1, 4.2 and 4.3 and presented as function max() in the pseudo code. These results are compared and if *mixwGB* or *mixwLB* yield a higher profit value, then particle assumes the *position* of *mixwGB* or *mixwLB* that yielded the highest value. However, if the particle's *position* yields the highest profit value, then a portion of the values in the particle's *position* are randomly changed (random jump) as described in Algorithm 1 below.

Algorithm 1 The SIB Algorithm

```
procedure MIX
    q = number of values to replace
    for all particles in swarm do
        lbest ← max(particle, informant1, informant2)
        diff ← | particle's position - lbest position |
        mixwLB ← swap q number of diff cells from lbest into particle
    for all particles in swarm do
        gbest ← max(swarm)
        diff ← | particle's position - gbest position |
        mixwGB ← swap q number of diff cells from gbest into particle
procedure MOVE
    for all particles in swarm do
        if particle = max(particle, mixwGB, mixwLB) then
            new position ← random jump
        else
            new position ← max(particle, mixwGB, mixwLB)
```

The SIBv Algorithm: Our SIBv algorithm is a variant and an improved version of SIB where each particle is compared with the global best (*gbest*) and informants' best (*lbest*). However, unlike in the SIB algorithm where direct swaps of cells are performed; in the SIBv, we use a randomised point between the particle's and the target particle's value. However, if the chosen random value breaks the supply or demand constraints, then a legal random jump is sought to meet constraints. This approach gives a directional, goal-oriented, but more systematic and finer-grained refinement approach with less opportunities to miss global optimum between movements. It also uses suitable randomisation to explore the solution space, thereby avoiding trapped in a local optimum. Algorithm 2 gives the procedure MIX for the *gbest* algorithm which has the same procedure logic for *lbest*. SIBv deploys the same MOVE procedure logic as in SIB.

Algorithm 2 The Global Best algorithm of SIBv

```
procedure MIX
    q = number of values to replace
    for all particles in swarm do
        gbest ← max(swarm)
        diff ← | particle's position - gbest position |
        for q numbers of diff cells in particle & gbest do
            r ← rand(particle position value, gbest position value)
            mixwGB ← replace q number of diff cells of particle with r
```

4.3.2 Experiments Setup and Results

All algorithms follow the same supply chain model. Each algorithm was run for 500 iterations and with 20 particles. A ring-topology neighbourhood was used to choose informants. Each algorithm was run 30 times on the same computer and each time the swarm was randomly initialised. In Figs. 4.1, 4.2 and 4.3 we can see the iteration count on the x-axis and the profit value returned by the algorithm on the y-axis. All three algorithms were able to find better solutions from the randomly initialised starting positions and return results that met demand and supply constraints.

Table 4.1 gives the summary of the experiment results. Based on these results, we see that the new SIBv (SIB variant) algorithm returned configurations that yielded the highest maximum profit value compared to the SIB and CPSO+ algorithms, and also had the highest median profit value. This may be due to the fact that the SIBv algorithm is in a sense of a "combined" algorithm of the other two—where particles take an "elite" selection approach of SIB to move towards a more superior position, but it also adopts the PSO algorithm where a more systematic and incremental step is taken that may give it competitive advantages. However, the newly modified CPSO+

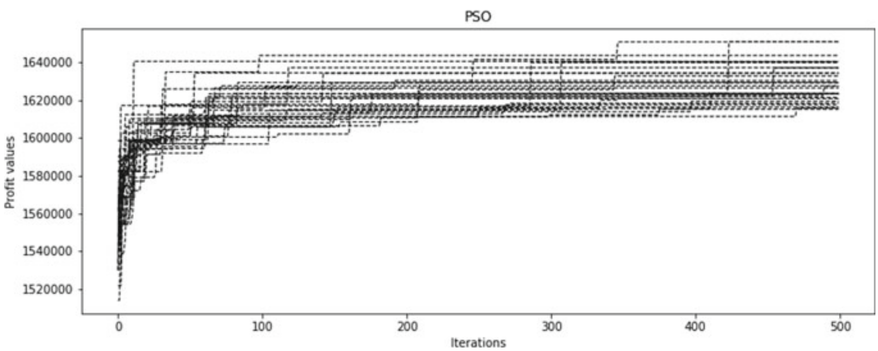

Fig. 4.1 CPSO+ Gbest profit trends

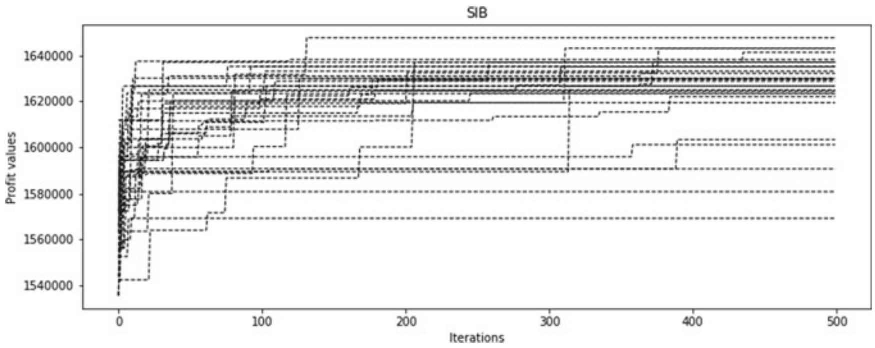

Fig. 4.2 SIB Gbest profit trends

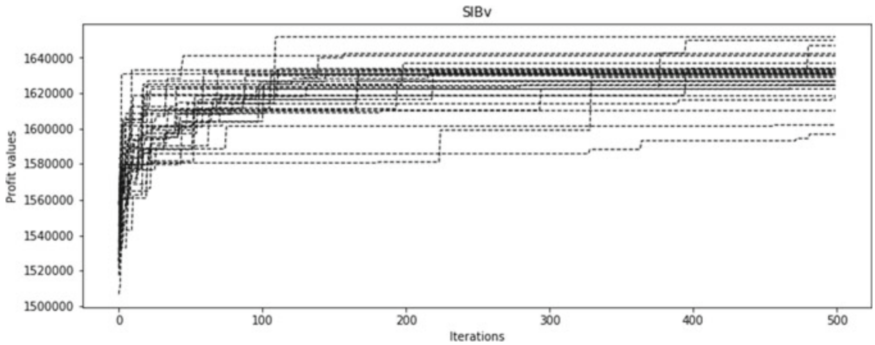

Fig. 4.3 SIBv Gbest profit trends

algorithm was able to find configurations that yielded the highest profit values at the worse case scenario and on average. The SIB algorithm produced the highest standard deviation (18,476.66) for finding its final converged profit values, when it is compared with the other two algorithms. This corroborates the phenomena shown in Fig. 4.1, 4.2 and 4.3, where the SIB algorithm's converging values are further away from each other when it is compared with the other two algorithms.

In Table 4.1, the 'Iteration to convergence' refers to the iteration number on which the algorithm was able to find the highest profit value of the run. The SIB algorithm on average (mean) and in terms of median requires the lowest number of iterations to reach its convergence. This means SIB is generally able to find a stable answer quicker than the other two algorithms. It also has the lowest standard deviation to show that this performance is rather consistent. In this experiment, although SIBv algorithm produced the best results for profits for both the Max and Median categories, its converge rate may be varied. It achieved the fastest convergence iterations (2) but also obtained the highest convergence iteration (497). Based on these results we found that the newly modified SIBv algorithm returns the highest profit values (Max);

Table 4.1 Performance Comparison of CPSO+, SIB and SIBv algorithms

		CPSO+	SIB	SIBv
Final profit values	Max	$1,651,106.64	$1,647,783.13	**$1,651,870.06**
	Min	**$1,615,112.88**	$1,569,280.95	$1,596,824.42
	Mean	**$1,629,354.38**	$1,625,019.43	$1,629,066.25
	Median	$1,628,415.95	$1,629,700.02	**$1,630,742.75**
	StdDev	**9998.13**	18473.66	12123.24
Iteration to convergence	Max	494	435	**497**
	Min	11	4	**2**
	Mean	265	**191**	209
	Median	277	**156**	170
	StdDev	157.77	**140.33**	160.81

while the newly modified CPSO+ algorithm produced the highest profit values at the worse case scenario (Min). We also found that the CPSO+ algorithm returns the most consistent results for finding the highest profit values (smallest StdDev).

4.4 Conclusions and Future Work

In this paper, we explored an agriculture sector where Artificial Intelligence algorithms are not often utilised. We demonstrated how complex, sometimes messy, real-world layer-egg trade data may be formalised and captured in formal models. We then demonstrated successful optimising approaches with promising results. We have constructed both of the demand and supply models for the layer-egg market in Taiwan and have created a buyer's model based on their purchasing and trading patterns. In addition, we have merged these models with relevant warehousing, vehicle and logistics information, and costing and pricing structures to form a coherent layer-egg supply chain network. Such formal models enable us to deploy our newly modified CPSO+ and SIBv algorithms to compare with the traditional SIB algorithm when seeking the optimisation of profits for egg sales over the supply chain. We found that the newly modified SIBv algorithm returns the highest profit values (Max); while the newly modified CPSO+ algorithm produced the highest profit values at the worse case scenario (Min). All the algorithms have been deployed using a standard laptop and the run time required for these algorithms to successfully yield high quality results is relatively short. They are also efficient in using computational memory.

Based on the successful formalisation and optimisation of the Taiwanese layer-egg supply chain, we believe more features of the supply chain can be added and optimised using the swarm intelligence algorithms. Additional features for consideration may be time issues on transportation, egg qualities over time as they are left on shelves unsold, and product damages and returns, etc.

Due to the stochastic nature of the algorithms, it is impossible to say how close each algorithm's particle's positions were to the true global maximum. Further experiments with all algorithms starting from the same initial particle positions could yield additional insights into their comparative performance. Given the large number of variables in the supply chain, it was also not possible to capture all variables, or whether the algorithms were able to find a global optimum. Further experiments with these algorithms on discrete search spaces should yield additional insights. Additionally, although volume-based discount is included, buyer's behavioural changes due to discounts are not included that will be an interesting extension of this work.

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Chapter 5
Collaborative Framework for Implementation of Accessible Digital Solutions

Iva Topolovac, Ivana Rašan, Željka Car, and Ivo Majerski

Abstract The paper presents an innovative framework for collaboration in the telecommunication sector that engages regulators, academia, telecommunication operators, and organizations of people with disabilities in the application of expertise, knowledge, and digital technologies to create wealth and welfare in society and increase public awareness of the communication issues of people with disabilities. The framework is one possible approach in dealing with practical implementations of digital accessibility solutions and a way to encourage all stakeholders in today's digital world to consider certain steps that will significantly improve the quality of life of people with disabilities. Within the framework presented, several accessible digital solutions have been developed and published. The paper presents in detail the application developed to raise awareness about the importance of proper interaction with people with different types of disabilities (people with intellectual disabilities, deaf, blind, etc.).

5.1 Introduction

The aim of this paper is to raise awareness about the importance of a multidisciplinary approach when working on accessibility and to encourage all stakeholders in today's

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digital world to consider certain steps in the process of developing digital solutions that significantly improve the quality of life of people with disabilities (PwDs). The focus is on an innovative collaboration framework related to the telecommunication sector that involves regulators, academia, telecom operators, and organizations of PwDs. The Croatian Regulatory Authority for Network Industries (HAKOM) and the Faculty of Electrical Engineering and Computing at the University of Zagreb have been cooperating for many years in the field of accessibility and raising awareness on all issues of PwDs not only in the digital environment but also in general. The collaboration between the two actors (industry–academia) is based on project collaboration, but it is also important to point out that the key to the success of software and other solutions related to accessibility is to involve end-users when thinking about the development of software and other solutions, defining the goals to be achieved, and in the process of testing and further improving these solutions. In addition, it is very important to raise awareness on the need to involve experts in speech therapy, education and rehabilitation, psychology, and others in the development of software solutions such as those presented in this paper. Since today's society is digital and having access to the Internet and other digital, both hardware and software solutions, is necessary, telecommunications operators are recognized as important stakeholders in the field of accessibility and they have been actively involved in the cooperation. The synergy of all these actors involved in projects has led to different software solutions that directly improve the quality of life of PwDs and indirectly help to raise awareness of all the challenges they face.

This is particularly demonstrated in the following software solutions: The prototype of accessible website "Accessible window into the world of information about telecom operators' offers,"[1] where the offers of all telecom operators are available in one place and the website supports most accessibility options for PwDs [1]. The implemented accessibility options were selected based on the actual needs of PwDs during the project "The prototype of accessible mobile application"[2] containing accessibility features and information in an accessible website but designed for mobile applications for Android. Furthermore, the HAKOM quiz application[3] serves, not only for educational purposes but also shows people without disabilities and difficulties how PwDs or difficulties perceive certain digital content.

The application described in detail in this paper is the Encounter application *(ICT-AAC Susretnica* in Croatian).[4] The application is designed to raise awareness about the importance of properly interacting with people with different types of disabilities (people with mental disabilities, deaf people, blind people, etc.).[5] Given

[1] Accessible window into the world of information about telecom operators' offers http://usluge.ict-aac.hr/pristupacni-web-2/o-projektu/, http://usluge.ict-aac.hr/pristupacni-web-2/.

[2] http://www.ict-aac.hr/images/pristupacni_prototip/PristupacniMobilniPrototip_1.3.apk.

[3] http://pristupacnost.hakom.hr/.

[4] https://play.google.com/store/apps/details?id=hr.unizg.fer.ictaac.Susretnica&hl=en&gl=US; https://apps.apple.com/hr/app/ict-aac-susretnica/id1543868054.

[5] http://www.ict-aac.hr/index.php/hr/novosti-aplikacije/512-objavljena-nova-aplikacija-ict-aac-susretnica.

that people often act inappropriately in good faith, the purpose of this app is to use practical, real-life examples to show which is the right way to approach people with disabilities. An additional motive for the development of this application lies in the EU Directive 2016/2102,[6] which emphasizes that the Member States should implement measures to raise awareness about accessible applications and websites. It is important to point out that without the given framework in the context of the already mentioned collaboration and involvement of key stakeholders, the development of this application would not be possible.

5.2 Description of the Collaboration Framework

In the Digital Age and Digital Economy, everyone should have equal opportunities to access Internet-based content, applications, and services. Unfortunately, this is not the case today. Many people with different types of disabilities do not have the same opportunity for the simple reason that telecom content and service providers are not sufficiently informed and/or do not have enough knowledge to implement accessible solutions or universal design that is suitable for most people, regardless of their disability.

This challenge has also been identified in the Electronic Communications Industry by the National Regulatory Authority (NRA). Telecom Operators, which provide communication services and Internet access, are the first ones who users encounter if they want to use the Internet at all. Operators should be among the first actors to lead the change to make the entire Internet space as accessible as possible and enable almost everyone to participate in the digital society.

The model of the collaboration, in this case, is addressed to all interested operators in the Electronic Communications market and the NRA. The regulator imposes itself as a logical focal point and the bearer of the realization of the idea, but such cooperation is not enough if one wants to understand the real needs of most PwDs. Therefore, PwDs simply must be included in such a project and in the research. Their involvement should be arranged in a way that is fully acceptable to them, and all involved parties must be motivated to make the project flow optimal. The solution to this challenge is to involve the scientific community as the project leader, commissioned and funded by the NRA. This ensures, not only a scientific approach and method during the project, involvement of all needed experts but also enables easier inclusion of PwDs in such a research. Civil associations dealing with persons with disabilities cooperate more sincerely and more willingly in science-led research than in projects conducted independently of operators or the NRA.

Therefore, interdisciplinary work and cooperation between all the above-mentioned parties are crucial. This way, the challenges faced by PwDs in using

[6]Directive (EU) 2016/2102 of the European Parliament and of the Council of 26 October 2016 on the accessibility of the websites and mobile applications of public sector bodies, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016L2102.

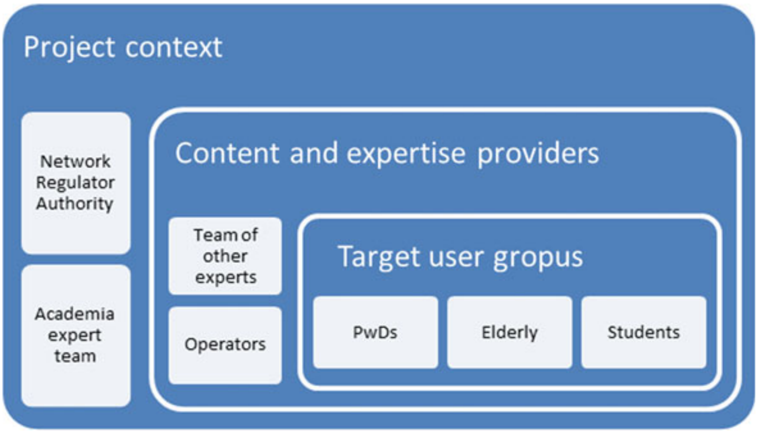

Fig. 5.1 Structure of the proposed collaborative framework

an operator's services can be accurately identified, and the scientific approach offers optimal solutions so that PwDs are satisfied with the implementation and ready to use it.

The structure of the proposed collaborative framework is presented in Fig. 5.1. The collaborative environment generally includes the organizational environment and the type of collaborative tasks performed [2]. In the presented framework, this environment is project-based, as projects allow for strict collaboration rules, deadlines, and resources with a clear goal and vision of what needs to be done, while decisions regarding technical implementation are based on technical expertise and the nature of the problem. The project objectives are set based on the available resources, as well as on identified and prioritized problems of PwDs and older people in the telecommunication sector. Therefore, the requirements gathering phase includes research on the needs of the target users and the problems they face in the selected area. For example, the research on the needs of target users in terms of website accessibility also yielded information about other problems they face, either in the area of mobile applications or in terms of usability, all of which are issued on the websites of telecommunication operators. One of the conclusions was that there is a lack of knowledge and awareness of how to approach them in different situations (in the street, in the shop, in communication with telecom operator agents, etc.) and this was the motivation for developing the solution presented in the second part of this thesis. Therefore, it is advisable to always use open-ended questions at this stage of requirements elicitation and to hold a discussion with user representatives, based on which the problems are identified, prioritized, and future directions of research and actions in this area are defined.

Key stakeholders in the collaborative framework are:

- **Network Regulator Authority** (NRA) acting as a sponsor and decision-maker in terms of analyzing and evaluating potential actions and initiatives and making a choice by releasing calls for proposals with project specifications, deadlines, and financial resources. For example, the research described in [3] demonstrates that commercial incentives pervade the implementation of web accessibility policies and provide the opportunity to expand models of relational regulation referring to the interactions that occur between the public and private actors that manage regulatory objectives and practice. NRA act in projects as an escalation point for decisions and issues that are beyond the authority of the project manager and provide the communication link between the operators and project team [4].

- **Academia expert team** consists of individuals who have expertise in a particular area and the ability to work effectively with others, resulting in a high-performance team [5]. In the field of ICT-based assistive solutions, the team should have expertise in computer science, software engineering, and accessibility, as well as universal design.
- **Team of other experts** is composed of professionals in the fields of psychology, rehabilitation, and graphic design, who have a high level of skills and knowledge in these areas, acquired over many years of experience [5]. Their input adds value to the overall effort in the decision-making stages, especially in the stages where several equally valid choices are available and only one is to be selected. They also actively participate in the evaluation phase of the developed solutions. In addition, graphic designers are responsible for making the interface of the ICT solution attractive and usable.
- **Representatives of user groups**—PwDs, Elderly, and Youth. Implementing accessibility in the digital domain is not an easy task and requires negotiating on a lot of contradictory requirements. Therefore, their active engagement in all stages is essential to achieve a quality outcome that is beneficial to them. According to the previously mentioned research findings, it can be concluded that the social awareness of the younger population regarding the issues of accessible ICT solutions is low, while on the other hand, the interest of the young people is very high. Therefore, there is a significant need for communicative activities targeting the younger population to make them aware of the challenges that arise not only in the everyday life of PwDs but also due to the significant aging of the population, i.e., the higher life expectancy of the general population. Involving the young population in these activities during the stages of the requirements gathering survey is one way of increasing their awareness and motivation in this area.
- **Operators**—Some telecom operators have developed inclusive strategies to encourage the participation of PwDs as customers or as employees. These strategies consider both customer-facing and internal business activities of operators, such as the provision of accessible mobile products and tailored packages, the inclusive promotion of mobile services, products and devices that are accessible to the customers, and the provision of accessible customer services and digital products [6]. Developing products and innovations for customers with disabilities to enable them to access basic and value-added services is their motivation for participating in this collaborative framework. Also, developing organizational

strategies for inclusion required training their employees on how to appropriately communicate with PwDs.

To share this vision among collaborative framework stakeholders, the importance of the efforts and results should be clearly pointed out at the very beginning of the collaboration, as well as the awareness of teamwork, expected behaviors, and chosen strategies on how the information and outcomes will be shared. High-quality planning in the early stages of teamwork is required [7].

Collaborative scenario includes the following activities: (i) NRA analyzes the needs and requirements of PwDs as a customer population in the telecommunications sector; (ii) NRA initiates collaboration project with Academia expert team; (iii) Academia expert team identifies the members of other expert teams, assesses interest, and contacts organizations of PwDs; approaches elderly and young population representatives; (iv) Operators are involved as providers of information about their telecommunication services to the target user groups and in all dissemination activities where they are informed about the project results related to providing more accessible services to PwDs.

The results of the Collaborative framework are technically implemented in the form of the accessible website and mobile application prototype with operators' offers for PwDs, young people, and the elderly, and as a series of multiplatform applications to raise awareness in this area, one of which is the Encounter application, described in the following section.

5.3 Serious Game for Raising Awareness on How to Approach PwDs Developed Within Proposed Collaborative Framework

People often try to help those who are in need. However, contrary to the popular belief, people with disabilities do not always need or want our help, so it is important to determine when and how to approach them. This was the main idea behind the development of the Encounter application. As the name implies, the application provides advice for various "encounters" with people with disabilities. Similar to the existing social rules provided by the etiquette, the Encounter application is a kind of etiquette that suggests how to behave in everyday situations involving people with different types of disabilities. It aims to raise awareness about people with disabilities by sharing knowledge, provided by PwDs themselves, on how to properly approach them. Since fear is often the thing that keeps people from initiating communication, even when the situation calls for it, this transfer of knowledge that occurs while playing the serious game gives one the confidence required to overcome that fear and offer help to those in need.

The development process followed the collaborative framework described in the previous section. In the following text, key stakeholders of the framework are mapped to the project participants and the project activities, listed below, are mapped the collaborative scenario. By analyzing the requirements of PwDs, The Croatian Regulatory Authority for Network Industries (**NRA**) initiated the collaboration project with the University of Zagreb, Faculty of Electrical Engineering and Computing (**Academia expert team**) that resulted, among others, in the Encounter application. These make the first and second activities of the Collaborative scenario. The end users were included in every stage of development as well as experts from multiple fields of science, such as pedagogues and psychologists (**Team of other experts**). The end users of the application are, in fact, everyone, especially the younger population which is why students from the University of Zagreb, Faculty of Electrical Engineering and Computing (**Representatives of user groups**), were the ones who tested and evaluated the prototype of the application, as well as the alpha and beta (final) versions. In addition, the representatives of associations of PwDs also participated in the development (**Representatives of user groups**), contributing the most in the initial stages by sharing their experiences and evaluating the final version of the application. Before developing the alpha version of the application, a prototype was created to evaluate the idea behind the Encounter application. The answers to the evaluation questionnaire showed that more than 90% of the participants have found themselves in the proximity of a person with a disability for whom they thought needed help (see Fig. 5.2). Developing the alpha version, which was tested and improved to satisfy the end user's requirements, resulted in the release of the final version described in Sect. 5.3.2. Prior to providing the description of the final version, a method used to collect the content for the so-called scenarios implemented in the application is described in Sect. 5.3.1. After the evaluation was conducted and improvements were implemented in the application, as the final step of the project and the fourth activity in the collaborative scenario, the project results (including the Encounter application) were presented to the telecom operators (**Operators**) during an online session with all project participants.

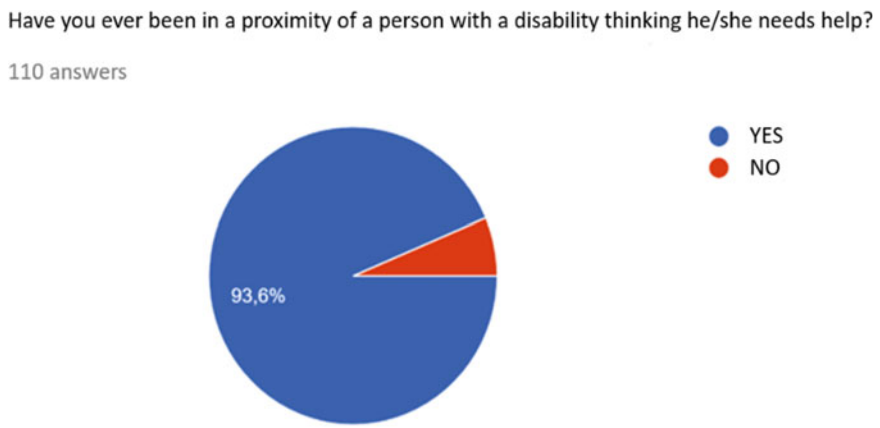

Fig. 5.2 The results for one of the questions in the survey for the evaluation of the idea behind the Encounter application

5.3.1 Creating Scenarios for the Serious Game

Considering that the Encounter application aims to provide knowledge on how to approach people with disabilities, it was necessary to gather this knowledge from the representatives of associations of PwDs. Along with the evaluation that included both students and PwDs, mentioned in the previous section, this makes the third activity of the collaborative scenario described in Sect. 5.2. The knowledge of PwDs was implemented in the scenarios which represent real-life situations and were designed in collaboration with the PwDs during several online brainstorming sessions. The collaboration, organized by the Academia expert team (FER team), took place online as social distancing measures were necessary due to the COVID-19 pandemic. The PwDs described their experiences for situations in which they needed help or were offered help by a stranger, shared information on what they wanted people to know, and suggested how people should approach them in certain situations. They also suggested how to start the conversation, with the two, simple but most important phrases being: “Do you need help?” and “What can I do to help?”. They emphasized the fact that one must first determine if a person needs help at all, and then what can be done to provide that help. Following PwDs suggestions, a total of six scenarios were implemented and are the main feature of the application. Additional comments, ideas, and expert knowledge on scenario and game design were collected from pedagogues during another online brainstorming session.

5.3.2 The Encounter Application

The application is designed as an interactive quiz offering six different scenarios divided between two games: “Going to the movies” and “Going to the store.” Each game implements three scenarios and describes situations in which one might find oneself on the way to the goal (movie theater or store). Each scenario includes an avatar and a person with a different type of disability. The user can choose a male or female avatar before starting the game and change the initial choice in the main menu (see Fig. 5.3) of the application. When starting a game, the user sees a map with milestones on the way to the goal. Upon reaching a milestone, a scenario representing a real-life situation is loaded along with a question and several answers to choose from (see Fig. 5.4). Once a user selects an answer, he or she receives visual feedback (in form of an airplane with the corresponding label), as well as audio feedback (if the application sound is on). If the selected answer was correct, a corresponding animation is played, showing the conversation between the avatar and the person with a disability providing information about what to do in the presented situation. To make the animation seem more dynamic, if the sound is on, the conversation is also read aloud. After the animation, the user can go to the next milestone and the next scenario is loaded. If the selected answer is wrong the user must try again until he or she gets it right. When the user goes through all the scenarios, he or she reaches

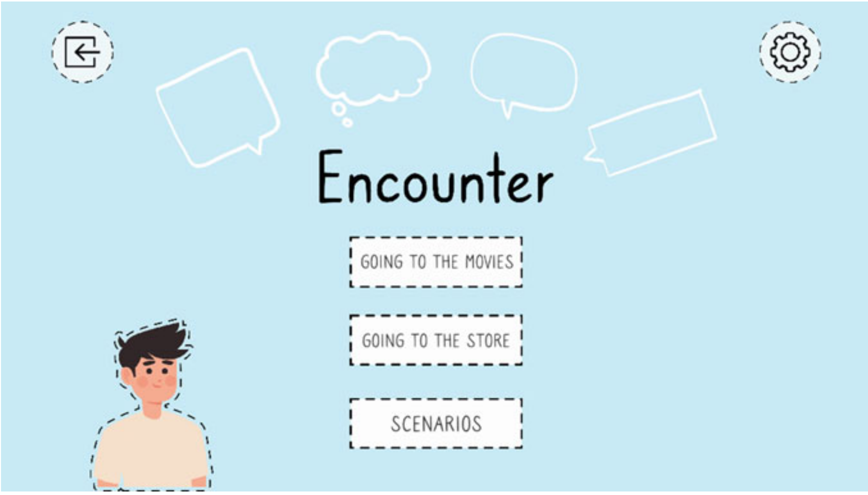

Fig. 5.3 The main menu of the Encounter application, with the male avatar

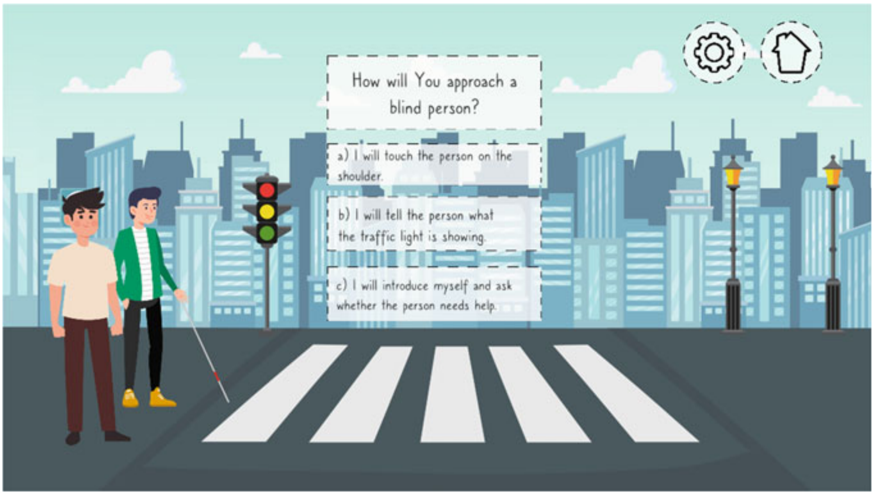

Fig. 5.4 The first scenario of the Encounter application, with the male avatar

the goal and is returned to the main menu. Besides the two games, the user can access all implemented scenarios individually in the main menu.

In the application settings, the user can change the accessibility options in addition to the default options to turn the sound on and off. For example, there is an option to change the font to make it accessible for people with reading disorders such as dyslexia. Also, one can turn on the zoom option to enlarge the content of each screen of the application. Finally, the user has the option to turn on the unique screen reader system—the narration. This screen reader system was implemented due to the incompatibility of screen readers with games created with Unity (game development platform that was used to develop the Encounter application) and is intended for visually impaired users. Anyone can easily turn it on when they launch the application for the first time by following instructions that are, by default, read aloud.

As mentioned, the application was developed using the Unity game engine and the C# programming language as a 2D scenario-based serious game. The same implementation process, code flow, and logic were used for each scenario of the game and a unique narration feature was implemented along with other accessibility features (options for changing the application font and enabling screen zoom). All the animations for scenarios are made using the Unity animation system. The design is a result of combining custom-made content with existing resources. The application is available only in Croatian for now and can be played as a web application as well as a mobile application for both Android and iOS supporting devices. The text in the screenshots below has been translated for this paper, to give the reader a clear sense of what the application is about.

It is important to note that this type of application can be easily modified by adding more content in the form of different scenarios. The method used to develop this application can be used as a guide for developing similar ones with alternative goals. For example, to teach store employees how to approach PwDs, to teach how to encounter children with autism, etc. In addition, by modifying the design, it can be made more suitable for different age groups of users.

5.4 Conclusion

Collaboration among the key stakeholders and the multidisciplinary approach is key to successful and targeted action on accessibility. For the described framework of action and project collaboration, the key actors and their roles in the collaboration are listed in the context of examples of good practice. Although today's society stands out as one of the equal opportunities, there are still changes to be done to ensure that there are truly equal opportunities for all. Therefore, this paper aims to motivate everyone in the digital environment to act in the field of accessibility. Furthermore, it gives an insight into the collaborative framework that has so far led to high-quality results, confirmed by the satisfaction of the end users. In the case of the application described in the paper, user evaluation was conducted during the test phase involving 109 participants (PwDs and other users of different ages). A total of 83.5% participants did not find any failure in the application and some of them provided feedback that was the basis for the application improvement. In summary, the scope for action in the field of accessibility is wide but given that it is a specific and relatively new field of action, it is necessary to continuously encourage not only all stakeholders to act but also to point out important preconditions and frameworks for action to achieve meaningful results.

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Chapter 6
Task Selection Based on Worker Performance Prediction in Gamified Crowdsourcing

Helun Bu and Kazuhiro Kuwabara

Abstract This paper presents a method for selecting tasks in gamified crowdsourcing. Knowledge collection is important for constructing a high-quality knowledge base. The knowledge collection process is targeted in our word retrieval assistant system, in which knowledge is presented as triples. Four types of quizzes are introduced that can be used to collect knowledge from many casual users. The quizzes are variations of a fill-in-the-blank format, in which the user provides a piece of information by filling in the blanks in the quiz. To collect knowledge efficiently even when the required knowledge is distributed among many users, a prediction method is introduced to select a quiz that is best suited for a particular user. The simulation results demonstrate the potential of the proposed method.

6.1 Introduction

Gathering knowledge is important for building high-quality knowledge bases. A knowledge graph, a notable format for representing knowledge, is considered to be a promising tool for converting a large number of documents into a machine-readable format and expressing them meaningfully [1]. For example, academic knowledge has been represented using a knowledge graph called the Open Research Knowledge Graph (ORKG) [2].

One method to build a higher quality knowledge base is not only collecting the existing knowledge graphs but also collecting knowledge from human users.

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Although existing knowledge bases have emphasized objective knowledge such as world facts, crowdsourcing can be a useful approach for collecting subjective knowledge [3].

One of the challenges associated with crowdsourcing is user motivation. The combination of gamification and crowdsourcing is considered to be an effective approach for motivating crowd workers [4]. Gamification is a means to incorporate gaming elements in non-gaming contexts to keep casual users motivated [5]. Games with a purpose (GWAP) are examples of collecting knowledge through gamification. This approach is a powerful crowdsourcing mechanism for collecting implicit annotations from human users [6]. For example, a GWAP method was used to collect annotations for a text segmentation task [7]. Through an appropriate game design, a system can be created that can collect knowledge as users play the game, giving the users an incentive to provide information.

By introducing a gaming element into the task of knowledge collection and presenting a *quiz* to collect each piece of knowledge, users are expected to execute a task by answering an assigned quiz. However, it is not clear which tasks should be assigned to which users. In particular, when each user has different pieces of knowledge, that user can only answer specific quizzes. In this case, a task (or a quiz) must be carefully selected for each user so that the user can complete the assigned quiz and more efficiently contribute to the knowledge collection effort.

This paper focuses on our word retrieval assistant system [8] as an example of a knowledge base. This system aims to support people with aphasia who suffer from word finding difficulty. Through a series of questions and answers, the system guesses the word that the person with aphasia wants to express using the knowledge in the system. The system must contain knowledge on topics that often appear in daily conversation. Therefore, incorporating the contributions of many casual users can be effective for this knowledge base. For the knowledge collection process, the concept of gamification is adopted, and the knowledge collection task is performed through a quiz presented to casual users. A task selection method is also introduced for more efficient knowledge collection. Furthermore, to verify the characteristics of the proposed method, simulation experiments are conducted.

The remainder of the paper is organized as follows. Section 6.2 describes several related studies on task selection methods in crowdsourcing. Section 6.3 presents the proposed method for collecting knowledge from many casual users, and in Sect. 6.4, the simulation experiments are presented and their results discussed. In Sect. 6.5, the conclusions are presented.

6.2 Related Work

Previous studies have proposed many approaches to control the quality of crowdsourcing [9]. Maintaining worker motivation and matching workers with an appropriate task are two of these approaches. To keep users motivated during crowdsourcing, a task-matching algorithm that uses the worker's past preferences and performance was proposed, in which the algorithm helps the worker to select a task [10]. It was reported that the efficiency of task completion improved using this method. The task selection method is often considered among agents where an agent selects tasks to execute to maximize its gain. One approach proposed the use of a Markov decision process to consider the uncertainty in local task selection [11].

Another algorithm was proposed to schedule spatial tasks associated with a location and time to maximize the number of tasks performed [12]. The algorithm was developed for when workers autonomously select their tasks. For mobile cloud sensing applications that combine crowdsourcing and mobile technology, an asynchronous and distributed task selection method has been proposed for different types of users to help them select their tasks [13]. Additionally, for spatial crowdsourcing, where a worker is assumed to be traveling to perform tasks, a problem called In-Route Task Selection (IRTS) was formulated and a heuristic approach has been proposed to produce a solution that properly combines detours and rewards [14].

These methods essentially recommend a task to a worker based on the characteristics of the task and worker. However, other approaches can be used to prioritize individual tasks to efficiently achieve the overall goal. For example, it has been reported that for a task such as evaluating document relevance using crowdsourcing, high-level overall performance can be achieved with a smaller budget by inferring the relevance of unevaluated documents [15].

The task selection method in this study aims to select tasks to collect knowledge from casual users through crowdsourcing. A case is considered in which the task is presented as a quiz to a worker, and the worker does not choose the task. For this application, therefore, it is important for the system to determine which tasks to assign to which worker for the efficient collection of knowledge.

6.3 Collecting Knowledge

6.3.1 Quiz Game

The knowledge in our word retrieval assistant system is represented as triples [8]. A triple consists of a subject, predicate, and object. For example, the fact that *the color of an apple is red* can be represented as `(<apple>, <color>, <red>)`.

In this study, fill-in-the-blank quizzes are introduced to collect knowledge from many casual users; generally, the user is presented with a triple with one or two missing items. A piece of knowledge is collected when the user answers the quiz by filling in the blank. More specifically, when the user starts a game, a sentence with a blank is displayed along with the choices NEXT, SKIP, and END (Fig. 6.1). NEXT is for sending the user's answer to the server and requesting a new quiz. SKIP is pressed when the user does not know the answer to the quiz. When the user presses END, the quiz game ends.

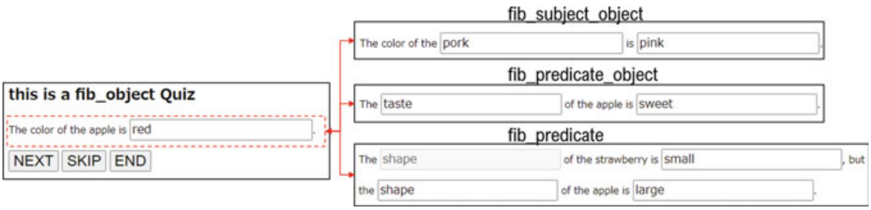

Fig. 6.1 Quiz game screenshots

6.3.2 Task Selection Method

When a quiz is presented to the user, the system must select a quiz that can contribute information missing from the knowledge base. It is also important to present a quiz that the user can answer; otherwise, the user simply skips the quiz without adding new triples.

To select the quiz, the following heuristics are adopted (Fig. 6.2). First, it is ensured that all object items for any pair of subject and predicate in the knowledge base are collected. If not, a proper subject–predicate pair is selected using a scoring function as described in detail below, and a *fib_object*-type quiz is created.

Since the target knowledge base is intended for use in the word retrieval assistant system whose goal is to guess a particular word, it is important that the word corresponding to the subject in the knowledge based can be distinguished. If there is an indistinguishable subject items, a new predicate needs to be collected from the user. For this, *fib_predicate* quiz is created. In addition, to add new subject items,

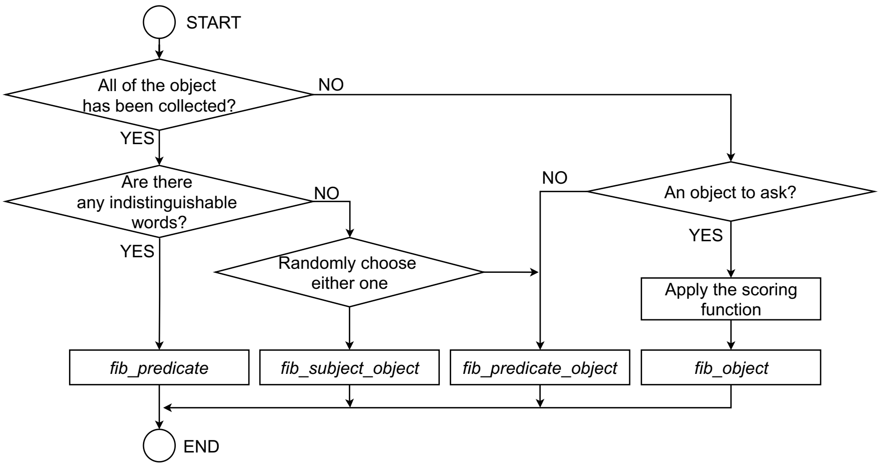

Fig. 6.2 The task selection flow

a *fib_subject_object* quiz is defined, which asks the user for a subject–object pair. Moreover, to add new predicate items, a *fib_predicate_object* quiz is defined to collect predicate–object pairs.

6.3.3 Scoring Function

For the *fib_object* quiz, it is necessary to select a proper subject–predicate pair. A scoring function for subject–predicate pairs is introduced, in which the pair with the highest score is selected. If there are multiple pairs with the same score, one is selected at random.

More formally, the scoring function is defined according to the following. Let $S_i (1 \leq i < n)$ be the subject item in the knowledge base and $P_j (1 \leq j < m)$ be the predicate item in the knowledge base. For user u_k, $c_{i,j,k}$ represents u_k's history, which is initialized to 0 and is updated according to

$$c_{i,j,k} \leftarrow \begin{cases} 1 & \text{when } u_k \text{ responds with NEXT for quiz } Q_{i,j} \\ -1 & \text{when } u_k \text{ responds with SKIP for quiz } Q_{i,j} \end{cases},$$

where $Q_{i,j}$ represents a quiz with subject S_i and predicate P_j. The value of $c_{i,j,k}$ indicates if user u_k knows information regarding S_i and P_j. Additionally, let b_i be the total number of missing object items for subject S_i.

Here, two types of scoring functions are defined for quiz $Q_{i,j}$ and user u_k: a function that does not predict the user's performance (*wo_pred*) and a function that includes a prediction (*w_pred*). For the *wo_pred* scoring function, only b_i is used.

$$SCORE_{wo\_pred}(Q_{i,j}, u_k) = b_i \ . \tag{6.1}$$

The quiz regarding S_i is selected if it has the greatest number of missing object items. Predicate P_j is randomly selected from the list of predicates without object items. The score is same for all users and is considered to be a baseline for the scoring function.

The other type of scoring function, which predicts the user's performance, (*w_pred*), is defined as

$$SCORE_{w\_pred}(Q_{i,j}, u_k) = \sum_{j=1}^{m} c_{i,j,k} + \sum_{i=1}^{n} c_{i,j,k} + b_i \ . \tag{6.2}$$

In this scoring function, user u_k's past history is considered. If u_k had previously answered quizzes with a subject S_i or predicate P_j, quizzes with these subjects or predicates will be given a higher priority.

6.3.4 Implementation

An early prototype system was implemented using the chat service LINE, which is popular in Japan and other countries. To handle multiple inputs from the user, the prototype uses the LINE Front-end Framework (LIFF),[1] which allows users to fill in multiple blanks in the form using smartphones.

To confirm that the prototype could be used to collect knowledge, a preliminary trial was conducted with a human user. In this trial, the system initially had only one subject item (*apple*) and one predicate item (*color*). Following the task selection flow explained above, the first quiz was a *fib_object* quiz that asked for the *color* of an *apple*. In this trial, 44 triples were obtained using 51 quizzes. This indicates that the proposed method can be used to collect knowledge.

6.4 Simulation Experiments

To examine the characteristics of the proposed knowledge collection method in a crowdsourcing setting, simulation experiments were performed in which a bot program operated as a virtual user in place of a human user, allowing the investigation of the behavior of the system under many users.

6.4.1 Simulation Model

It was assumed that there are M triples in the simulation. Initially, the system does not have any triples, but rather contains one subject item and one predicate item. It does not have a corresponding object item. Instead, virtual users are assumed to know M triples in total. The goal of the simulation was to confirm that the system could have M triples after the quiz games have been conducted.

The following two situations were defined to represent the distribution of knowledge:

- Omniscient user α: there is only one omniscient virtual user α that knows all M triples.
- User β_i $(1 \leq i \leq N)$: there are N virtual users, and the M triples are divided equally among the N virtual users.

In the simulations, N was set to 100 and M was set to 1200. Thus, in the multi-user scenario, each virtual user β_i has 12 triples. The number of subjects m was set to 300 and the number of predicates n was set to 4. One of the predicates contains information regarding the *genre* of the subject. When triples were divided among

[1] https://developers.line.biz/ja/docs/liff/.

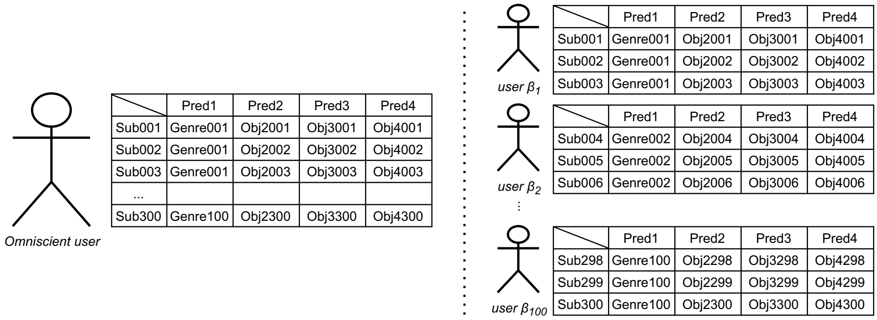

Fig. 6.3 Distribution of knowledge among virtual users for two scenarios

N virtual users, each user was supposed to have triples in the same *genre*. Figure 6.3 shows the distribution of knowledge in both scenarios.

User Model The bot program is a program that operates by receiving a quiz from the server, searching for a related triple, filling in the answer to the quiz, and sending it to the server. It is assumed that the virtual user adheres to the following rules:

- If the virtual user knows the answer to the quiz, it sends the correct answer by pressing the NEXT button. The virtual user does not withhold an answer or give a wrong answer.
- When the user has no corresponding triple for the quiz, SKIP is pressed.
- When the user has sent all the knowledge, END is pressed.

Simulation Rules The following rules were assumed for the simulation experiments.

- The simulation stops when all triples from all users have been collected.
- If the user returns SKIP for a quiz, that quiz will not be delivered to the user again.
- As described above, the server side is assumed to begin with only one subject item and one predicate item, and the object item is missing for this subject–predicate pair.

6.4.2 *Experimental Results*

To verify that the proposed method can be used to collect all triples from the virtual user(s), three cases were considered:

- An *omniscient user* where only one omniscient user α exists. The scoring function does not incorporate the user's performance prediction.
- *Without prediction* where there are user β_i $(1 \leq i \leq N)$, and the scoring function does not predict the user's performance (*wo_pred*).
- *With prediction* where there are user β_i $(1 \leq i \leq N)$, and the scoring function predicts the user's performance (*w_pred*).

Figure 6.4 shows the relationship between the number of quizzes sent and the number of triples acquired at the server for these three cases. For the *omniscient* case, all the triples were collected at the server using 1488 quizzes. When multiple virtual users were assumed, all triples were also collected. With the *wo_pred* scoring function 22,305 quizzes were used, while with the *w_pred* scoring function, 9334 quizzes were used.

To compare the effect of the user performance prediction, the simple metric of *quiz efficiency* (*QE*) was introduced, which is defined as the number of triples collected divided by the number of quizzes used. A larger *QE* indicates that the knowledge content can be collected more efficiently. *QE* was calculated for the three cases as shown in Table 6.1.

Figure 6.5 shows the breakdown of the responses from the users for the four quiz types. The most frequently used quiz type for triple collection was *fib_object*. It can be seen that the number of skipped *fib_object* quizzes had the greatest adverse effect on the triple collection among the four types of quizzes. Reducing the number of SKIP responses for *fib_object* quiz could effectively improve the collection efficiency of the triples.

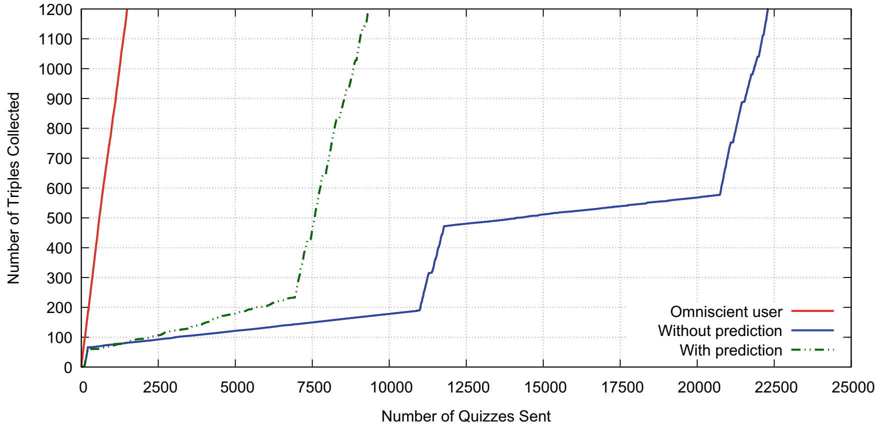

Fig. 6.4 Results of the simulation experiments

Table 6.1 *Quiz efficiency* (*QE*) for the three cases

	Omniscient user	Without prediction	With prediction
QE	0.806	0.054	0.129

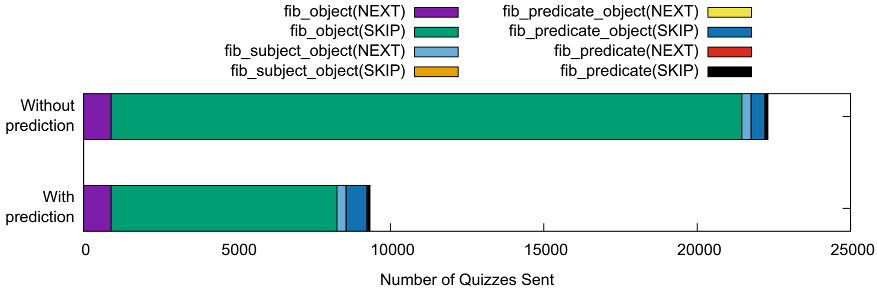

Fig. 6.5 Breakdown of the responses for each quiz type

6.4.3 Discussion

Simulation experiments were conducted to investigate the characteristics of the proposed method. For an *omniscient* virtual user who has all of the knowledge (triples), the system could acquire all the knowledge using all the four types of quizzes. When the triples are distributed over many virtual users, while the system can also collect all the triples from the virtual users, the efficiency is lower than for an *omniscient* virtual user.

As seen in the quiz number breakdown, the *fib_object*-type quiz had a large effect on the efficiency of triple acquisition. Therefore, if a *fib_object*-type quiz is not answered, this can adversely affect the collection of knowledge. By incorporating performance prediction according to the history of the virtual user using the *w_pred* scoring function, the system could more efficiently acquire knowledge as compared with a *wo_pred* scoring function, which incorporated no performance prediction. Since the number of SKIP responses occupies a large percentage for the *fib_object*-type quiz, there is room for further improvement.

6.5 Conclusion

In this paper, a task selection method was presented for crowdsourcing. Four types of fill-in-the-blank quizzes were created as tasks to acquire knowledge from casual users. A simple user model was created and simulation experiments were conducted to verify that knowledge could be obtained from many users. Furthermore, to acquire knowledge more efficiently from many users who have different knowledge backgrounds, a method was proposed for selecting the quiz for each user according to a user's past performance. The results of simulation experiment indicate that the proposed method can improve the efficiency of knowledge acquisition.

The future introduction of other types of gamification elements into the proposed method is planned to increase the efficiency of user input. For example, the use of true-or-false quizzes has been experimented with to verify the acquired knowledge [16]. Further studies should integrate other types of quizzes into the system and predict user performance more precisely based on the results of various types of quizzes.

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Chapter 7
Detection of Asynchronous Concatenation Emergent Behaviour in Multi-Agent Systems

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Abstract Multi-Agent Systems (MASs) use collective agents to attain a common goal. However, the implementation of MASs may present a potential for failure caused by the system's unexpected behaviours, known as Emergent Behaviours (EBs) or Implied Scenarios (ISs). The early assessment of these behaviours in the development life cycle can reduce the cost, effort and maintenance time and contribute to the sustainability of the process. To detect EBs implied by the Asynchronous Concatenation (AC) of scenarios, we verify that the agents' interactions are compliant with the system specifications. The proposed methodology allows automatic detection of EBs by the direct analysis of scenario-based specifications. Moreover, this methodology allows the anticipated correction of EBs and can potentially support the development of MASs. We studied the validity of this methodology by adopting a formerly published model and a pattern mining technique to prove the existence of the EBs detected by our approach in the runtime. The results show that our methodology outperforms those in previous related works in the detection of AC EBs.

7.1 Introduction

An MAS is inherently a Distributed Software System (DSS) composed of a set of agents [1]. Analyzing the scenario-based specifications to find property violations helps minimize the vulnerability of MASs (e.g. decentralized control, transmission

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delays and asynchronous communications) to the generation of EBs [2]. Verifying these systems for the exhibition of EBs is more valuable in the early phases of system development.

Among the various types of EBs, identified in previous research [3, 4], we name the EBs by the AC of the scenarios. The AC of scenarios is more difficult to design and analyse, despite being more natural to the nature of MASs compared to Synchronous Concatenation (SC). The AC of scenarios is the concatenation of scenarios along lifelines. Consequently, the agent may follow another path other than the path defined by its high-level structural interaction diagram.

In this work, we propose a new approach for detecting EBs issued from the AC of the scenarios. We also implement an automatic detection tool to provide visual and textual support for the stakeholder and the designer to verify the MAS's behaviours. This approach allows correcting the design effectively or handling it in later phases and improving the software endurance by identifying characteristics that can lead to EBs. Moreover, the proposed methodology sustains the implementation of new MASs and improves the reusability of applications.

The rest of this paper is organized as follows: in Sect. 7.2, we discuss related work; in Sect. 7.3, we describe our methodology; in Sect. 7.4, we present a detailed analysis of the study case used throughout the paper and compare our approach with existing ones. In addition, a runtime verification is conducted to show the efficiency of our methodology. After discussing the obtained results in Sect. 7.5, we conclude this paper with a discussion on future work.

7.2 Related Work

Scenario-based specifications are essential in the design of MASs and DSSs. They propose a visual and intuitive description of the system requirements. Among the communication paradigms based on messages, we name Message Sequence Charts (MSCs) and sequence diagrams [5]. Both diagrams present the message communication between the entities of the system (agents). The high-level MSC (hMSC) visually displays the relation between the MSCs. It gives the order in which the MSCs occur and helps keep track of the expected flow of execution of the MSCs contained [6].

According to the hMSC, the assembly of MSCs could be synchronous or asynchronous. In SC, all events in the scenario must be finished before any event in the next scenario may be executed. However, this concatenation results in an impractical scenario collection, especially in DSSs and MASs [7]. AC implies that assembly is done along a lifeline. Therefore, AC demands that all the events of an agent in an MSC have to be terminated before starting the execution of its events in the successor MSC [8]. In this work, we consider the AC of the scenarios. The unexpected behaviour resulting from the execution of the scenarios at different times by processes is regarded as a potential IS.

Pan et al. [9] focused on analysing MSCs with AC considering the timing. The research aims at the detection of reachability and bounded delay problems. The analysis checks if the behaviour of the MSC is within a specified time interval. This approach may require expert knowledge to define the delay constraint for the verification. Contrary, we opted to analyse the scenario-based specifications independently from the language and technology used as a first verification step.

Fard et al. [10] considered the detection of AC by detecting the high-level scenario of the component that does not have the same branching as the system's high-level structure. To detect the branches that may cause EBs, scenarios are converted to matrices, then the matrices are visualized in the form of a graph, and finally, EBs are detected. This approach could not identify the cause of EBs in the system-level analysis. Instead, the visualization can lead to the detection of agents with higher betweenness centrality. These agents should be considered for further analysis.

While the existing works addressed the detection of AC EBs, further investigation of the results is required to understand the cause of EBs. In the following, we present a novel approach for detecting EBs caused by AC.

7.3 Methodology

7.3.1 Rationale and Problem Formulation

According to the definition of an AC, if an MSC $M1$ proceeds an MSC $M2$ based on system's hMSC, a process may proceed to the next scenario $M2$, while other processes may still be involved in $M1$. When a process does not wait for other processes to finish their execution according to the specification, a new path between two MSCs can be implied. This implied path is considered as potential AC EB if it does not conform to the hMSC. These unintended behaviours may lead to costly and irreversible damages.

The hMSC maps the sequence of transitions between n finite scenarios MSCs. A feasible path is a traceable path from a start scenario MSC_i to an end scenario MSC_{i+l} with respect to the system hMSC, such that MSC_i precedes MSC_{i+l}. Each scenario of MSCs presents the sequence of interaction between agents $\{a_1, a_2, \ldots_m\}$. If agent a_i has interactions in MSC_i, if it is an active agent in MSC_{i+l} (l >1), and if it is in a ready state in MSC_k (0 < k < l), a new path $MSC_i \rightarrow MSC_{i+l}$, which is infeasible according to the system hMSC, is implied.

The aim of this research is the detection of potential AC EBs in the scenario-based specifications. Our proposed methodology will allow software developers to make an accurate decision before implementing an MAS. It considers the detection of EBs directly from studying the information used to build the interaction diagrams. Thus, transforming the scenarios to intermediate modelling for analysis (e.g. Message Sequence Graph or Graph Neural Networks) is not required. Additionally, this methodology is message-independent, which enhances system scalability. Moreover, modifying the system specification does not require much time or restarting the analysis from scratch.

7.3.2 Proposed Methodology

Our approach allows the detection of AC EB in DSSs and MASs. While a process performs its actions in a scenario, another process may finish its actions in the current scenario and start interacting in the next scenario. This order of execution may lead to a new sequence of events that do not conform to the system specifications. The collaboration between the MAS's agents could be synchronous or asynchronous.

Figure 7.1 presents a sample case study. On the left side of Fig. 7.1, the hMSC shows the relation between the MSCs. The right side of the figure shows the interactions between the agents in each MSC. After sending the message $m1$, the agent A proceeds to execute its next action by sending the message $m5$. Thus, skipping the execution of the scenario $MSC2$. This change in the order of execution of the scenarios may lead to two possible scenarios: (1) The system resumes its interaction in the $MSC1$ and then $MSC2$, (2) The system continues its actions in the $MSC3$ when the agent B sends the message $m6$ after receiving the message $m5$. In asynchronous communication, the system may start with the execution of the $MSC2$. In $MSC2$, the C agent is an active process, whereas it is only a receiver in the $MSC1$. This order of execution of the scenarios does not conform to the hMSC.

The algorithm for the detection of AC EB is outlined in algorithm 1.[1] To reduce the computational complexity, we extract the active processes list in each scenario using `GetActiveComponents(interaction_diagrams)`. An active process is an independent process that initiates the execution of the scenario by sending a message to another process. For each of the detected active components, we extract scenarios where the agent is in a ready state using `GetReady(C)`. In a synchronous system, we refer to a process to be in a ready state when it has no interaction within the scenario. However, in an asynchronous system, the component is ready when it has no interaction within the scenario, or it is playing only the receiver's role in the interactions involved within the scenario. For each identified scenario where the component has no communication, we analyse the successor and the precedent scenarios for detecting the IS. `GetPredecessors(S)` returns the list of scenarios precedent to the component's ready state, where the component is interacting. The implied path is the combination of the predecessors and successors. The function `InfeasiblePath()` returns true if the implied path is infeasible according to the system's hMSC. Only infeasible paths are reported as AC EBs.

[1] Due to the space limit, `end-if` and `end-for` statements are removed from the pseudo-code.

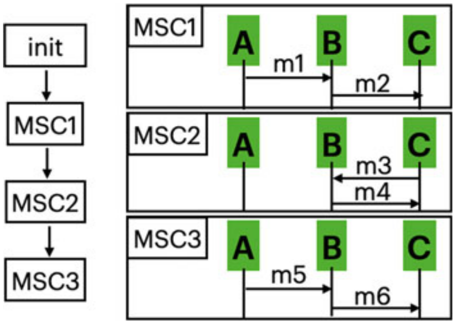

Fig. 7.1 MSCs and hMSC of a sample system

A scenario may have one or multiple successor scenarios, depending on the high-level structure (hMSC). Suppose the component under analysis is active in the successor scenario, and the implied path is infeasible, in this case, it is reported as an AC IS. Active components are not dependent on the scenarios that they are not part of and can start the next scenario without waiting for other processes to finish. The implied path is the concatenation of the antecedent and the subsequent to the scenario under analysis (e.g. the process is on the ready state). Moreover, the system could follow other implied paths as a consequence of the EB (e.g. returning to the previous scenario to finish the execution of other processes). Suppose that there are three scenarios MSC_1, MSC_2 and MSC_3 and a component C. As C is in a ready state in the MSC_2 and active in MSC_3, the implied paths could be $MSC_1 \rightarrow MSC_3$, $MSC_1 \rightarrow MSC_3 \rightarrow MSC_2$ or $MSC_1 \rightarrow MSC_3 \rightarrow MSC_1$. The latter path is only implied if the $MSC1$ has more than one message.

Algorithm 1: AC EB detection algorithm

Input: Interaction diagrams, hMSC
Output: AC EB
Components$_{active}$ $\longleftarrow$ **GetActiveComponents(interaction_diagrams)**
for each $\mathtt{C}$ **in Components**$_{active}$
  scenarios $\longleftarrow$ **GetReady(**$\mathtt{C}$**)**
  for each scenario $\mathcal{S}$ **in scenarios**
    successors $\longleftarrow$ **GetSuccessors(**$\mathcal{S}$**)**
    predecessors $\longleftarrow$ **GetPredecessors(**$\mathcal{S}$**)**
    for each successor $\mathcal{SUC}$ **in Successors**
      if IsActive($\mathtt{C}$, $\mathcal{SUC}$**)**
        for each predecessor $\mathcal{PREC}$ **in predecessors**
          if InfeasiblePath($\mathcal{PREC}$, $\mathcal{SUC}$**)**
            report an AC IS

7.4 Experimental Evaluation

7.4.1 Case Study Analysis

The specification of the Boiler Control System is described in [10]. The analysis of the case study using our methodology depicts four EBs and seven ISs as a result of the AC of the MSCs. We will refer to EBs caused by the AC of scenarios and subsequent implied behaviours by IS.

As shown in Fig. 7.2, the component *Control* has no interactions in the scenario *Register*, whereas it is an active process in the successor scenarios *Stop* and *Analysis*. The component *Control* may proceed with its execution from the scenario *Initialise* to either *Stop* or *Analysis* scenarios and from *Analysis* to *Analysis* or *Stop* causing four EBs. These EBs may create subsequent ISs during the runtime (e.g. resuming the skipped scenario's execution and then the implied path *Analysis-Stop* conducts to the IS *Stop-Register*).

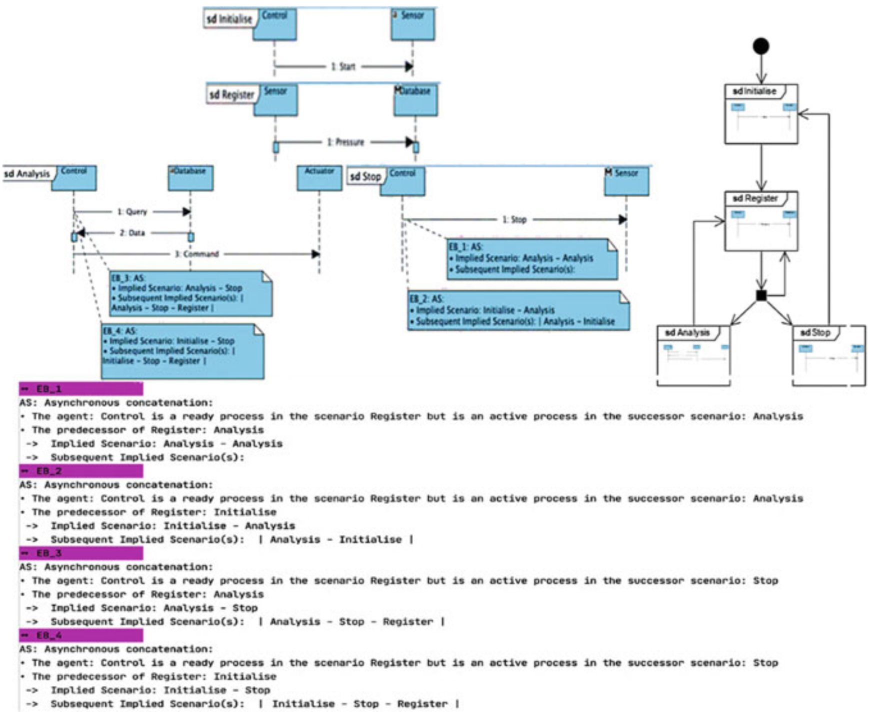

Fig. 7.2 Implied scenarios detected in the boiler control system, assuming synchronous communication

Additionally, the component *Sensor* has no interaction in the scenario *Analysis*, whereas it is active in the scenario *Register*. This condition may cause a loop for the scenario *Register*. However, the implied path is a feasible path, according to the hMSC. Thus, this case was not reported as an EB in our analysis.

Considering asynchronous communication, the case study's analysis reveals five EBs and a total of nine potential ISs. In addition to the EBs detected in synchronous communication, the component *Sensor* may initiate the system's execution. This component is an active component in the $MSC2$, and the start of its actions is independent of the precedent scenarios.

The presence of loops in the hMSC may also be the cause of EBs if not controlled appropriately. The loop can be executed more than once by one of the agents, whereas another agent performs its actions in the successor MSC.

Other types of EBs (e.g. non-local branching EBs) were also detected but not reported. The detection of these types of EBs is not within the scope of this paper. In our work, we adopted the classification of the EBs according to the catalogue presented in [11].

7.4.2 Comparative Study

In this section, we aim to compare the number of ISs detected using our methodology versus those detected by related work methodologies. For this comparison, we chose the works of Fard [11] and De Melo et al. [12]. Fard considered the detection of the same type of EB studied in this work whereas De Melo et al. classified the ISs in common behaviours from which we can extract the occurrence of AC EBs. The number of common behaviours detected by De Melo et al. [12] is shown between parentheses in Table 7.1. These approaches assume synchronous communications in MSCs.

From the results presented in Table 7.1, we were able to detect more EBs caused by the AC of scenarios than other approaches.

Table 7.1 The # of ISs detected in each case study—the total number of ISs is given between parentheses

Case studies/Approaches	Our approach	Fard [10]	De Melo [12]
Boiler control system [10]	4 (7)	4	2 (2)
GSM mobility management [13]	4 (8)	4	3 (16)
Passenger transportation system [14]	23 (28)	6	N/A

7.4.3 Dynamic Verification

In this section, we opt for the dynamic verification of the Boiler Control System. The system traces analysis will allow the analysis of the system's behavioural aspects in runtime and check conformance to the system's specifications.

The workflow presented in Fig. 7.3 presents the performed steps towards the dynamic verification of our methodology. To prove our methodology's correctness, we check the relation between the expected system behaviour according to the system modelling ($Data$) and the expected behaviour according to other hypotheses (e.g. $H1$, $H2$, etc.) by the adoption of Hyptrails [15]. This model is a first-order Markov chain model with Bayesian inference. The idea is to express hypotheses and compare their plausibility to get an ordered ranking given the data. The Markov Model allows us to model the relationship between the system scenarios. In our study, a first-order Markov chain model is used because the transition to the next state (scenario) is based on the current state.

Four hypotheses are proposed: (1) H_1 assumes that the system runs according to its hMSC, (2) H_2 corresponds to the assumption that the system shows some unwanted behaviours in addition to its expected behaviours and obtained by applying our methodology, (3) $H3$ assumes that in the presence of loops, the system may re-execute the same scenario infinitely and (4) the self-loop hypothesis H_4 supposes that the system stays in the same state in the loop.

To simulate the system, we used the Java Agent Development Framework (JADE) [16]—an open-source software framework that simplifies the implementation of

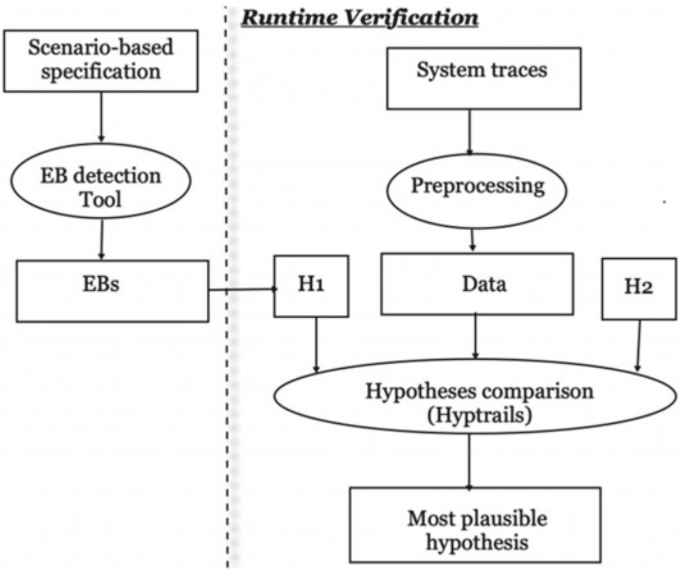

Fig. 7.3 Dynamic verification workflow

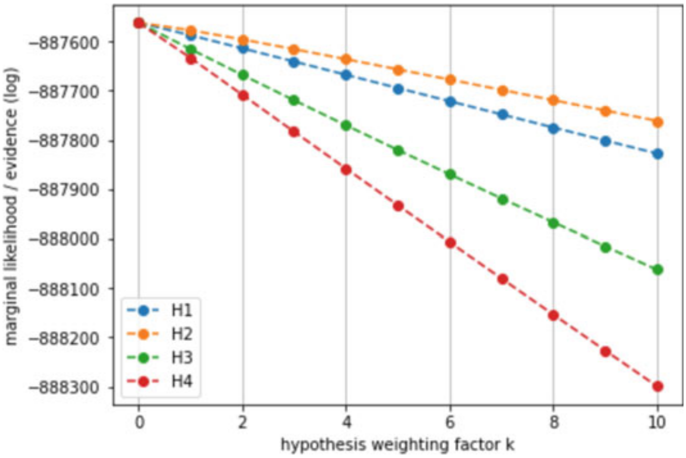

Fig. 7.4 Results of comparing hypothesis using hyptrails

multi-agent systems. The system is implemented according to the scenario-based specifications. This simulation aims to trace the system behaviour.

The trace of the system behaviour is transformed into a set of events (i.e. the path between the MSCs according to the hMSC), and it is used to fit the Markov chain model. In this case, the event is extracted based on the order of execution of the scenarios. We generated the data for H_1 and H_2 through a random walk on the corresponding networks to compare the different hypotheses. The generated data and the data obtained from the system's simulation are processed to have the same structure. The objective behind this analysis is to retrieve the relation between the MSCs. Thus, we applied a sliding window of two scenarios (Source and Target) on the data.

Comparing the hypothesis using different concentrations (e.g. parameter k), we obtained the results presented in Fig. 7.4. The parameter k presents the level of belief in given hypotheses. The x-axis corresponds to the hypotheses weighting factor k, whereas the y-axis reports the evidence. The more plausible hypothesis is the one with stronger evidence for the same values of k. As shown in Fig. 7.4, our work resulted in the most plausible hypothesis.

Moreover, to verify our methodology's completeness, we analysed the system trace using a pattern mining technique. As we are interested in the transition between the system's scenarios to verify its conformance to the system's high-level structure, we applied a sliding window of width two over data. Then, we applied a closed contiguous sequential patterns CCSpan on the system tracing to detect the system's recurrent behaviour. In Fig. 7.5, the graph network shows the transition between the scenarios based on the common patterns detected in the tracing. The red arrows accentuate AC EBs existing in the tracing. Comparing the outcomes of this analysis and the analysis of the scenario-based specifications in the previous section shows

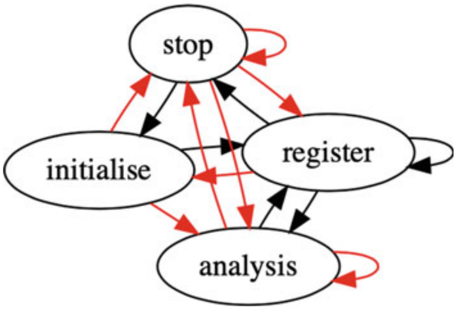

Fig. 7.5 Network graph presenting the boiler control system behaviours based on sequential pattern mining analysis

that the EBs detected using our methodology are included in the common pattern detected in the system tracing, which supports our methodology's validity.

The Boiler Control System analysis showed that the component $Sensor$ may initiate the system execution. To test the correctness of this hypothesis, we collected the traces of 20 different runtimes. MASs may execute differently in each runtime and, thus, are the collected traces. The results show that the component $Sensor$ initiates the system execution in $MSC2$ at a rate of 50%.

7.5 Discussion

This study shows that the interactions between the system components in MASs can exhibit complex system behaviours, which do not conform to the scenario-based specifications. Assuming synchronous communication between the system components, we detected more EBs than related works. The analysis of the system assuming an asynchronous communication transmission shows more EBs in some case studies. Based on these results, we opted to test our analysis's accuracy by comparing it to the runtime system's behaviours.

Through the simulation of the case study, we demonstrated the validity of our approach using dynamic analysis. By comparing the hypothesis using the Hyptrails model, the results showed that the hypothesis H_1 assuming the system behaves according to the results obtained by our analysis is the most plausible. Also, the system traces analysis shows that the EB's support is less than the support of the system's proper behaviour. These results confirm the theory that EBs are unexpected behaviours that may or may not appear in the system's execution. Other unexpected behaviours were also detected using this technique. These potentially unwanted behaviours may be the results of other types of EBs not covered by this article. Thus, we will investigate the cause of the appearance of these behaviours in future work. Among the advantages of our methodology is that it depicts the IS's cause, contrary to other approaches that demand the investigation of the cause of the detected ISs. The occurrence of an EB may imply the occurrence of other ISs. Thus, avoiding the EB in runtime allows us to avoid all possible subsequent and unwanted execution paths. As our proposed tool implemented the depicted methodology to show all the ISs, it assists designers in making decisions on whether to ignore or avoid the erroneous ISs in runtime.

7.6 Conclusion and Future Work

In this work, we have proposed an efficient and accurate approach to predict the potential failure of MASs based on scenario-based specifications. This approach provides the designer and the software engineer with details about the cause of the ISs early in the design process. Moreover, it can be used in large-scale software specifications iteratively and without requiring prior expert knowledge of a specification language. This makes the decision-making based on our analysis results on implementing more reliable software quality and at a lower cost.

This approach also facilitates dealing with EBs as it groups ISs caused by a specific condition. Thus, eliminating the source of EBs implies the elimination of subsequent ISs. It is the designer and the stakeholder's decision to eliminate the IS and in which phase of the software development.

The proposed solution to AC EBs is to add extra information into the successor interactions to each scenario where the component may be the source of an IS. A condition on the first interaction of the scenario based on this information will trigger the execution of the process in the correct scenario. Adding the control on the starting of the MSC may prevent this issue by limiting the process action on when to proceed to another MSC. Also, the proper use of blocking and waiting functions can solve this issue.

We are currently working on extending this methodology to detect more EBs in the component and the system level (e.g. race condition, and non-local branching). Moreover, considering the detected cause of potential EBs for testing purposes would be efficient in preventing unwanted behaviours in runtime.

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Chapter 8
A Mobile Agent-Based Framework to Monitor and Manage Interoperability of C-ITS Services in Vehicles

Ameni Aloui, Hela Hachicha, and Ezzeddine Zagrouba

Abstract Cooperative Intelligent Transport Systems (C-ITSs) aim to improve safety, traffic efficiency, energy efficiency, and comfort. The C-ITS uses technology to allow vehicles to communicate with each other and with roadside infrastructure. C-ITS services generate and use local information shared by vehicles and infrastructures to improve transport systems, to increase energy efficiency and road safety. Development and deployment of C-ITS services for fixed and mobile components and for road users are not linked and each service provides independent information. However, these C-ITS services need interoperability to have visibility to all system and then to take the right decision and to be monitored and controlled. In this paper, we propose a mobile agent-based framework to deploy C-ITS applications in fixed components (roadside infrastructure) in order to monitor and manage C-ITS services' interoperability in mobile components (vehicles). This framework aims to allow the linking between some C-ITS services and then to allow the management of local information collected and generated by deployed C-ITS services. An example of a safety C-ITS services scenario is illustrated to show the usefulness of the proposed framework.

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8.1 Introduction

Over the last years, advanced digital technologies have progress and they are integrated into transport to provide intelligence to the road infrastructures, vehicles, and to other road users. Intelligent Transport System (ITS) is a technology, application, or platform for improving the quality of transportation based on applications in different domains [7] that monitor, manage or enhance transportation systems. Cooperative Intelligent Transport System (C-ITS) refers to transport systems, where the cooperation between two or more ITS sub-systems (personal, vehicle, roadside, and central) enables and provides an ITS service [9] that offers better quality and an enhanced service level, compared to the same ITS service provided by only one of the ITS sub-systems [19].

In recent decades, Cooperative Intelligent Transportation Systems (C-ITSs) have been developed and deployed to improve transportation security and mobility, reduce environmental impact, promote transportation development, and improve productivity. C-ITS combines high technology and improvements in information systems, communication, sensors, controllers, and advanced mathematical methods with the classical world of transport infrastructure. C-ITS focuses on the communication between vehicle with another vehicle, with the infrastructure, or with other C-ITS systems. Then, each of these components equipped with C-ITS can exchange real-time information with others (such as weather change [20], accident, congestion [10], and traffic situation).

C-ITS is based on Information and Communication Technologies (ICTs) [12, 14], such as sensor technology, telecommunications, information processing, and control technology. Since some years, many works have proposed applications, platforms [16], frameworks [6] to develop transport applications such as [13, 17, 19]. Recently, some works and projects such as SAFESPOT [22], C-Mobile [25] have focused on C-ITS services [21]. For example, the SAFESPOT project [22] is interested in the vehicle part only, CVIS [23] is interested in the infrastructure part, on the other hand, the FREILOT [24] project takes an interest in the transport of goods and offers services. Since 2016, the concept of interoperability has been of great interest to all projects and the idea of C-ITS services began to be deployed in 2017 and to be tested in different countries in Europe (9 countries) to combine all the services offered in old projects, possibly adding new services and consequently other new C-ITS services can be developed over years.

Development and deployment of C-ITS services in ITS sub-system are promising solutions; however, in our point of view, it is also very important and beneficial to monitor to manage all local information of these services. In fact, in some situations and conditions, when an entity (driver, authority center, user, etc.) needs to make a decision it needs to manage all information. Also some entities (authority center, base station) need to monitor the system based on all information. Then, we judge that manage the interoperability between some C-ITS services in the same ITS sub-system will make the decision more efficient and monitoring of the system more easier.

Harmonization and interoperability of C-ITS services require an effective compliance assessment framework that allows services to be checked against. In order to address this challenge, and therefore, in order to enable large-scale and interoperable C-ITS services, we propose to define a mobile agent-based framework. This framework allows managing local information of different C-ITS services in the same ITS sub-system. Also, this framework allows monitoring C-ITS services.

In this paper, we are interested to manage and monitor C-ITS services in mobile components (vehicles).

This paper is organized as follows: the first part concerns a small summary drawn up following an in-depth review studied. The second part is devoted to present related works' discussions and some limits. The third part presents our proposed work in the form of a generic approach based on mobile agent technology for cooperative systems (C-ITS) to manage and monitor the interoperability of C-ITS services. Then, we present our simulation to validate our approach. The last part at which we will present our summary of this paper with perspectives that we aim to achieve in our next work.

8.2 Related Works

In the literature, there is a lot of research that involves the Multi-Agent System (MAS) paradigm in the transport domain, more specifically in C-ITS systems. Since mobile agents are considered to be a MAS technology, their incorporation into intelligent transport systems presents an improved outcome in a complex, uncertain, and dynamic system. In this context, the work of [1] has exploited this technology within the framework of a hierarchical approach that combines stationary agents and mobile agents. In order to manage unexpected conditions or unforeseen events which in some way disrupt the flow of traffic and consequently cause congestion in the route, the authors have employed new algorithms and control operations. In [18] the authors proposed an abstract architecture that includes all the components of C-ITS, the physical components, the stationary agent component, and the domain component which are interconnected. The C-ITS system is considered as a subset of mobile agents intended to perform different tasks of the proposed abstract architecture. In addition, [26] proposed a network architecture composed of three levels including a two-layer agent architecture. This work is based on vehicle clusters in the first level. The second level concerns the grouping of its clusters by establishing communication between them. This communication takes place through the base stations. The third level is intended to control the infrastructures and offer on-demand services for vehicles by the road. In this context, the domain of Cooperative Intelligent Transport System (C-ITS) has been developed in many countries and recently it aims to deploy sustainable services in all road categories. The benefits of having vehicles and infrastructure share data are many, and offer huge potential for improving traffic safety, reducing congestion, reducing fuel consumption, and improving the overall comfort and ease of driving. On the other hand, the approach of [27] integrates the BDI agents to model the behavior of the driver and control it.

8.3 Discussion

In the literature, few research works have proposed mobile agent technology in cooperative transport systems within the framework of a generic approach which can, in turn, be instantiated on any application of C-ITS. Besides, the integration of BDI agent is very expensive in terms of execution time. We notice eventually that many works have proposed to develop, deploy and, execute C-ITS applications in vehicle.

According to our studies, we think that these C-ITS applications are not linked and are not interoperable and each application provides an independent information as [4, 5, 8, 15]. Therefore, it is the responsibility of the driver to manage the received information to make the best decision. As an example, an application which indicates to the vehicle the speed limits, but if this application should be interoperable with the accident management application or congestion application thereby informing the driver and vehicle of the appropriate speed for the accident or congestion condition. Also, we notice these deployed applications are not monitored and just communicate the vehicle the needed information or decision. For example, an application that indicates to the driver the speed limit to be respected in the current road in order to avoid accident or congestion [10]. However, it is also important to control driver behavior and to apply the law if he did respect the rules of this current road or not.

In our point of view, it would be especially beneficial if these applications should be linked and exchange information. In fact, these C-ITS applications must be harmonized and interoperable in order to have large information and allow the driver to make the best decision, perform the good choice and to facilitate the control of traffic and therefore to improve the safety.

In order to facilitate the monitoring and the interoperability of C-ITS applications, we propose to develop a framework based on mobile agents and VANET technologies. This framework takes care to apply the rules of the current road and allow to manage all information in order to facilitate the driver to have the best decisions.

8.4 Proposed Framework

8.4.1 Consideration

In our research, we assume that each ITS sub-system either vehicles or road-side infrastructure (fixed and mobile components) must be equipped with C-ITS services and can exchange real-time information with other ITS sub-system (such as weather change, accident, congestion, and traffic situation). These C-ITS services generate local information (about speed, weather, works, etc.), use the information received by another C-ITS sub-system, or generated by another C-ITS services. Then, it is very important to manage and monitor all local information.

In fact, manage local information of C-ITS services helps the driver to take the right decision and adapt to the traffic situation. Also, monitoring of C-ITS services helps to control the behavior of the driver during his travel and be sure if he respects the policies and guidelines defined to the appropriate road. We propose a framework to manage C-ITS services information in road-side infrastructure to allow interoperability of C-ITS services in vehicles and offer some finalities, such as:

- Assist driver to choose the best itinerary according to different situations: weather, congestion, works, accident, …
- Assist driver to choose the best speed limit according to different situations: weather, congestion, works, accident, …
- Assist driver to choose the best parking place
- Control driver behavior in travel (accident made, speed limits, non-respect of traffic …)

8.4.2 Proposed C-ITS Architecture

Based on the results of various studies and projects [22–25], C-ITS system is structured on hierarchical architecture and implies a set of components, which are authority center, agency (base station), and urban road. Like the existing work [1, 2, 11, 16], we consider our system is composed of three layers: layer 1 (authority center), layer 2 (Base station), and layer 3 (urban road). The complex systems rely on recent advances in communication and information technology to improve the flow of traffic flow. In addition, the road infrastructure as a base station (layer 2) is shared by connected and unconnected vehicles of the urban road (layer3). Connected vehicles via a wireless communication protocol, exchange information between them via the On-Board Units (OBUs) (Vehicle to Vehicle—V2V) and with the infrastructure (Infrastructure to Vehicle—I2V and Vehicle to Infrastructure—V2I). In the C-ITS, the control units on the infrastructure side, called Roadside Units (RSUs), have the role of collecting data on their dedicated section. More than simple information relays, an RSU can also play the role of a decentralized traffic regulation unit by propagating instructions to vehicles connected by I2V communication. The authority center represents the central system that manages all traffic applications. The base station represents the infrastructure of the route which manages and monitors all the components of the roads (vehicles) and transmits general information of the traffic such as (warnings and weather changes …). The urban Road is composed of mobile components (vehicles). These vehicles are equipped with various sensors to detect warnings, for example, from the base station and to offer it information such as speed and itinerary …

In our framework, we propose that the urban road is structured as a set of clusters. Each cluster can contain fixed components hosting such as traffic lights, billboards (equipped with Road Side Units, RSUs) and mobile components hosting such as vehicles, buses, trams (equipped with On-Board Units, OBUs). Communication of static and mobile components is based on VANET technology. Mobile and fixed components represent an ITS sub-system.

We consider also that each cluster is delimited with a number of specific fixed components that define its allocated space, called Road Parent. The Road Parent represents the first encountered roadside infrastructure when a vehicle enters into the cluster. The number of Road parent represents the number of the entering way of vehicles. For example, if in a cluster, we have three enter way; the cluster has three Road Parent.

Each way of a cluster must be managed by a Road Parent. When a new vehicle enter, this Road Parent is responsible to detect this vehicle and responsible to manage all information during its travel in the cluster. When a vehicle exits cluster, the Road Parent is responsible to detect this vehicle to unsubscribe it, and, in order to collect all information managed by this vehicle during its travel (accident made, speed, light, …) (Fig. 8.1).

Each Road Parent in a cluster must deploy a set of C-ITS services and each mobile component (vehicles) entered in a cluster must subscribe these C-ITS services. Then, the Road Parent in a cluster is responsible to centralize and manage C-ITS services information and it acts as responsible to transfer these information and notify all related mobile components.

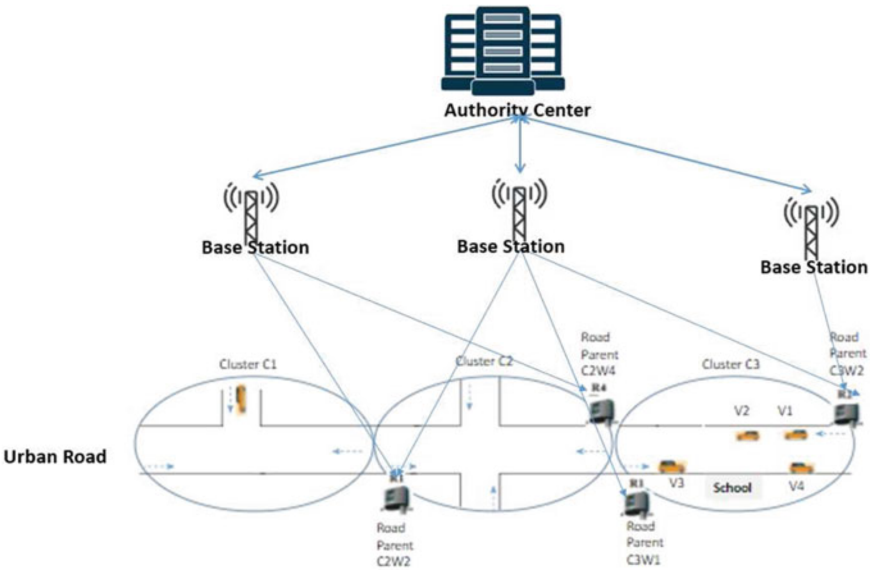

Fig. 8.1 Proposed structure of urban road

Each vehicle in the cluster acts as a transmitter and receiver and delivers the information to the responsible Road Parent through RSU and OBU. The figure (Fig. 8.1) illustrates an example of the proposed architecture. In this example, we have three clusters. The cluster C3 as an example has two way to enter a new vehicle, and then we have two Road Parent R1 and R2. R2 of C3 is responsible to manage enter of new vehicles (V1 and V2) and manage the exit of vehicle V4.

Each cluster has its specificity and policies to apply and which should be respected by vehicles. For example, if in a cluster the road contains a school or residential quarter this can affect speed. Also, if the road in the cluster contains work, this can affect speed, congestion, accident. … So, the policies and guidelines of each cluster can be updated depending on the events which can be occurred. The event which occurs in the cluster can also affect other clusters and, then the neighbor's clusters must take a good decision in real-time.

When a vehicle enters a cluster, this vehicle must respect the different policies and guidelines defined by this cluster. Therefore, in our framework, we propose that when a new vehicle enters a new cluster, the responsible Road Parent must monitor and control the behavior of the driver during travel in this cluster. These policies in the cluster can be adapted and updated according to new events.

Also, when vehicles exit from a cluster, the road parent must be informed in order to collect data from the vehicles before passing to another cluster.

The other road infrastructure (light, camera, …) helps to detect real-time information and transfer it to the near road parent or vehicles.

8.4.3 Proposed Agent-Based Framework

In our framework, we assume that each ITS sub-system (fixed components, mobile components) is equipped with an Agent Platform and each component must deploy a set of C-ITS services (such as detect speed, weather conditions and road works, …). In this paper, we are interested to monitor and manage C-its services in vehicles by fixed components.

Our framework is based on stationary and mobile agents (Fig. 8.2). We propose that each Road Parent contains a set of stationary agents in order to manage subscription and un-subscription of mobile components, to manage all received information, to broadcast important information to components, and to manage all policies and guidelines related to the current cluster. In addition, these stationary agents are responsible to manage communication between different layers of the system.

We propose that each Road Parent contains a mobile agent (Called RAP) which is sent by the base station to deploy C-ITS applications that manage and monitor the interoperability of C-ITS services in vehicles. Also, this RAP must guide and assist the driver and control the behavior of this vehicle in the road cluster.

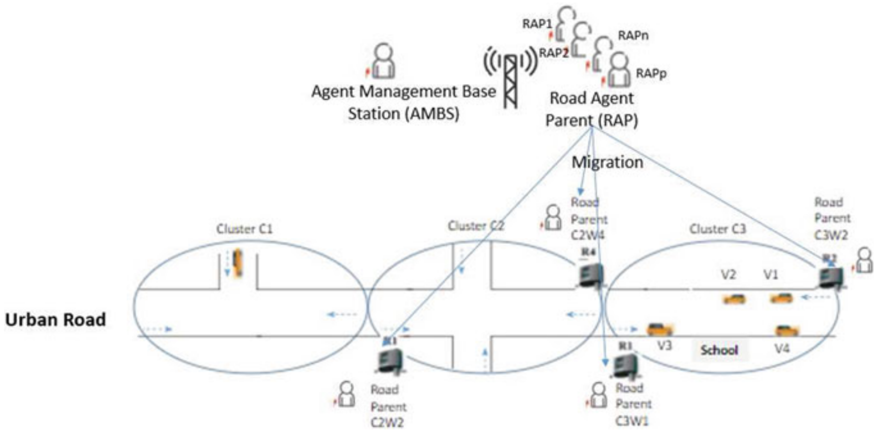

Fig. 8.2 Agent-based framework

8.5 Simulation

In order to implement our system, we decide to use the SUMO traffic simulator [28] to represent the road network with the vehicle and the traffic control (physical) infrastructure. In order to represent the multi-agent systems, we opted for the JADE platform [29] which implements the agents. Figure 8.3 presents the prototype that we have developed in the Eclipse environment.

In this prototype, the Infrastructure package (Fig. 8.3) is considered as a set of C-ITS applications that offer a set of C-ITS services in the Road Parent. In this paper, we have developed the C-ITS application which detects and controls the speed limit of vehicles in a given cluster.

The SumoSimulation package (Fig. 8.3) refers to the project that we have developed to simulate the road network. We have chosen an extract of a real part of the road (Fig. 8.4). This project consists of a set of applications and each of them offers some C-ITS services. These C-ITS services represent the generated data from the road (such as the identifiers of each vehicle, their speed, their position, accident, distance, and congestion, …). In this paper, we focus on the application that offers data on vehicle's speed during the current road.

In our prototype, we have created two containers in the JADE platform (Fig. 8.5). The Base Station container in which we have defined two agents, respectively, the stationary agent Agent Manager Base Station (AMBS) and the mobile agent RAP (Road Agent Parent). The agent AMBS has the knowledge of the control logic to be applied in each cluster of road (speed control logic, distance control logic, accident control logic, …). The AMBS agent is responsible for creating the RAP, append it to this logic, and request it to deploy this C-ITS application in Road Parent. The AMBS is in charge also of sending RAP to the Road Parent container.

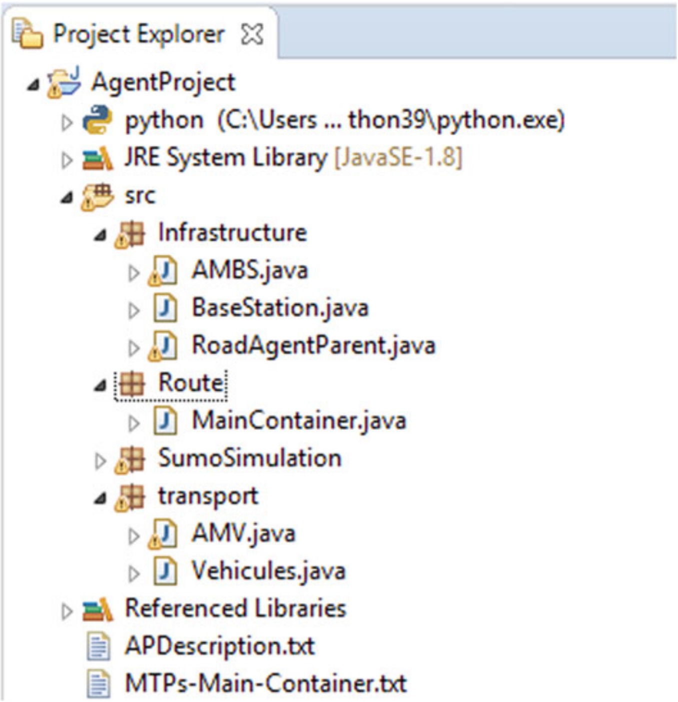

Fig. 8.3 Developed prototype structure

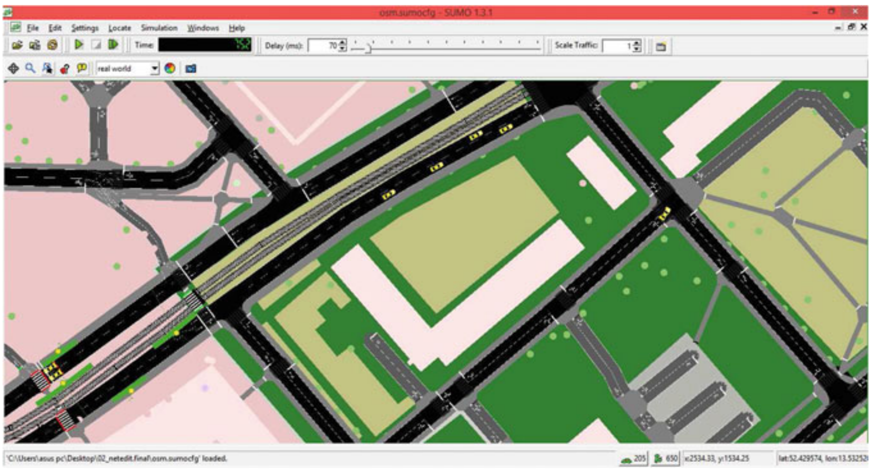

Fig. 8.4 An extract of a real part of the road

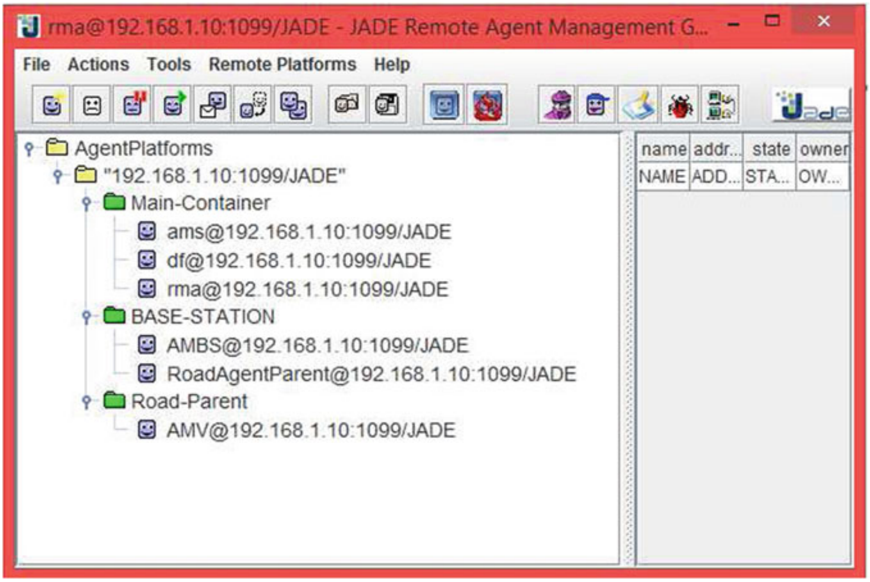

Fig. 8.5 Prototype structure in JADE platform

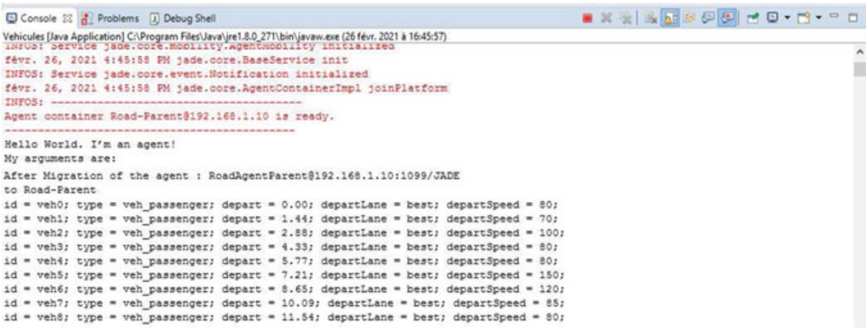

Fig. 8.6 List of information collected by the RAP after migration

The Road Parent container includes the Agent Manager Vehicle (AMV) responsible for subscription and un-subscription of vehicles and manage local information. This agent communicates all information to the received RAP (Fig. 8.6).

As a scenario, we propose the following offered C-ITS service: we consider that in the selected road there are some road works, so the maximum speed to be applied is 80. The AMBS in the base station creates the RAP, offers the service of Warnings road work and appends it to the speed control logic (speed limit 80) and sends it to the Road Parent. The RAP has a mission to detect and control the behavior of the driver if he respects the defined speed or not.

Fig. 8.7 An extract of the generated report by RAP agent

```
id = veh2;  departSpeed = 100;
id = veh5;  departSpeed = 150;
id = veh6;  departSpeed = 120;
id = veh7;  departSpeed = 85;
id = veh10; departSpeed = 93;
id = veh11; departSpeed = 82;
id = veh15; departSpeed = 100;
id = veh19; departSpeed = 120;
id = veh20; departSpeed = 90;
```

Upon arrival at Road Parent, the RAP request the AMV all information about the vehicles on the road such as the total number of vehicles (in our example there are 1248 vehicles in the cluster), and deploy the warning road works service. The AMV transmits the "Warning service" to vehicles. Then, vehicles of the current cluster transfer these services to other vehicles with V2V communication. This communication must be established with a protocol. We suppose that all vehicles receive the service without taking into consideration any loss of information. We assume that the responsibility of the protocol of communication is to guarantee the send/receive of information.

Then, the RAP collects all information about vehicles (Fig. 8.6) generated on the current road (these information are generated by an application developed in SumoSimulation package).

After that, the RAP runs its code, analyzes data, and generates a report of all vehicles that have not respected the speed limit. As a result, in this route there are 1248 controlled vehicles, RAP detects 728 vehicles that do not respect the rule. After the RAP sends to the AMBS the list of the vehicle that did not respect the rule. Finally, the RAP must inform the subscribed vehicle of the speeding performed during the current road. Figure 8.7 illustrates an extract of the generated report.

8.6 Conclusion and Future Work

In this paper, we address how multi-agent systems and especially mobile agents can offer many benefits to the deployment of the C-ITS services. In this context, we have outlined a mobile agents framework for vehicular network. This framework is generic, and it is independent of the physical component and the nature of C-ITS that be implemented. This framework contains stationary and mobile agents. The stationary agent provides services facilitating the development and implementation of C-ITS services whose business logic is carried by mobile agent. To illustrate the feasibility of our proposal, we test our framework for a speed management system. Hence, we use jade platform and SUMO simulation to evaluate the performance of the system.

In our future work, we consider that if the mobile agent will manage each vehicle, it will give us more details to manage and perform control of vehicles. We need to use eventually other services either from infrastructure or urban road to make the C-ITS services more interoperable. We aim also to use learning in our future work to allow driver making decision and consequently avoid congestion and decrease the number of accident.

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Chapter 9
Revising Ethical Principles and Norms in Hybrid Societies: Basic Principles and Issues

Matteo Cristani, Francesco Olivieri, and Luca Pasetto

Abstract In this work, we describe the main processes by which an agent operating in a normative/ethical system may formulate a new normative/ethical rule. This is an issue that emerges as fundamental in hybrid societies, where humans and autonomous agents shall live together. In these environments, it may occur a situation that is totally unknown to the agent, who may be unable to apply existing rule and need to create new ones to deal with the novelties encountered. We employ, as a means to devise the revision operators, the defeasible deontic logic (DDL), a non-monotonic logical system that accommodates rules of ethical origin, and has been widely employed for normative and moral reasoning. New rules may be acquired by an external source, possibly an institution, or a human interacting with an intelligent agent. The agent itself may learn it in a number of manners. We introduce two revision operators for norms that are able to manage the effects of all the above-mentioned processes.

9.1 Introduction

Consider an agent acting in a hybrid society, i.e. a society where both natural and artificial components play an important role. The norms that govern the behaviour of such an agent can be either ethical or legal, and in this context new regulatory challenges emerge and need to be investigated. While an agent may follow some

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rules that stem from its internal state of mind, many rules are externally imposed on it.

The rules of the first kind, the internal ones, can be described by the *rule of justice* principle, while the external rules can be described by the *rule of law* principle. The rule of justice principle establishes that on a general basis the internal rules prevail against the external ones. The rule of law warrants the opposite.

These two principles can clash, that is, a rule of one kind may be conflicting with a rule of the other kind. When such situations arise, assuming that we are representing the normative system by using defeasible deontic logic [16], a superiority relation on rules can be used to solve the conflict and determine which is the rule to be applied.

There exist, however, many cases in which an agent itself has to formulate a new normative principle, and possibly solve a conflict that arises per se when the normative principle clashes with other existing ones (see [14] for issues regarding the introduction of new preferences in nonmontonic reasoning frameworks). Consider, for instance, the case in which an artificial agent has yet no way to manage a new token of information that appears out of nowhere during its acting. In particular, imagine a driverless car that is passing the boundary of a right-driving country towards a left-driving country (for instance, when passing towards the channel tunnel coming from France to the UK). Many of the ethical rules the agent has been used with at that stage have to be changed with other rules the agent may have not yet incorporated for it has been designed for right-driving countries. What would be the solution to this? One possibility would be that the agent acquires the new rules by an internet connection, and establishes the correct application of the rules (namely by devising a correct interpretation of the situation as provisional).

Now consider the case of an industrial robot that is operating in an unsupervised way within a factory. One worker, alone, enters the room and suddenly he fell on the floor, because of a heart attack. The robot has not been provided with a specific rule for this kind of emergency, but it has an ethical apparatus that is specified to work with novel situations by analogy with other situations. The robot has recorded a situation in which humans have to act in a similar context and they have proceeded by calling an emergency number. By analogy, the agent computes a new rule that says: when an intelligent agent sees an emergency situation, she calls an emergency number. Here, the analogy is obtained by substituting intelligent agent for human.

Both the examples shown above require the ability to introduce *new* rules in the system, and possibly solve contradictions arising that way. Defeasible deontic logic can accommodate the solution to the emerging conflict when we introduce new *specific* revision operators that act on the basis of actions to be carried out to match situations that are not covered by the existing rules.

In this work, we focus on the problem of an agent generating (by acquisition or learning) new legal or ethical rules in the language of DDL, and on the effect that this has on the agent's normative system.

The rest of the paper is organized as follows. Section 9.2 introduces basic definitions of Defeasible Deontic Logic and discusses the formalism structure. Section 9.3 is devoted to provide a general framework for acquisition of new norms from external sources and provide room for the different concepts of acquisition and learning.

In Sect. 9.4, we discuss two revision operators able to modify an ethical/normative system and show how to accommodate the types of processes discussed in Sect. 9.3 with these operators. Section 9.5 discusses some related works and finally Sect. 9.6 takes conclusions and sketches further work.

9.2 Basic Definitions

Defeasible Logic is a rule-based skeptical approach to non-monotonic reasoning. It is based on a logic programming-like language and is a simple, efficient but flexible formalism capable of dealing with many intuitions of non-monotonic reasoning in a natural and meaningful way [2].

Consider a set PROP of propositional atoms. The set Lit = PROP $\cup\{\neg p | p \in$ PROP$\}$ denotes the set of literals. The *complement* of a literal q is denoted by $\sim q$; if q is a positive literal p, then $\sim q$ is $\neg p$, and if q is a negative literal $\neg p$ then $\sim q$ is p.

A defeasible theory D is a tuple $(F, R, >)$. $F \subseteq$ Lit are the facts which are always true pieces of information. R contains three types of rules: strict rules, defeasible rules and defeaters. A rule is an expression of the form $r : A(r) \hookrightarrow C(r)$, where r is the name of the rule, the *arrow* $\hookrightarrow \in \{\rightarrow, \Rightarrow, \rightsquigarrow\}$ is to denote, resp., strict rules, defeasible rules and defeaters, $A(r)$ is the antecedent of the rule, and $C(r)$ is its consequent. A strict rule is a rule in the classical sense: whenever the antecedent holds, so does the conclusion. A defeasible rule is allowed to assert its conclusion unless there is contrary evidence to it. A defeater is a rule that cannot be used to draw any conclusion, but can provide contrary evidence to complementary conclusions. Lastly, $> \subseteq R \times R$ is a binary, antisymmetric relation, with the exact purpose of solving conflicts among rules with opposite conclusions by stating superiorities. We use the following abbreviations on R: R_s is to denote the set of strict rules in R, R_{sd} the set of strict and defeasible rules in R, and $R[q]$ the set of rules in R s.t. $C(r) = q$.

A *derivation* (or *proof*) is a finite sequence $P = P(1), \ldots, P(n)$ of *tagged literals* of the type $+\Delta q$ (q is definitely provable), $-\Delta q$ (q is definitely refuted), $+\partial q$ (q is defeasibly provable) and $-\partial q$ (q is defeasibly refuted). The proof conditions below define the logical meaning of such tagged literals. Given a proof P we use $P(n)$ to denote the n-th element of the sequence, and $P(1..n)$ denotes the first n elements of P. The symbols $+\Delta, -\Delta, +\partial, -\partial$ are called *proof tags*. Given a proof tag $\pm\# \in \{+\Delta, -\Delta, +\partial, -\partial\}$, the notation $D \vdash \pm\# q$ means that there is a proof P in D such that $P(n) = \pm\# q$ for an index n.

In what follows we only present the proof conditions for the positive tags: the negative ones are obtained via the principle of *strong negation*. This is closely related to the function that simplifies a formula by moving all negations to an innermost position in the resulting formula, and replaces the positive tags with the respective negative tags, and the other way around.

The proof conditions for $+\Delta$ describe just forward chaining of strict rules.

$+\Delta$: If $P(n + 1) = +\Delta q$ then either

(1) $q \in F$, or
(2) $\exists r \in R_s[q]$ s.t. $\forall a \in A(r).\ +\Delta a \in P(1..n)$.

Literal q is definitely provable if either (1) it is a fact, or (2) there is a strict rule for q, whose antecedents have all been definitely proved. Literal q is definitely refuted if (1) it is not a fact and (2) every strict rule for q has at least one definitely refuted antecedent.

The conditions to establish a defeasible proof $+\partial$ have a structure similar to arguments.

$+\partial$: If $P(n+1) = +\partial q$ then either
(1) $+\Delta q \in P(1..n)$, or
(2) (2.1) $-\Delta{\sim}q \in P(1..n)$ and
(2.2) $\exists r \in R_{sd}[q]$ s.t. $\forall a \in A(r) : +\partial a \in P(1..n)$, and
(2.3) $\forall s \in R[{\sim}q]$. either
(2.3.1) $\exists b \in A(s) : -\partial b \in P(1..n)$, or
(2.3.2) $\exists t \in R$ s.t. $\forall c \in A(t) : +\partial c \in P(1..n)$ and $t > s$

A literal q is defeasibly proved if, naturally, it has already strictly proved. Otherwise, we need to use the defeasible part of the theory. Thus, first, the opposite literal cannot be strictly proved (2.1). Then, there must exist an applicable rule supporting such a conclusion, where a rule is applicable when all its antecedents have been proved within the current derivation step. We need to check that all counter-arguments, i.e. rules supporting the opposite, are either discarded (condition (2.3.1), at least one of their premises has been defeasibly rejected), or defeated by a stronger, applicable rule for the conclusion we want to prove (2.3.2).

We assume that norms are represented in defeasible deontic logic by the definition that follows.

Definition 9.1 (*Norm*) A norm n is a finite set of rules in defeasible deontic logic, where each rule takes one of the following forms:

- A definition $l_1, ..., l_n \to l$,
- A fact l,
- An unconditional rule in the norm body $\mathcal{M}\ l$, or
- A conditional rule in the norm body $l_1, ..., l_n \Rightarrow\ \mathcal{M}\ l$,

where $l, l_1, ..., l_n$, with $n \geq 1$, are propositional literals that represent a state, an action, or an event (asserted or negated); $\mathcal{M}$ is a deontic operator indicating an obligation O, a prohibition F, or a negation of one of them. The operator $\sim$ represents either the empty string or the logical negation $\neg$.

As common in modal logic, the modals are dualised: in the specific case of deontic logic, given a literal l, $Ol \Leftrightarrow F\neg l$ and $O\neg l \Leftrightarrow Fl$. In the rest of the article, we focus on rules in the norm body.

9.3 Norm Acquisition and Learning

The new rule formulated by the agent may be acquired from the outside or learned by analogy or homology. The process can be one of the kinds described below.

External Acquisition The rule is acquired from the outside and is incorporated into the agent's normative system. An agent may incorporate an external rule because it is legally bound to do so (for instance, because the institution that issued the rule has power over the agent), or because it trusts the issuing institution or the content of the rule. In the first case, we say that the rule is *externally imposed*, while in the second case the acquisition is voluntary and is based on the concept of *trustability*. The revision process provoked by this method can issue negotiation strategies that we take into consideration in further work.

The incorporation has to be made in relation with the rules that are already in the system, and the existing superiority relation may have to be enriched in case of conflicts. Typically, the externally imposed rules are legal rules, the trusted rules are ethico-moral rules, the already existing rules can be of either kind, and the agent may use the principles of rule of law or rule of justice to solve emerging conflicts. If the conflict is between two rules of the same kind (legal or ethico-moral), the agent has to use other principles to define the superiority, for instance the principles of *lex superior derogat inferiori*, *lex specialis derogat generali*, or *lex posterior derogat priori* can be adopted for legal rules.

Learning by Analogy: Abstraction The rule is learned after observing a situation that is not regulated but is similar to a situation where an existing rule applies. The learned rule is formulated by analogy to the existing rule. For instance, consider an existing rule $a,\ b \Rightarrow c$ and a rule to be learned $a',\ b' \Rightarrow c'$: one rule can be obtained from the other by analogy if there is an abstraction function α such that $\alpha(a) = \alpha(a')$, $\alpha(b) = \alpha(b')$, and $\alpha(c) = \alpha(c')$.

Learning by Homology: Generalization The rule is learned after observing a situation that is not regulated but is a generalization of a situation where an existing rule applies, and also the rule can be generalized. For instance, consider an existing rule $a,\ b \Rightarrow c$ and a rule to be learned $a \Rightarrow c'$: the second rule can be learned if c is a logical consequence of c', that is, $c' \models c$.

Learning by Homology: Specialization The rule is learned after observing a situation that is regulated only in a general form, and a more specific rule can be formulated. For instance, consider an existing rule $a \Rightarrow c$ and a rule to be learned $a,\ b \Rightarrow c'$: the second rule can be learned if c' is a logical consequence of c, that is, $c \models c'$.

Learning by Averaging The rule is learned after observing a situation for which there are a general rule and a rule that is too specific to apply. The learned rule is formulated by "averaging" these two existing rules. For instance, consider existing rules $a \Rightarrow c$ and $a,\ b,\ d \Rightarrow c''$: the rule to be learned $a,\ b \Rightarrow c'$ can be obtained if c is a logical consequence of c' and c' is a logical consequence of c'', that is, $c' \models c$ and $c'' \models c'$.

The incorporation processes depend on the legal context, and we can exemplify this by the process of legislative acquisition and incorporation of GDPR as an EU *regulation* in a national legislation.

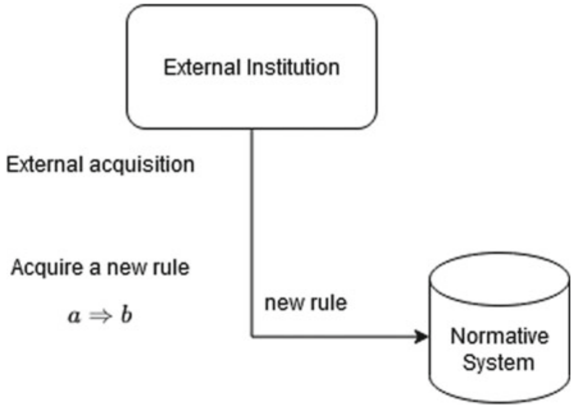


Fig. 9.1 External acquisition

Example 1 The GDPR has been issued as an EU law that unifies the regulation on data protection and privacy within the EU. Since it is a regulation and not a directive, it is directly applicable in EU states, that is, in our framework, the GDPR rules are externally acquired in the national normative systems. Moreover, the GDPR provides some flexibility for the norms to be adjusted by individual member states, and it is used as a model for many national laws outside EU (a phenomenon known as the Brussels effect), therefore it is also an example of a combination of external acquisition and norm learning.

On the other hand, let us consider the following specific application in healthcare and robot ethics.

Example 2 A nurse robot is active in a hospital to treat patients. Suppose it is of paramount importance that the robot can provide a specific treatment drug d, among others. An operator may choose to add an ethic rule for the robot to stop everything it is doing if it runs out of the drug in question, and immediately start to refill its supply. Based on this data, we may be interested for the robot to automatically learn a new rule, analogous to the one written by the operator, for a treatment drug that is at least as important as d.

See Fig. 9.1 for External Acquisition, Fig. 9.2 for Learning by Analogy: Abstraction, Fig. 9.3 for Learning by Homology: Generalization and Specialization, and Fig. 9.4 for Learning by Averaging, that are the processes that are formalized below.

9.4 Revision Operators for Norm Acquisition and Learning

In this section, we formalize some of the processes described above with the introduction of a revision operator that expands a theory D, composed of norms as in Definition 9.1, with new information to obtain theory D', where new norms are learned or acquired.

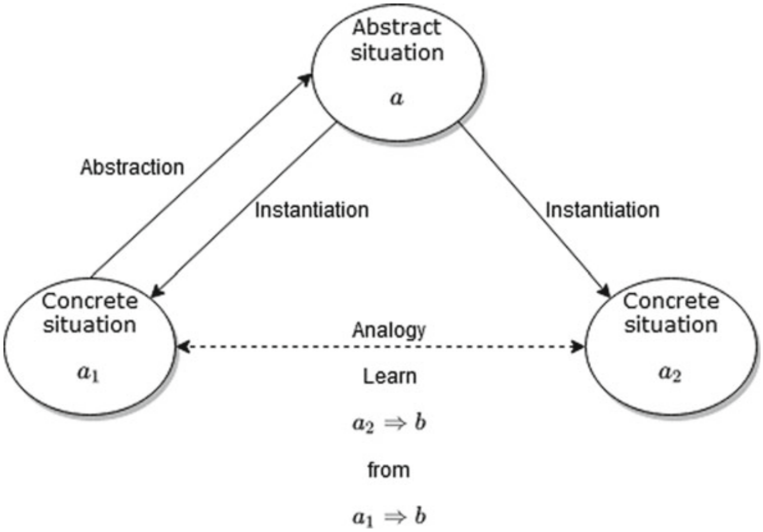
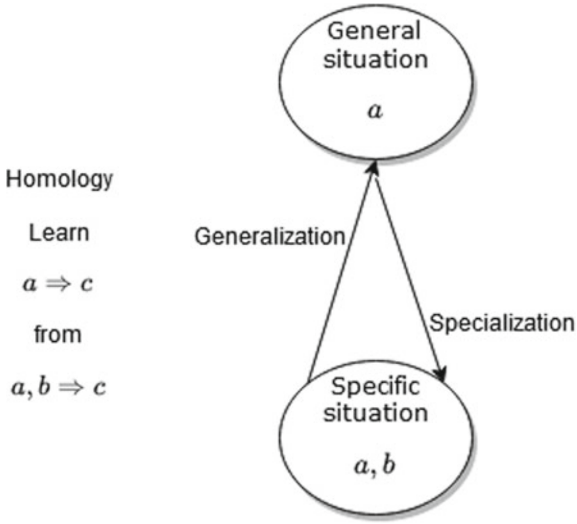


Fig. 9.2 Learning by analogy: abstraction

Fig. 9.3 Learning by homology: generalization and specialization



Definition 9.2 (*Norm creation operator*) Given a defeasible theory D, the *norm creation operator* NC is a revision operator that can be used to obtain a new theory $D' = NC(D, H, I)$, where

- the set $H = \{h_1, ..., h_t\}$ contains rules that D is expanded with, and
- the set $I = \{i_1, ..., i_u\}$ contains pieces of information that are used to create new rules in D.

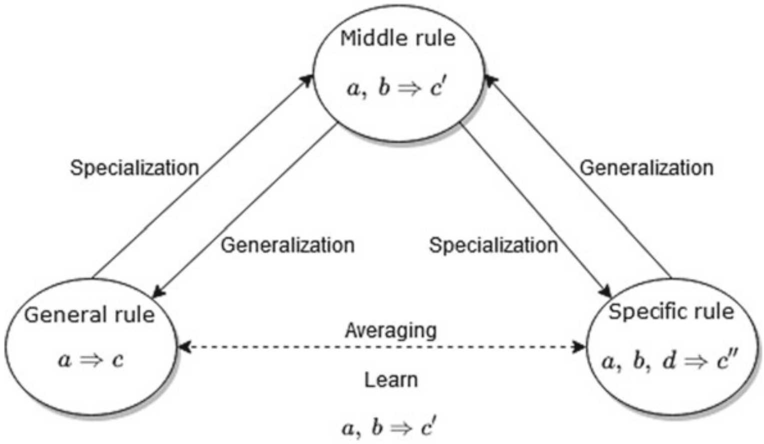


Fig. 9.4 Learning by averaging

In particular, an element of set I can be of two kinds:

– a redundancy $\mathcal{R}(l,\ r)$ of literal l for a rule r, or
– a similarity $\mathcal{S}(l_1,\ l_2,\ r)$ between literals l_1 and l_2 for a rule r.

The theory D is expanded with rules in H by the usual expansion operation known in belief revision. On the other hand, the processing of set I is introduced for the first time in this article: the idea is that a literal l such that $\mathcal{R}(l,\ r)$ can be removed from the premises $A(r)$ of rule r, while literals l_1 and l_2 such that $\mathcal{S}(l_1,\ l_2,\ r)$ can be replaced one for the other in $A(r)$.

Given theory $D = (F, R, >)$, we formalize the process to obtain $D' = (F', R', >')$ for each of the operations described above.

– *External Acquisition* $NC(D, H, \emptyset) = (F, R', >') = D'$, where $R' = R \cup H$ and $>'$ is $>$ enriched to handle conflicts.
– *Learning by Analogy: Abstraction* $NC(D, \emptyset, I) = (F, R', >') = D'$, where $R' = R \cup G$ and $>'$ is an enrichment of $>$. The set G is obtained in this way: for each similarity $\mathcal{S}(l_1,\ l_2,\ r)$ between literals l_1 and l_2 for a rule r, a rule r', corresponding to r with l_1 and l_2 swapped when they appear in the premises $A(r)$, is added to G.
– *Learning by Homology: Generalization* $NC(D, \emptyset, I) = (F, R', >') = D'$, where $R' = R \cup G$ and $>'$ is an enrichment of $>$. The set G is obtained in this way: for each redundancy $\mathcal{R}(l,\ r)$ of literal l for a rule r, a rule r', corresponding to r with l removed when it appears in the premises $A(r)$, is added to G.
– *Learning by Homology: Specialization* $NC(D, \emptyset, I) = (F, R', >') = D'$, where $R' = R \cup G$ and $>'$ is an enrichment of $>$. The set G is obtained in this way: for each redundancy $\mathcal{R}(l,\ r)$ of literal l for a rule r, a rule r', corresponding to r with l added when it does not appear in the premises $A(r)$, is added to G.
– *Learning by Averaging* $NC(D, \emptyset, I) = (F, R', >') = D'$, where $R' = R \cup G$ and $>'$ is an enrichment of $>$. The set G is obtained in this way: given two rules

$r,\ r'' \in R$, with $A(r) \subset A(r'')$ and $C(r'') \models C(r)$, add to G a rule r' such that $A(r) \subset A(r')$, $A(r') \subset A(r'')$, $C(r'') \models C(r')$ and $C(r') \models C(r)$. Moreover, each literal l such that $l \in A(r'')$ and $l \notin A(r')$ has to be a redundancy $\mathcal{R}(l,\ r'')$ for r''.

A part the external acquisition revision operator, the other four methods are *observational*. In other terms, we can see them as *base revision* operators with an inductive reasoning mechanics.

9.5 Related Work

Some effort has been posed by scholars in the field to identify methods able to revise defeasible logic, and in general non-monotonic frameworks. Boella et al. [3] propose a Defeasible Logic framework to model extensive and restrictive legal interpretation. This is achieved by using revision mechanisms on constitutive rules, where the mechanism is defined to change the strength of existing constitutive rules.

Also on revision of Defeasible Logic we can find [12], where the key idea is to model revision operators corresponding to typical changes in the legal domain, specifically, abrogation and annulment. Further on this, some investigation effort has been posed on temporary norm change [10], and more generally on the ways in which those changes can be performed [11].

Other works related to the development of revision methods are [1, 15, 18]. In [1], it is possible to have rules of the form $r : a \Rightarrow (s > t)$ where s and t are identifiers for rules. Accordingly, to assert that rule s is stronger than rule t we have to be able to prove $+\partial a$ and that there are no applicable rules for $\neg(s > t)$. In addition, the inference rules require that instances of the superiority relation are provable (e.g. $+\partial(s > t)$) instead of being simply given (as facts) in $>$, that is $(s, t) \in >$. This is the base for a method of revision for preferences, amply discussed in literature by some of the authors [13, 14, 17, 19].

9.6 Conclusions

There are different ways in which this study shall be brought to maturity. At first we shall investigate methods to integrate trustability, and consequently negotiation processes [4–6]. In particular, the purpose of this research line shall be to confirm variants of the methods employed to perform integration of new rules when derived by observations. Consider the case in which I trust someone and observe her performing some activity. I see that her behaviour has some coherence, that I regard as invariant. On the other hand I can see that someone whom I distrust, behave in ways that do not correspond to the invariant I have recorded for my trusted one. If the conditions above mentioned occur I may distill a new principle that establishes correct and incorrect behaviours *learning by examples*. Analogous and extended aspects shall be derived from the observation of punishments and rewards associated with good and bad behaviours.

We shall also advance the study by adding functions related to the interaction processes to be modelled in this scenario, by means of the social interactions in hybrid societies [8, 9]. That would provide room for another further aspect, similar to the one specified above: reputation. When trust is communicated in a public audience, it makes sense to value the communication, especially when it comes from someone, whom I trust in turn. The result of this combination shall result in a further extended model. Some of the authors looked at hybridation processes of logical systems [7] that is the base of external acquisition methods.

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Part II
Multi-Agent and Smart Systems

Chapter 10
Asymmetry of Ties in Organizational Performance

Hitomi Inagaki and Setsuya Kurahashi

Abstract This study aims to investigate how networks, both within and outside of an organization, affect performance and to gain insight into performance management within organizations. An online survey was conducted with two project management teams from different companies to calculate network metrics through social and multilayer network analysis. We adopt psychological safety as a measure of performance. The results indicate that higher performance can be achieved through an asymmetry of ties: in which cohesive ties are more effective for relatively close relations, such as teams and intra-organization networks, and bridging ties are more effective for external networks.

10.1 Introduction

Knowledge collaboration and integration is essential in a company wherein business operations are becoming increasingly specialized and complex. Individuals are being challenged to accomplish tasks independently in this environment. This environment emphasizes working within a team as well as with external experts to integrate knowledge and create value. In this setting, activating employees' internal and external networks has attracted considerable interest for organizational management [1, 2].

Thus, this study explores how employees' internal and external networks affect knowledge workers' performance, applying multilayer social network analysis. We use two datasets to examine how cohesive and bridging ties affect employees' performance in their individual and departmental networks.

This paper is organized into five sections. Section 10.2 provides an overview of related research on network structure and performance. Section 10.3 describes the research methodology, including the calculation method applied to the network

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metrics used in this study. Section 10.4 shows the results of the regression analysis between the network index and performance. Section 10.5 discusses the implications of the results. Section 10.6 discusses the conclusion and limitations of the study.

10.2 Previous Research

10.2.1 Social Network Analysis

Social network analysis is an approach that measures interactions and the social structures using graph theory. Relationships typically comprise nodes (e.g., people and organizations) and edges that represent the connections between nodes. When V and E respectively refer to a set of nodes and edges, such network G is defined as $G = (V, E)$ [3].

A multilayer network is defined as $M = (\mathcal{A}, \mathcal{L}, V, E)$, given a set of actors $\mathcal{A}$ and a set of layers $\mathcal{L}$. Multilayer network analysis enables us to uncover complex relationships within a group by exploring connections across multiple layers [4, 5]. Since employees are likely to construct various relations that are both formal and informal, this study uses social network analysis and multilayer network analysis to reveal the relationships between such complex networks and performance.

10.2.2 Network Structure and Performance

Regarding network structure and performance, two streams have been identified, which are known as cohesive ties and bridging ties.

Coleman argued that cohesive networks are necessary for facilitating individual competence [6]. According to Coleman, rather than an open structure, a cohesive network makes it easier to establish behavioral expectations and norms and also promote social capital within a community. His empirical study of Catholic high schools demonstrates that parents who knew each other were more likely to build trust and norms than those who did not, resulting in lower dropout rates among their children.

Conversely, Burt argued that bridging ties are more beneficial than cohesive ties. He found that a network with many "structural holes" (i.e., positions in the network connecting to various groups with a little overlap) has a higher probability of generating novel ideas and solutions because of the reduced redundancy of information [7]. According to Burt, such bridging ties enable employees to control the flow of information from multiple groups, thus increasing competitive advantage.

Some hypothesize that bridging ties are more effective for generating innovative ideas, whereas cohesive ties aid in the accumulation of long-term improvements over time. However, there remains a need for an exploration of how those ties function [8].

Besides, most studies have tended to only focus on formal business relationships [9, 10]. Accordingly, this study also considers informal networks in a multilayered manner.

10.3 Methodology

10.3.1 Scope of Network

This study divides the network into internal and external categories. Within the internal network, intra-group and inter-group networks are identified.

Internal networks
An intra-group network is the network of employees that belong to the same department. We consider four layers in the analysis, including business communication (work layer), advising each other (advise layer), going to lunch together (lunch layer), and connection through a private messaging application (SNS layer). The work and advice layers are regarded as more formal relationships, whereas the lunch and SNS layers are more informal.

An inter-group network is the network of people who belong to different departments within the same company.

External network
By contrast, an external network refers to the network of people who belong to different companies other than the study participants.

10.3.2 Data Outline

To understand internal and external networks from different perspectives, we engaged two separate datasets. The first dataset focuses on a personal network (hereafter referred to as a personal-level dataset). The data comprise 20 employees from two different organizations. All employees are engaged in project management work and regularly communicate with other departments both within and outside of the company. We asked each member how they connect with each other within the internal and external networks. The example questions are as follows: "For each person on your team, please indicate how often you communicate with them for work related topics." "For each person on your team, please indicate how often you go to lunch together." We used the responses to calculate network metrics at a personal level, such as centrality.

The second dataset covers 800 employees from 44 departments (hereafter referred to as group-level dataset). These employees are also involved in project management. Instead of a questionnaire survey, this dataset is based on behavioral data extracted from real email exchanges and a meeting log captured in a 1 month period in 2020. The data includes "Sent From," "Sent To," "Timestamp" for emails and meeting invitations. We used this dataset to calculate network metrics at a group level. Most of these employees work in groups, so it was meaningful to look at performance from the perspective of group's structure.

10.3.3 Performance Metrics

Team and organizational performance have been measured in many different ways [11]. We determined that organizations must reduce the fear of failure among employees to create value under states of uncertainty and unpredictability. Thus, we used the concept of psychological safety as a measure of group performance. Psychological safety refers to an atmosphere in which one can express ideas and feelings without fear of being punished or devalued [12]. Several empirical studies have shown that such psychological safety is positively related to team performance [13, 14]. To assess this metric, referencing [1], we asked three items to evaluate levels of agreement to disagreement, such as "In this team, I can express my opinions without worrying about being ridiculed or denied." We then calculated the average of the three items as the performance score for psychological safety.

10.3.4 Network Metrics

Metrics for the personal-level dataset We used the following methods to calculate individual metrics using the personal-level dataset.

Degree centrality: This metric values a node having more edges than others [15]. This is defined as $C_d(i) = k_i/(\mathrm{n}-1)$ where k_i is the degree of node i, and n is the number of nodes in the network.

Betweenness centrality: This represents how many people are mediated in the network, meaning the degree to which a node is located on the shortest path between other nodes [3].

$$C_b(i) = \sum_{i \neq j \neq k} \frac{g_{jk}(i)}{g_{jk}} \tag{10.1}$$

where $g_{jk}(i)$ is the number of shortest paths between node j and node k that pass through node i, and g_{jk} is the number of shortest paths between node j and node k.

Xrelevance: The ratio between the neighbors of an actor connected by edges that belong to a specific layer and the total number of one's neighbors [4].

$$xrelevance(a, L) = \frac{xneighborhood(a, L)}{neighborhood(a, \mathcal{L})} \tag{10.2}$$

Let a layer L be a subset of $\mathcal{L}$ and neighborhood(a, $\mathcal{L}$) be the neighborhood directly connected to actor a on all layers $\mathcal{L}$, and xneighborhood(a, L) be the neighborhood that is connected to actor a only at layer L.

Network efficiency: Burt proposed network efficiency as a concept to describe a lack of structural holes [7]. Efficiency refers to the percentage of nodes that do not overlap with each other. The higher this value, the less overlap between nodes; meaning the more diverse the information sources. Network efficiency requires both redundancy and effective size [16, 17]. When we denote t as the number of connections other than those connected to a node (we call it the ego), redundancy can be expressed as $redundancy = 2t/n$. The effective size is the total number of nodes other than the ego minus duplicates, so it is defined as $effective\,size\; S_i = n - (2t/n)$. If we denote the ego's degree as k_i, then efficiency is the effective size divided by the ego's degree.

$$Efficiency = \frac{S_i}{k_i} \tag{10.3}$$

Network diversity: This indicates the number of people belonging to the same group who are in an ego's network: the smaller this value, the more diverse the network. The formula is $H = 1 - \sum P_s^2$ [18]. In this case, P_s represents the relative size of the population in the network. The square of P_s represents the probability that each member in the network will meet people who belong to the same population.

Metrics for the group-level dataset The group-level dataset was used to calculate the following two network metrics:

Density: The ratio of the actual number of edges to the number of all edges [3]. The formula can be expressed as $2m/\{n(n-1)\}$ where the maximum number of possible edges in an undirected graph with n is $n(n-1)/2$ and the number of edges in the graph is m.

Centralization: A measure of the degree to which high centrality is concentrated at only a few nodes in a graph. The degree centralization is measured by the sum of the difference of the largest centrality value minus the other nodes' centrality values [3]. We measure the centralization of a graph by the ratio of the sum of its differences to the sum of the largest theoretically possible difference. The following equation calculates the degree of centralization in an undirected graph:

$$C_d = \frac{\sum_{i=1}^{n} [C_d\,(i^*) - C_d(i)]}{(n-1)(n-2)} \tag{10.4}$$

Density and centralization are used to understand the graph's structure. Those are independent, as each can vary regardless of the other [19]. For example, a decentralized group can exist in a low-density network if only a few members interact directly with each other, or in a high-density network if most interacting members conduct social interaction with multiple recipients. Unlike the personal-level dataset, which focuses on individual metrics, such as centrality, we assess density and centralization to explore how group structure is related to the concept of psychological safety.

10.4 Results

10.4.1 Trends in the Personal-Level Dataset

Table 10.1 presents the summaries of the metrics in each network with the personal-level dataset. After calculating the individual network metrics for 20 respondents, we also calculated the average and standard deviation for the group, summarized in Table 10.1. The high average degree of intra-group centrality (0.99) means that the respondents are strongly connected within their groups. In contrast, that of the lunch and SNS layers are lower (0.53 and 0.38, respectively), indicating that their connections are weaker on informal layers. The average xrelevance of 0.17 indicates that on average 17% of one's connections only belong to the work layer. The mean and standard deviation of psychological safety performance were 3.2 and 0.73, respectively.

To examine which network indicators affect performance, we conducted a Lasso regression analysis between network metrics and psychological safety score. Lasso regression has several key features, including "shrinkage of the vector of regression coefficients toward zero with the possibility of setting some coefficients identically equal to zero, resulting in a simultaneous estimation and variable selection procedure" [20]. We chose the Lasso regression for this study because of these features, considering the personal dataset's small sample size and multiple independent variables. We used the cross-validation method to set the optimal regularization parameters.

Table 10.2 presents the result of the Lasso regression in terms of the internal network. In the intra-group network (the left table), the lunch layer's degree centrality has the highest coefficient (0.26), indicating that the lunch layer's connectedness contributed positively to the group's psychological safety. Looking at the inter-group network (the right table), the coefficient of degree centrality with other departments' seniors and supervisors is highest (0.22). This indicates that the more employees that have seniors and (former) supervisors in other departments, the more they feel psychological safety in their department.

Table 10.3 shows the result of the Lasso regression in terms of the external network. Here, the network efficiency shows a high contribution (0.31), indicating that the more the employees have a diverse connection with external networks, the higher their psychological safety is within the department.

10.4.2 Trends in the Group-Level Dataset

Table 10.4 presents an overview of the network metrics for 44 departments and the correlation coefficients between the group-level dataset metrics and psychological safety. The correlation coefficient between density and psychological safety is 0.3

Table 10.1 The mean and the standard deviation of internal and external network metrics with the personal-dataset

Internal network (Intra-group)			Internal network (Inter-group)			External network		
Network index	Mean	SD	Network index	Mean	SD	Network index	Mean	SD
Degree centrality (work)	0.99	0.02	Gender diversity	0.32	0.20	Degree centrality	0.86	0.25
Degree centrality (advice)	0.53	0.25	Age group diversity	0.42	0.25	Gender diversity	0.23	0.23
Degree centrality (lunch)	0.53	0.17	Department diversity	0.58	0.23	Age group diversity	0.38	0.29
Degree centrality (sns)	0.38	0.22	Network efficiency	0.24	0.13	Organizational diversity	0.25	0.31
Betweeness centrality (advice)	5.10	7.86	Degree centrality with seniors and supervisors	0.47	0.09	Relational diversity	0.56	0.39
Betweeness centrality (lunch)	2.05	3.89				Network efficiency	0.79	0.17
Betweeness centrality (sns)	3.65	5.17						
Xrelevance (work)	0.17	0.12						

Table 10.2 Regression coefficients in the internal network

Internal network (Intra-group)		Internal network (Inter-group)	
Item	Coefficients	Item	Coefficients
Lunch layer's degree centrality	0.26	Degree centrality with other department's seniors and supervisors	0.22
Gender (female) dummy	−0.06	Gender (female) dummy	−0.08
		Department diversity	0.05
Regularization parameter	0.03	Regularization parameter	0.02
R^2	0.49	R^2	0.56

Table 10.3 Regression coefficients in the external network

External network	
Item	Coefficients
Network efficiency	0.31
Gender diversity	−0.30
Gender (female) dummy	−0.15
Degree centrality	−0.06
Nonregular employment dummy	0.02
Regularization parameter	0.01
R^2	0.68

Table 10.4 Summary of network by department and correlation coefficient with psychological safety

Item	Mean	SD	Correlation coefficient with psychological safety
Density	0.09	0.11	0.30*
Centralization	0.55	0.18	−0.32**

Note $*p < 0.05$, $**p < 0.01$

($p < 0.1$), which shows a somewhat positive correlation. Meanwhile, the centralization and psychological safety are negatively correlated (−0.32, $p < 0.05$).

Additionally, we categorized the 44 departments into four groups based on the results of density and centralization; for example, when a group has a higher density and centralization than the average of all groups, the group is categorized as "1. High density and High centralization." As a result, 10 groups were classified as "High density and High centralization group," 9 groups were "Low density and Low centralization group," 12 groups were "High density and Low centralization

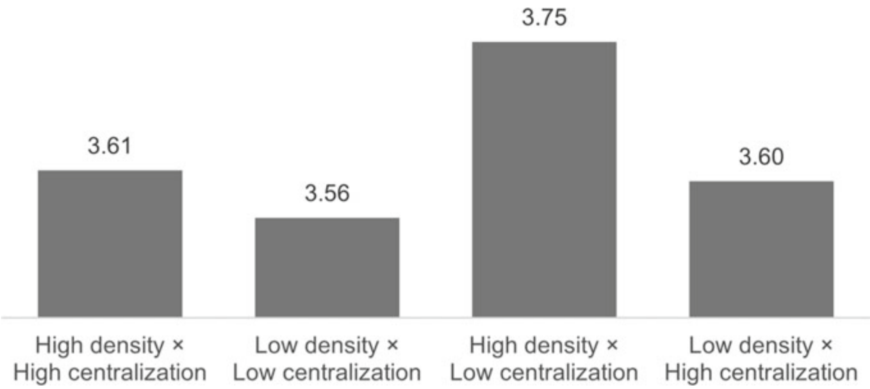

Fig. 10.1 Average of psychological safety by grouping

group," and 13 groups were "Low density and High centralization group." Figure 10.1 presents the average psychological safety score of the four groups, revealing that groups with higher density and lower centralization have the highest psychological safety among the groups.

10.5 Discussion

Table 10.5 summarizes which type of ties affect the performance in each network. We consider the degree centrality and density as cohesive ties and network efficiency as bridging ties.

The table suggests that cohesive ties affect performance in the internal network (both intra-group and inter-group), whereas bridging ties influence the external network. In the intra-group, cohesive ties, such as the lunch layer's degree centrality in the personal-level dataset positively influence the group's psychological safety. This tendency corroborates with previous work in informal communication. Infor-

Table 10.5 Network indicators with strong influence in each network

		Influential network ties
Internal network	Intra-group	Cohesive ties (Personal-level dataset: Lunch layer's degree centrality, Group-level dataset: High density and low centralization)
	Inter-group	Cohesive ties (Degree centrality with other department's seniors and supervisors)
External network		Bridging ties (Network efficiency)

mal communication is said to help maintain relations among employees and increase their motivation. It also allows employees to learn each other's backgrounds to promote tacit understanding between them, which is integral to work progress [21]. This study similarly suggests the importance of informal interactions, such as chatting and going to lunch together, for increasing the sense of psychological safety in a group.

Additionally, the result from the group-level dataset shows similar trends in the intra-group network; a denser and more decentralized group has higher psychological safety. This may suggest those groups might have a less siloed group so that each member is more likely to feel connected to each other. Also, low centralization in a group means that the communication is not biased to a specific person, such as a manager. This may indicate that a flatter group, wherein each member directly interacts with each other and communication is more balanced, has a better work atmosphere. However, we should note that the results come from the data of both meetings and emails. While maintaining weak contact via emails may lead to the ease of consulting within a group when a problem arises, too much email communication might decrease work efficiency. Likewise, meeting communication may lead to faster decision-making as well as connectedness among group members, but it could harm work efficiency because of prolonged and frequent meetings. That tendency might vary depending on the type of work (e.g., whether the job needs more creative work or more routine work). Thus, the different impacts of emails and meetings on various performance indicators should be examined in future work.

Moreover, cohesive ties are influential in the inter-group network. The result suggests that the more one connects to other departments' seniors and (former) supervisors, the higher their psychological safety. One reason might be that having a connection outside of the group but within the company helps one to view their work from a new and positive perspective other than that of the group.

In contrast to the internal network, however, bridging ties affect the performance in the external network. This indicates that diverse connections positively affect the group's sense of psychological safety.

10.6 Conclusion

This study aims to investigate how internal and external networks affect performance. We consider performance metrics in terms of psychological safety and conducted a Lasso regression with network metrics. The results of the analysis demonstrate that the highest performance can be achieved when ties are asymmetrical (i.e., cohesive ties are significant in the internal network, whereas bridging ties are more influential in the external network).

These observations have two main implications for future research into network and performance. First, we found that cohesive ties may be better for inside a company and bridging ties for outside a company. A company's valuing of informal communication and maintaining of flat relationships may enhance psychological safety and lead to better performance. This study specifically revealed that effective ties differ, depending on the type and performance of the network. Second, we revealed that network efficiency may benefit teams and organizations. Although previous studies have suggested that bridging ties, such as via promotion, help individuals, our research indicates that diverse connections with external networks might influence a group's psychological safety, which is ultimately beneficial for an organization's performance.

We are aware that our research may have two main limitations. The first is that given that the study's focus was on psychological safety, different results could have arisen if the focus had been on other types of performance metrics. For example, if we look at the performance from a different perspective, such as work efficiency and decision-making speed, then being connected in a group does not necessarily enhance the performance because the extra communication can become a distraction from work. Thus, it will be necessary to explore how to balance psychological safety with other indicators, such as work efficiency in future work. The second is that we applied a multilayer approach at the individual level, but not at the group level. The group-level dataset only included the formally work-related network, such as email and meetings. Thus, future work should be conducted to investigate how informal networks impact performance at the group level with statistical validation.

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Chapter 11
Analysing Tweets Sentiments for Investment Decisions in the Stock Market

Zhicheng Hao and Yun-Heh Jessica Chen-Burger

Abstract The increasing practice of using social media as the basis for decision-making has made social media an important alternative information source. This is, in particular, true for investors in the stock market due to their needs to gain dynamic, real-time information and strategic persons' views. It is therefore very interesting to investigate the relationships between the sentiments of the text as published on social media and how they may influence investors' minds. In this paper, we selected several influential Twitter accounts, inc. Bloomberg, Forbes, Reuters, WSJ and Donald Trump, for sentiment analysis using SentiStrength. We found a fair amount of agreement between the sentiments as generated by the tool and those assigned from investors' point of view, esp. when plenty of positive words have been used in Tweets. However, we also discovered that not all Tweets with many positive words may generate positive sentiments in investors' minds. Furthermore, we identified interesting differentiated sentiments expressed in different Tweeter accounts that may indicate the stance of their holders, e.g. using an upbeat tone thus to promote economic growth; or being conservative, thus maintaining one's authority. Overall, we found many Tweets scored a neutral sentiment, as many of them contain references that their views cannot be determined without examining additional sources.

11.1 Introduction

Financial-market-based information is increasingly attracting attention in recent years. Traditionally, investors heavily rely on information reported in financial news articles to decide whether to buy, sell or hold stocks in the stock market. These days, social media provides much speedier, near-real-time market information and from

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a variety of rich sources, inc. independent investment advisers, personality's self-publishing, or government's financial announcements. One such example outlet is Twitter. Twitter users produce millions of Tweets simultaneously which can be used to gauge stock market sentiments and investors' trading intentions. However, it is difficult to predict the financial market accurately using Twitter information. Tweets can be cryptic that they include investment jargons or information that requires financial background to interpret; they may also include unrelated, conflicted or ambiguous information, such as sarcasm; they are also available in large volume that cannot all be manually processed in a timely manner. Carefully designed Sentiment Analysis (SA) tools are therefore often used to help understand the sentiments of Tweets. Such example SA tools are SentiStrength [1], Weka [2], NLTK [3] and Mozdeh [4].

In fact, over the years, microblogging platforms, such as Twitter, Facebook and Instagram, have become popular sources of information for analytics purposes. For example, companies are increasingly seeking automated methods to exploit social media for information about what people think about their products and services. Twitter has a large user base globally and is a great narrative of the public mood. It therefore also offers great potential for exploration in the stock market.

Twitter indeed provides a huge amount of information that can be automatically extracted to provide features to analyze and explore more hidden information. To gauge the public mood, the traditional way of a survey by questionnaires can be very expensive and time-consuming to investigate sufficiently large samples [5]. Automated text mining and sentiment analysis techniques have therefore been used to analyse moods in short text, such as Tweets [6].

However, the ambiguous or context-specific topics in Tweets can pose a challenge for automated methods. In addition, performing sentiment analysis on Tweet messages is difficult also due to the wide use of informal languages and expressions, inc. slang, abbreviations, icons and misspells. The sentiment analysis techniques can be divided into two groups [7]. The first group uses a lexicon of positive and negative words and phrases to determine the sentiments of encountered texts [1]. The second group uses machine learning techniques such as Support Vector Machine and Linear regression to classify texts based on their sentiments using results of previously learned texts [8, 9]. Zhang [10] reported the different types of Neural Network techniques applied to assess the sentiments at the document-, sentence- and aspect-levels.

Investors and researchers use SA tools for analysing the price discovery process and to make smart investment decisions. Sentiment analysis can judge the opinions of Tweets as positive, negative, or neutral, and of varying degrees—called sentiment polarity (SP) [1]. For example, SentiStrength reports two sentiment polarity values (positive and negative), which are -1 (not negative) to -5 (extremely negative) and 1 (not positive) to 5 (extremely positive). The main aim of the sentiment analysis is to infer people's points of view—by assigning contextual polarity to the text that they have expressed opinion within.

However, the opinion of Tweets may also be expressed when no obvious subjective or sentimental clues are given. In this paper, it is therefore very interesting to examine how a generic purposed SA tool, such as SentiStrength, may perform when used in a specialised domain, the stock market sentiments, and to compare the results with how the investors' may interpreter them.

11.2 Research Methodology

Figure 11.1 shows the research methodology framework. The first step is to identify promising or highly influential financial Twitter accounts by using suitable measurements. For this, we favour Twitter accounts that are operated by traditional news agents that are related to finance and have a wide readership, and influential individuals that are known to have strong impact on the stock market. In the second step, we identified an interesting period for observation. We preferred a duration where significant events have occurred, because Tweets published during this period are more likely to exhibit interesting or stronger sentiments. This is then followed by using a suitable automated tool, e.g. Twint, to collect sample Tweets within the chosen time period and Twitter accounts in the third step. The fourth step carries out the pre-processing of collected Tweets. All noises and special characters that are not processable by the SA tool will be removed.

The fifth and sixth steps are to produce the ground truth and to use a SA tool (e.g. SentiStrength) to generate sentiment scores for each Tweet. As we wish to simulate the mentality of investors when reading these Tweets, the ground truth has been created independent of stock market prices, but based on general financial and stock market knowledge to determine the impact of each Tweet that may have on the stock market. The goal here is to evaluate the SA abilities of the tool to determine

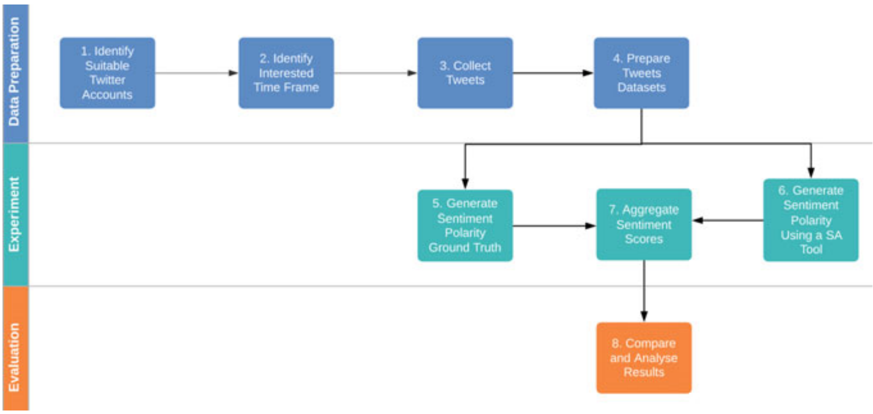

Fig. 11.1 The research methodology

a Tweet's effect on an investor in the stock market; but not in its ability to predict stock market price movements. The stock market price movements are an aggregated result of many factors other than just the particular examined Tweet. The authors, therefore, wish to separate these factors and focus on the effect of the individual Tweet in concern when evaluating the performance of the SA tool. In the seventh step, we combine the pair of sentiment polarity (SP) scores of each Tweet to generate a composite sentiment score to provide a single value sentiment measurement. We also aggregate SP scores for each Tweeter account. Finally, the SP scores are compared between the different Tweeter accounts, and between the machine-generated values and the ground truth. The distributions of sentiment values are also being analysed to derive insights.

11.3 Experiments Design

11.3.1 Data Selection and Preparation

There are many traditional, long-standing financial news outlets that have substantial readerships and are influential to the stock market. Moving into the Era of the Digital Economy, they run very active Twitter accounts that are very well followed. Examples of these are Yahoo Finance (1 million followers), Bloomberg (7 M), Forbes (16.6 M), Wall Street Journal (18.6 M) and Reuters (23.1 M). In addition, distinct personalities, such as the former US President Donald Trump who, while in the office, had a great influence on the stock market over his tweets. He also enjoyed great many followers (88 M) during our sampling period.

For this study, we therefore selected five top influential newsagent Twitter accounts for analysis, namely Bloomberg@business, @Reuters, @Forbes, @WSJ and @realdonaldtrump. These accounts are interested in the stock market and have great influence on investors' opinions [11, 12]. The selection of news providers are also based on their neutral position on stock market investments (i.e. not supporting or biased towards a particular company), the frequency of posting (so that they are active and current), and the usefulness and relevance of their Tweets to the stock market (i.e. less advertisements or social-related postings) [13]. In addition, as our sampling period overlaps with his presidency, we included the Tweeter account of the former US President Donald Trump. As his Tweets, when holding such an influential role, have been observed to have significant impacts on the movements of the stock market's prices [14]. This includes Tweets of policy announcements ahead of their implementations. These five accounts are financially related, and their followers have similar interests, reflecting a strong likelihood that their followers belong to the active investment community.

There are several relevant Tweets datasets, such as Trump's Twitter Archive [13], which includes 50,049 Tweets from the former US President Donald Trump. Also, there are useful Python tools that scrape Tweets, such as Twint. However, most datasets are not free to use and have time restrictions. Twitter's official API also has the restriction of time that users cannot acquire Tweets for more than a week old. In addition, Twitter limits each IP address to 2,000 requests per hour via their API. In this paper, the Python tool Twint was used to scrape Tweets data from several users. It mimics a user's search using the Twitter search bar to overcome the aforementioned limitations.

The data set was collected from Twitter from "29 February 2020" to "3 April 2020". This was an interesting period because there is a major and sudden global stock market crash between 20 February 2020 and 7 April due to Coronavirus. The safety measure of "trading curb" was triggered four times during this period. On 9 March 2020, stock market prices fell all around the world dramatically, such as S&P 500 in the US fell 7.6%, FTES 100 in the UK fell 7.7%, the TSX Composite Index in Canada fell more than 10% and the STOXX Europe 600 fell more than 20% [15].

We randomly collected 1,000 Tweets from each of the above-selected Tweeter user accounts to a total of 5,000 Tweets. Each Tweet download includes a unique id, permalink (link to access the Tweet), username, text, publication date, the number of reTweets, number of favourites, number of mentions and hashtags. The texts of each Tweet were extracted and prepared for sentiment analysis where noises and non-text symbols have been removed.

11.3.2 Sentiment Analysis and Sentiment Polarity

The lexicon-based sentiment analysis method is to make use of sentiment lexicons which include labelled positive and negative words and that each word can be weighted with a degree of sentimental. The input texts are matched with these sentiment lexicons and assessed to generate their sentiment values. This represents the sentiment polarity (SP) of the text.

In this paper, the SentiStrength, a lexicon-based classifier, has been used to detect the sentiments of Tweets [1]. The sentiment polarity is indicated by two integers: the positive sentiment is denoted between 1 and 5; and the negative sentiment between -1 and -5. Two scales are used because every text may include both positive and negative sentiments. It is important to detect them separately before an overall sentiment is proposed. 1 represents no sentiment and 5 strong positive sentiment. The result of 3, -5 means moderate positive sentiment and strong negative sentiment. 1 and -1 indicate neutral sentiments.

There are several useful features in SentiStrength. It provides a sentiment lexicon assigned with polarity and strength judgements. SentiStrength also contains booster word lists, idiom lists and negating word lists. It can identify the sentiment of common phrases and overrides individual sentiment word strengths. For example, "is like" has a score 1 (means neutral text). "like" is a comparator after "is" rather than a positive term (positive 2). The algorithm of SentiStrength detects each word to check whether there is an increase or decrease of 1. The algorithm repeats until all words are checked.

Weka is an open-source machine learning software that can be used by terminal applications, Java API and graphical user interfaces. It includes a lot of built-in tools and useful packages. SentiStrength is wrapped in the AffactiveTweets Weka package, and it can be accessed through the WekaPackage manager. The collections of Tweets are saved as CSV files and loaded through the Weka SentiStrength Package. Next, the newly generated CSV files with sentiment scores will be analysed.

11.4 Results

11.4.1 Tweets Statistics and Their Interpretations

The outputs of SentiStrength include a positive (from 1 to 5) and a negative (from −1 to −5) polarity scores. These two scores are summated to represent the sentiment composite value. Figure 11.2 shows the distributions of the composite and ground truth scores. Most Tweets produce a 0 (neutral) result, and that reflects the fact that most Tweets are informative and do not express sentiments directly in their texts. Ground truth values are generated based on judgements of their influence on the stock market from an investor's view. When a 0 value is produced, it indicates that the Tweet, based on its text and without reading into additional information such as attached links/URLs, does not have an obvious influence on stock market price movements.

To do this, for each Tweet, the two pairs of negative and positive sentiment values as produced by the tool and the ground truth are each summated to produce two composite scores. As a result, the Reuters produced the most neutral scored (0) sentiment Tweets as assessed by the tool (728), as seen in Fig. 11.2 (left) and Table 11.1. However, it was judged to have an overall slightly negative sentiment (−1) from its ground truth scores. Figure 11.2 (right) shows a skewed line peaked at −1. This indicates that although Reuters use a lot of neutral words/phrases in their Tweets, they are perceived to have a slightly negative influence on the stock market.

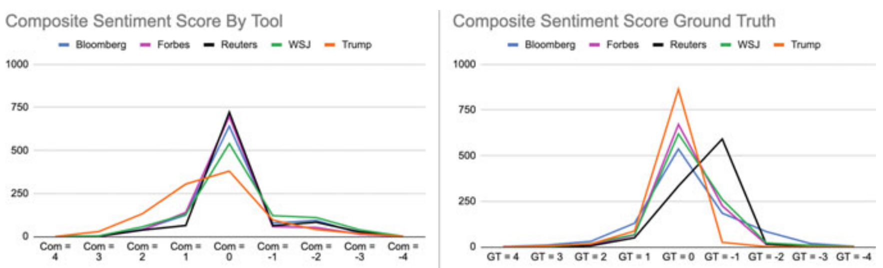

Fig. 11.2 Distributions of composite sentiment scores as generated by SentiStrength (left) and ground truth (right)

Table 11.1 Sentiment polarity scores by tool

	Positive	Neutral	Negative
Bloomberg	167	642	191
Forbes	178	698	124
Reuters	104	**723**	173
WSJ	189	540	**271**
Donald Trump	**466**	380	154

On the contrary, Donald Trump uses a great number of positive words and phrases and that the positive composite sentiment scores generated by the tool are much higher than other users. This is evident by the skewed curve that is leaning to the positive spectrum as seen in Fig. 11.2 (left). However, when comparing them with the ground truth, their potential influence on the stock market is only moderately more positive—the orange peak is only slightly leaning to the left, as seen in Fig. 11.2 (right).

Overall, the distributions of the sentiment scores generated by the tool among all users are relatively similar, except for Donald Trump's. As the president of the time, it is understandable that he would wish to project positivity into the stock market—esp. at a time when stock market crash was observed. Overall, the results are within the normal distribution, and many Tweets obtained the scores as 0. Most of them exhibit similar distributions between the machine-generated and ground truth scores.

Table 11.1 gives the summary of the Sentiment Polarity Scores by tool. Based on our samples, Donald Trump has the most positive Tweets (466), and WSJ has the most negative Tweets (271). Reuters produces the most neutral Tweets (723) that may be an indication that it is more informative rather than judgmental. Table 11.2 shows the ground truth results of SP classification. It shows Bloomberg has the most positive scores (172) that is similar to the assessment by the tools (167). Reuters has the most negative Tweets in ground truth results, but many of these negativities were not detected by the tool (only 173 were assessed to be negative). Overall, it also shows that most Twitter users have more negative sentiments, when they are compared with machine-generated sentiments, except for Donald Trump.

Figure 11.3 shows the differences in scores between the ground truth and SentiStrength generated composite scores. There is not a big difference between them: 40.2% (difference = 0) indicates no disagreement was found and 40.4% (difference = 1) indicates slightly disagreement. These closely matching results may also

Table 11.2 Sentiment polarity scores of ground truth/in investor's eyes

	Positive	Neutral	Negative
Bloomberg	**172**	537	291
Forbes	79	671	250
Reuters	56	334	**610**
WSJ	88	619	293
Donald Trump	109	**864**	27

Degree of Disagreement							
	Bloomb	Forbes	Reuters	WSJ	Trump	Total	Disagreement
Diff = 0	444	525	281	400	361	2011	No Disagreement
Diff = 1	325	343	572	354	424	2018	Slightly Disagree
Diff = 2	172	101	103	189	159	724	Partly Disagree
Diff = 3	44	26	43	51	52	216	Disagree
Diff = 4	10	5	1	4	3	23	Very Disagree
Diff = 5	4	0	0	2	1	7	Mostly Disagree
Diff = 6	1	0	0	0	0	1	Strongly Disagree
Diff = 7	0	0	0	0	0	0	Extremelly Disagree
Diff = 8	0	0	0	0	0	0	Entirelly Disagree

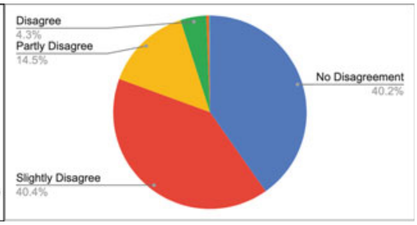

Fig. 11.3 Degree of disagreement between ground truth and SentiStrength scores

be contributed by the fact that many Tweets are information based and do not contain obvious sentiments towards stock market movements or otherwise.

11.4.2 Accuracy and Evaluation

To measure the performance of SentiStrength, we used standard calculation methods for calculating the Accuracy as provided in Formula 11.1 and 11.2 below [16]

$$Accuracy = \frac{Numbers\ of\ results\ predicted\ correctly}{Counts\ of\ all\ possible\ results} \tag{11.1}$$

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{11.2}$$

where True Positive (TP) and True Negative (TN) indicate where both the tool and ground truth detected the same sentiments of either neutral, positive or negative; and False Positive (FP) and False Negative (FN) indicate where the tool and the ground truth disagree. Table 11.3 presents the results of the tool performance evaluated using composite sentiment scores. Formulas 11.3, 11.4 and 11.5 provide the calculation for generating the Precision, Recall and F1 Scores.

$$Precision = \frac{TP}{TP + FP} \tag{11.3}$$

Table 11.3 SentiStrength performance based on composite scores

	Accuracy	Precision	Recall	F1 score
Bloomberg	0.690	0.746	0.852	0.796
Forbes	0.412	0.387	**0.869**	0.5355
Reuters	0.435	0.394	0.836	0.5357
WSJ	0.638	0.737	0.760	0.748
Donald Trump	**0.839**	**0.980**	0.852	**0.911**

$$Recall = \frac{TP}{TP + FN} \tag{11.4}$$

F1 score strikes a balance between the precision and recall. It is the harmonic mean of precision. When the result is difficult to decide by using precision and recall, the F1 Score is often used to validate the performance of results.

$$F1Score = \frac{2 * Precision * Recall}{Precision + Recall} \tag{11.5}$$

Based on sampled Tweets, SentiStrength obtained the best performance on Donald Trump's dataset for Accuracy (83.9%), Precision (98%) and F1 Score (91.1%). Such high scores may be due to the fact that Donald Trump uses a lot of generally positive words, such as lovely, brilliantly, right, support and confidence that the sentiments of Tweets can be easier detected. Although comparably high on the Recall counts, other performance indicators for Forbes are at the lowest. This may be because most texts from Forbes merely state facts, but they do not include sentimental or subjective clues. For example, the below Tweets from Forbes:

> The stock market bounced back today amid reports that the Trump administration is making progress on plans for a massive fiscal stimulus package that could exceed $1 trillion in an effort to reinvigorate the U.S. economy.
>
> Facebook has announced a $100 million grant for small businesses being impacted by COVID-19.

It is, however, not difficult for an investor (inc. a novice one) to know that these two Tweets would have big positive effects on the stock market. But the results of SentiStrength were neutral. For SentiStrength, it will also be difficult to judge the polarity of the texts in a specialised context, because it classifies sentiments based on generic lexicon. Although it can identify some specific idioms, it does not explore the meaning of a sentence beyond the literature text. The case of Forbes therefore highlights a great challenge that is similarly presented in the case of Reuters. The performance of the tool can be summarised using the F1 score that is a composited measurement based on Precision and Recall. Overall, the performance for determining the sentiments of Donald Trump's Tweets gained the highest scores.

Figure 11.4 shows a comparison box plot diagram of the ground truth and tool-generated scores. The differences of medians are less than 1 across different Tweeter accounts. Most medians are located between 0 and −1, except for Donald Trump's that is observably higher (0.425 of grey box). It shows most texts have the neutral or slightly negative sentiment (approx. 75% of the population is below 0). It also shows that the automatically generated results from SentiStrength and ground truth exhibit similar distributions.

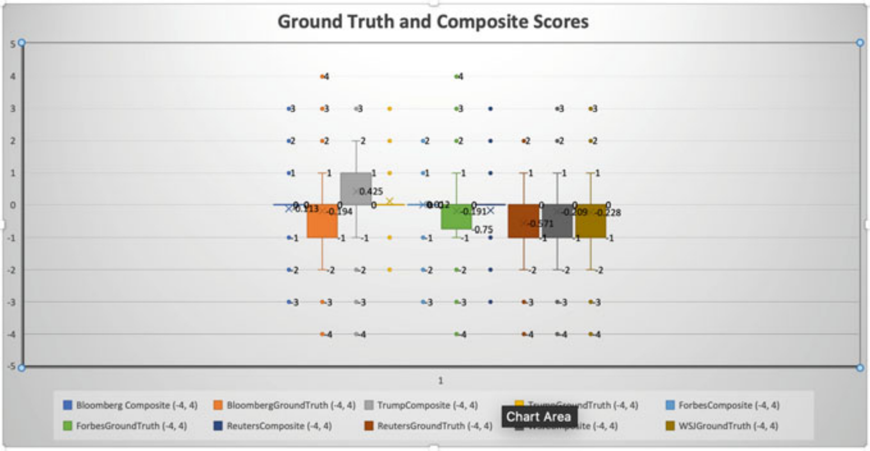

Fig. 11.4 Box plot of ground truth and SentiStrength composite scores

11.5 Related Works

Yuan [17] found Trump's Tweets have obvious impacts on Dow Jones Indexes—which is amplified when re-iterated by other newsagents. Trump's Tweets were found to be useful in predicting stock market price movements. However, their impacts tend to be short term. This finding agrees with our results that Trump publishes many encouraging Tweets, but many sentiments were judged as neutral in investor's mind, therefore many impacts of these Tweets would be short lived. Bollen [5] investigated whether generic Twitter mood could be used to predict the Dow Jones Index movements. The "calm" mood assessed by Google Profile of Mood States classifier was found to have a delayed impact on the stock market within the 2–5 days duration, whereas the OpinionFinder's mood classification did not show correlation. This research also showed that there is a close Tweeter's public mood correspondence with the presidential election and Thanksgiving holiday. Rather than comparing the sentiments of generic Tweets with stock market movements, we use financial-related Tweets and compare them with the minds of stock market investors. Interestingly, Schumaker [18] noted an "inverse" effect of sentiments in news articles, i.e. prices go up when there are negative sentiments and vice versa—indicating contrarian manners of investors. This research reached the best prediction accuracy of 59%. Hagenau [19] deploys a combined approach of using selected 1- and 2-words from news articles and a feedback mechanism for their SA analysis and found their best accuracy at 76%. In this paper, SentiStrength employs 1-, 2- and 3-words lexicon and the best accuracy generated for Donald Trump's Tweets is 83.9%, but not quite as high for other Tweeter accounts.

11.6 Conclusions and Future Work

One of the goals of this research is to determine the influence of Tweets on investor's mind in the context of stock market trading, especially for Tweets generated by influential news providers and well-known Tweeter users. One way of doing this is by comparing the sentiments of their Tweets and the Ground Truth values as would be perceived by investors.

Twint was utilised to extract Tweets from Twitter. The data was collected from five accounts: Forbes, Reuters, WSJ, and Bloomberg, and the former US President Donald Trump during a very interesting time period where global stock market crashes due to Coronavirus. This duration was chosen as Tweets during this period may exhibit stronger sentiments. We used the generic purposed SentiStrength SA tool to assign sentiment polarity to each Tweet and determine whether it is suitable for the specialised domain of stock market. We found a high correlation of sentiments between machine-generated results and the ground truth when obvious positive words and phrases were used in a Tweet. It is, however, much more difficult for the machine to detect sentiments when only fact-based information is provided without any emotional clues.

Overall, we found a fair level of agreements on the distributions of machine-generated and ground truth sentiment values. It was very interesting to find sampled news outlets produced only slightly negative sentiments during a period when there is a global stock market downturn (trading curb triggered four times in the US) via what is conveyed through the text—this may reflect a conservative stance of these companies. However, understandably as someone who would promote US economic growth and ensure stability, the former president Donald Trump, published many Tweets containing positive, encouraging words and phrases. Unfortunately, not all of these Tweets generated similar positive sentiments in the investor's eyes.

The best accuracy results achieved by the SentiStrength were obtained on Tweets of Donald Trump's (83.9%) because they deliver his opinion more clearly. We also found most users have their majority of Tweets judged to be neutral, except for Donald Trump's that is leaning to the positive spectrum—with its median arrives at a positive sentiment of 0.425; where news agents' medians are between neutral 0 and slight negative sentiment of -1.

Based on sentiment scores by tool, WSJ has the most negative Tweets (27.1% of their Tweets are negative)—for ground truth, Tweets of negative sentiments increase to 29.3%. Reuters has the greatest number of neutral scores (72.3%) and 17.3% of its Tweets were determined to be negative by the tool. However, many of these neutral Tweets were perceived to be negative by investors, i.e. 61.0% of their Tweets were judged to have a negative impact on the stock market. This phenomenon indicates that Tweets that do not contain emotional words can still cause negative sentiments on the financial market.

It is challenging to judge text precisely and acquire correct sentimental polarity from words and phrases. Many Tweets may have meanings beyond the text. SentiStrength can categorise sentiments based on words, but it is difficult to explore the concealed information beyond the actual concepts of sentences. Some sentences are also complicated, and they cannot be easily understood accurately. The lexicon of sentiments might be quite general which is not specific to finance or the stock market. The domain-related sentiments may require more specific words and meanings and for specific contexts. The content of the lexicon would therefore ideally be expanded and improved.

Future work may also focus on the understanding beyond the text such as sarcasm and ambiguous words. Tweets would ideally be classified based on words in context and their weightings placed on the whole sentence and not just words, to improve the quality of polarity classification. In this paper, the generic SA tool of SentiStrength has been put to the test in a very specialised domain and had produced variable performance. More syntactic patterns can be considered to indicate subjectivity and sentiments to improve their accuracy. The lexicon sets can be enlarged to include more domain-specific words, phrases and idioms to enhance the performance. It will be important to develop finance-related lexicon to improve the accuracy of sentiment analysis. Furthermore, ontology-based methods may be utilised to enable domain-specific sentiment annotations and to help build decision support systems by combining knowledge from several related ontological sources.

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Chapter 12
Impact of the COVID-19 Crisis on Digital Business Models—Contactless Payments

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Abstract The COVID-19 crisis affected society and economy worldwide and has an increasing influence on all industry sectors. That opens up completely new digital business models and does not stop at people's payment behavior. New payment options such as Apple Pay, Amazon Pay, and others enable people to pay without cash. The aim of this research project is to identify what effects the COVID-19 crisis has on people's behavior with regard to contactless payment. It will be investigated whether the participants are increasingly using contactless payment options due to the COVID-19 crisis and what advantages and disadvantages are associated with the options. Since there are hardly any studies on this topic at the current time, this paper strives to fill this research gap. For this purpose, the authors have conducted a quantitative study. The hypothesis framework is derived from literature research. The resulting study was conducted with 528 participants. Study analysis show that the vast majority of hypotheses have a significant impact on the potential of contactless payment systems.

12.1 Introduction

The COVID-19 crisis is currently affecting our society and is having a great impact on digital business models during this period. Companies must rethink in order to remain competitive and adapt to new digital technologies. Contactless payment becomes more and more important, especially in these times. It is impossible to imagine life without it. The modern world is digital, paperless, and cashless. The traditional cash is slightly disappearing from our wallets and from our society, and this phenomenon is becoming even more intense due to the COVID-19 crisis. Mobile payment should make the payment process easier, faster, and more convenient. Contactless payment is still used comparatively little in Germany, but it is accelerating the trend of recent

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years toward the disappearance of traditional cash and is even being reinforced by the COVID-19 crisis [1].

Since 2018, German retailers are using other ways of payment than cash more frequently for the first time. Although around 22.7 billion cashless transactions have already been counted in Germany in 2018, this is only the middle range in an EU-wide comparison [2]. Luxembourg, Sweden, and Finland take the top positions in cashless transactions per capita of the population and are on their best way to a cashless society [3]. In Germany, NFC technology is about to become part of the complete standard equipment at checkouts by 2020, which should increase customer acceptance. The payment process will also be faster and operation will be less complicated. In the future, it should also be possible to pay with a wide variety of devices [4].

12.2 Theoretical Background

In this chapter, the theoretical background of the presented study is presented. First of all, the COVID-19 crisis and contactless payment are examined in detail. History shows the development of contactless payment. This few allows a better understanding for interpretations of the extent to which the COVID-19 crisis is changing payment behavior.

12.2.1 COVID-19 Crisis

The COVID-19 pandemic, also known as the coronavirus pandemic, is an ongoing global threat, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [5]. The outbreak was first identified in Wuhan [6], China, in December 2019. The World Health Organization declared the outbreak a Public Health Emergency of International Concern on January 30, 2020, and a pandemic on March 11. Until the end of February 2021, more than 114 million cases of COVID-19 have been reported in more than 188 countries and territories, resulting in more than 2.5 million deaths; more than 110 million people have recovered [7]. The current situation shows a longer-term evolution of the pandemic. This means adjustments in lifestyle are necessary.

12.2.2 History of Contactless Payments

Contactless payment transactions are payment transactions that do not require physical contact between the consumer's payment device and the physical terminal. In this type of payment, the consumer holds a contactless card, device, or mobile phone close to the terminal and the payment information is transmitted wirelessly over radio frequencies [8]. They originated in 1997, when ExxonMobil introduced an innovative means of payment—the *Speedpass*, a small key fob that could be used on the gas pump to pay for refueling without having to take cash or a payment card out of your pocket. This *Speedpass*, which used Near Field Communication (NFC) to transmit user and payment information to the dispenser, was widely marketed by ExxonMobil as a faster and safer way to pay for gasoline. Within a short period of time, this new payment technology, which became known as "tap-and-pay," was adopted by ExxonMobil customers [9].

This concept was also interesting for payment card companies. American Express (ExpressPay), MasterCard (PayPass), and Visa (Visa Wave) entered the contactless card space by 2004, and major credit and debit card issuing banks such as MBNA, Citibank, JPMorgan Chase, and Key Bank began issuing cards with contactless functionality to large parts of their customer base [9]. In the beginning, they had great challenges finding business partners who accept contactless payments. In order to process transactions, merchants had to upgrade their POS terminals, an effort that many were reluctant to make because of the vague promise that contactless payments would make a noticeable difference in the bottom line. This technology also led to a certain reluctance on the part of the customer, because they were afraid for security. Studies showed that enterprising thieves could theoretically intercept the transmitted payment data at the payment terminal or steal the card formats simply by standing near you on the subway with an NFC reader in their pocket. As unlikely as these scenarios were, the reports damaged the perception of contactless cards in the eyes of many consumers. Even today, the proliferation of RFID-blocking wallets and purses indicates that these fears are still present [9]. But in recent years, trust in the contactless payment method has grown. One reason for this is the introduction of Apple Pay, an NFC-based contactless payment tool that integrates payment information into the iPhone or Apple Watch. In 2015, Samsung Pay and Android Pay were also launched, enabling users to make mobile payments. By early 2020, consumers with a contactless card or mobile device will be able to use contactless payment at many, if not most, merchants [9].

12.3 Background and Research Design

In order to analyze the impact of contactless payments during the Corona pandemic in Germany, a hypothesis model was developed based on the current literature [10], which is shown in the following graph (Fig. 12.1).

Regarding the research design above, nine determinants have been found. Based on literature review, different hypotheses were identified which are explained in the following. The created hypotheses resulted in the questionnaire to find out how people think about the following statements. The first part is generally about the use of contactless payment systems and what it leads to…

… a decline in cash use. When consumers use contactless payment methods, there is usually no need to carry cash because they can pay contactless with card,

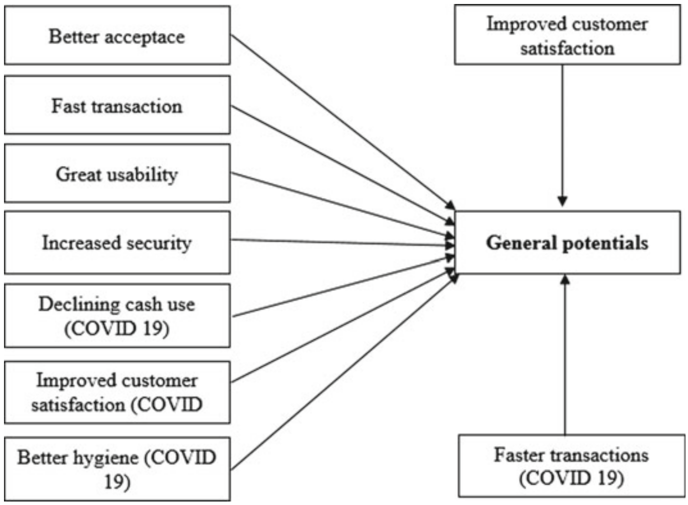

Fig. 12.1 Hypotheses model

smartphone, or further modern gadgets. It is an advantage for consumers, retailers, and financial institutions [11, 12].

…*faster transactions.* When customers pay without any contact, this is much faster than paying with cash and it leads to faster transactions which is often mentioned as an advantage in connection with contactless payment methods [11, 13].

…*higher user-friendliness.* Higher user-friendliness results out of higher security, dependable means of payment and settlement for a big scope of products and enterprises offered worldwide, for example, over the Web or other electronic systems [14].

… *increased security during the payment process.* People who want to use contactless payment systems are mostly uncertain about their safety. But an e-commerce payment gateway, for example, ensures security on electronic systems. It´s an access point to the national banking system and every single online exchange must handle it [14].

…*improved customer satisfaction.* Besides the aspects of increased higher user-friendliness, improved customer satisfaction results from different aspects. For example, the facts of faster transactions, an increased security, or the reliable means of payment lead to an improved customer satisfaction [14–16].

… *better acceptance.* Contactless Technology has generally been accepted by consumer, mainly due to the fact that contactless technologies are offered by many companies. The consumers know the benefits of contactless technologies and are more willing to accept new payment processes with a higher personal level of information. Trust in contactless payment methods increases acceptance [11, 13, 17].

The second part of the questionnaire contains the use of contactless payment systems to the aspect of the COVID-19 pandemic with the same hypotheses. The results are as follows. Customers increasingly use contactless payment methods to

Table 12.1 Summary of literature review contactless payments regarding COVID-19 crisis

Determinants	References before crisis	References regarding the crisis
Cash use	[11, 12]	[11, 12, 18]
Fast transactions	[11, 13]	[18]
User-friendliness	[14]	[19]
Security	[14]	–
Customer satisfaction	[14–16]	[19]
Acceptance	[11, 17]	[13, 18]
Hygiene	–	[19, 20]

avoid contacts which naturally lead to a decline in cash use [11, 12, 18]. A short click is all it takes, for example, when consumers paying with a smartphone, to transfer the money while buying something. It takes less time than paying cash and leads to faster transactions [18]. Contactless payments during the COVID-19 crisis lead to faster transactions and the avoidance of contacts which results in improved customer satisfaction [19]. COVID-19 changes the payment behavior of people, especially during the COVID-19 crisis. The consumers know the benefits of contactless payment systems and use new payment procedure more likely [13, 18]. Customers only have to hold their credit card or other device at the merchant's terminal. Contacts with staff at the cash registers and potential transfers can be avoided which also leads to better hygiene [19, 20]. The following table summarizes the literature review for the questions of contactless payments with and before the COVID-19 crisis (Table 12.1).

The hypotheses were evaluated in the form of questions where the test persons answered on a 5-point Likert scale. This allows a quantitative review. Participants replied to questions about what contactless payments may lead to in general. Following the aspects of COVID-19 were taken into account and questions about evaluating the changing behavior related to contactless payments were conducted. The questionnaire contained descriptive questions to consider different groups separately.

12.4 Research Methods and Data Collection

The authors examined the hypotheses using a quantitative research approach with the help of a web-based online survey that corresponds to the research model. Conducting the survey using the open-source software LimeSurvey took advantage of reaching many participants. The main study started on June 26, 2020, and ended on July 17, 2020, collecting a sample of $n = 761$ responses. The survey is limited to German-speaking countries (Germany, Austria, and Switzerland). After data cleaning and elimination of incompletely answered questionnaires, the authors received a final sample of $n = 528$ participants. The structural equation modeling was chosen to analyze the collected and processed empirical data from the quantitative survey. Using the SmartPLS program, the corresponding influences and effects of the individual variables on the research question can be evaluated. This system makes it possible to test and validate the collected data in relation to the research question. From this, it can then be determined if and how strongly the hypothesis and the theoretical model are confirmed by the collected data [21].

The first information on data sets is about the gender of the interviewed participants. About 49% (261 persons from all 528 of the involved participants) are female. A further 246 participants and thus about 47% stated that they are male. In addition, 3 persons, and therefore about 1%, declared diverse for their gender. The remaining 3% with 18 entries replied that they have a different gender or did not want to give any information at all about their gender. Most of the respondents (122 persons) with about 23% are between 23 and 27 years old. Only a few of the respondents with a share under 1% are between 58 and 62 years old. About 74% are up to 42 years old. From the age of 43, there are only 24% left. In the sample, 11 did not give any information about their age. The average age is 35.5 years. With 495 persons from the total number of 528 (about 94%), most of the participants came from Germany. Another 19 persons (about 3%) came from Austria and Switzerland. The last proportion of the respondents, 14 participants (about 3%), stated that they came from another country.

In summary, there is almost a balanced proportion in the gender of the participants between female and male participants. The sample was quite young in terms of age and with an average age of 35.5 years. That value is slightly below the usual average age of about 45 years in Germany [22]. Moreover, the survey was mainly conducted in German-speaking countries.

12.5 Results

To analyze the theoretical causal model with empirical data, structural equation modeling with SmartPLS was chosen. The relationships between different variables can be calculated with SEM [22]. This type of modeling is regarded as a second generation of multivariate analysis to gain a deeper insight into the analysis of different relationships. The measurement model validates the latent variables, while the structural equation model analyzes different relationships between the research model and latent variables [23]. The following results were obtained after evaluating the data sets of the empirical sample with SmartPLS (Fig. 12.2).

The analysis with SmartPLS shows seven out of nine items evaluated ($p < 0.05$) have a significant potential for contactless payment systems. The original sample and the average sample value should exceed a value of 0.2 for the result to be considered good [24]. The standard deviation, on the other hand, should be as small as possible. The significance level in this study is 5%, so the T-statistic should reach at least a threshold value of 1.96 [25]. The p-values should also reach as small a value as possible. This should be close to be zero and positive [26]. In summary, the items *Improved customer satisfaction due to COVID-19* (1,977) and *Declining cash*

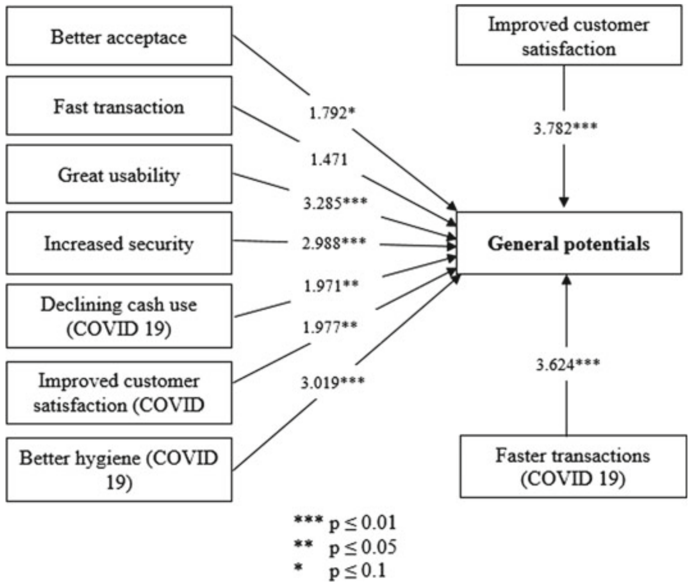

Fig. 12.2 Structural equation model with single items

use due to COVID-19 (1,971) can be described as significant potentials ($p < 0.05$) with a high positive impact. With a p-value below 0.01, *Improved customer satisfaction* (3,782), *Faster transactions due to COVID-19* (3,624), *Great usability* (3,285), *Increased security* (2,988), and *Better hygiene due to COVID-19* (3,019) even have a statistically highly significant influence on the potential of contactless payment systems. Customer satisfaction increases because contactless payment system technologies offer customers more options. Security and hygiene are also improved by avoiding direct contacts between customers and vendors. As a result of the COVID-19 pandemic, contactless payment systems will enable transactions to be carried out more quickly, which will benefit both customers and stationary retailers. More alternatives and flexibility also increase user-friendliness. The items *Fast transactions* ($p = 0.142$) and *Better acceptance* ($p = 0.074$) are not very meaningful in the results. Detailed information about the structural equation model and the influence of the determinants are presented in Table 12.2.

Since only single items and no multiple constructs were formed for the structural equation model, quality criteria by Homburg shows values of 1.000 for Cronbach's Alpha, Composite Reliability and Average Variance Extracted [27].

In order to have a consistent model, it is important to take a brief look at the quality criteria for SEM. Here we take a look at the coefficient of determination "R square" as a quality criterion for the dependent variable *General potential of contactless payment systems*. The value of 0.637 lies in the interval between 0.6 and 0.8 and shows that the survey is very meaningful and the model is of very high quality.

Table 12.2 Results of structural equation model

Single items	Original sample	Average sample value	Standard deviation	T-statistics	*P*-value
Better acceptance	0.228	0.231	0.060	1.792	0.074
Fast transactions	−0.078	−0.078	0.053	1.471	0.142
Greater usability	0.163	0.164	0.050	3.285	0.001
Increased security	0.098	0.097	0.033	2.988	0.003
Improved customer satisfaction	0.228	0.231	0.060	3.782	0.000
Declining cash use (COVID-19)	0.077	0.077	0.039	1.971	0.049
Improved customer satisfaction (COVID-19)	0.099	0.095	0.050	1.977	0.048
Better hygiene (COVID-19)	0.133	0.132	0.044	3.019	0.003
Faster transactions (COVID-19)	0.203	0.205	0.056	3.624	0.000

A total of 528 persons were interviewed. In order to enable a transparent statement, from these statements, the structural equation model already explained could be developed and interpreted.

The answers of the participants were found out and then the arithmetic mean was calculated. It can therefore be specified that with the average score of 2.01, respondents tend to agree that contactless payment systems generally lead to a decline in cash use. Looking at this statement in the context of COVID-19, the average is 1.68. This means that contactless payment systems generally lead to a decrease in cash usage during COVID-19. In terms of the arithmetic means of 1.73, respondents tend to believe that contactless payments lead to faster transactions. In the context of Covid-19, no major difference is apparent. Here the average is 1.78. The statement that contactless payment leads to user-friendliness is more in agreement with the respondents with 1.99. On average (2.58), the respondents think that contactless payment systems have a rather high or neutral effect on secure payment. Comparing the answers with improved customer satisfaction, the average is 2.23 and within the Covid-19 the average is 2.08. In both cases, the respondents tend to agree with the statement. The respondents with an average value of 2.4 also confirm the statement that contactless payment has a better accent, this statement was confirmed in the context of Covid-19 with a mean value of 2.06.

In general, respondents feel that the general potential of contactless payment is rather positive (2.07).

12.6 Conclusion

A structural equation model was created to investigate the potential of contactless payment systems. The investigation shows 11 individual elements that aim at the potential of contactless payment systems. The elements could be comprehensively confirmed on the basis of a literature search: *improved customer satisfaction*, *faster transactions through COVID-19*, and *great usability*. B*etter hygiene* and *increased security* have a highly significant influence on the potential of contactless payment systems. *Declining cash use through COVID-19* and *improved customer satisfaction through COVID-19* have a normal significant impact. Other factors investigated include *fast transactions* and *better acceptance* which seem to have a lower positive impact on the use of contactless payment systems in retail. The individual elements *better acceptance through COVID-19* and *declining cash use* were not included in the evaluation, as they do not seem to have a significant impact on the potential and use of contactless payment systems. Therefore, the paper focuses on nine of the previously identified 11 hypotheses, which might be a limitation. Other factors, such as the age or gender of the respondents, may have an additional impact on the results of the survey.

This study can serve as a basis for further research on new applications and their potential benefits of contactless payment systems. Furthermore, a qualitative research design can help to gain further insights into factors affecting the potential of contactless payment systems. Contactless payment systems are attracting additional interest from (potential) users, in particular due to the COVID-19 pandemic. Contactless payment systems are an increasingly important tool for faster, cleaner, and smoother payment processing, which is reflected in increased customer satisfaction among users.

Due to the high acceptance of contactless payment methods influenced by Covid-19 and the increase of digital natives, it can be assumed that results could change significantly in future. With over 500 data sets, a certain basic population has already been achieved. For further surveys, this could be extended to additional participant groups in order to achieve a better representation of the relevant population. In addition, an expansion to respondents outside of Germany should also take place. A different number of respondents as well as a different structure can lead to variations in the results.

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Chapter 13
A Smart Lighting Context-Aware Model Based on Colored Petri Net

Katarina Mandaric, Pavle Skocir, and Gordan Jezic

Abstract Internet of Things (IoT) has stimulated the development of numerous innovative applications in various domains, but the real potential of IoT has not been reached yet. A new paradigm, Cognitive Internet of Things (CIoT), is a step toward grasping that potential. With cognitive capability applied to IoT solutions, a whole new level of comfort is introduced to users. For example, smart home systems can make independent decisions on ambient condition adjustments based on user preferences. Handling all context types, i.e., the information about user preferences and current ambient conditions, is a rising challenge. With the aim to resolve this issue, we propose a smart lighting system based on Colored Petri Nets. The system is context-aware as it takes into account previously learned preferences of each individual user, the outside luminosity condition, as well as the current period of the day. The proposed system relies on an Artificial Neural Network for the calculation of optimal lighting settings.

13.1 Introduction

Internet of Things (IoT) has been the initiator of many changes in the daily life of users and enabling the development of new products, increasing the quality of life of users which is visible daily. For example, Internet of Things has made possible the development of smart homes, smart environments, smart buildings, smart cities, smart traffic control, smart garbage management, industrial automation, precise agriculture, smart autonomous cars, monitoring of climate conditions, and remote health

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care (which proved very important in the Sars-Cov2 pandemic). The Internet of Things has opened many possibilities and since its beginning attracted the intention of both industry and academics, but it has been often pointed out that the full potential of IoT is yet to be reached. One of the options to get the full potential out of the Internet of Things is the Cognitive Internet of Things (CIoT).

The cognitive Internet of Things opens up new possibilities by giving the Internet of Things a "brain", as Wu et al. [12] pointed out that the Internet of Things by itself is *all brawn and no brains*. The "brain" that enables the creation of cognitive Internet of Things comes from many different new technologies, for example, machine learning, artificial intelligence, pattern recognition, language processing, machine vision, and big data analytics.

For example, the upturn that CIoT offers over IoT in smart environments is more comfort. Users don't have to manually control their appliances anymore. Previously, users were offered the virtues of amortization to control their homes, but the cognitive possibilities that characterize CIoT are a very notable and important progress. With CIoT, devices and appliances can adapt to the users' wishes based on context.

In this paper, the focus is a smart lighting context-aware model. The presented idea of smart lighting is centered around adjusting the lighting based on the previous preferences of the individual user, the current time, and the reading of the light sensor. Light adjustment refers to the intensity and color of the light. An Artificial Neural Network is responsible for the adjustment calculation for each user. The model is defined by a Colored Petri Net. Colored Petri Nets have been often used for context modeling and evaluation of various types of systems.

The rest of this paper is organized as follows: in Sect. 13.2, an overview of related work is given. In Sect. 13.3, Petri Nets and Colored Petri Nets are briefly introduced. Section 13.4 contains a detailed description of the use case and model simulation with Colored Petri Nets. With Sect. 13.5, the paper is concluded and future work is discussed.

13.2 Related Work

Petri Nets have been used in various researches on automation and context modeling as they are a useful graphical notation tool for supervision and control.

Niu and Wang [11] proposed a smart home hybrid context-aware modeling approach using UML and Colored Petri Net. There are many smart home scenarios and in their work, they modeled the leave home scenario that involves two concurrent operations that are independent of each other: open fire detection system and open security system. In addition to CPN, they also used UMLs.

Kissoum et al. [7] also focused on smart homes. Their approach features the paradigm of "nets within nets" which they used because of its ability to capture mobility intuitively without loss of formal accuracy. They modeled a mobile robot which is able to take care of home work because of it's sensitivity, adaptability, and responsiveness to the human presence.

Garcia-Contsantiono et al. [4] modeled Activities of Daily Living (ADLs) with Petri Nets to capture the behaviors of ambient systems. The activities they modeled were preparing tea, coffee, and pasta. In their model, they used contact and thermal sensors for monitoring the activities in the kitchen. They concluded that Petri Nets are a reliable and effective tool to represent the examined system that detects users' activities, even if they show normal or abnormal behavior.

In their research, Lu and Zhao [9] point out that context-aware services, upon detection of changing circumstances, when adapting to them, may cause conflict as the adaptation may cause context changes that affect different services. This leads to a cascade reaction of adaptations. They proposed a Petri Net to simulate these events to discover potential conflicts. Their case study was a smart home scenario whose results showed that their proposed approach is an efficient way to locate conflicts caused by adaptations by different services in the smart home.

Konios and Koutny [8] used a new class of Colored Petri Nets for the formal modeling of Ambient Systems. They are called Ambient Petri Nets (APNs) which are intended for application on Ambient Systems. The main goal for the new class of CPNs was to describe the characteristics of Ambient Systems in an accurate and flexible way.

Bouazza and Deabes [1] also point out the adequacy of Petri Nets for supervision and control of discrete event control systems. In their work, they propose a smart energy-saving framework with the goal to integrate new advanced technologies with conventional Air Conditioning systems in order to increase comfort, create optimum energy efficiency, and, consequently, profitability. They used a Petri Net model to monitor users and forward the users' temperature preferences to the next stage of their framework.

Petri Nets are also used for modeling smart cities. Dolinina et al. [2] used a Petri Net model to describe the actions and activities needed for the development of efficient waste removal as garbage collection is an essential step to cleaner cities. Their project "Smart Clean City" has been tested in Saratov in Russia which is inhabited with approximately 1 million people. The pilot implementation resulted with a 21% decrease of processing time of containers in comparison with the traditional manual planning.

Smart hospitals are one of the application areas of Petri Nets as well. Harifi and Nikravanshalmani [5] used a Petri Net to model their smart hospital ideas. They argue that they used Petri Nets because of the detailed rules set in the design of Petri Nets that simplify the transformation of the initial heuristic selection criteria in formalized modeling procedures.

13.3 Colored Petri Net

A Petri Net (PN) consists of a finite number of places ($P = p1, p2, p3, ..., pn$) that are presented as circles (or ellipses), a finite number of transitions ($T = t1, t2, t3, ..., tn$) presented as rectangles (bars), and arcs are used to connect places and transitions. It

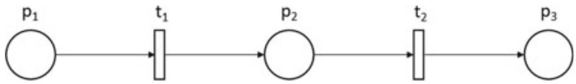

Fig. 13.1 Simple example of a Petri Net

is also called the network of places and crossings. Figure 13.1 shows a simple Petri Net example with three places and two transitions.

The application of Petri Nets covers a wide spectrum of areas, not only in computing. Murata [10] stated many application areas, successful, promising and considered, such as performance evaluation, communication protocols, modeling and analysis of distributed-software systems, distributed-database systems, concurrent and parallel programs, flexible manufacturing/industrial control systems, discrete-event systems, multiprocessor memory systems, data flow computing systems, fault-tolerant systems, programmable logic and VLSl arrays, asynchronous circuits and structures, compiler and operating systems, office-information systems, formal languages, logic programs, local-area networks, legal systems, human factors, and digital filters. As pointed out by Harifi and Nikravanshalmani [5], Petri Nets have been gaining a lot of attention in artificial intelligence researches because they are adequate for the representation of knowledge and reasoning processes graphically.

Colored Petri Nets (CPNs) are the answer for the need for more powerful net types with the ability to describe more complex systems by introducing the concept of token types and transition firing rules [3]. In Colored Petri Nets, each token has an attached token color and its usage is analogous to the use of types in programming languages as pointed out by Jensen [6]. Jensen [6] states several advantages of CPNs: their graphical representation, well-defined semantics, ability to describe a large variety of different systems, few powerful primitives, explicit description of both states and actions, semantics which build upon true concurrency, hierarchical descriptions, integration of the description of control and synchronization with the data manipulation, stability toward minor changes of the modeled systems, interactive simulations, large number of formal analysis methods, and computer tools supporting their drawing, simulation, and formal analysis. CP-nets are defined by a 9-tuple: CPN = (Σ, P, T, A, N, C, G, E, I) described in Table 13.1 [6].

Table 13.1 Definition of colored Petri net [6]

CPN = (Σ, P, T, A, N, C, G, E, I)	
Σ	Finite set of non-empty types, color sets
P	Finite set of places
T	Finite set of transitions
A	Finite set of arcs
N	Node function
C	Color function
G	Guard function
E	Arc expression
I	Initialization function

13.4 Use Case: Smart Lighting

The use case is a smart lighting system that adjusts the room lighting, its intensity, and color to users' preferences. When the user enters by unlocking the smart lock with his ID, the system determines the optimal settings based on his previous preferences and adjusts the lighting. The optimal setting of the user is determined by an artificial neural network (ANN) that was previously trained on already existing preferences of the user. The user's preferences are based on luminosity readings by the sensor and current time of the day so the input to the ANN are the user's ID, sensor luminosity reading, and current time. The outputs of the ANN are the lighting settings: intensity and color of light. Of course, the user's preferences are subject to change so the system implements that option as well. When the user inputs his new wishes, if the system doesn't have a preference for that time of day and sensor luminosity reading, it is added to the user's set of preferences. If the system does have a preference already for that sensor luminosity reading and time of day, the old preference is overwritten with the new one.

When more users enter the room, the need for a mutually agreed lighting setting arises. This is to be handled by a mathematical model taking into account each individual user's preferences to calculate a lighting setting that will accommodate all users present in the room.

Every time a user enters or leaves the room, the system calculates a new optimal setting. When only one user is present, the multiple users calculation model is not activated. Of course, when all users leave, the lighting is turned off for energy saving. Also, system calculations repeat when the luminosity sensor reading or time of day changes.

This system has been implemented in the Internet of Things Laboratory at the Faculty of Electrical Engineering and Computing at the University of Zagreb. For the implementation of the system, Philips Hue LED white and color bulbs and one Philips Hue GO were used as they offer 16 million color options and intensity management. The luminosity sensor was connected to a Waspmote device that transmitted the data to a Raspberry Pi device that served as a gateway.

13.4.1 Use Case Simulation by CPN

The program *CPN Tools* was used for the realization of this smart lighting system. The modeled system is shown in Fig. 13.3 and the color sets used in this model are shown in Fig. 13.2.

For the simulation of different possible events, two functions were used: *C.ran()* and *N.ran()*. The function *C.ran()* is to simulate one of three possible changes: number of users changing, luminosity sensor reading changes/time period change, and the user entering a new preference or changing an old one. The function *N.ran()* is used

Fig. 13.2 Color sets for smart lighting model

```
colset BOOL = bool;
colset INT = int;
colset STRING = string;
var users, c, n, OS_calc: INT;
colset N= int with 0..1;
colset C = int with 0..2;
colset Users_OS= product INT*INT;
colset Users_OS_c= product INT*INT*INT;
colset UsersN_OS_np = product INT*INT*STRING;
```

to randomize the change of the number of users present, whether a user is leaving or entering the room.

The integer variables used are *users*, c, n, and OS_calc. The variable *users* is used to keep track of the number of users in the room. The variables c and n are used like flags to determine which event occurred. The variable OS_calc is used to determine for how many users the optimal setting has been calculated by the ANN.

The color set $Users\_OS$ represents the users and their calculated optimal settings. For this model, the information is only shown as an integer to determine the number of users and their calculated optimal settings. The color set $Users\_OS\_c$ is the same information of color set $Users\_OS$ with the addition of an integer for the determination of which change occurred in the room. The color set $UsersN\_OS\_np$ is also the same information of color set $Users\_OS$ but it carries the new preference information so the ANN will be trained with it.

The simulation starts with no users present in the room. As a user enters, the system begins the process to determine his optimal settings. The sensor is read and the time period is determined and with that information, everything is ready to calculate the user's optimal settings. The neural network calculation is the transition "*Calculate user's OS*". After the calculation, as there is only one user present, the multiple user calculation is not needed so the system sets the room lighting to the user's preferred settings.

If the user leaves, the system turns the lights in the room off, but if another user enters, the system proceeds to calculate the new user's optimal settings and after that the multiple users calculation model is used to determine the lighting settings that will satisfy both users.

If the sensor values change or time period, which is not specifically shown, but follows the same way of processing as the sensor reading changing, the optimal settings for each users are calculated again.

Every user has the option to change his preferences. The new preference input isn't restricted to the current conditions of time and luminosity because the user can input a new preference for any conditions of time and luminosity. After a user inputs his new preference, the ANN will be trained with it. After that the system will calculate a new optimal setting for that user. If more users are present when that happens, the system will calculate optimal settings again for only the user that had input a new preference as the other users' optimal settings didn't change. After having all users' optimal settings calculated, the system proceeds to the multiple users calculation model and sets the calculated settings.

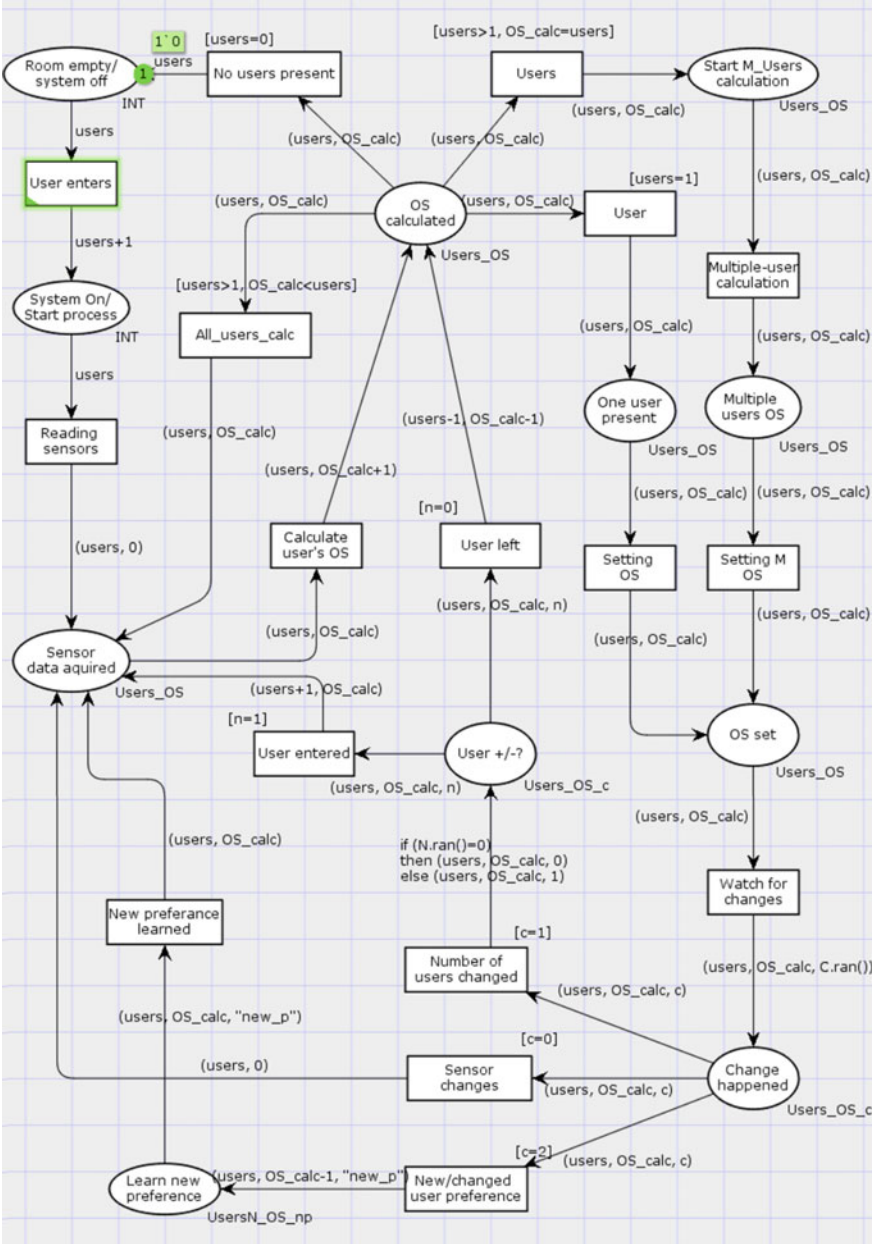

Fig. 13.3 Smart lighting CPN

13.5 Conclusion and Future Work

In this paper, a context-aware model based on Colored Petri Net approach for smart lighting has been proposed. Colored Petri Nets are a proven powerful tool which enables the modeling of various types of systems, particularly smart environment modeling, so the decision to use them was logical. With this system, users are provided with more comfort as they don't have to set the lighting manually. The system adjusts the lighting settings based on previous users' preferences, luminosity sensor reading, and time period of the day, powered by an Artificial Neural Network. The success of the system largely depends on the accuracy of the ANN and the multiple user calculation model.

New ideas are being considered for the future work of this model to maximize user comfort. The goal is to include more factors in the context reasoning to broaden the services offered by the system. For example, lighting setting can be adjusted not only according to the context described in this paper, but can be dependent on user activities in the smart environment as users do not need the same lighting settings when watching TV, reading, or cooking. Another idea for the further development of this system is to connect the HVAC system to it and adjust its settings based on context.

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Chapter 14
A Simulator for the Internet of Moving Things

Mohamed Mouatacim, Jean-Philippe Kotowicz, and Cecilia Zanni-Merk

Abstract Intelligent agents and multi-agent systems are efficient tools for studying and simulating Information and Communication Technology Infrastructures and, more particularly, the Internet of Moving Things. Based on a case study in the military and defense field, we worked on building and simulating this kind of infrastructure with smart mobile devices simulated as intelligent agents, to study their behavior in real situations. The efficiency of the mobile devices is estimated with some indicators that, generated after every simulation, allow measuring their performance.

14.1 Introduction

To create smart societies, Information and Communication Technology Infrastructures (ICT-I) have become increasingly important. An ICT-I encompasses all the devices, networks, protocols, and procedures used to enable the deployment of the ICT technology and to foster interactions among the different stakeholders. An ICT-I includes a network of parts, i.e., more or less smart and some mobile, devices, sensors, and services in the surrounding environment, e.g., the Internet of Things (IoT) [2, 11, 13]. The IoT is a system of physical objects that can be discovered, monitored, controlled, or interacted with electronic devices that communicate over various networking interfaces and eventually can be connected to the wider Internet [10]. As mentioned, ICT-I require integrating hardware and software to provide certain services. However, nowadays most of the available devices are mobile. This means that these infrastructures need to become volatile, malleable, and adaptive [11]. Smart devices and services need to be capable of reasoning and performing negotiations, in smart ICT-I [12]. These smart infrastructures will be virtual and dynamic, built on

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ordinary available ICT-I, supporting collaborations among different parts, as well as co-operations to perform complex tasks [11]. This means that instead of relying on the classical IoT, the Internet of Moving Things (IoMT) needs to be developed.

An IoMT is a network of physical objects that are mobile and can be remotely measured or controlled. But the deployment of mobile devices in the same ICT-I raises several problems [14]. In this paper, we will study **world understanding problems** which are associated with the partial views of the whole network that the moving devices can have at a certain time.

Studying situations involving human actors is not easy in practice (e.g., building evacuation problem [3]). To solve this kind of problem, simulators are used. They are capable of simulating agent-based social situations, based on Multi-Agent Systems (MAS) [3]. An Intelligent Agent (IA) is an autonomous computer system that does not require human intervention to achieve its goals. It is able to evolve in its environment, act on it, perceive it, communicate with other agents, have and achieve goals, and also perform tasks independently [5, 15]. A MAS is a group of IAs sharing the same environment, interacting with each other by sharing information to achieve a goal [3]. All agents may have a common goal as each one or a subgroup of them can have its own goal.

We aim to work on world understanding problems of smart ICT-I by analyzing collaborative decision-making of a group of mobile devices, considered as IAs, according to their relative positions, on a use case in the military and defense field, called **Policemen and Thieves**. The use case was provided by an industrial company, in the framework of a research collaboration about the IoMT.

In this case study, a group of policemen needs to collaborate to catch a team of thieves (who are trying to escape) within a known time frame. Agents of the same type can communicate with each other, however an agent, whatever its type, can see all other types of agents. The agent environment is a grid that models a neighborhood where all the agents can move freely in the streets. The behavior of these agents is designed according to the BDI architecture [4].

In this paper, firstly, we introduce the architecture of the agents, how they make their decisions, and how they coordinate with each other. Next, agent performance measurement indicators are discussed. Finally, conclusions and perspectives of future work are presented.

14.2 Agent Architecture and Behavior

An agent's behavior differs depending on its type, whether it is a policeman or a thief, but both types have the same architecture and reasoning mechanisms.

All agents in this work are designed according to the BDI architecture [4]; an agent of this type relies on three mental states for decision-making : its **Beliefs** (**B**), **Desires** (**D**), and **Intentions** (**I**). B, D, and I represent, respectively, what the agent knows about its environment, what it wishes to achieve, and what it seeks to

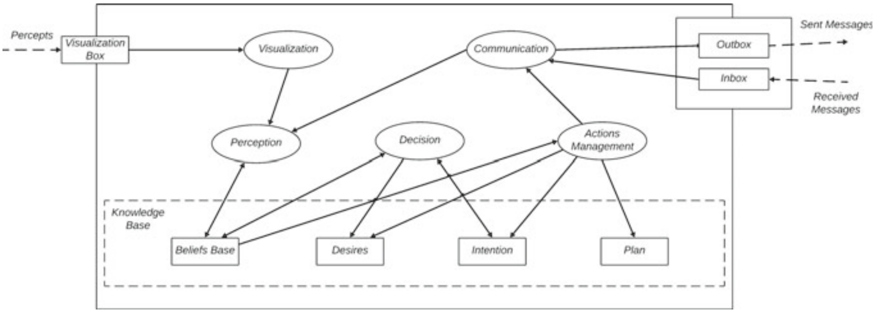

Fig. 14.1 Agent architecture

achieve through action plans [1]. The architecture of both kinds of agents is shown in Fig. 14.1. Perceiving and acquiring information takes place through visualization and communication modules.

At each time step, the agent checks the visualization box and the inbox for new information. To send information, it adds information to the outbox, from where transmission is done automatically. Based on information in the beliefs base, the decision module adds desires to the set of desires by associating each one with its priority. Then, it transforms the desire with the highest priority into an intention. Each intention is associated with a plan, which is a set of actions.

14.2.1 Structure of the Beliefs Base

The beliefs base of an agent contains all the pieces of information it has about its environment. In our case study, pieces of information required for each type of agent differ according to its type. All that a policeman knows about a thief is its identifier and the position where it noticed him. The same thing happens for the thieves: a thief knows the identifier of the policeman and the position where it saw him. Agents can store knowledge about several agents at the same time as they can update these pieces of information each time a change occurs.

14.2.2 Perception

Perception allows agents to fill their beliefs base with the needed knowledge to achieve their goals. It takes place at each time step, which lets them update their beliefs according to the environmental changes. Algorithm 1 shows the process of perceiving and updating the beliefs base of a policeman.

Perception of a policeman In the beginning, speed, visual distance, communication distance, arrest distance, and maximal number per pursuit are used to initialize variables (Alg. 1, line 2). Then, a policeman fills its beliefs base with the lists of policemen it sees and those with whom it can communicate based, respectively, on its viewing and communication radius and also on its current position (Alg. 1, line 3). It memorizes, in hash-maps, the identifiers and the positions of the thieves it saw ($thvs\_seen$) and those it received by a message from other policemen in its communication area ($thvs\_rcvd$). Updating the knowledge base consists in checking, at each time step, the conformity of newly acquired information (either by visualization or communication) with that one already existing and correcting it if necessary. A policeman searches in its beliefs base (all_thvs) the position of a thief that is supposed to be visible to it using the V.CanSeePos[1] function that takes as argument the position of the thief ($thf.pos$). If it really does, it looks for the thief using the identifier associated with this position and it checks if it is also visible using the V.CanSee function. If that is the case, it renews its current position with the V.CurrentPos function, which takes as argument the identifier of the concerned thief, removes the old value, and adds the new one. If the policeman cannot see it, it removes all pieces of information about this thief from its knowledge base.

To ensure coordination among agents in the same group, an agent always receives the identifiers of the agents that share their goal (Alg. 1, Line 18).

In order to be able to negotiate and to be more effective at the pursuit, among the relevant pieces of information, there are **paths already chosen by other policemen** in order to move toward target information. If a policeman chooses its path to a specific target based on this knowledge, it will allow the team members to choose several optimal paths and surround the targeted thief. In Alg. 1, line 19, the list of paths already taken by other policemen to a target is returned according to the received messages and the current target.

[1]The V and C prefixes indicate that the concerned pieces of information are acquired, respectively, through visualization or communication.

Algorithm 1 : Algorithm of perception and update of beliefs - Policeman

Input : $spd, visual_dist, com_dist, arst_dist, max_pol$
/* Fill in beliefs base and Variables initialisation */
$all_thvs = thvs_seen \bigcup thvs_rcvd$
for all $thf \in all_thvs$ **do**
  if V.CanSeePos($thf.pos$) **then**
    if V.CanSee($thf.id$) **then**
      let new_pos = V.CurrentPos($thf.id$)
      $rcvd_thvs = thvs_rcvd - \{(thf.id :: thf.pos)\}$
      $thvs_seen = thvs_seen \bigcup \{(thf.id :: new_pos)\}$
      $all_thvs = all_thvs \bigcup \{(thf.id :: new_pos)\}$
    else
      $thvs_seen = thieves_seen - \{(thf.id :: thf.pos)\}$
      $thvs_rcvd = thvs_rcvd - \{(thf.id :: thf.pos)\}$
      $all_thvs = all_thvs - \{(thf.id :: thf.pos)\}$
    end if
  end if
end for
$frnds_same_trgt_rcvd$ = C.RcvPlceSmTrgt ($current_trgt$)
$paths_taken$ = C.PthOccpTwrdTrgt($current_trgt$)

Perception of a Thief A thief agent builds its knowledge base with the list of policemen it sees using its visualization distance and its current position. It stores the identifiers and the positions of visible policemen within the limit of the visualization area.

14.2.3 Decision-Making

An intelligent agent makes its decision based on its beliefs. Considering that we implement agents with the BDI architecture, the decision-making for an agent is the declaration of a desire accompanied by a real value which represents its priority. Algorithm 2 represents the policemen's decision-making process.

Policeman Decision-Making At the beginning of the simulation, each policeman adds the desire to search for a thief to the desires list with priority 2.0 ("*search_for_thf*", 2.0). If a policeman knows about some thieves while its current intention is *search_for_thf*, it chooses the closest one, so that it becomes the new target. ClosestOne function takes as argument the current position of the policeman and the list of thieves it knows about. Then, it cancels the current intention, and the desire to go and catch the nearest thief is added with priority 3.0 (higher priority than looking for a thief ("*catch_thf*", 3.0)). A policeman re-evaluates its target when its knowledge base changes; if another thief added to the beliefs base is closer than the current target, it becomes the new target.

Algorithm 2 : Policeman Decision making algorithm

$closest_one = \textsc{ClosestOne}(self.pos,\ all_thvs)$
if $current_intention == "look_for_thvs"$ **then**
  $current_intention = null$
  $desires_list = desires_list \bigcup \{("catch_thf", 3.0)\}$
else if $current_trgt\ != null$ and $\textsc{CloserThn}(closest_one, current_trgt)$ **then**
  $current_intention = null$
  $desires_list = desires_list \bigcup \{("catch_thf", 3.0)\}$
  $current_trgt = closest_one$
end if

Thief Decision-Making At the beginning of the simulation, a thief's desires list contains only the desire to notice one or many policemen. The decision a thief makes is to escape if it sees them ($pol\_seen \neq \emptyset$). It adds ("*escape*", 3.0) to the desires list to escape from the policemen it sees (pol_seen).

14.2.4 Plans

In the BDI architecture, a plan is a set of actions that allows an agent to accomplish its desires. The desire with the highest priority is transformed into an intention and each intention corresponds to a plan. Each of the agents has two plans, the first plan of a policeman corresponds to the intention ("$look\_for\_thvs$", 2.0); it concerns the policeman's movement strategy during the search for thieves. The second plan is $catch\_thf$ plan; its purpose is to coordinate with other policemen to arrest a targeted thief, and it corresponds to the intention ("$catch\_thf$", 3.0). The first plan of a thief is $spot\_pol$ plan, in which a thief's movement strategy is defined and the second one ($escape$) allows the thief to avoid the policeman it has seen.

Possible Actions of a Policeman Policemen can execute two possible actions: Patrolling and Coordination.

Patrolling: Policemen and thieves have two common movement strategies. The first one allows them to stand in the same position until they find a target (for policemen) or until they perceive a policeman (for thieves). The second strategy is $random\_move$; it allows the agent to move randomly in the streets. An extra possible policemen movement strategy is called $weighted\_random\_movement$. The choice of the next destination is made by weighting and taking into account streets previously visited. The movement can be made between 4 neighbor cells ([N, S, E, O]) or 8 neighbor cells ([N, S, E, O, NE, NO, SE, SO]), depending on the choice of the user.

Coordination: Coordination is activated between two or more policemen who have the same target. The purpose is to allow the policemen to take different paths in order to surround the thief and to increase the possibility of meeting other thieves in their way. When a policeman gets a target, it informs the other policemen in its communication area. Via this information, a policeman can extract, thanks to the function C.EXTFRNDSSAMETRGT, the list of policemen with the same interest.

Imagine a situation where there are three policemen: p1, p2, and p3. They all have the same target but p1 can only communicate with p2, and p3 communicates only with p2. To ensure coordination between the three agents, p2 will transmit the information from p1 and p3 and vice versa. For p2, $frnds\_same\_trgt = [p1, p3]$ and it will send this list to the other two policemen (p1 and p3), then p1 will realize that p3 is going to be part of the pursuit. The same thing happens for p3: it will realize that p1 will participate in the chase. Usually, each policeman sends $frnds\_same\_trgt$ to the policemen in the list to make sure that all of them know their partners and they all have the same information. Then, all policemen will have the same list because they update their beliefs base by adding missing elements to the list $frnds\_same\_trgt$, and the list of $frnds\_same\_trgt$ is sorted from the closest policeman to the furthest one from the current target with SORTBYDIST function.

It is possible to set a maximum number m of policemen who can pursue a single target. Then a policeman updates the list of its colleagues with the same target, keeping only the first m policemen in the list with (Alg 3, Line 2). If it does not belong to the selected policemen, it initializes its current target and current intention to null and it adds the desire to look for a new thief ("$look\_for\_thief$", 2.0). If m equals 0, then there will be no coordination.

In a policeman's beliefs base, there is also the list of taken paths ($busy\_paths$) which contains the paths already taken by other policemen to the target. The closest policeman to the target takes the shortest path without taking into consideration any other path (Alg 3, Line 12) and if it has a successor, it sends him the path it followed. If a policeman is in the middle or at the end of the list, it must consider all the paths taken by its predecessors. It calculates its path with the CALCPATH function that returns a free path (not followed by any predecessor); it follows it and it sends, in addition to the one it followed, all the paths already taken by predecessors to its successor (Alg 3, Line 16,17,18).

If the distance between the policeman and the target is less than or equal to the arrest distance of a thief, it removes the current intention and adds the desire to look for a thief. Indeed, if the distance between a thief and a policeman is less than or equal to the arrest distance, then the thief will be automatically caught. More than one thief can be arrested at the same time by one policeman.

Algorithm 3 : Actions management algorithm - Policemen

C.SEND($current_trgt$, $frnds_access_com$)
$frnds_same_trgt$ = C.EXTFRNDSSAMETRGT($current_trgt$) $\bigcup$ $\{self\}$
C.SEND($frnds_same_trgt$, $frnds_same_trgt$)
$frnds_same_trgt$ = UPDATE($frnds_same_trgt$, $rcvd_frnds_same_trgt$)
$frnds_same_trgt$ = SORTBYDIST($frnds_same_trgt$, $current_trgt$)
$frnds_same_trgt$ = GETACTPOL($frnds_same_trgt$, $max_pol_per_prst$)
if $self \notin friends_same_trgt$ **then**
  $current_trgt, current_inten = null$
  $desires_list = desires_list \bigcup \{("look_for_thief", 2.0)\}$
else
  if FIRST($frnds_same_trgt$) $==$ $self$ **then**
    $path$ = CALCPATH({}, $current_trgt$)
  else
    $path$ = CALCPATH($busy_paths$, $current_trgt$)
  end if
  FOLLOW($path$, $speed$)
  C.SEND($busy_paths \bigcup \{path\}$, $successor$)
end if

Possible Actions of a Thief: Escaping

A thief always tries to get away from visible policemen which are represented in the beliefs base by the pol_seen list. To escape, a thief chooses a position in its viewing zone that will no longer allow it to see any of these policemen with the FREEPOSITION() function which returns the necessary position (Alg. 4, Line 1). In case the thief does not find any position which satisfies this condition, it only takes into consideration the nearest policeman ($nearest\_pol$); it moves away from it by moving toward the furthest neighbor cell which is returned by the FARTHESTNEIGHBORPOS() function and it redoes the calculations for all the policemen at the next time step (Alg. 4, Line 5,6,7). When the thief reaches the desired destination, its current intention becomes null and it begins spotting policemen by adding the desire ("$spot\_policeman$", 2.0) (Alg. 4, Line 9).

Algorithm 4 : Actions management algorithm - Thief

1: nxt_destin = FREEPOSITION(pol_seen, $visual_dist$)
2: **if** $nxt_destin \neq null$ **then**
3:   $path$ = CALCPATH({}, nxt_destin)
4: **else**
5:   $nearest_pol$ = NEARESTPOL($self.position$, pol_seen)
6:   $neighbor_cell$ = FARTHESTNEIGHBORPOS($nearest_pol$)
7:   $path$ = CALCPATH({}, $neighbor_cell$)
8: **end if**
9: FOLLOW($path$, $speed$)

14.3 Agent Performance Indicators

In order to measure the performance of policemen and thieves, we measured different indicators. The first one is the duration of the simulation; it serves to know if policemen could catch all the thieves before the expiration of the simulation time; if the duration of the simulation is equal to the Maximal Duration of the Simulation (MDS), then it is very likely that policemen couldn't accomplish the mission. On the other hand, if the duration of the simulation is less than the MDS, then necessarily all the thieves were caught. The policeman performance is measured by the distance traveled by each policeman, the average distance traveled by all the policemen, the number of thieves caught by each policeman, the time lapse a policeman spent looking for thieves, the time lapse a policeman spent pursuing thieves, and the number of times a policeman saw a thief. The thief performance is measured by their lifetime, the distance traveled by each one, the average distance traveled by all thieves, the time lapse spent in escaping from policemen, and the time lapse spent in spotting policemen.

We ran 50 simulations with an MDS of 1 h (3600 s), 4 policemen, and 4 thieves in a neighborhood represented with a grid. While agents move, they take into consideration only 4 possible directions (N, S, E, O); the dimensions of the grid are 510 m by 510 m. Policemen move with a speed of 6,5 km/h, and their visualization and communication distances are, respectively, 50 m and 250 m. The maximal number of policemen per operation is 2, and they move randomly taking into account cells recently visited. On the other hand, the visualization and communication distances of thieves are also, respectively, 50 m and 250 m but they move faster than policemen, 7.5 km/h, and they stay at the same position until they perceive a policeman. Buildings block the view for agents.

This architecture and these mechanisms can be implemented on any MAS that supports the BDI architecture. We chose to run this simulation using the GAMA platform [7, 9], a free open-source platform in Java. It has its own programming language, GAML. GAMA offers many tools to easily develop complex agent behaviors; each type of them can be developed independently from the rest of the simulation. Agents will communicate using FIPA Agent Communication Language (FIPA ACL) [6] which deals with message exchange, interaction protocols among agents, and content language representations.

Figure 14.2 shows some statistical results of the 50 simulations. In the first bar-plot, we see that the average of the lifetime of all simulations is about 3500 s (dashed light blue) while 20 min for the period while no policeman has seen a thief yet (dashed dark blue). We conclude that with these parameters, in most cases, policemen don't find easily the thieves as they cannot catch them (this is represented in the third bar-plot). The second bar-plot is about the distance traveled by policemen and thieves; we notice that the distance traveled by all policemen in each simulation is very high because their movement strategy is *weighted_random_movement* (mentioned in Sect. 14.2.4) while thieves stay at the same position until they perceive a policeman. We conclude that these conditions are not good for the policemen to accomplish their

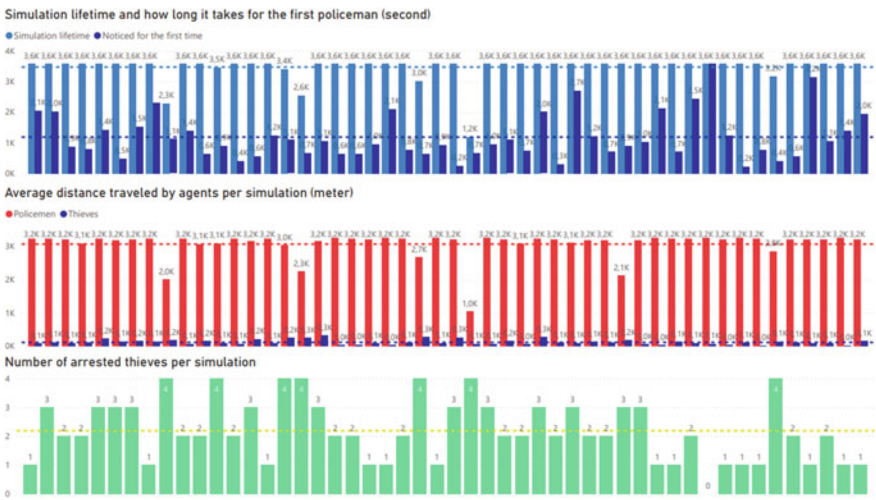

Fig. 14.2 Results of all the simulations

mission while they let some of the thieves stay free until the end of the experiment. This analysis, done with different simulation conditions, can help choose the best strategy for each kind of agent.

14.4 Conclusion

In this paper, we presented a simulator for the IoMT to study world understanding problems using different approaches for integrated collaborative decision-making among mobile devices, which was implemented on an illustrative case study called **Policemen and Thieves**.

We introduced the architecture of the intelligent agents and their behaviors according to the BDI architecture using algorithms that explain the processes of acquiring information, making decisions, and applying them for each kind of behavior. We also presented how the performance of the agents was measured.

Batch processing is interesting in this case study, because the movement of agents, most of the time, is random. The execution of several simulations with the same input parameters allows statistical studies on the performance of the agents according to them. Subsequently, executing several simulations with different input parameters will allow making a comparative study on the obtained results to conclude on the best strategy for the behavior of each agent.

As future work, the notion of coalition will be explored, where a team leader for each kind of agent can make the coordination among them more efficient.

The **Policemen and Thieves** use case is a good example illustrating collaborative decision-making in the framework of the IoMT. Through this work, we show that we can build a smart environment provided with smart mobile devices. They can perceive knowledge, think, negotiate, and make decisions, based on their perception of the world at a certain time. The perception of the world by one agent can be incomplete, erroneous, or even incoherent with regards to the perception of the other agents. However, rational decisions based upon this situation still need to be made, by achieving effective collaboration among mobile devices. The agent architecture introduced in this paper can be applied in any case that requires this kind of negotiation, even in more complex situations. We have demonstrated that this architecture is appropriate to achieve effective decision-making in the IoMT context.

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Chapter 15
A Multi-Agent-Based System for Intrusion Detection

Younes Tesnim and Jemili Farah

Abstract Nowadays, with the immense amount of data that is circulating every second, the cybersecurity concerns are also growing. In recent years, cybersecurity-intrusion detection has become a very difficult research area in communication network and big data. Hence, traditional intrusion detection systems (IDSs) could not respond to the new security challenges. Therefore, IDSs require an effective and improved detection mechanism capable of detecting distributed intrusive activities and serious threats to network security. In this paper, we have proposed A Multi-Agent System (MAS), which is very suitable for IDSs as it meets the features required by the networks and Big Data issues, through cooperation, autonomy, and proactivity between agents to ensure the effective detection of intrusions without the intervention of an expert. Moreover, some experiments were conducted to evaluate the performance of our model in a Microsoft Azure Cloud, as it provides both processing power and storage capabilities using Apache Spark, and its Machine Learning Library (MLlib) to detect intrusions. A Random Forest algorithm is used to provide for the nature of the incoming data. Also, the use of the recent CSE-CIC-IDS2018 dataset will give better perspective about the system abilities against cyber-attacks. The results show that the proposed solution is much accurate than traditional intrusion detection systems.

15.1 Introduction

In recent years, cyber-attacks are increasingly sophisticated and pose more and more problems in detecting intrusions [1]. Hence, data protection against cyber-attacks becomes the major issue that needs our attention especially after the apparition of Big Data notion [2]. This concept involves Volume, Variety, and Velocity restrictions,

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which increase the number and the types of attacks. For this reason, big data tools are used to process large volumes of data such as Apache Spark [3] and Apache Hadoop [4].

Intrusion detection systems are believed to be the last line of defense in the network security. These are the systems which analyze and find abnormal patterns. According to Benyettou [5], an IDS can be defined as a monitoring mechanism to detect internal or external threats that affect the effective operation of the system. However, IDS components alone are not able to analyze all of the large reports generated due to their incapability to respond to some network characteristics such as the variation in user behavior, the increasing evolution of the types of intrusions, and the speed of attacks that can occur concurrently on several machines. A multi-agent solution seems to us very appropriate to solve these problems [6]. Such an architecture gives the system more robustness and responds to intrusions through lowering response time. Mokhtari and Moulkhaloua [7] defined a Multi-Agent System as a distributed system composed of a set of intelligent agents that interact most often in modes of cooperation, competition, or coexistence to perform actions in a common environment.

In this article, we propose a Distributed IDS that combines the advantages of the high accuracy of Apache Spark and its Machine Learning Library (MLlib) on Microsoft Azure (HDInsight) which makes the architecture more fast and scalable. Indeed, our model consists of a set of intelligent and autonomous agents that cooperate with each other to detect accurately known attacks with less response time.

The rest of the paper is prepared as follows. In Sect. 15.2, we discuss several related works in the area existing of intrusion detection systems that use big data processing tools. Section 15.3 explains the proposed model, its components, and operating principle. Section 15.4 presents the details of a performance evaluation and the effectiveness of our proposed model based on an experimental study. Finally, Sect. 15.5 concludes the paper and points out the future work.

15.2 Related Works

Intrusion Detection Systems are the subject of several extensive research studies that have been conducted to find new models for more effective and performant IDSs. In this section, a few studies have been carried out on Big Data tools like Apache Spark and machine learning models related to intrusion detection.

Ouiazzane et al. [8] used a Multi-Agent Model for Network Intrusion Detection based on Hadoop to detect unknown attacks in real time. The authors proposed a model based on four autonomous and cooperative agents that are able to detect abnormal activities using all nodes of HDFS Cluster for storage data and MapReduce for data processing. A decision tree is applied which can classify the network traffic.

Hafsa and Jemili [9] introduced a cloud-based distributed IDS that uses Apache Spark Structured Streaming and its MLlib to detect anomalies in real time. Their work shows that the Decision Tree classifier yields a 99.95% accuracy using a daily updated dataset MAWILab. The system can also process more than 55,175 records in one second using two worker-node cluster. This study has been implemented by using simulation in the Microsoft Azure platform.

Belouch et al. [10] evaluated the performance of intrusion detection by applying Apache Spark and four supervised machine learning algorithms which are Naïve Bayes, Support Vector Machine, Random Forest, and Decision Tree, using UNSW-NB15, a recent public dataset for network intrusion detection. The experiments proved that Random Forest has the best performance in terms of accuracy (97.49%), sensitivity (93.53%), specificity (97.75%), and execution time 0.08 s.

Zhang et al. [11] applied a network intrusion detection framework based on a distributed random forest algorithm and adapt it to the Apache Spark stream processing system to realize real-time detection. The experimental results are compared on the CICIDS2017 open dataset and show that the distributed random forest based on Spark (or DRFBS) yields the best performance against the existing systems such as the RF algorithm, gradient boosting decision tree (GBDT), multi-class SVM (M_SVM), and AdaBoost. Hence, DRFBS has a shorter detection time, a higher accuracy and can realize real-time intrusion detection in a high-volume and high-speed network environment.

The author of [12] presented a design of Apache Spark and classification algorithm-based IDS and used Chi-square selector to select top-most features among all the attributes present in the dataset. The performance of Logistic Regression, Decision Tree, and Support Vector Machine (SVM) with SGD is computed in the design of Apache Spark-based IDS with AUROC and AUPR performance metrics to identify whether the data is normal or intrusion. In planning all the tests, they used the NSL-KDD dataset.

15.3 Proposed Model

Our approach involves several steps that start with ingesting data all way to detecting attacks. For each step, various tools are used to get the best of Microsoft Azure services, then, we implement our IDS in a multi-agent architecture to get a more efficient and accurate system. Two major sections are discussed here. The first part tackles the extraction of data files from CSE-CIC-IDS2018 dataset, then, the preparing of these files and finally binary classification with the help of a Machine Learning pipeline. The second section will integrate the IDS in a multi-agent architecture.

15.3.1 Data and Methods

Dataset Description

To define the intrusion of a system, normal and abnormal demands should be trained by using a dataset [13]. In our work, we use "CSE-CIC-IDS2018" a realistic cyber defense dataset, the latest Intrusion Detection Dataset available in 2018/2019, developed by the Communications Security Establishment (CSE) and the Canadian Institute for Cybersecurity (CIC) on Amazon Web Services (AWS) [14]. The final dataset includes seven different attack scenarios such as Brute-force, Heartbleed, Botnet, DoS, DDoS, Web attacks, and infiltration attack [15], with size more than 400 GB [16].

The CIC team recorded the raw data each day including the network traffic and system logs of each machine. Then, they used the network flow generator and analyzer CICFlowMeter-V3 and extracted 80 network traffic features. Finally, they saved them as a CSV file per machine [17].

Multi-Agent System (MAS)

An agent is a computer system located in an environment, capable of autonomously performing an action in order to meet objectives [18].

In the context of intrusion detection, a multi-agent system is a set of multiple agents that can drastically reduce the workload in the network by distributing responsibilities among agents. According to Achbarou et al. [19], an agent can be characterized by certain properties:

- Autonomy: agents can act and cooperate without external intervention. They have the ability to control their behavior and actions;
- Communication: Agents are exchanging messages with each other in order to collaborate and coordinate their actions. The most popular agent communication protocol is Agent Communication Language (ACL);
- Sociability: Agents interact and collaborate with each other to achieve a common goal;
- Reactivity: Agents can change their behavior through learning in order to act according to external changes in the environment;
- Proactivity: Agents have the ability to take initiative to achieve a goal.

Apache Spark

One of the important frameworks for Big Data Analytics is Apache Spark [20]. It was developed by a research team from the University of California, Berkeley, in 2009 [21]. It is an open-source cluster-computing framework for large-scale data processing and Machine Learning tasks.

The main characteristic of Spark is the in-memory computation, which executes all programs up to 100 xs faster in memory, or 10 xs faster on disk, than Apache Hadoop. An Apache Spark system consists of several main components including Spark core and higher level libraries [22] including Spark SQL for SQL and structured

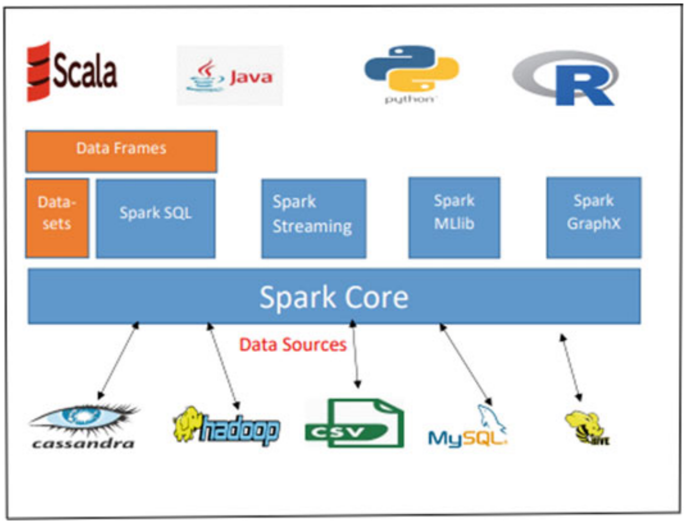

Fig. 15.1 Apache Spark ecosystem

data processing, Spark MLlib which is a rich evolving library of machine learning and data mining algorithms, GraphX for graph processing, and Spark Streaming for real-time stream processing which also provides a high-level API which is accessible in Scala, Java, Python, and R programming languages.

Figure 15.1 give a brief idea about Spark's diversified ecosystem.

The Spark computation model is based on the Resilient Distributed Dataset (RDD) it is the heart of Spark. RDDs store the datasets in memory, which directly avoids overhead that arrives concerning particular drive disk. These paradigms of evaluation, in-memory storage, and immutability make Spark fault tolerant [23, 24]. To overcome the limitations in Apache Spark RDD such as no input optimization engine, a Data Frame is evolved which reduces the processing time. It is the core concept of Spark SQL [25]. Most of the RDD-based libraries are changing to the new Data Frame-based API. Therefore, an RDD-based MLlib is replaced with Spark ML that uses Data Frames, due to its fast and efficient processing capabilities.

Microsoft Azure

Azure is Microsoft's Cloud platform was available in 2010. Originally, it was called Windows Azure. It provides software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS) [26]. Moreover, it allows developers to use any language, infrastructure, or tool to create, deploy, and manage applications. Microsoft Azure yields various services such as machine learning that provides valuable tools for data analysis. Also, it provides infrastructure to process big data sets [27].

Azure HDInsight is a managed Hadoop service in the cloud to analyze large volumes of data, which uses Microsoft HDInsight Server called Hortonworks Data Platform (HDP). HDInsight provides cluster configurations for Apache Hadoop, Spark, HBase, and Storm. It uses Azure Blob Storage (ABS) or Azure Data Lake Storage instead of HDFS, to collect data on the computational cluster, distribute it, and replicate across multiple cluster nodes hosted on virtual machines.

Random Forest Classifier

Random Forest (RF) is a type of supervised machine learning algorithm. It can solve both continuous data in regression and categorical data in classification problems with large datasets. It is a simple and powerful algorithm comprised of a set of independently trained decision trees, which considers the output of each tree before providing a unified final response. It is a good model if you want high performance with less need for interpretation.

In this approach, we used Random Forest due to its high prediction and efficiency. After testing well-known classifiers, we found the following results: Decision Trees gave 99.33% accuracy, Naïve Bayes gave 97.78% accuracy, Support Vector Machine gave 92.28% accuracy, and Random Forest gave 99.97% accuracy.

15.3.2 Collect and Prepare

Collect data: We start with collecting CSV files from the dataset and loading it into Microsoft Azure Blob Storage (ABS) [28], which is a storage service where the data can be exposed to the public or stored privately. It is massively scalable object storage for unstructured data. The operations will be executed on Apache Spark cluster in Azure HDInsight that uses Azure Blob Storage as cluster storage.

Preparing data: In this step, we start with the creation of an Apache Spark cluster in HDInsight, using Jupyter Notebook and the Python API (PySpark) to manipulate data at large scale over a distributed file system following by the creation of a Data Frame from a CSV file. The CSV file is included in all HDInsight Spark clusters.

Before feeding the data to the machine learning model, this task involves three approaches consisting of feature selection, removing duplicate values and filling missing values.

Firstly, the feature selection approach consists of selecting the most required characteristics [29], by removing columns containing “Infinity” and “NaN” values. Also, unnecessary features such as IP address, port numbers of the source hosts, and TimeStamp are dropped from the dataset, which do not affect the performance of the ML model.

Secondly, after selecting the appropriate features, it was necessary to delete duplicate values. Redundant records will increase computation expense, slow down model training, and reduce accuracy. Therefore, it is necessary to remove them from the dataset. This strategy makes the computation faster because it must process less data with reduction in the size of the dataset.

Finally, to complete the dataset and improve the quality of information. Instead of removing records with missing values, we proposed to fill them with default values to avoid value errors when working with machine learning models.

After cleaning data, we end up with a total of 9 features organized in Listing 15.1.

```
impute_cols = ['flow_duration', 'flow_byts_s', 'flow_pkts_s',  'flow_iat_min', 'fwd_iat_tot','fwd_iat_min',
 'init_fwd_win_byts', 'init_bwd_win_byts', 'fwd_seg_size_min']
```

Listing 15.1 Selected columns

15.3.3 Classification

After cleaning the data, in this step the Machine Learning pipeline is fitted, the training dataset is transformed, and the validity of the resulting dataset is asserted. Listing 15.2 indicates the pipeline loading operation. For testing the dataset, we load our Machine Learning pipeline model that contains the Random Forest classifier, and transform the incoming data to get predictions for each record.

```
pipeline_model = pipeline.load(train_df)
train_transf_df = pipeline_model.transform(train_df)
```

Listing 15.2 Pipeline Fitting

The Spark MLlib API provides the pipelines API for creating, debugging, and setting Machine Learning pipelines. A pipeline is a sequence of connected stages running in a specific order to create a machine learning workflow. A stage can be either a transformer or estimator. The data input will be a dataframe, which is fundamental to Spark MLlib; it also passes through each stage of the pipeline. In our research, we are using two transformers: StringIndexer and VectorAssembler.

1. StringIndexer: It converts string columns of labels to indices, whose indices are sorted by order of label frequency, so the most frequent label is set to 0.
2. VectorAssembler: Spark MLlib algorithms need the features be stored in a single vector column. Therefore, VectorAssembler is a transformer that combines a list of columns into a single vector column in order to train our Machine Learning model.

Then, we add the Random Forest classifier to our pipeline and train it using a portion of data collected from the datasets, and save the trained ML pipeline in ABS for future use.

15.3.4 Architecture Multi-Agent for Intrusion Detection

The majority of existing intrusion detection systems are generally for well-defined environments and do not offer a solution to certain network characteristics such as changes in user behavior and services offered and the increasing evolution of the types of attacks.

Our decision to situate our intrusion detection system in a multi-agent architecture is justified by our intention to remedy the problems of detection robustness, and to solve some of the problems encountered in traditional IDS.

MAS is a promoter tool for optimizing security in the network. Its integration in IDS modeling makes the exploitation of protection mechanisms more efficient, and it provides better attack management.

The proposed MAS for IDS is composed of three types of agents: Preparing agent, Agent classifier, and Alert Manager Agent.

- **Preparing agent**

The task of the Preparing agent is to receive and prepare the data as already discussed in Sect. 15.3.2.

This agent will have to select the data about the traffic of the network, followed by cleaning of these Packets. Then, it allows the processing and the storage of data on the different nodes of Cluster Spark HDInsight. After preparing the data, this agent sends it to the agent classifier.

- **Agent classifier**

This agent is responsible for making decisions after analyzing the prepared data. It can classify a packet as intrusion or as normal.

The agent classifier enters the training phase and builds its model, and once the model is built, it can be used for the next predictions. Finally, it sends its result to the Alert Manager agent.

- **Alert Manager Agent**

After receiving abnormal data from the agent classifier, the alert manager agent is responsible for generating alerts of all detected intrusions. It allows network and security administrators to perform tuning tasks on all alerts that are generated. Then, the result will be stored in Azure Blob Storage.

These three agents cooperate with each other to detect intrusions accurately as shown in the following Fig. 15.2.

The overall workflow of the proposed approach is shown in Fig. 15.3 and described as follows:

Step 1: Preparing agent is responsible for collecting and pre-processing the data. Firstly, it receives the dataset which is stored in Azure Blob Storage, then it collects the CSV files.

Step 2: The preparing agent then passes to the pre-processing phase, starting with the selection of the relevant features.

Step 3: It removes redundant attributes and then fills in the missing values to complete the dataset.

Fig. 15.2 Agents architecture

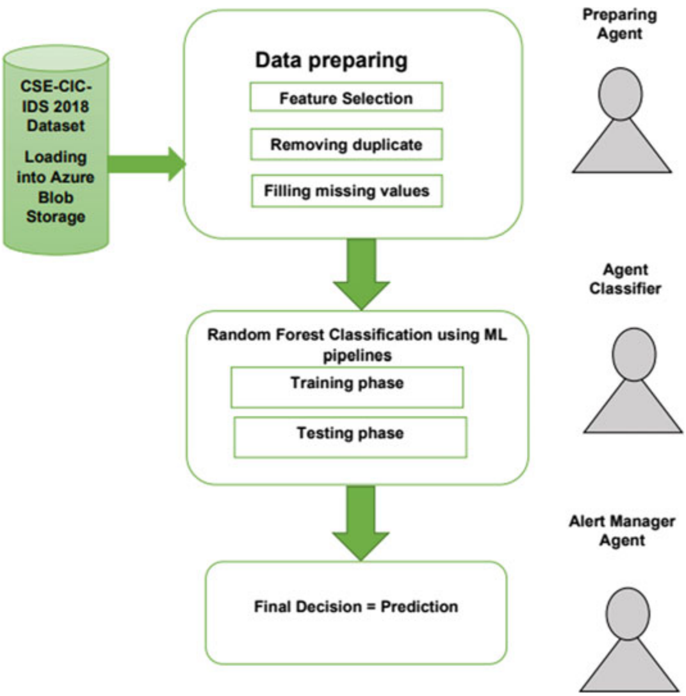

Fig. 15.3 The structure of the proposed approach

Step 4: Finally, the preparing agent sends the pre-processed data to the agent classifier.

Step 5: The Random Forest classifier (agent classifier) enters the training phase in order to build its own model. Else it uses its model to make predictions on new models (testing set).

Table 15.1 Configuration used to test our solution

	Head node	Worker node
Number	2	2
Name	D3 V2 optimized	D4 V2 optimized
CPU	4 vCPUs	8 vCPUs
GPU	GPU acceleration not used	GPU acceleration not used
RAM	14 GB	28 GB
OS	Linux (CentOS) x64bit	Linux (CentOS) x64bit
Storage	200 GB SSD	400 GB SSD

Step 6: The Classifier agent classifies the data into 2 types, normal or intrusive and then sends the prediction results to the Alert Manager agent.

Step 7: The Alert Manager agent manages the detection results in order to generate reports to inform the administrator about the intrusion.

In the next chapter, we present the experimental results of our distributed system and compare it with traditional IDSs.

15.4 Experimental Results

15.4.1 Experiment Setup

To perform our experiments, we applied Microsoft Azure as it provides HDInsight running on Linux virtual machines and Spark version 3.0.0 running on top of YARN, using Jupyter Notebook and Python API (PySpark). Also, the agents of our approach were developed using Python programming language.

The features of our HDInsight Spark Cluster are illustrated in Table 15.1.

15.4.2 Performance Metrics

In order to verify the performance of our intrusion detection model, Apache Spark and its MLlib [30] are used to evaluate the result analysis of Machine Learning models. To evaluate the performance of the pipeline, we applied the metrics as shown in Table 15.2.

In this study, the use of a Random Forest provided excellent results, as shown in Table 15.3; this was made possible, thanks to the Spark MLlib, which facilitated the implementation of the machine learning algorithms.

To evaluate the performance of our proposed approach, we will analyze our CSE-CIC-IDS-2018 intrusion detection dataset.

Table 15.2 Evaluation metrics

Measure	Description	Formula
Accuracy	It is defined as the number of correct predictions divided by all predictions	$\text{AC} = \frac{(\text{TP+TN})}{TP+FP+TN+FN}$
Precision	It reflects the ratio of correct detections over total detections obtained	$\text{Pr} = \frac{TP}{TP+FP}$
Recall	It is the ratio between the number of correctly detected intrusions and the total number of intrusions	$\text{R} = \frac{TP}{TP+FN}$
F-measure	The harmonic mean F that combines recall and precision in a number between 0 and 1	$\text{Fm} = 2\frac{Pr*R}{Pr+R}$

Where TP = True Positives, TN = True Negatives, FP = False Positives, and FN = False Negatives

Table 15.3 Results of the proposed model

Accuracy	Precision	Recall	F-measure
99.97	99.94	99.93	99.91

As shown in Sect. 15.3.1.1, there are more than 80 attributes that can extract from the dataset by applying CICFlowMeter-V3 such as packet number, segment size, duration, and time interval between packets. Then, save these features in CSV format, which can be analyzed for the network traffic. Some of the CSE-CIC-IDS2018 features are given in Table 15.4.

Based on these concepts, Table 15.5 presents the performance of our model based on DDOS attack-HOIC.

This approach improves the intrusion detection rate with a few samples in the CSE-CIC-IDS2018 dataset (Fig. 15.4).

Table 15.4 Some samples of features extracted via CICFlowMeter-V3 and their descriptions

Feature name	Description	Data types
fl_dur	Represents the flow duration	String
tot_bw_pk	Represents the total number of packets in the inverse direction	Integer
tot_fw_pk	Represents the total number of packets in the direction of advancement	Integer
fw_iat_min	Represents the minimum time delay between two packets sent in the direction of forwarding	Double
fl_iat_min	Represents the minimum delay between two flows	Double
fl_byt_s	Represents the flow byte rate, which is the number of packets transmitted per second	String
fl_pkt_s	Represents the flow packets rate, which is the number of packets transmitted per second	String
fw_seg_min	Represents the minimum size of the segments detected in the direction of advancement	Integer

Table 15.5 Experimental results

Samples of attack	Detection rate (%)
fwd_iat_min (fw_iat_min)	99.2
flow_iat_min (fl_iat_min)	92.6
fwd_seg_size_min (fw_seg_min)	94.5

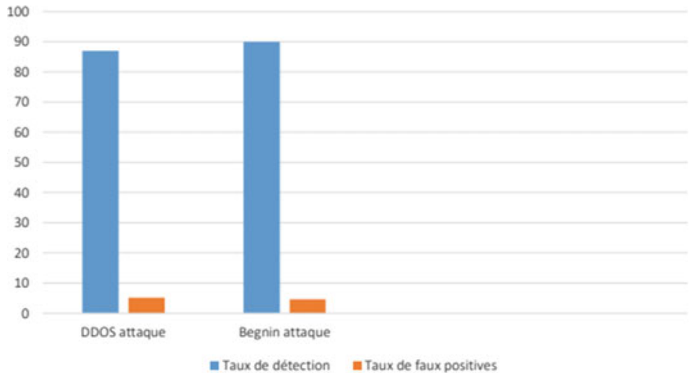

Fig. 15.4 Performance of our model

These results indicate that our solution is realistic, since the intrusion detection rate is increased and the false positive rate is decreased for tests involving simulated attacks. This means that our multi-agent system based on intrusion detection can detect an important number of attacks in a relatively short time.

The proposed model was compared to similar systems where there was an IDS which was not based on MAS. The results of this comparison are shown in Table 15.6.

Table 15.6 shows that our distributed IDS based on MAS outperforms other traditional approaches in terms of accuracy rate very well, and indicates that our model worked better in terms of both efficiency and response time.

This means that our MAS-based intrusion detection not only precisely detected the attacks in a relatively short time but also can be increased by adding more classifier agents that achieve good classification results, so the system becomes progressively more efficient.

15.5 Conclusion

In this article, we proposed a new distributed architecture of an intrusion detection based on the multi-agent system.

Table 15.6 Comparison between distributed IDSs

References	Contribution	Dataset	Accuracy Rate (%)
[31]	Machine Learning technique + Microsoft Azure Cloud	NSL KDD Cup 99	96.33
[12]	Apache Spark + Machine learning algorithms + Chi-square selector	NSL KDD	96.8
[9]	Apache Spark + Decision Tree algorithm + Microsoft Azure	MAWILab	99.95
[32]	Apache Spark + 2 feature reduction algorithms + 7 classification algorithms	UNSW NB-15	93.56
[33]	Spark MLlib + The convolutional auto encoder	CSE-CIC-IDS2018	98.20
[34]	Hadoop MapReduce + counter-based algorithm + SNORT	KDD CUP 99'	93.30
[10]	Apache Spark + 4 supervised machine learning algorithms	UNSW NB-15	97.49

The system we propose uses three autonomous and intelligent agents to process and detect anomalies with a reduced response time. The CSE-CIC-IDS-2018 dataset, a recent public dataset for Intrusion Detection Systems, was employed to evaluate the performance of the proposed system against cyber-attacks. To overcome the problems of storing large datasets and to accelerate the processing speed of data, this system is used with Microsoft Azure to demonstrate its performance within a distributed cloud infrastructure using Apache Spark and its Machine Learning Library which ensures the implementation of our Random Forest classifier in a simple and easy manner. We have also benefited from the desired features of the MAS approach that make our IDS more robust, fault tolerant, and efficient than using a traditional IDS. The experimental results indicate that our proposed system is capable of classifying records with an accuracy rate of 99.97%.

For future work, it would be wise to develop our system with a Deep Learning algorithm such as Convolutional Neural Networks (CNN) [16], to create much better models and achieve better results. Also, such a system can be more accurate and powerful by processing data in real time (online IDS). Moreover, we will use our architecture for intrusion detection by taking more advantages of MAS such as mobility in order to maximize the efficiency of the system.

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Chapter 16
Multi-Agent Systems in Mechanical Engineering: A Review

Stefan Plappert, Paul Christoph Gembarski, and Roland Lachmayer

Abstract In mechanical engineering, robust solutions have to be determined from open and ill-structured solution spaces. In order to actively support the engineer in this decision-making, multi-agent systems represent a promising approach for modular, decentralized, changeable, and complex tasks. To identify existing use cases of multi-agent systems in product development and their support for designers, the authors conducted an extensive literature search. A mental model is used for the literature analysis and synthesis that documents current applications and identifies potentials, which are summarized in a research agenda.

16.1 Introduction

Due to faster development cycles, increasing product complexity, and distributed development [1], more domain experts require support by intelligent systems. This is also shown by the increased use of knowledge-based engineering systems (KBES) and artificial intelligence (AI) in the embodiment design phase of the product development process [2]. Especially for novice engineers in industry or for students learning engineering skills, decision support systems can assist, because they respond to the user individually [3]. For this purpose, multi-agent systems (MASs) represent an interesting approach to actively support the engineer, as they are suitable for modular, decentralized, changeable, ill-structured, and complex tasks [4]. Through the capabilities of reasoning, knowledge representation, communication, and learning

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[5], knowledge can be elicited from experts or from data in a decentralized manner and shared in the MAS.

This paper is intended to provide an overview, based on an extensive literature review, to what extent MASs are used in product development and how they support the engineer. MASs are often used in the context of concurrent and collaborative engineering by multiple engineers to effectively coordinate communication and data exchange [6]. In contrast, this paper focuses on decision support systems in mechanical engineering, which supports the individual designer by providing recommendations for the product design.

In the following Sect. 16.2, agents and multi-agent systems are explained and the research questions are presented. The literature review is conducted using the methodology in Sect. 16.3. Section 16.4 illustrates the results of the literature review and synthesis with a mental model. Afterwards, the article is concluded in Sect. 16.5.

16.2 Agents and Multi-agent-Systems

The beginnings of the development of IT solutions based on the paradigm of distributed artificial intelligence and program agents date back to the 1990s [7] and are still relevant to research on agent-based technologies [8]. Although the term “agent” is only loosely defined in the literature [9], it can be agreed that an agent is an autonomous, computational entity that perceives its environment through sensors and acts on it through effectors [4].

A multi-agent system (MAS) consists of a number of agents, which interact with one another, typically by exchanging messages through some computer network infrastructure [10]. Thereby, capabilities such as autonomy, social ability, responsiveness, and proactiveness can be attributed to the agents [11]. The basic idea for networking agents is that they cooperate in solving problems, sharing knowledge, working asynchronously, are modular and robust through redundancy, and represent multiple viewpoints and expertise of experts [12]. Due to these characteristics, MASs are already used in the domains of electrical engineering, computer science, supply chain management, and production. To identify the tasks and use cases that already apply MAS in product development, the following research questions were defined:

– RQ1: How can multi-agent systems support the engineer in decision-making in mechanical engineering?
– RQ2: What are enablers and possible propositions for multi-agent systems in product development?

16.3 Methodology

In order to show which application fields exist for MAS in product development and how they support the engineer, the authors conducted a detailed literature search according to the methodological recommendations of vom Brocke et al. [13] as well as Webster and Watson [14]. The structure of the literature search can be divided into the following sections: (I) definition of review scope, (II) conceptualization of topic, (III) literature search, (IV) literature analysis and synthesis, and (V) research agenda.

The *review scope* was defined using the research questions from Sect. 16.2 and the *conceptualization of the topic* was done using keywords from product development (Table 16.1) that are related to MAS. Using search phrases consisting of product development keywords and words related to agents, like agent-based and multi-agent-systems, a *literature search* was conducted in the search engines Google Scholar, ScienceDirect, Web of Science, and IEEE Xplore to obtain a broad and interdisciplinary overview of the use of MAS in engineering.

Table 16.1 Keywords search in search engines

	Google Scholar	Science Direct	Web of Science	IEEE Xplore	$\sum$
Product life cycle	41	3	22	9	75
Process planning	87	10	1	10	**108**
Product development	60	14	0	37	**111**
Decision-making	28	3	1	1	33
Recommender systems	7	3	0	0	10
Multi-objective optimization	16	2	1	1	20
Problem-solving	9	3	1	1	14
Engineering design	59	15	0	34	**108**
Design process	41	12	0	33	86
Concurrent engineering	62	7	11	21	**101**
Collaborative engineering	50	18	6	8	82
Conceptual design	18	1	0	5	24
Embodiment design	14	0	1	1	16
Computer aided design	26	4	2	17	49
Solution space	9	0	0	0	9
Knowledge base	21	10	1	2	34
Product configuration	30	12	1	17	60
Product design	83	12	0	44	**139**
Engineering design Knowledge	57	19	6	15	97
Set-based parametric design	8	4	0	0	12
$\sum$	**726**	**152**	**54**	**256**	**1188**

16.4 Literature Analysis and Synthesis

16.4.1 Classification of Results

The authors found 1188 articles in the search engines Google Scholar (N = 726), ScienceDirect (N = 152), Web of Science (N = 54), and IEEE Xplore (N = 256) with the search methodology. As suggested by Webster and Watson, a full keyword search was performed and the articles were evaluated based on the titles, and duplicates were removed (Evaluation I: N = 434). In Evaluation II (N = 102), the articles were evaluated on the basis of the abstract and the thematic focus. Reviews, opinion and position papers, and previous articles by the same authors on the same topics were removed. Also excluded were papers from the domains of electrical engineering, computer science, and construction, as well as areas from the product life cycle such as supply chain management, project and process management, production, and maintenance that are not related to product design. The remaining 32 articles were verified as full text and selected according to their use in supporting the engineer during product development (Evaluation III).

16.4.2 Synthesis of Applications

The relevant articles from the literature search were analyzed and classified using a *Mental Model* (Fig. 16.1). Following Milsavljevic-Syed et al. [15], the mental model is divided into four quadrants according to temporal (Current and Future States) and domain-specific perspectives (Theoretical and Application Domains). In addition, a distinction is made between enablers, which facilitate the use of MAS, and propositions, which indicate the potential of MAS in product development.

The classified concepts can be divided into five clusters:

- **Development Methodology**: The Development Methodology cluster can be divided into Collaborative Design [16], Computer-aided Conceptual Design (CACD) [17], Constraint Satisfaction Problem (CSP) [18], Set-based Concurrent Engineering (SBCE) [19], as well as Failure Mode and Effect Analysis (FMEA), [20] and Quality Function Deployment (QFD) [21].
- **Decision Support Systems**: The Decision Support Systems cluster consists of Design Support Systems [1, 22] with Intelligent Feature Recognition [6, 23], Virtual Design Review [24], Learning Capabilities [25], and Eco-Design with design for end-of-life of products [8].
- **Knowledge Management**: The Knowledge Management cluster combines Expertise Finder [26], Ontology [27, 28], Case-based Reasoning [29], Data Mining [30], and Parametric Design [31] with Knowledge Reuse System [32, 33].
- **Computer Aided Engineering Environments**: The Computer Aided Engineering Environments cluster summarizes Optimization with Numerical Optimiza-

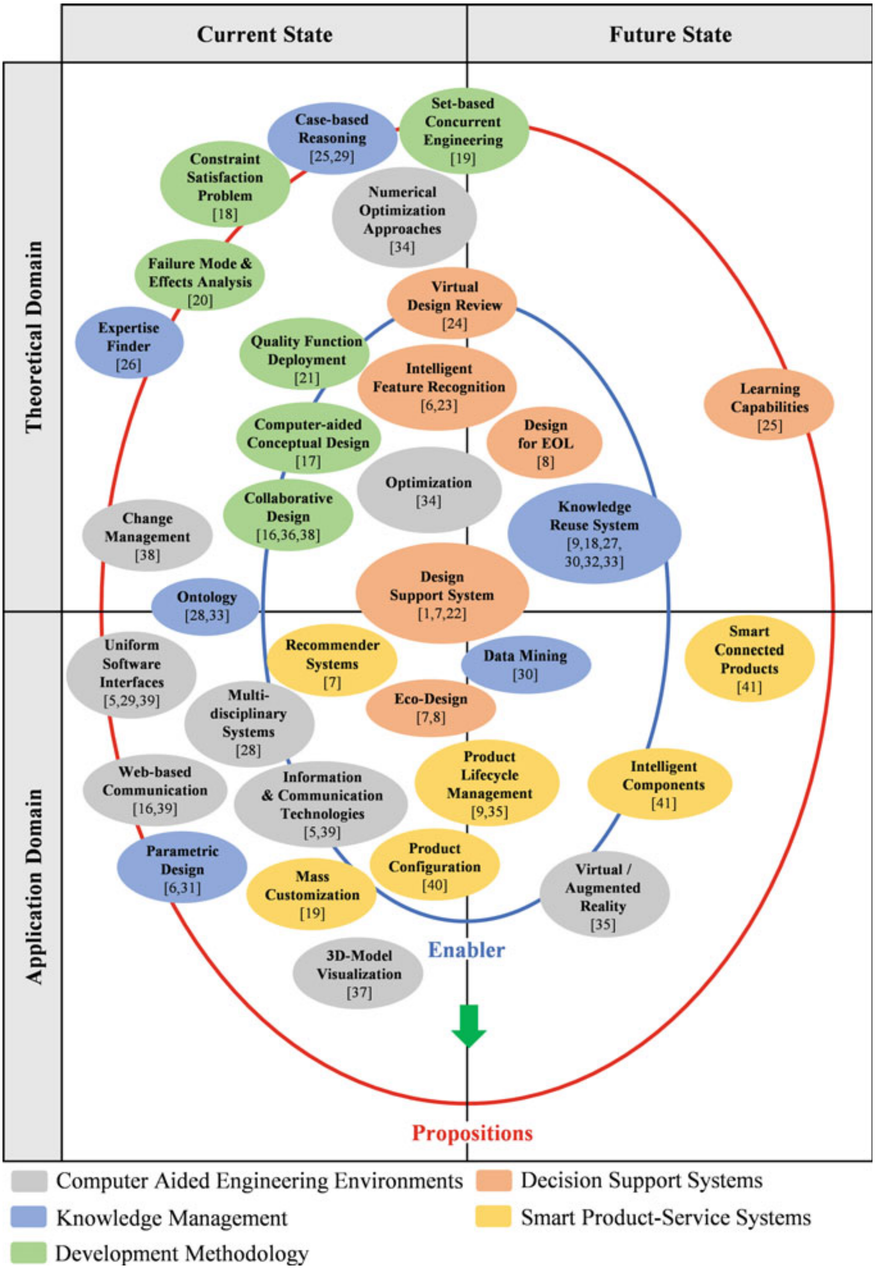

Fig. 16.1 Mental model for MAS in product development

tion Approaches [34], Information and Communication Technologies [5] with Web-based Communication and Virtual/Augmented Reality [35], and Multi-disciplinary Systems [36] with 3D-Model Visualization [37], Change Management [38], and Uniform Software Interfaces [39].
– **Smart Product-Service Systems**: The Smart Product-Service Systems cluster contains Mass Customization with Product Configuration [40] and Recommender Systems [7], and Product Life Cycle Management [9] with Intelligent Components and Smart Connected Products [41].

The active support of the engineer during product development is provided by the decision support systems, which will be considered in more detail here in order to explain their boundary conditions and, as a result, to determine expectations for the future.

16.4.3 Decision Support Systems

The design support systems provide a framework on which further propositions can be built, as they are capable of supporting designers and engineers toward making informed product design and development decisions [22]. For this, a MAS should be adaptive and upgradable, in addition to its strong communication capabilities and problem-solving function [1]. Possible extensions of design support systems represent intelligent feature recognition systems, where CAD models can autonomously adapt to new situations by transforming the conventional CAD models into intelligent objects [23], which also enables an adaptation of the level of detail [6].

This contrasts with systems in which agents externally influence the design, such as in a virtual design review, in which agents review the design with respect to design for excellence (DfX) guidelines and involve the designer in the decision-making process [24]. In recent years, there has been an increasing demand for a holistic approach to product development with regard to the product life cycle, as the decisions made during product development have a major impact on the use and recyclability of the product [7]. By accompanying the designer during the development by agents, they can suggest an improvement of the product design and thus reduce the environmental footprint of the product [8]. Since these processes are very knowledge-intensive, there is an increasing search for ways to provide agents with capabilities for learning, like case-based reasoning, in which agents rely on experience in a case base and apply this knowledge to a new problem [25].

The following characteristics of MAS according to Weiss [4] can be used as an explanation for the use of MAS in product design:

– **Technological and Application Needs**: MAS can be used to manage distributed, large-scale, dynamic, open, and heterogeneous computing and information systems. Chu et al. [6] therefore use MAS to allow a group of users geographically dispersed to perform synchronous collaborative 3D assembly.

– **Development and Reusability**: Individual agents can be developed separately by experts and then embedded in the overall system. Dostatni et al. [7], Gembarski [24], and Diakun and Dostatni [8] use agents to represent domain experts in a CAD development environment to analyze the design and make suggestions for optimization. Furthermore, Fougères and Ostrosi [23] uses agents as “smart objects” in a CAD system so that features can automatically adapt to changes. Agents can also represent different resources, such as 3D printers with their features [22].
– **Scalability and Flexibility**: The system can be extended by new agents as problems grow, without affecting the operationality of the other agents. Jia et al. [1] design their agents to have similar modular architectures so that they can be easily reused or upgraded. This also allows building hybrid structures to combine the MAS with a case-based reasoning approach [25].
– **Speedup and Efficiency**: Agents can act asynchronously and in parallel. In addition, they can perform multiple tasks through self-duplication during “rush hour” [1].

Based on the mental model, a research agenda can be derived in which a transformation of the concepts from the current state to the future state and from the theoretical domain toward the application domain takes place. The concepts of the decision support systems are to be regarded as interdependent, so that, e.g. further development of intelligent feature recognition systems or virtual design reviews also has an impact on the design support systems. The following points of the research agenda are based on two directions: on the one hand, the current state has to be further developed, e.g. in the learning capabilities of agents, and on the other hand, the existing theoretical approaches have to be made accessible in the application, like intelligent features in CAD systems.

– In order to apply the theoretical approaches, standardized frameworks for MAS need to be built so that designers can easily integrate them into their existing tasks in a CAD development environment. In addition, the agents should have standardized perceptual capabilities so that they can be used and reused for a variety of designs. In order to be able to use the MAS as an assistance system, they have to interact with the designer, either through recommendations or a direct adaptation of CAD models. Furthermore, information from the product life cycle can be collected and used for development with regard to eco-design. For this purpose, data collection by smart connected products would be conceivable.
– MASs also have to be easy for developers to maintain and adapt. For this purpose, the knowledge of experts can be determined, decentralized, and incorporated into the agents. When changes are made, only the relevant agents need to be adapted and not the entire system; this approach creates robustness and reliability of the system. To ensure the functionality of the overall system, the experts, developers, and users also have to work together or have a common understanding of the system architecture.

– With regard to learning capabilities, on the one hand, research has to be conducted on learning algorithms that learn even with few data, because in product development often only limited information is available. On the other hand, the existing learning capabilities must be implemented in the agents, e.g. through case-based reasoning [25], which is based on empirical knowledge, or probabilistic learning, in which conclusions are made based on the highest probability. Another interesting approach is reinforcement learning, in which the engineer can accept or reject the recommendations of a design agent in parallel to the design process, so that the agent is trained concurrently.

16.5 Conclusion

In this paper, a comprehensive literature review on multi-agent systems (MAS) in mechanical engineering was conducted with subsequent analysis and synthesis using a mental model. The developed research agenda indicates that a general framework for MAS in the context of CAD systems is lacking. Due to their special characteristics, such as modular, decentralized, and changeable structure, MASs are suitable for the complex and ill-structured tasks of mechanical engineering. Furthermore, the agents can be extended by learning capabilities.

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Chapter 17
Temporal Multi-Agent's Logic, Knowledge, Uncertainty, and Plausibility

Vladimir Rybakov

Abstract The paper studies temporal logic implementing multi-agent's approach and formalizing knowledge and uncertainty. We consider non-transitive linear time and multi-valued models—the ones using separate valuations V_j for the agent's knowledge of facts and summarized (agreed) valuation together with rules for computation truth values for compound formulas. The basic mathematical problems we study here are decidability and decidability w.r.t. admissible rules. First, we study the general case—the logic with non-uniform intransitivity—and solve its decidability problem. Also, we consider a modification of this logic—temporal logic with uniform non-transitivity—and solve the problem of recognizing admissibility in this logic. The conclusion contains a discussion and a list of open problems.

17.1 Introduction

Epistemic logic has been widely studied to reason about multi-agent systems (MAS), often in combination with temporal modalities. In the area of applications logic to Computer Science, a worthy place is occupied by temporal logic. It works very efficiently in various subdivisions of CS, Information Sciences, and KR, cf. [1, 2]. Historically, investigations of temporal logic (in mathematical/philosophical logic) based at modal systems were originated by Arthur Prior in the late 1950s. An important version of temporal logic for CS, linear temporal logic (with until and next), was introduced by Z. Manna, and A. Pnueli in the late 1980s. Since then, many impres-

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sive results concerning pure logical properties of temporal logic (e.g. decidability and axiomatization) were obtained (cf. e.g. Gabbay and Hodkinson [3], Venema [4]; for historical aspects cf. [5]). An essential component of information sciences is the notion of knowledge—a highly reliable information which is collected up to the moment and has some particular importance. The approach using various mathematical instruments is useful in many areas, e.g. in economics, cf. Lundberg [6].

Components of multi-agent reasoning and multi-agents' logic are broadly used in computer science. For example, in Linh Anh Nguyen [7], the author develops a logical technique for programming in Prolog using SLD-resolution calculi for logic programs in multimodal logics whose frame restrictions consist of (e.g.) the conditions of seriality. Obtained instruments and technique are applied for programming in multimodal logics intended for reasoning about multidegree belief, for use in distributed systems of belief, or for reasoning about epistemic states of agents in multi-agent systems.

In general, historically, modal and multimodal logics often have been used for investigating various aspects of reasoning in multi-agent environments (cf. [8, 9]). The approach to the concept of knowledge via a multi-agent environment is a popular area in Logic in Computer Science. Various aspects, including interaction and autonomy, effects of cooperation, etc. were investigated (cf. e.g. [10]). Concept of Chance Discovery in multi-agent's environment was investigated in Rybakov [11]); agents' interaction within temporal clusters was studied in Rybakov [12]. Formalization for logical operation—common knowledge—was suggested and technically developed in the 1990s in a series of papers; cf. [8] for a refinement of the notion of common knowledge; agents' interaction within temporal clusters was studied in [12].

Applications of logical technique are also broadly represented in applications. For example, in Vrdoljak et al. [13] we may see applications to the analysis of databases with multiple relations. In particular, in [13] testing has been performed on two diverse datasets and a comparison with other state-of-the-art multi-relational classifiers have also been performed.

In Pozna and Radu-Emil [14], tools using the signatures to expert systems modeling have been suggested. Signatures and their operators, viewed as a generalization of fuzzy signatures, represent a convenient framework for the symbolic representation of data. The proposed algorithm is advantageous because of its systematic and general formulation allowing for the modeling of uncertain expert systems. The paper Zall and Kangavari [15] authors develops multi-relational classifiers based on canonical correlation analysis.

This paper investigates intransitive temporal logic implementing multi-agent's approach and formalizing knowledge and uncertainty in this framework. It is primarily a theoretical paper. The new contribution here consists of applications to modeling various features in multi-agent environments, in particular to uncertainty, plausibility, etc. We are basing on non-transitive linear time and multi-valued models—the ones using separate valuations V_j for the agent's knowledge of facts and summarized (agreed) valuation and rules for computation truth valued for compound formulas.

We illustrate how the notion of knowledge and uncertainty might be represented in such a framework. The basic mathematical problems we study here are the fundamental ones for any logical system—decidability and decidability w.r.t. admissible rules. We start with a very general most important case—the logic with non-uniform intransitivity—and solve its decidability problem. The problem of recognizing admissible rules in this logic remains open. Next, we consider a modification of this logic—temporal logic with uniform non-transitivity—and solve the problem of recognizing admissibility in this logic. The conclusion contains a list of open problems and describes possible applications.

17.2 Notation, Logical Language

To make our paper easily readable (without looking for external literature), we recall necessary definitions and notation. We will use the language of the Linear Temporal Logic (LTL). It extends the language of Boolean logic by operations **N** (next) and **U** (until). The formulas are built up from a set $Prop$ of atomic propositions (synonymously propositional letters) and are closed w.r.t. applications of Boolean operations, the unary operation **N** (next), and the binary operation **U** (until). The formula $\mathbf{N}\varphi$ has meaning: φ holds in the next time point (state); $\varphi\mathbf{U}\psi$ means φ will be true until ψ will be true for the first time. Standard semantic models for LTL are the following infinite linear Kripke structures.

Each one is a quadruple $\mathcal{M} := \langle \mathcal{N}, \leq, \text{Next}, V \rangle$, where $\mathcal{N}$ is the set of all natural numbers, $\leq$ is the standard linear order on $\mathcal{N}$, and Next is the binary relation, where a Next b means b is the number next to a, i.e. $b = a + 1$.

Any model based at $\mathcal{M}$ has a valuation V for a set of letters $P \subseteq Prop$. V assigns truth values to elements of S; for any $p \in S$, $V(p) \subseteq \mathcal{N}$, $V(p)$ is meant as the set of all n from $\mathcal{N}$ where p is true (w.r.t. V). The triple $\langle \mathcal{N}, \leq, \text{Next} \rangle$ is a Kripke frame which we will denote for short by $\mathcal{N}$. For any Kripke structure $\mathcal{M}$, the truth values can be extended from propositions of S to arbitrary formulas constructed from these propositions as follows:

$\forall p \in Prop\ (\mathcal{M}, a) \Vdash_V p \ \Leftrightarrow\ a \in \mathcal{N} \wedge\ a \in V(p)$;

$(\mathcal{M}, a) \Vdash_V (\varphi \wedge \psi) \ \Leftrightarrow\ (\mathcal{M}, a) \Vdash_V \varphi \wedge (\mathcal{M}, a) \Vdash_V \psi$;

$(\mathcal{M}, a) \Vdash_V \neg\varphi \ \Leftrightarrow\ not[(\mathcal{M}, a) \Vdash_V \varphi]$;

$(\mathcal{M}, a) \Vdash_V \mathbf{N}\varphi \ \Leftrightarrow\ \forall b[(a \text{ Next } b) \ \Rightarrow\ (\mathcal{M}, b) \Vdash_V \varphi]$;

$(\mathcal{M}, a) \Vdash_V (\varphi\mathbf{U}\psi) \ \Leftrightarrow\ \exists b[(a \leq b) \wedge ((\mathcal{M}, b) \Vdash_V \psi) \wedge$;

$\forall c[(a \leq c < b) \ \Rightarrow\ (\mathcal{M}, c) \Vdash_V \varphi]]$.

For a Kripke structure $\mathcal{M} := \langle \mathcal{N}, \leq, \text{Next}, V \rangle$ and a formula φ with letters from the domain of V, we say φ is valid in $\mathcal{M}$ (denotation: $\mathcal{M} \Vdash \varphi$) if, for any b of $\mathcal{M}$ ($b \in \mathcal{N}$), the formula φ is true at b (denotation: $(\mathcal{M}, b) \Vdash_V \varphi$). The linear temporal logic LTL is the set of all formulas which are valid in all infinite temporal linear Kripke structures $\mathcal{M}$ based on $\mathcal{N}$ with standard $\leq$ and Next. Based on these preliminary definitions, we may introduce our temporal multi-agent models and the logic.

17.3 Temporal Multi-agents' Modes, Temporal Logic

Our approach is based on non-transitive temporal logic $\mathcal{LTL}_{NT}$ and technique allowing to find a decision algorithm for it. Here we first give a precise definition of our new, modified models and give rules for computation truth values of formulas. And immediately we will comment on how these new models may represent multi-agent information, knowledge, and uncertainty, and give illustrating examples.

Definition 1 A frame is $\mathcal{F} := \langle N, \leq, \text{Next}, \bigcup_{i \in N}[R_i]\rangle$, where each R_i is the standard linear order ($\leq$) on the interval $[i, m_i]$, where $m_i \in N, m_i > i$ and $m_{i+1} > m_i$. We fix notation $t(i) := m_i$; $a\ Next\ b \ \Leftrightarrow\ b = a + 1$.

The multi-agent's models $\mathcal{M}$ on such frames $\mathcal{F}$ are defined by fixing valuations $V_i, i \in A, ||A|| < \infty$ for a set of letters P—agents' valuations for truth of letters $p \in P$—i.e. $\forall i,\ \forall p \in P,\ V_i(p) \subseteq N$. A is a set of indexes for agents; for each model it may be different (any model may have its own fixed agents, their quantity may be different). For all n, $n \in V_i(p)$ is interpreted as p is true at the state n by opinion of the agent i. Yet we consider the agreed (global) valuation V for letters from P:

$$V(p) = \{n \mid n \in N, ||\{i \mid i \in A, n \in V_i(p)\}|| > k\},$$

where k is a fixed rational number (for that given model), which is bigger than $||A||/2$. That is, k is the threshold number, which shows that the number of the agents which are confident that p is true in the given state (world) is big enough, bidder than half.

The particular value of k may vary from model to model—each one has its own threshold. Now any such model $\mathcal{M}$ is a multi-valued model—with a finite number of different valuations. The logical language for our future logic based on such models is the extension of the one for LTL from the previous section. We extend it by the agent's knowledge operations $A_i, i \in A$ applied to only letters—for all $p \in P$, $A_i(p)$ is a formula.

We introduce rules for computation truth on models $\mathcal{M}$ for formulas as follows. For letters and Boolean operations, it is standard: $\forall p \in P, \forall n \in N$, $(\mathcal{F}, n) \Vdash_V p \Leftrightarrow p \in V(p)$; $(\mathcal{F}, n) \Vdash_V \alpha \wedge \beta \ \Leftrightarrow$

$[(\mathcal{F}, n) \Vdash_V \alpha\ and\ (\mathcal{F}, n) \Vdash_V \beta]$; etc.

For operation **N**—next, it works again as standard:

$$\forall n \in N,\ (\mathcal{M}, n) \Vdash_V \mathbf{N}\varphi \quad \Leftrightarrow \quad [(n\ Next\ m) \ \Rightarrow\ (\mathcal{M}, m) \Vdash_V \varphi].$$

But **U**—until operation, and agents' operations work in a non-standard way, since the models are intransitive and since agent's truth operations work as nominals. We suggest the following rules:

Definition 2 For any formulas φ and ψ,

$$\forall n \in N,\ (\mathcal{M}, n) \Vdash_V (\varphi\ \mathbf{U}\ \psi) \quad \Leftrightarrow$$

$$\exists m[(nR_n m) \wedge ((\mathcal{M}, m) \Vdash_V \psi) \wedge \forall k[(n \leq k < m) \Rightarrow (\mathcal{M}, k) \Vdash_V \varphi]];$$

$$\forall n \in N, \forall i \in A, \ (\mathcal{M}, n) \Vdash_V A_i(p) \ \Leftrightarrow \ n \in V_i(p).$$

The agent's knowledge operations A_i, as we see, are applied to only letters, and do not occur as nested operations in formulas. The reason for it is as follows. If we would allow the operations A_i to freely occur in formulas and sub-formulas, and use it in temporal (and modal) formulas, there may be an immediate clash/conflict in the computation of truth values: if we have a formula $A_i(\varphi)$ with temporal formula φ, we either have to redefine truth values for letters p always now and in future (which means to ignore knowledge of other agents), or to handle what to do with all other agent's formulas $A_j(p_m)$ w.r.t. the agent i, so to give some preference, but it is not clear what for to make an advantage to some ones (in this approach). So, because of this uncertainty, we prefer to let these cobwebs for future research and to study first this basic case.

It is easy to accept that the approach corresponds very well to our standard intuition about multi-agent information and and time, which may be intransitive. The agents have own knowledge about facts, and we code it by $A_i(p)$. But the rules for computation of complicated statements based on known facts are already objective, general, and global: the same for all agents. Though, to look at different rules for already computation of truth values for the complicated statements—compound, nested formulas—looking very attractive as well.

As our logic, we consider the collection of all general statements, formulas, which are true always, and globally are correct conclusions about general truth:

Definition 3 The logic TMA_{Int} is the set of all formulas which are valid at any model $\mathcal{M}$ w.r.t. any valuation.

Our logic is temporal, and therefore we may define via $\mathbf{U}$ the modal operations $\Box$ and $\Diamond$ in a standard way,

$$\Diamond\varphi := \top\mathbf{U}\varphi, \ \Box\varphi := \neg\Diamond\neg\varphi.$$

The logic is intransitive which allows, e.g. such formulas as $\Box\varphi \wedge \Diamond\mathbf{N}\neg\varphi$ to be satisfiable.

The understanding (formal definition(s)) of knowledge, uncertainty, and plausibility may be very convincingly interpreted if we consider the models with time and next directed to the past (not future). We may easily agree that knowledge is coming from the past, not future. The past time—in our human memory (in the storage of information in DBs from previous experience, length of protocols for completed computations, etc.)—evidently looks non-transitive. And we may look at knowledge as for the statements which are convincingly true for all periods of time which we remember (at least for the leading part of experts, agents, etc.). This locally, in models, to be expressed by formula $\Box\varphi$, φ was always true in past for dominating parts of experts (agents). There are good abilities now to model statements about multi-agent environment and possibilities

At first glance, the uncertainty (in this approach) may look as $\Diamond\varphi \wedge \Diamond\neg\varphi$—in some time points, we remember the agent's view for φ was for, and in some against. So, the truth for φ in the interval of time which we remember was uncertain, not stable. Here there is good room to refine this definition. For example, we may require that the same holds for all intervals of time of a predefined length or for a predefined number of intervals of time, etc.

Plausibility of φ may be interpreted in a similar way, e.g. $\neg\varphi \wedge \mathbf{N}\Box\varphi$: today experts hesitate about the truth of φ, but always before they accepted it to be true. Or else, consider $\neg\varphi \wedge \mathbf{N}\Diamond\varphi$; this is the same but before they meant it to be possible. Next, we may consider a predefined sequence of intervals of time to the past, etc. And many similar interpretations reflecting various subtleties of understanding uncertainty and plausibility may be suggested via this approach.

17.3.1 Technical Part, Decidability Algorithm of TMA$_{Int}$

Now we turn to main problems solved in this paper, first to decidability of TMA$_{Int}$. Here we use our well-verified approach extending it for the agent's knowledge operations. An essential part of this approach is the usage of the normal reduced forms for formulas, more exactly to inference rules to which formulas may be converted. It is very useful because it allows avoiding calculation and evaluations for complicated nested formulas. We need to repeat here this technique to make this paper easily readable. Recall that a (sequential) (inference) rule is an expression of the form

$$\mathbf{r} := \frac{\varphi_1(x_1,\ldots,x_n),\ldots,\varphi_l(x_1,\ldots,x_n)}{\psi(x_1,\ldots,x_n)},$$

where $\varphi_1(x_1,\ldots,x_n),\ldots,\varphi_l(x_1,\ldots,x_n)$ and $\psi(x_1,\ldots,x_n)$ are formulas constructed out of letters (variables) $x_1,\ldots,x_n$. Meaning of $\mathbf{r}$ is $\psi(x_1,\ldots,x_n)$ (which is called conclusion) follows (logically follows) from all formulas $\varphi_1(x_1,\ldots,x_n), \ldots, \varphi_l(x_1,\ldots,x_n)$.

Definition 4 A rule $\mathbf{r}$ is said to be *valid* in a model $\mathcal{M}$ if and only if the following holds: $[\forall n\ ((\mathcal{M},n) \Vdash_V \bigwedge_{1\leq i\leq l}\varphi_i)] \Rightarrow [\forall m\ ((\mathcal{M},m) \Vdash_V \psi)]$. Otherwise we say $\mathbf{r}$ is *refuted* in $\mathcal{M}$, or *refuted in* $\mathcal{M}$ *by* V, and write $\mathcal{M} \nVdash_V \mathbf{r}$. A rule $\mathbf{r}$ is *valid* in a frame $\mathcal{F}$ (notation $\mathcal{F} \Vdash \mathbf{r}$) if it is valid in any model based at $\mathcal{F}$.

For any formula φ, we can transform φ into the rule $x \to x/\varphi$ and employ a technique of reduced normal forms for inference rules as follows. We start from the following self-evident lemma.

Lemma 1 *For any formula φ, φ is a theorem of the logic TMA$_{Int}$ (that is $\varphi \in$ TMA$_{Int}$) iff the rule $(x \to x/\varphi)$ is valid in any frame $\mathcal{F}$.*

Definition 5 A rule $\mathbf{r}$ is said to be in *reduced normal form* if

$\mathbf{r} = \varepsilon/x_1$ where

$$\varepsilon := \bigvee_{1\le j\le l} [\bigwedge_{1\le i\le n} x_i^{t(j,i,0)} \wedge \bigwedge_{1\le i\le n} (\mathbf{N}x_i)^{t(j,i,1)} \wedge \bigwedge_{m\in A,\ 1\le i\le n} (A_m x_i)^{t(j,m,i,1)} \wedge$$

$$\bigwedge_{1\le i,k\le n, i\neq k} (x_i \mathbf{U} x_k)^{t(j,i,k,1)}]$$

always $t(j,i,m), t(j,i,k,1), t(j,m,i,1) \in \{0,1\}$ and, for any formula α above, $\alpha^0 := \alpha, \alpha^1 := \neg\alpha$.

Definition 6 For a rule $\mathbf{r_{nf}}$ in reduced normal form, $\mathbf{r_{nf}}$ is said to be a *normal reduced form for a rule* $\mathbf{r}$ iff, for any frame $\mathcal{F}$ for TMA$_{Int}$, $\mathcal{F} \Vdash \mathbf{r} \quad \Leftrightarrow \quad \mathcal{F} \Vdash \mathbf{r_{nf}}$.

Theorem 1 *There exists an algorithm running in (single) exponential time, which, for any given rule* $\mathbf{r}$*, constructs its reduced normal form* $\mathbf{r_{nf}}$*.*

Based at this reduction of formulas to rules in reduced forms and technique borrowed from our previous works, in particular from Rybakov [16, 17], we may prove the following theorem.

Theorem 2 *Logic TMA$_{Int}$ is decidable; the satisfiability problem for TMA$_{Int}$ is decidable: for any formula, we can compute it if it is satisfiable and if yes to compute a valuation satisfying this formula in a* **special** *finite model $\mathcal{F}(N(r))$, and to covert it in a standard infinite model.*

This is the first main technical result of our paper.

17.4 Problem of Admissibility

Recall that a rule $\mathbf{r} := \varphi_1(x_1,\ldots,x_n),\ldots,\varphi_l(x_1,\ldots,x_n)/\psi(x_1,\ldots,x_n)$ is said to be *admissible* in a logic L if, for every tuple of formulas, $\alpha_1,\ldots,\alpha_n$, we have $\psi(\alpha_1,\ldots,\alpha_n) \in L$ whenever $\forall i\ [\varphi_i(\alpha_1,\ldots,\alpha_n) \in L]$.

The solution to the admissibility problem for the logic LTL itself (i.e. finding an algorithm recognizing admissibility of inference rules) was obtained in Rybakov, 2008, [12] (cf. also [18]); basis for rules admissible in LTL was found by Babenyshev and Rybakov, cf. for admissibility rules also [19, 20].

We have to specify the notion of admissibility for inference rules for our multi-agent's logics because we use agent's knowledge operations A_i which cannot be used above nested formulas.

Definition 7 Any rule

$$\mathbf{r} := \frac{\varphi_1(x_1,\ldots,x_n),\ldots,\varphi_l(x_1,\ldots,x_n)}{\psi(x_1,\ldots,x_n)}$$

is said to be *admissible* in the logic TMA_{Int} if, for every tuple of formulas, $\alpha_1, \ldots, \alpha_n$, we have $\psi(\alpha_1, \ldots, \alpha_n) \in \mathrm{TMA}_{Int}$ whenever $\forall i\ [\varphi_i(\alpha_1, \ldots, \alpha_n) \in \mathrm{TMA}_{Int}]$, where for any x_i above if x_i has at least one occurrence in r in the form $A_j(x_i)$ then $\alpha_i = x_i$.

The restriction for substitutions above is necessary since our multi-agent logic cannot admit nested formulas bounded by agent's knowledge operations A_j. A restriction for substitutions in defining admissibility was already considered in the literature (cf. for instance, Odintsov, Rybakov—[21]). We currently cannot answer the question about recognizing admissibility in the logic TMA_{Int} from the previous section, but we are able to do it for its restricted version—the one with models with bounded intransitivity.

Definition 8 A temporal frame $\mathcal{F}$ with uniform non-transitivity m is a particular case of frames for TMA_{Int}:

$$\mathcal{F} := \langle N, \leq, \mathrm{Next}, \bigcup_{i \in N} [R_i] \rangle,$$

where each R_i is the standard linear order ($\leq$) on the interval $[i, i+m]$, where ($m \geq 1$), and m is a fixed natural number (measure of intransitivity).

So, the only distinction from our general case in the previous section is that instead of arbitrary measure on intransitivity m_i for any world i, we consider the same and fixed one—m. It looks as we assume that models (objective world), not agents, always must remember the same interval of the time in the past—the one with length m. Then we define models on such frames as we did earlier above (bearing in mind the presence of multi-agent's valuations for agent's knowledge about truth, the facts, and agreed truth valuation V).

Definition 9 The logic $\mathrm{TMA}_{Int,m}$ is the set of all formulas which are valid at any model $\mathcal{M}$ with the measure of intransitivity m.

The definition of admissibility for inference rules in this logic is exactly the same as we defined above in this section for TMA_{Int}. It seems that to consider and discuss such logic is reasonable, since we may put limitations on the size of time intervals that agents (experts) may introspect in the future (or to remember in the past). An easy observation concerning the logic $\mathrm{TMA}_{Int,m}$ itself is that it is decidable: it is **trivial** (since for verification if a formula of temporal degree k is a theorem of $\mathrm{TMA}_{Int,m}$, we will need to check it on only the initial part of the frames consisting only $k+1$ subsequent intervals of length at most m). One more immediate observation is

Proposition 1 *$TMA_{Int,m} \not\subseteq TMA_{Int}$ for all m.*

Proof is evident since

$$\left(\bigwedge_{i \leq m} [p \wedge \mathbf{N}^i p] \ \rightarrow\ \Box p\right) \ \in \mathrm{TMA}_{Int,m}.$$

The main technical result of this section is the solution to the admissibility problem for logics $\text{TMA}_{Int,m}$, which is already not very trivial:

Theorem 3 *For any m, the linear temporal logic with* uniform *non-transitivity $TMA_{Int,m}$ is decidable w.r.t. admissibility of inference rules.*

17.5 Conclusion, Open Problems

We think there are several open problems concerning this research. Most important and necessary is (1) To embed here the proposed technique in the real verification technique for databases and other storage for knowledge and information. (2) To extend the obtained results on branching time logic which linear parts by operation NEXT look as frames of this paper. (2) Study the problem of unification for studied in our paper logics. The logical unification problem is an impotent one as applications in AI and CS and may be seen as an algebraic problem of finding solutions for equations in free algebras. That problem was in active investigation earlier (cf. Baader [1, 2]) and it looks very attractive to find a solution for our introduced logic. (3) Study admissibly problem for it. The problem of admissibility was investigated for many logics (cf. e.g. [18–20]). But concerting non-transitive temporal linear logic, the most progress was achieved only for a logic with uniform limitations on time intervals with transitivity. (4) Consider the question of axiomatization for our logic. In precise terms, the open question may be formulated as

(i) Decidability of TMA_{Int} itself w.r.t. admissible inference rules.

(ii) Decidability w.r.t. admissible rules for the variant of $\text{TMA}_{Int,m}$ with non-uniform intransitivity, when intransitivity intervals are of length at most m, but the length may be different.

(iii) The problems of axiomatization for TMA_{Int} and for $\text{TMA}_{Int,m}$.

(iv) It looks reasonable to extend our approach to linear logics with linear non-transitive but continuous time.

(v) Multi-agent approach to the suggested framework when any $n \in N$ would be represented by a cluster (circle) with m agents' knowledge relations K_i is also open and interesting.

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Part III
Business Informatics and Agent-Based Modelling

Chapter 18
Two-Stage Lean Startup Model for Subscription Business

Yoshiyuki Udo and Yoko Ishino

Abstract Over the past decade or so, a customer-centric, iterative process methodology for growing startups, known as lean startup, has emerged. Because lean startup emphasizes its versatility in applying it in various industries, it mainly focuses on qualitative aspects. Therefore, it is difficult to quantitatively predict the future based on product and service improvements. This study deals with a business that can be defined as a subscription-type business by rethinking it from the traditional one-shot sales to continuous sales. We then propose a two-stage lean startup as a business model for fostering startup companies engaged in this type of business. In the upstream stage of this model, the policy of the business is discussed mainly through qualitative observations and experiments, and in the downstream stage, quantitative investigations and surveys are conducted to quantitatively understand the development potential of the startup. Finally, the Monte Carlo simulation is used to present numerical suggestions for achieving the target KPIs. As a practical example, we take up a venture that has started the business-to-consumer e-commerce (B2C-EC) of health food products and show the results of applying the proposed method in the company and verify its effectiveness.

18.1 Introduction

Nowadays, humans are living in a world of volatility, uncertainty, complexity, and ambiguity (VUCA). For companies to survive in this VUCA environment, they need to accurately determine their customers' wants and provide products and services that are valuable to them. An iterative process of hypothesizing, verifying, and learning customer needs and wants based on customer-centered thinking is effective in developing products or services with less risk. The lean startup method has been proposed for such new business startups [1].

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The key to the lean startup is to keep the initial investment low, create a product with minimal functionality, test it with a small number of customers to determine their reaction, and then immediately improve the product or service or renew the business. This process is repeated until a satisfactory product or service is obtained. This method prevents misunderstandings about customers from leading the business in the wrong direction and eventually making the business unsustainable. Successful cases of a lean startup have been reported in ICT and manufacturing ventures, as well as internal corporate ventures of major companies [2]. These case studies qualitatively illustrate how the lean startup process has improved products and services. Although the lean startup is a generalized business model that can be applied to a variety of industries, it is difficult to quantify the degree of improvement resulting from its application.

From a completely different perspective, there is a business model that has been attracting attention in recent years: subscription. A subscription is a business model in which a customer pays a fee to use a product or service for a certain period. Subscriptions started as a service business model in the past, such as the use of gas and water. In recent trends, the concept has been extended and increasingly applied to products that customers purchase regularly. A major factor that has brought subscriptions into the spotlight is the change in consumer intention. Traditionally, consumer attitudes and behaviors are based on the desire to own things, but this has recently changed; many people now think that it is enough to use things rather than own them.

In this study, we deal with businesses in which the traditional one-shot product sales can be reconsidered as continuous product-service combination sales and therefore can be regarded as a subscription-type business. This study proposes a new two-stage process model, which is called a two-stage lean startup, to effectively and efficiently manage startups engaged in subscription-type business. In the proposed model, the first stage mainly involves qualitative observations and experiments that are used to determine the direction of the business, and the second stage involves quantitative experiments and surveys to enable a quantitative understanding of the development of a startup company. In the last part of the second stage, important improvements for achieving the target key performance indicators (KPIs) can be shown through Monte Carlo simulations.

We applied the proposed model to a practical example, which is a food-tech venture that conducts a B2C-EC business of health food, and examined the results. Finally, it was demonstrated that the target KPIs could reach enough values for the venture to continue the business and win additional investment from venture capital.

18.2 Related Work

In the past decade or so, a new customer-centric iterative process (learning-by-doing) methodology known as a lean startup has emerged [1]. Its purpose is to help early-stage teams iterate business ideas until they can make good decisions about them [1, 3, 4]. Lean startup is a blend of the learning-by-doing methods previously identified. They are briefly described below.

First, customer development [3] is a formal methodology for building startups and new corporate ventures. This methodology focuses primarily on customers and developing customers by identifying customer needs and revenue potential. Customer development is the premise of a lean startup.

Agile engineering [5], which has been proposed in the field of software development and in which development is carried out by repeated implementation and testing in small units, can also be regarded as a customer-centered iterative process. Agile engineering is preferred because, in the conventional waterfall software development, it is difficult to respond flexibly to specification changes and revisions in the development process.

Among the iterative processes, one that focuses on finding customer issues is design thinking [6], which originated from human-centered design [7] and was led by Stanford University and IDEO. Design thinking focuses on the initial idea generation in creating services and products.

Lean startup emphasizes the importance of understanding the emerging needs of customers and providing products and services that meet those needs before other companies do. Lean startup is a repeated cycle comprising of the following four steps: (1) hypothesize customer needs and generate ideas to meet them, (2) build a minimum viable product (MVP) from the ideas at a lower cost, (3) measure the response of trend-conscious consumers (early adopters) by providing them with an MVP, and (4) learn the insights to reflect the results of the response to the product. The goal is to create an innovative business while minimizing the costs incurred by rapidly executing this cycle of "build, measure, and learn." During this process, if there is a large gap between the facts found and the hypothesis or if the MVP is not acceptable to the customers, a major change in direction, called a pivot, is made.

18.3 Proposed Method: Two-Stage Lean Startup Model

We deal with businesses in which the traditional one-shot product sales can be classified as continuous product-service combination sales; an example is an e-commerce business selling Chinese herbs and therefore can be regarded as a subscription-type business. A two-stage lean startup model is proposed to manage startups of this subscription-type business well. In this section, we first describe the nature of a subscription business and then discuss the metrics used for subscription. Finally, our proposed model is described.

18.3.1 Subscription Business

Subscription, when considered from the user's perspective, refers to a system in which the user pays a fee based on the period of use. Subscriptions to newspapers or magazines, payment of utility bills, such as electricity and water, are traditional examples. On the other hand, looking at subscription from the business perspective, it can be regarded as a business model that continuously provide services or sell products by receiving fees from users based on the period of use. Subscriptions provide financial stability to businesses by converting traditional sell-out sales into continuous sales [8].

The subscriptions that are currently being implemented worldwide can be classified into two categories: online (digital) and offline (real). Within these two categories, there are services for individuals (B2C) and services for organizations (B2B).

Regarding B2C, subscriptions tailored to individual preferences and usage trends have emerged in recent years. For example, "Just the Right Book" provides a subscription service where books recommended by experts are delivered to the user's home every month based on the user's inputted reading history and tendencies [9]. "Zenamins" offers a service that regularly delivers supplements based on the results of questionnaires about the user's basic data and physical condition for a fixed fee [10]. In B2B, cloud-based models, such as SaaS (Software as a Service), PaaS (Platform as a Service), and IaaS (Infrastructure as a Service), have been established to provide various services to enterprises [11].

18.3.2 KPIs for Subscriptions

To succeed in the subscription business, in addition to acquiring new users, it is important to reduce the churn rate (CR) and accumulate the existing users. Therefore, it is essential to increase customer loyalty and make them feel attached to the product or service and continue to use it. The strength of digital data-driven subscription is that customer data accumulated through service provision can be analyzed from the user's perspective and improvements can be made to make the service more user-satisfying.

Company financial and customer success KPIs are two types of KPIs that are important for successful subscriptions. Financial KPIs include monthly recurring revenue (MRR), annual recurring revenue (ARR), recurring profit margin (RPM), and growth efficiency index (GEI). However, in most cases, these indicators are not stable values in the early stages of a startup company engaged in a subscription business. Thus, it is better to focus on cost per acquisition (CPA) and lifetime value (LTV) to determine whether to accelerate business investment or not. CPA refers to customer acquisition cost, which is the amount of marketing and sales expenses incurred to acquire a single customer. LTV refers to customer lifetime value, which is an indicator of how much profit a single customer brings in from the time the customer signs up for a service to the time the customer cancels the service. If the LTV does not exceed the CPA, the business cannot continue because the cost exceeds the revenue from customers. In general, LTV should be at least three times higher than the CPA.

Next, LTV and CR are two important KPIs for customer success derived from customers' experience. The higher the LTV, the higher the value that the customer places on the product. The business value is obtained by multiplying the LTV by the number of customers. CR and average revenue per user (ARPU) are two factors that affect LTV. ARPU represents the average revenue per customer and is important when there are multiple types of services or products. When considering a single service, CR is the main factor to consider. CR, which measures customer retention, is one of the most important KPIs in the subscription model. This is because, from a long-term perspective, CR has the greatest impact on profitability. A high CR indicates that the customer is not satisfied with the service and that the value of the service is not appropriately conveyed to the customer.

Based on the discussion above, CPA, LTV, and CR are the main KPIs in the initial stage of a startup company engaged in a subscription business. However, for a startup company to obtain additional investment from venture capital, corporate valuation is also important. The net present value (NPV) derived from the discounted cash flow (DCF) method is generally used as an index for this purpose. NPV is the value of all future cash flows over the entire life of an investment discounted to the present value. DCF analysis is a method of valuing security, project, company, or asset using the concepts of the time value of money. We selected CPA, LTV, CR, and NPV as the key indicators to measure the success in the early stages of a startup company engaged in a subscription business.

18.3.3 Two-Stage Lean Startup Model for Subscriptions

Our proposed model of a two-stage lean startup in a subscription business is presented in Fig. 18.1. In this model, we divide the lean startup process into two cycles: the first (upstream) and the second stages (downstream).

In the upstream cycle (the cycle on the left side of Fig. 18.1), the main objective is to qualitatively understand the needs of customers by conducting qualitative observations and experiments and to define the direction of the business. When launching a subscription business in a lean startup, the first step is to build an idea for the new business by hypothesizing, as the theory goes, that "such customers may have needs for such products." Then, a prototype product based on the idea is developed with as little cost as possible. The product or service developed at this stage is called MVP. Next, the MVP is provided to early adopters who are highly sensitive to new products, and they are interviewed. Then, based on their opinions, the MVP is improved. The process of product or service improvement at this stage in the lean startup process is called pivoting, and it can involve quite large business changes. This process is the lean startup traditionally proposed by Ries [1].

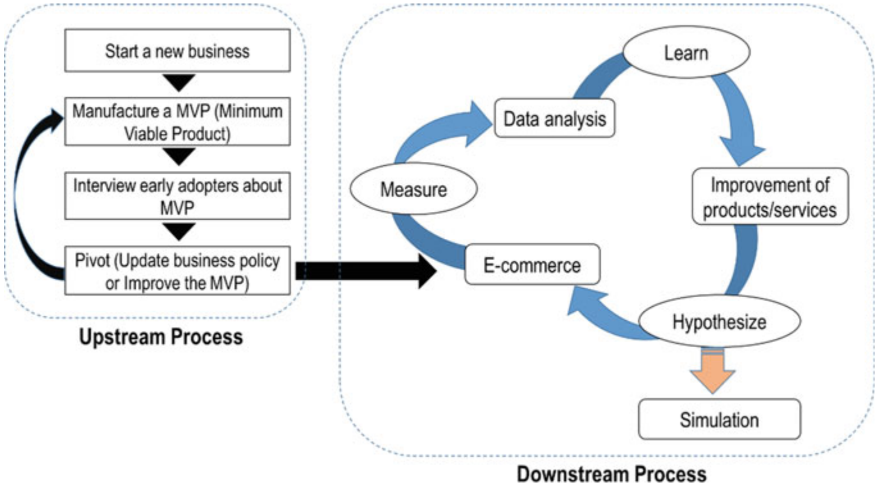

Fig. 18.1 Two-stage lean startup model for subscription

In the two-stage process that we have proposed, qualitative observations and experiments are conducted in the upstream cycle, whereas quantitative investigations and surveys are conducted in the downstream cycle (the cycle on the right side of Fig. 18.1). Dividing it into upstream and downstream processes is a major difference from previous models. In the proposed model, once the basic business policy is determined in the upstream, the downstream process does not involve any major pivoting, although some updates or changes are necessary to make the product or service better.

In the downstream cycles, small-scale e-commerce of the improved product or service where the listing advertisements linked to search keywords are executed is launched. During the sale, data, such as the number of impressions and conversions, are measured. By learning from these results, further improvements in products or services are made, and the downstream cycle could be iterated when necessary.

Through the downstream process, products and services are elaborated and come closer to embodying the needs of customers. At this stage, CPA can be calculated using data such as the numbers of impressions and conversions measured and the advertising costs spent. However, accurate CR values are often not available because the e-commerce test is not conducted for a long enough period of time to determine them. Therefore, as shown in the following formula (18.1), we model customer retention as an exponential decay variable, which is derived from our empirical data. CR is obtained by subtracting $f(t)$ from 1:

$$f(x) = R_{nat} + (R_{init} - R_{nat}) \times e^{-k(t-1)}, \tag{18.1}$$

where $f(t)$ denotes the customer retention rate, t denotes time, R_{init} denotes the customer retention rate at the initial time, R_{nat} denotes the natural rate of the customer

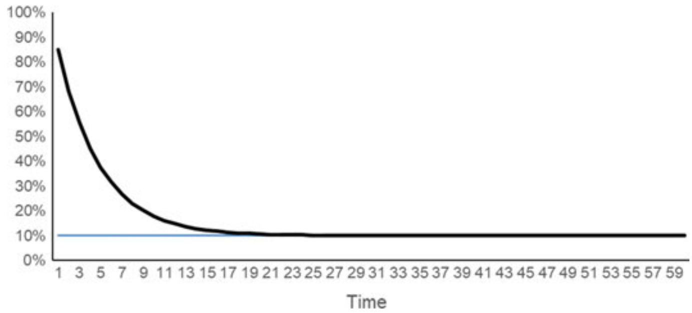

Fig. 18.2 Example of the customer retention rate

retention that means the minimum value, and k is the decay constant describing rate of decay of the retention rate. As an example, the customer retention rate under the conditions, $R_{int} = 0.85$, $R_{nat} = 0.1$, and $k = 0.25$, is illustrated in Fig. 18.2.

By substituting appropriate real numbers for the variables in Eq. (18.1) and simulating them together with CPA, it is possible to decide whether the target KPIs (LTV and NPV) can be reached or not. Moreover, by regarding CR and CPA as probability distributions, Monte Carlo simulations (the lower part of the right side cycle of Fig. 18.1) can be used to estimate the probability of achieving the target KPIs.

The contribution of the proposed model is that the simulations indicate how the target KPIs (LTV and NPV) change by altering important indicators, CPA and CR, so the results can be used to make marketing managerial decisions. Then, the measures that should be taken to achieve the target KPIs can be found.

18.4 A Case of Health Food Startup Company

The first author is the Co-Founder COO of Omoi Foods Co., Ltd., which is a food-tech venture company founded in 2015 and sells vegetable powders. As of January 2021, the company was in the seed round and is aiming to grow into Series A with funding from both angel investors and venture capital. In this phase, identifying the added value to customers and increasing customers' satisfaction, while proving that sufficient cash flows can be obtained soon, are essential.

This section briefly describes the process and results of improving the product and service according to the proposed two-stage lean startup model for subscriptions and the results of a simulation for the future.

18.4.1 Basic Information About Products

The main products, vegetable powders of various vegetables, are manufactured by pulverizing vegetables into a fine powder, which are differentiated from other supplements that encapsulate only specific ingredients. People can easily take essential nourishment of vegetables from the products. Only vegetables that are grown to ripeness without using pesticides from planting to harvesting are used to manufacture the products. The strength of the company is that it has an exclusive contract with the farmhouse that has a unique technology (patent pending) to make concentrated powder without damaging the nutritional components of green and yellow vegetables. The products can be stored at room temperature. It also has the potential to solve the problem of wastefully disposing of surplus vegetables, which has become a serious problem in Japan in recent years.

18.4.2 Upstream Stage of the Two-Stage Lean Startup

First, we assume that consumers with high health and naturalism consciousness are the main targets of the products, and their need is to easily take in the natural nutrients of nutritious vegetables. Then, we made MVP by encapsulating vegetable powder in gelatin capsules and named the product "Yasai Pastel" and set the price of the product at approximately 10,000 yen per package containing 180 capsules.

We test-marketed the product from May 1st to June 30th, 2020, using the BASE service as a prototype EC site. Then, we conducted interviews with purchasers to analyze customer needs and points of satisfaction and dissatisfaction. Customers at the time when advertising was insufficient might be considered early adopters. Therefore, they are important market-leading customers. The interviews were conducted by telephone. Ten out of 25 purchasers were randomly selected for the interviews.

We found that all early adopters were highly conscious of vegetables since all of them mentioned the word "vegetables" as the reason for purchasing the product. Five out of 10 respondents replied level 10 as a net promoter score, which is used to measure customer loyalty based on the 11-level evaluation (0 for "do not want to at all" and 10 "for definitely wants to"). These results indicate that the product has high customer loyalty. Regarding "improving the product," most respondents requested that the packaging box should be smaller. Upon request, we reduced the shipping size and changed the product packaging from bottles to bags. As a result, the cost of packaging and shipping charges was reduced.

Another interview was conducted from July 25 to August 20, 2020, to ask the cancelers the reason for the cancelation. At that time, 11 persons had canceled their regular purchase, and we asked 8 of them about the reasons for the cancelation by phone. The main reasons for cancelation are as follows: "I could not finish the product within the consumption period and there was a surplus of the product" for six, "I did not understand the effects" for one, and "The capsules were too large" for one.

Based on these results, we added a 90-grain product to our product lineup since there was only a 180-grain product lineup. Moreover, the regular delivery cycle, which had been available for 15, 30, or 45 days, was limited to a 30-day cycle from then in order to deal with leftover pills and simplify operations.

18.4.3 Downstream Stage of the Two-Stage Lean Startup

The basic changes (pivots) of products and services were completed in the upstream part of the two-stage lean startup. Therefore, in the downstream part of the two-stage lean startup, paid listing advertisements were deployed on social network sites (SNSs), such as Instagram and Twitter, and each indicator was measured. The downstream cycle, which comprises measuring, learning, and hypothesizing, was executed twice. The first e-commerce, which involves data measurement, was conducted from September 17 to 28, 2020, and the second was conducted from December 8 to 31 of the same year.

First Cycle in the Downstream Stage. The purpose of the first cycle was to examine customer response to parts of the listing advertisement, which are article contents, photos, and keywords, and to set the target segment in more detail.

First, we prepared four types of articles, which were about salad, green juice, nutritional value, and aversion to vegetables. The following three metrics were measured for each article: conversion (CV: number of products purchased), cost-per-click (CPC: cost to gain one access to the destination website), and cart transition rate (the rate at which users that reach the product details transition to the purchase cart screen). The higher the CV and cart transition rate, the better, and the lower the CPC, the better.

We prepared the following 6 types of photos for the top image of ads: (a) “Yasai Pastel” products, (b) lifestyle, (c) a ball of salad, (d) vegetables, (e) convenience store’s salad pack, and (f) female figure. Then, the number of impressions (IMP: the number of times the advertisement was displayed to the user) for each combination was measured. Since this survey introduces a search-linked advertising mechanism, combination advertisements close to the search keywords used by the user are displayed. The ones with the highest number of IMP denote the ones that users are most interested in.

The results show that the article about salad got the best consumer response. The results of the measurement of the IMP are as follows. The highest number of IMP was for “Yasai Pastel,” with 112,975 times. The high cart transition rate of salad and green juice articles suggests that directly promoting a quick and easy way to nourish your body is the most effective.

We also analyzed the above SNS advertisements by the age group of women. We divided the age groups into five categories and examined the responses. The cheapest CPC was found in the 35–44 age group.

As described above, as a result of the first cycle of the downstream stage of the lean startup process, we set women between the ages of 35 and 44 who like vegetables and buy salads at convenience stores as the main target. Therefore, we changed the product name from "Yasai Pastel" to "Capsule Salad" to match this demographic. This was because the latter name was more directly associated with the product and seemed to be more acceptable by the target women. In the same way, the customer browsing page was changed to match the target women, and the sales channel was changed to accept a variety of payment methods.

Second Cycle in the Downstream Stage. Next, we implemented a full-scale paid listing advertisement and measured its effectiveness. We put a listing advertisement from December 8 to 31, 2020, to acquire new customers.

To measure the effectiveness in detail, the following settings were used for the ad landing pages (LPs), top images (portal images), and ad platforms. We prepared three types of LPs for the ads: (a) LPs with articles, (b) LPs with images for women, and (c) LPs with images for men. For the top image, we prepared three new images in addition to the existing three images of "Capsule Salad" products that had been used in the first cycle. The following four advertising platforms were used: (i) Facebook, (ii) Instagram, (iii) Audience Network, and (iv) Messenger.

The results are as follows. The number of new customers acquired during the second cycle was 64. More than 70% of the customers were female, and the largest age group was 35–44 years old (37%). The highest CV and CVR were in LPs with images for women.

The highest number of the respondents (72%) purchased products via the image of a Capsule Salad product package and contents, which is shown in Fig. 18.3, among the 6 types of top images.

The results of examining CVs and CVRs on four platforms are as follows. Instagram recorded the highest number of CVs, accounting for 83% of all CVs. However, Facebook recorded a higher number of CVR than Instagram, so Facebook is more efficient. The CPA value differs depending on the platform and attributes, but the overall average is 9,534 yen.

Fig. 18.3 The top image that gained the highest IMP

18.4.4 Simulations

To implement full-fledged e-commerce sales and listing advertising in the future, we conducted a monthly sales simulation from January 2021. The projections are as follows:

- KPIs for the simulation are NPV and LTV (calculated for 3-year and 5-year periods)
- To induce regular purchases, different prices are introduced (the price for the first single purchase is 5,900 yen; the price for the first regular course is 2,900 yen, and the price for the second and subsequent regular courses is 5,200 yen). Therefore, we assume that 90% of new buyers will purchase the regular course (10% will purchase the first time as a single item).
- In the first year, the advertising cost is increased from 500,000 yen/month to 10,000,000 yen/month, and from the second year, it is assumed to be constant at 12,000,000 yen/month.
- Fixed costs other than advertising costs are 1,500,000 yen/month.
- Variable costs include shipping charges, settlement fees, raw material costs, and packaging material costs; all are based on sales volume.
- At the start of the project, in January 2021, the company will have 30,000,000 yen cash on hand.
- The discount rate used in the DCF method is assumed to be 10%.

Then, in the simulation, we consider two different CPA and two different CR for a total of four scenarios. Regarding the CPA, there are two possible values, 9,000 and 10,000 yen. The former has a higher level of customer success. However, since this variable is considered to fluctuate stochastically, a triangular distribution, with monotonically increasing and decreasing values from −10 to +10%, is adopted for each value.

Assuming that there are two sets of values for different CR levels which are generated by Eq. (18.1), one with $R_{init} = 0.85$, $R_{nat} = 0.05$, and$k = 0.2$ and the other with $R_{init} = 0.75$, $R_{nat} = 0.03$, and $k = 0.25$. We assume that R_{init}, R_{nat}, and k are stochastic variables and normally distributed with a standard deviation of 0.01.

Based on the above, we set four cases for Monte Carlo simulations (Table 18.1).

Table 18.1 Four cases for simulations

	CPA	CR
Case #1	9,000 yen	CR is low ($R_{init} = 0.85$, $R_{nat} = 0.05$, $k = 0.2$ in Eq. 18.1)
Case #2	9,000 yen	CR is high ($R_{init} = 0.75$, $R_{nat} = 0.03$, $k = 0.25$ in Eq. 18.1.)
Case #3	10,000 yen	CR is low ($R_{init} = 0.85$, $R_{nat} = 0.05$, $k = 0.2$ in Eq. 18.1.)
Case #4	10,000 yen	CR is high ($R_{init} = 0.75$, $R_{nat} = 0.03$, $k = 0.25$ in Eq. 18.1.)

The lower the CPA and the CR, the better. In each of the four cases, 50,000 trials are conducted to get 3-year and 5-year NPVs.

The results are as follows. The averages of NPV and LTV for each case are shown in Fig. 18.4. Simulations of Case #1, the most desirable case, indicate that the probabilities of 3-year NPV exceeding 1.5 billion yen and 5-year NPV exceeding 1.5 billion yen are 14.1% and 96.3%, respectively. At this level, the venture can proceed to the next stage, Series A, overcoming the hurdle set by VCs. Therefore, the values of CPA and CR of Case #1 are set to be the future targets. In Case #1, the average LTV after five years is 27,770 yen, and the probability of exceeding 27,000 yen, which is three times the CPA, is 79.8% (Fig. 18.5).

Furthermore, by comparing the results of Cases #2 and #3 in Fig. 18.4, we find that the impact of CR is greater than that of CPA. While it is important to acquire

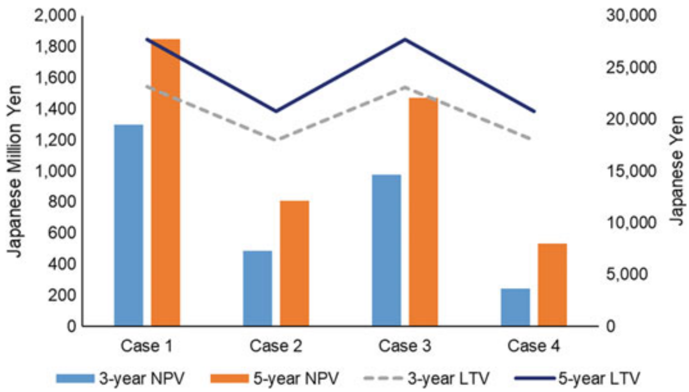

Fig. 18.4 Averages of NPV and LTV by case

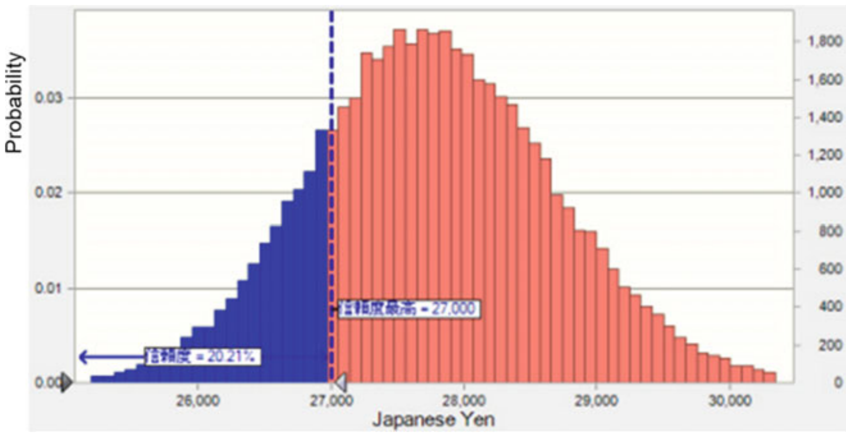

Fig. 18.5 5-year LTV in case #1

new customers through appropriate advertising activities, it is more important to take measures to retain existing customers. In other words, companies should focus on strengthening their brand power and devising ways to make people realize the benefits of their products and make further efforts to keep CR low.

18.5 Conclusions

In this study, we proposed a two-stage lean startup model. We divided the lean startup model into two parts, the upstream and downstream stages in the B2C-EC business, and showed that it is possible to make predictions by quantitatively measuring the effect of each indicator in the downstream stage. Specifically, we treated a startup company dealing with health food as a case study and used the proposed method to grow the business by reconsidering its business as a subscription-type business. In addition, we demonstrated that the target NPV and LTV values can be quantitatively grasped, and making business decisions is possible by tracking indicators, such as CPA and CR.

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Chapter 19
An Exploratory Study on Policy Evaluation of Tourism by Using Agent-Based Model

Atsumi Nakamura and Hiroshi Takahashi

Abstract This study examines the effectiveness of pricing strategies in business hotels. Through the analysis, we will attempt to identify the impact on the lease period and sales of business hotels, and how it changes with the introduction of policy simulation. In this study, pricing strategy is considered as a policy. Through Agent-Based Simulation, we will match borrower and lender agents and analyze the results of the balance between supply and demand, and we will consider pricing strategy in our analysis. We will measure the policy effects from individual strategies, using the framework created by previous studies that considered prices. A bottom-up policy evaluation will be conducted, and exploratory studies will be conducted to determine that it is an effective tool.

19.1 Introduction

Japan's "Omotenashi" (hospitality), which appealed to the world in the Olympic bid presentation, has become a synonym for the high quality of Japan's service industry. Perhaps because of the success of this appeal, Japan succeeded in its bid to host the 2020 Tokyo Olympics, and with the expectation of an increase in the number of foreign tourists, Japan's service industry, especially those in the hospitality-related industries such as lodging, food, and beverage, has been energized for a long time. The number of foreign visitors to Japan has increased rapidly since the 2010s. The number of foreign visitors to Japan has increased rapidly since the 2010s and exceeded 30 million in 2018 [1].

However, the country is facing an unprecedented economic downturn due to the Corona Shock, which began to occur around February 2020. According to the

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FY2020 Tourism White Paper, there are 28 trillion yen in tourism demand in Japan. According to the FY2020 Tourism White Paper, Japan's tourism demand is 28 trillion yen, of which inbound tourism accounts for 4.8 trillion yen. The number of inbound travelers is 30 million, and 20 million Japanese are going on overseas trips, which means the forecast is for a decrease of 30 million from the previous fiscal year and a return of 20 million. The tourism market has been discussing how much of the demand can be recovered by the domestic demand in Japan. In total, 90% of the revenue will be lost in April–May 2020, and if the corona continues for 2–3 years, the tourism industry is expected to shrink.

19.2 Related Research

Agent-based models (ABMs) have been gaining popularity across disciplines and have become increasingly sophisticated [2]. In computer science, the Agent-Based Approach is proposed as an effective method to analyze the relation between micro-rules and macro-behavior. The Agent-Based Approach is an attempt to explain the macro-behavior of systems by local rules [3]. As a result of applying this approach to social science, it is found that a variety of macro- behavior emerges bottom-up from local micro-rules [4, 5].

Airbnb is a Website for people who rent out lodging and guest houses. It offers more than 800,000 lodgings in 33,000 cities in 192 countries worldwide. A study by Vinogradov et al. [6] addresses the question of how the growth dynamics of Airbnb can be predicted by comparing scenarios with and without policy intervention. This study suggests that the Agent-Based Model can be applied to model both the sharing economy and other phenomena related to tourism. Vinogradov et al. [6] show that in the rental market, as in other markets, the market mechanism can be modeled in terms of demand and supply.

The previous study utilized simulation to analyze the growth potential of Airbnb by utilizing ABM. As a result of the analysis, we assume that (1) the price of short-term rentals is exogenous and that the duration and the number of vacancies may be interrelated. (2) In the rental market, as in other markets, the market mechanism can be modeled in terms of supply and demand. (3) They are able to elucidate the simulation run by taking into account the policy measures of Airbnb regulation. The contribution of these previous studies is that they link the sharing economy, such as Airbnb, with the development of housing markets in tourist destinations.

It is assumed that the price of short-term rentals is exogenous and that the duration and the number of vacancies may be interrelated. Moreover, the expected rate of return depends on the price, which is also determined by excess demand or supply, which in turn affects the vacancy rate and the vacancy period [7]. However, previous studies did not consider the pricing strategy, therefore this study will incorporate the pricing strategy in the analysis.

19.3 Objective

The objective of this study is to compare the impact of private accommodation and business hotels in the tourism industry and to conduct a policy evaluation. Based on the replicability of the model in the previous study, we examine the impact of business hotels on the lease period and sales, and how it changes with the introduction of regional taxation and policy simulation.

In this study, we will match borrower and lender agents through agent-based simulation and analyze the results of the balance between supply and demand, and then consider pricing strategies. We will measure the policy effects from individual strategies, using the framework developed in the previous study to take prices into account. Also, we will conduct a bottom-up policy evaluation and verify that it is an effective tool. The system used will be S4 (NTT Data Implementation Simulation System).

As for the managerial findings, we consider hypotheses such as pricing strategies through computational simulation and attempt to verify the following hypothesis: (1) short-term rentals are filled first, (2) pricing strategies have utility, and (3) the price volume zone is close to the market average.

19.4 Simulation Settings

In this study, we address the challenges faced by the real estate rental market through agent-based modeling. There are two types of executing agents in the rental market: borrower agents and lender agents. In building the model, we use our own data to verify whether the theories of previous studies apply to privately owned rental properties in Japan. The term of the rental market will be set at 360 days. We start with 9,000 borrower agents including long-term and short-term agents and 3,600 lender agents.

As a situation scenario, we consider the change in the number of vacancies depending on the ratio of short-term properties. As a policy scenario, we will consider the existence of a pricing strategy. The four pricing strategies assumed are (1) dynamic (large swing), (2) dynamic (small swing), (3) static, and (4) minimum price.

The matching setup between the borrower agent and the lender agent is as follows. First, a demand (the borrower agent) is generated. Demand has attributes (e.g., businessman, domestic traveler), length of stay (long or short), and level 1–6. The next step is to match them with lender agents. The borrower agent looks for the agent with the closest level of availability and length of stay. If a match is found, the lending agent turns off the vacancy. If there is no matching lender agent, continue the simulation until all agents match desirable rooms.

19.4.1 Borrower Agents

In the rental market, a tenant agent is a person who searches for a property that matches the length of stay. We set up four types of borrower agents: businessmen, domestic tourists, couples, and inbound agents. The number of agents is set to 9,000 (360 days $\times$ 25 agents). The simulation starts on January 1, and 1/360th of the borrower's days are put into the borrower's market each day to start the rental search. If there is no matching lender agent, it is counted as a lost opportunity. The clientele has a level from 1 to 6 as a value representing the ability to pay. Each agent has a different range of levels, but the number of people in each level is assigned by a normal distribution. The percentage of the total demand also varies from agent to agent, however, we set the total to be 100%.

In addition, the total number of days of stay is 100% for both short and long term, and the details of the number of days of stay are also 100% for both short and long term. These distributions are all calculated from the past data of the company's business hotels. From the left side of Table 19.1, the purpose of action, internal data, and data are indicated. The goal of the borrower agent is to match the length of stay with the budget. Therefore, if he does not get a perfect match the first time, he will search for a place to stay with a level of -1 or -2. The percentage of salarymen (40%), domestic tourists (30%), couples (10%), and inbound travelers (20%) in the data item column and the length of stay column are as follows: salarymen, short-term 90%, long-term 10%; domestic tourists, short-term 80%, long-term 20%; couples, short-term 90%. Long-term 10%, inbound short-term 60%, long-term 40% are all allocated to make a total of 100%.

Table 19.1 Step 1 (1st matching)

		Agent					
		Type 1 (%)	Type 2 (%)	Type 3 (%)	Type 4 (%)	Type 5 (%)	Type 6 (%)
Price	Level 1 (Low)	23	34	3	10	15	20
	Level 2	20	16	15	10	15	20
	Level 3	5	15	40	15	20	15
	Level 4	11	4	30	15	20	15
	Level 5	18	3	3	20	10	10
	Level 6 (High)	23	28	9	20	10	10

Note In the table, the left column shows Price level 1 to 6, which means the parameter from low price to high price. The right column shows the results for Agents Type 1–6. Each agent type has a particular probability to the appropriate price matching. All agents apply to the most desirable rooms

19.4.2 Lender Agents

In the rental market, the person who secures the necessary vacancies is called a lender agent. Rents will be divided into six levels ranging from 4,000 to 9,000 yen. The pricing strategy is to lower the price after the minimum vacancy period. The price reduction range is -1 to 2. The minimum vacancy period is set at 50% each for short term (1–9 days) and long term (30, 60, 90, 180 days). The ratio of properties is set at 60% short term and 40% long term. The next step is to set the pricing strategy for the assumed hotel. This is the result of analyzing the pricing strategy using the average hotel price as an index. There are four volume zones where prices change depending on whether there are big events in the vicinity such as the Olympic Games or live performances.

The lowest price has a large fluctuation range because the price fluctuates a lot. In addition, the highest price has a small fluctuation range because the price fluctuation is small. The assumed hotel strategy is as follows: dynamic (large swing range) 4,000–5,000 yen. This is because there is a big price change depending on the presence or absence of the event. Dynamic price is (small swing width) 8,000–9,000 yen. The price is changed depending on the presence or absence of an event. The static price is 6,000–7,000 yen, and the price is not changed from the initial setting. The lowest price of 4,000 yen is always sold at the lowest price sold in that period.

Regarding the location as micro-factors, generally, the best-suited locations for properties differ depending upon the use; for residential property, a secluded and quiet spot is preferred rather than a noisy place on the main street and, conversely, for office and commercial property, a location with high visibility on the main street or with easy accessibility from other locations, such as any intersection points, with a high degree of street network centrality. Therefore, it is known that a variety of micro-location attributes affect the rent; however, they have been regarded as qualitative factors, and little is taken into account as rent factors. Each building use, such as residential, offices, or commercial, has its own best-suited location, which is possible to clarify through quantitative location valuation [8].

19.5 Analysis Results

19.5.1 System Construction

In this study, we adopted the point in the time vacancy rate, which is based on the point in time of vacancy. The vacancy rate is the ratio of the number of vacant units to the total number of units at that point in time, where vacancy rate = the number of vacant units divided by the total number of units (the number of units that can be rented) $\times$ 100. This is the calculation method used when you want to get a simple vacancy rate. The number of vacancies is the number of rooms that are unoccupied at the time of the calculation. The vacancy rate is calculated by dividing the number of vacant rooms by the number of units available for rent (the total number of properties available for rent that are vacant at that time) and multiplying by 100. The biggest advantage of the unit-based formula is that the number of rooms is relatively easy to figure out, and it is also easy to calculate.

On the other hand, the vacancy rate does not reflect the size of the rooms, so there may be a large discrepancy in the vacancy rate for properties with different room layouts and space sizes. Although the Gabriel and Nothaft equation model (2001) shows the annual apartment vacancy rate, in this case, I created our own parameters for the business hotel rental market. The denominator was set so that the total would be 100. The short-term vacancy rate was calculated by dividing the short-term vacancy rate by the number of short-term rooms. The long-term vacancy rate was obtained by dividing the term vacancy rate by the number of long-term rooms. Adding up the results gives the total vacancy rate.

19.5.2 Changes in the Number of Vacant Rooms

In this analysis, we attempted to clarify the change in the number of vacancies and the number of days required for matching through simulation. As a result of the analysis, we found that (1) agents with pricing strategy matched the price level more evenly than those without pricing strategy, (2) the price range was close to the market average, and (3) the number of price changes took about 33 days to complete matching. Up to Sect. 12.4, there was only one complete matching, but this analysis performed the behavior until all agents Ire matched. These contribute to the hypothesis that short-term rentals are relatively easy to match. The following sections describe the process and rules of this analysis.

Step 1: All agents apply to the most desirable rooms. Refer to the "(First Matching) Table" to probabilistically select a room based on your level. For example, a person at Level 1 would choose $P1 = ¥4{,}000$ with a 23% probability, $P2 = ¥5{,}000$ with a 20% probability, and $P3 = ¥6{,}000$ with a 5% probability.
Step 2: Set up the supply side not to select an agent and rent the room if it is available.
Step 3: If the room selected in Step 1 is not available, select it probabilistically by referring to the table in "Step 2 (Desirable Level Matching)". However, make sure to select a room other than the one selected in Step 1.
Step 4: If there is no room available, we will make a probabilistic selection by referring to the table in "Step 3 (Second matching, matching to something close to the request)." If the selected room is not available, return to Step 3 (Tables 19.2 and 19.3).

Figure 19.1 shows the results of running the above simulation 100 times. The number of lender agents is the number of cases to 3,600, and the bubble chart shows the degree to which the price levels 1–6 matched. The price range of level 1–6 is from 4,000 to 9,000 yen. The number of vacancies decreased from the top to the

Table 19.2 Step 2 (desired level of matching)

		Agent					
		Type 1 (%)	Type 2 (%)	Type 3 (%)	Type 4 (%)	Type 5 (%)	Type 6 (%)
Price	Level 1 (Low)	20	15	30	34	10	3
	Level 2	20	15	20	16	10	15
	Level 3	15	20	5	15	15	40
	Level 4	15	20	10	4	15	30
	Level 5	10	10	15	3	20	3
	Level 6 (High)	10	10	20	28	20	9

Note In the table, the left column shows price level 1–6, which means the parameter from low price to high price. The right column shows the results for Agents Type 1–6. Each agent type has a particular probability to the desired level of matching

Table 19.3 Step 3 (2nd matching, matching to something close to the request)

		Agent					
		Type 1 (%)	Type 2 (%)	Type 3 (%)	Type 4 (%)	Type 5 (%)	Type 6 (%)
Price	Level 1 (Low)	25	25	28	19	25	15
	Level 2	16	6	11	8	22	18
	Level 3	19	27	9	24	10	21
	Level 4	17	14	23	16	17	18
	Level 5	10	21	16	24	5	15
	Level 6 (High)	13	7	13	9	21	13

Note In the table, the left column shows price level 1–6, which means the parameter from low price to high price. The right column shows the results for Agents Type 1–6. Each agent type has a particular probability to something close to the request. If the selected room is not available, return to Step 3

bottom of each circle. The size of the circle indicates the percentage of vacancies. In the case of no price strategy, vacancies are concentrated in 4–6. On the other hand, Fig. 19.2 shows that vacancies are concentrated in the 1–3 range for those with a pricing strategy. It was confirmed that the behavior was more even overall in the case of those with strategies. This is thought to be a result of the concentration of vacancies in levels 1–3, as a result of the price being set to −2 to match the agents who Ire not matched at level 6 with rooms close to the ideal.

According to a questionnaire survey conducted every year since 2014 by the A Card Hotel System, the volume zone for accommodation charges in Tokyo and Osaka has been between 9,000 and 10,000 yen for the fifth consecutive year, accounting for 25–26% of the total [9]. The next highest price range is 7,000–8,000 yen, accounting

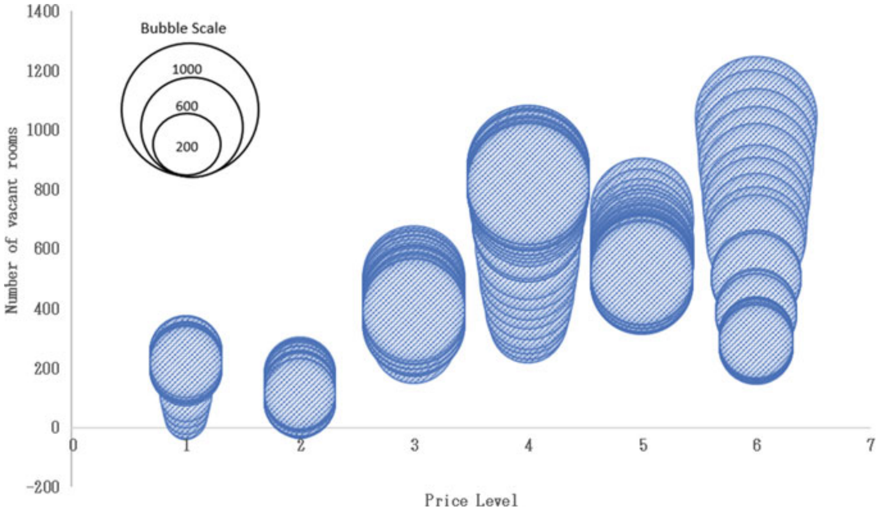

Fig. 19.1 Change in the number of vacant rooms without pricing strategy

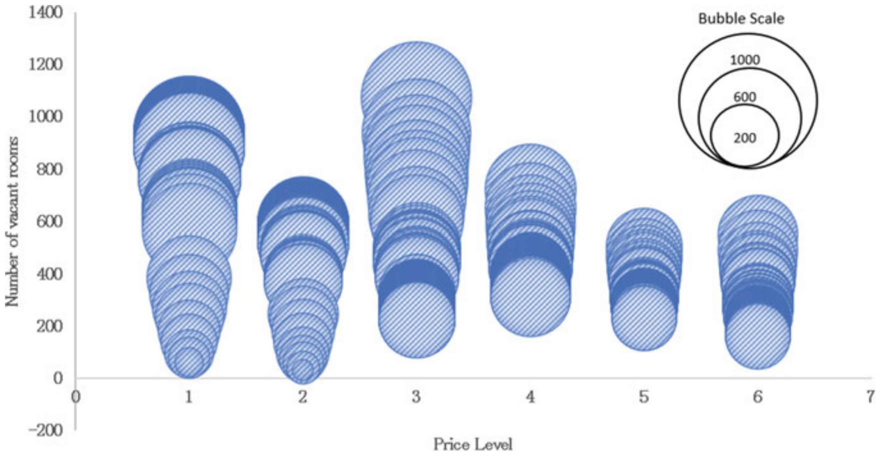

Fig. 19.2 Change in the number of vacant rooms with pricing strategy

for 21–22% of the previous year. On the other hand, outside of Tokyo and Osaka, 7,000–8,000 yen remained at 25–27%. Accommodation costs for business trips in local cities are about 2,000 yen cheaper than in Tokyo and Osaka. The next highest price range is 9,000–10,000 yen, which is 19–20% of the previous year.

Outside of Tokyo and Osaka, the price range of 6,000–7,000 yen in 2018 alone increased by 3 points from the previous year to 21%, making it the second-highest price range. The price range of 5,000–6,000 yen also accounts for 11%, up 3 points.

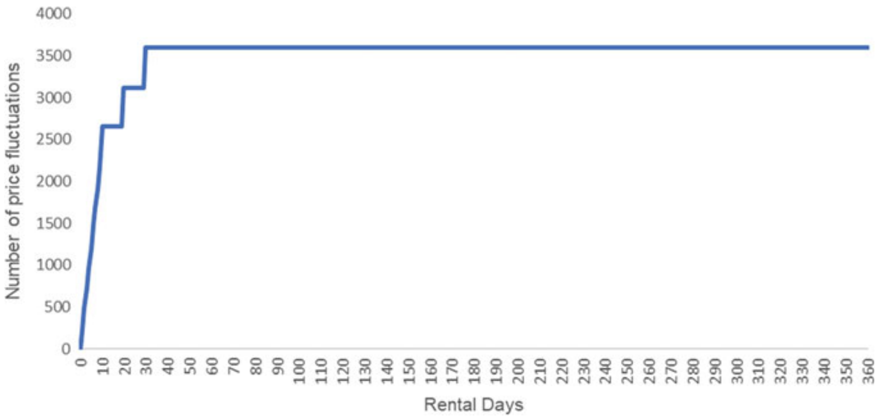

Fig. 19.3 The number of price changes

Therefore, it is thought that people can easily concentrate on the volume zone of 7,000–9,000 yen (Fig. 19.3).

3,500 price changes can be seen until about 33 days, however, after 33 days, the number stopped. This indicates that it takes about 33 days for all agents to be matched. One possible reason for the relatively high short-term vacancy rate is the change in behavior until all lender agents are matched.

19.6 Price Elasticity

The elasticity of price refers to a numerical value that indicates the degree to which the demand for or supply of a given product changes as a result of price fluctuations.

In this analysis, we examined whether changes in the price of a hotel would change the demand for or supply of the product. The results of the analysis showed that when the price elasticity of demand was calculated at the midpoint of the price range, it was found to be inelastic. Detailed analysis to determine whether demand changes with the price range and the optimal price is a future task.

First, we tried a method of calculating the midpoint, which is the middle of the two points to be compared. The midpoint between the lowest price of 4000 yen and the highest price of 9,000 yen is 6,500 yen. Dividing the amount of change by this midpoint, the rate of change is (9,000–4,000 yen)/6,500-yen $\times$ 100 = 76.92%. Similarly, we find the rate of change of the quantity demanded. The midpoint of the number of demands is (250 + 400)/2 = 325. Dividing the amount of change by this midpoint of 325, I get (400–250)/325 $\times$ 100 = 46.15%. Next, the formula for calculating the price elasticity of demand is (−% change in demand)/(% change in price). If we apply the rate of change in demand and the rate of change in the price calculated above, we get $-46.15\%/76.92\% = -0.59$. In general, the price elasticity of demand is called inelastic if it is less than one.

Therefore, the result obtained by the midpoint formula is that the midpoint of the price is inelastic. This is because hotel rooms are an inelastic good, and no matter how much the price rises, the compartment called room cannot be increased, and therefore the supply may not be able to be increased arbitrarily. The longer the time period is taken when considering demand, the greater the price elasticity of demand tends to be. In contrast, when a small period of time is used for analysis, it tends to be relatively inelastic. In addition, a detailed analysis of how demand changes depending on the price range and how to find the optimal price is an issue for the future.

19.7 Summary

In this study, we attempted to construct an agent-based model for the study of pricing strategies for business hotels. Specifically, we created demand and supply levels for lender and borrower agents and conducted a basic analysis of hotel occupancy. As a result of the analysis, we found that (1) short-term rentals are filled first, (2) there is utility in the pricing strategy, and (3) the price volume zone is close to the market average. We believe that these findings contribute to the usefulness of our hypothesis and model based on previous studies and to the uniqueness of our introduction of pricing strategies. We also consider it a contribution that this study conducted a bottom-up policy evaluation and explored that a model is an effective tool. Future work includes adding indicators such as room quality, further investigation of price elasticity, and finding the optimal price.

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Chapter 20
A Study of the Impact of Crypto Assets on Portfolio Risk-Return Characteristics Before and After COVID-19 Outbreak (2014–2020)

Mengyao Liu, Hiroaki Jotaki, and Hiroshi Takahashi

Abstract Following the COVID-19 outbreak, unlike the plunge in traditional mainstream assets, crypto assets have performed very well. Indices that reflect changes in the crypto assets market have also grown in recent years. However, in terms of cryptocurrency index-related studies, there are not many, and the period analyzed is mostly three years. This study analyzes historical data from July 2014 to April 2020 based on the cryptocurrency index CRIX and six other traditional mainstream assets to verify the impact of crypto assets on traditional portfolios. By using the DCC-GARCH model, this study finds out the low dynamic correlation between the crypto assets and traditional ones. Furtherly, by using the mean–variance model, Cornish-Fisher expansion and T-copula CVaR approach to check the frontier line and portfolio performance, this study finds out that crypto assets have the potential to improve the risk-return characteristics of traditional portfolios.

Keywords Crypto assets · Portfolio analysis · CRIX

20.1 Introduction

The outbreak of COVID-19 at the end of 2019 has affected the global economy and was a central factor in the performance of major assets in the first half of the year, during which the oil price war and the dollar liquidity crisis exacerbated the financial market turmoil. The global financial markets have been violently volatile since March. Risky equity assets fell sharply. Many commodity prices plummeted. Crude oil prices were negative at one point, and the U.S. stock market saw four circuit breakers in a short period, costing investors dearly. The importance of diversified allocations was further highlighted. How to invest, how to build and refresh portfolios is a common topic among investors.

Driven by risk aversion and global monetary easing, gold is supposed to be the safe harbor, however, it is crypto assets that are outperforming gold. Bitcoin's price

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has more than quadrupled since March, making it one of the most sought-after investments this year. The Bloomberg Galaxy Cryptocurrency Index is up about 65% in 2020, outpacing gold's more than 20% gain and outpacing the returns of global stock, bond, and commodity markets.[1] There are claims that crypto assets such as bitcoin are already diversifying investors' exposure to gold and other such assets. A growing number of institutional investors are getting in on the act. For example, Massachusetts Mutual Life Insurance Company announced that its investment fund will buy $100 million of bitcoin, becoming the latest mainstream company to dip its toe into crypto assets.[2] If these U.S., Eurozone, U.K., and Japanese pension funds and insurance companies allocate 1% of their assets to bitcoin, the demand for bitcoin could soar.

However, bitcoin's daytime price volatility is four times that of gold. The risk remains high. This study will discuss and analyze the possibility or potential of crypto assets as an investment object.

20.2 Related Work

A number of studies on crypto assets have been reported that analyze bitcoin as an investment. For example, the paper "The influence of Bitcoin on portfolio diversification and design" by Akhtaruzzaman, Sensoyc, and Corbetd discussed the portfolio diversification with Bitcoin in bond index and global industry portfolios. They conclude that investing in bitcoin can be an effective hedging strategy for a bond risk management portfolio based on the fact that a portfolio of bitcoin and bond index has higher returns and volatility than a bond index portfolio alone.

In recent years, investment in a variety of crypto assets has been taking place, and analysis using crypto assets other than bitcoin as investment targets has also been reported. For example, the paper "The Effect of Cryptocurrency on Investment Portfolio Effectiveness" by Yanuar Andrianto and Yoda Diputra(2017) analyzes historical data of Bitcoin, Ripple, Litecoin, and four traditional financial assets: foreign exchange, commodities, stocks, and ETFs from December 2013 to December 2016. Based on their analysis, it seems that the formation of a portfolio involving assets has been able to beat the performance of the S&P 500 and the Dow Jones index.

In addition, Chuen/Guo/Wang (2018) conducted an analysis on a crypto assets index (CRIX) from August 11, 2014 to March 27, 2017 and used models such as DCC to show that CRIX and crypto assets are excellent investment assets for portfolio risk diversification.

[1] Source: https://www.bnnbloomberg.ca/crypto-is-beating-gold-as-2020-s-top-asset-so-far-1.1497858.

[2] Source: https://www.investopedia.com/decoding-insurance-giant-massmutuals-bitcoin-investment-5092586.

20.3 Analysis Method

Firstly, after confirming the yield distribution of each asset and the dynamic correlation (DCC model) between each asset, this study will use the Monte Carlo simulations to generate 20,000 portfolios with stochastic investment weights. Using the mean–variance model of modern portfolio theory, this study will find the efficient frontier curve as well as the minimum variance portfolio and the portfolio with maximum Sharpe ratio, respectively. This study will repeat this process twice, the first time for the traditional portfolio without the crypto assets index and the second time for the new portfolio with the crypto assets index. This study will compare the change in returns, risk, and weighting of each asset in the minimum variance portfolio and the maximum Sharpe ratio portfolio before and after the addition of the crypto assets index. The overall portfolio performance and the size of the weighting of the crypto assets after adding it and its contribution to the risk-return characteristics of the portfolio will be analyzed.

Also, this study will examine the effect of crypto assets in the case of sudden market fluctuations. The COVID-19 outbreak in late 2019 saw intense global market fluctuations, somewhat similar to the 2008 market situation. There is an argument in the market that diversification fails when markets are sharply volatile, such as the 2008 market underworld level financial crisis. This study will compare the portfolio risk-return characteristics of 2008 and 2020, analyze the effect of diversification with a look at the new asset type scenario for crypto assets.

To verify the effect of diversification in the interval affected by the Covid-19 epidemic in 2020, this study will analyze the historical data of the first three years before 2008 and the whole year of 2008 for six assets to confirm the presence or absence of and differences in the effect of diversification in 2008 and the first four months of 2020.

Also, due to none of the return distributions of the assets are standard normal, it is likely to underestimate the risk using the mean–variance model. Therefore, this study will use the Cornish-Fisher expansion and T-copula approach separately to get the CVaR values at the confidence level of $\alpha = 0.01$. By simulating the portfolios and finding the effective frontier line, this study will check the difference between the results from the mean–variance approach and CVaR approach.

20.4 Data

Focusing on 7 indices representing the stock market, crude oil, gold, private equity, real estate investment trusts (REITs), commodities, and crypto assets, this study conducts portfolio analysis based on the hypothesis that crypto assets may improve the risk-return characteristics of traditional portfolios.

Table 20.1 Indices used in this analysis

	Name of indices
1	S&P500
2	Crude oil
3	Gold
4	S&P listed private equity
5	MSCI U.S. REIT Index
6	Goldman sachs commodity index (GSCI)
7	Cryptocurrency index (CRIX)

The data source is mainly from the Yahoo finance website and the data stream, the market is aimed at the U.S. market. The data period is from July 31, 2014, to April 22, 2020.

The purpose of this study is to clarify the risk-return characteristics of portfolios that include crypto assets (Table 20.1).

20.5 Result

20.5.1 DCC Correlation

Regarding correlation, the correlation between digital currencies and several other traditional mainstream assets is very low, none of them exceed 0.1, the highest is the correlation with gold, about 0.05, which is also very low, especially with the S&P 500 and REITs is a negative correlation.

Considering that the data span six years and correlations may change over time, this study employs a DCC model to analyze the dynamic correlation between the crypto asset index and other assets indices. As can be seen, the dynamic correlation between crypto assets and other assets is low, throughout the 6 years' data period. The average DCC value is less than 0.07, with a maximum value of 0.268 (CRIX and crude oil) and often negative correlation appears. Overall, CRIX shows good potential for diversifying portfolio risk and increasing diversification as an alternative investment asset class option that is in line with expectations (Table 20.2).

Furthermore, this study had analyzed the changes in the average DCC dynamic correlation after the outbreak of COVID-19 from January to April 2020.

As shown in Fig. 20.1, after the outbreak of COVID-19, there were sharp fluctuations in market prices and changes in the average dynamic correlation between crypto and traditional assets. The dynamic correlation between gold and CRIX became larger, even exceeding the highest value in the last 6 years. This may validate the notion that more and more investors in the market are investing in crypto assets as a safe-haven asset like they do in gold.

Table 20.2 DCC correlation

	S&P500	Gold	Oil	GSCI	REIT	PE
Min	−0.1909	−0.128	−0.1027	−0.1158	−0.1096	−0.1801
Q25	−0.0389	−0.0064	0.0209	0.0273	−0.0391	−0.007
Median	0.0083	0.0309	0.0612	0.0669	−0.0095	0.0301
Mean	0.0049	0.0329	0.0596	0.0653	−0.0044	0.0307
Q75	0.0448	0.0757	0.1017	0.1033	0.0228	0.0695
Max	0.1986	0.2599	0.268	0.2217	0.193	0.2081

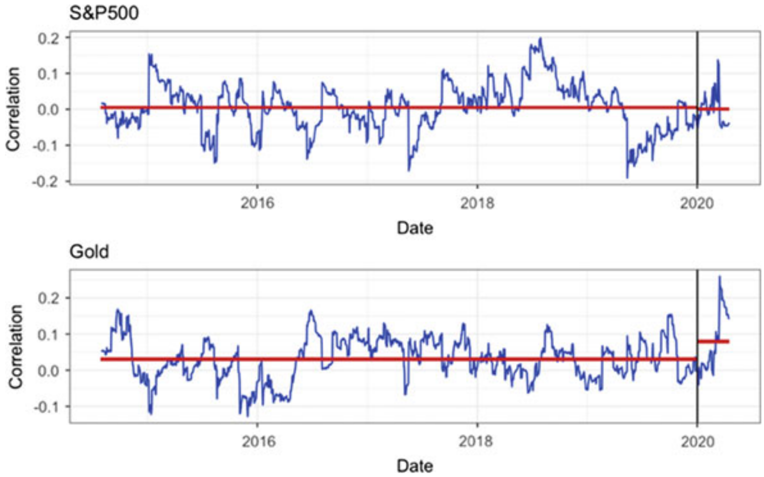

Fig. 20.1 Dynamic correlation coefficients between CRIX and stocks and gold

20.5.2 Portfolio Analysis Result (2014.07–2020.04)

By simulating the portfolio in two scenarios including and including crypto assets separately, this study obtains the following table showing that the inclusion of crypto assets improves the portfolio risk-return performance under the analysis of historical data from July 2014 to April 2020. The minimum variance portfolio has a risk of about 12%, a return of 8%, and a CRIX weight of 4.36%. This compares to a 1% increase in risk and a 7% increase in return for the minimum variance portfolio without the inclusion of digital currency. The portfolio with the highest Sharpe ratio has a risk of about 28% and a return of 31%, with 34.78% of the investment in the digital currency asset index CRIX. Comparing this to the case without the crypto assets index CRIX, overall, the risk improves from 11 to 28%, roughly doubling, while the return improves from 6 to 31%, roughly a fourfold increase (Table 20.3).

Table 20.3 Portfolio performance with and without CRIX in 2014.07–2020.04

Without CRIX									
Allocation	S&P500 (%)	Gold (%)	Oil (%)	GSCI (%)	REITs (%)	PE (%)	CRIX	Return (%)	Volatility (%)
Max sharpe ratio	42.73	44.92	0.17	1.62	1.72	8.84	0	6.00	11.00
Min volatility	23.50	46.84	0.33	17.45	8.57	3.31	0	1.00	11.00
Adding CRIX									
Max sharpe ratio	41.86	3.83	0.43	0.36	1.49	17.25	34.78%	31.00	28.00
Min volatility	41.45	41.86	0.53	3.36	4.42	4.01	4.36%	8.00	12.00

20.5.3 Mean–Variance Approach Result (2020.01–2020.04)

As for the analysis of the impact of COVID-19 in 2020, under sharp market fluctuations, this study first analyzed the first 3 years of 2008 and the entire year of 2008 historical data and found that the otherwise very effective diversification failed in 2008.

The same analysis results appear in the analysis without the inclusion of digital currency assets in 2020, while the situation changes with the inclusion of digital currency assets. Investors with a high-risk tolerance have the opportunity to reap the benefits by adding crypto assets into the portfolio with a weight of around 37.24% (Table 20.4).

20.5.4 Mean–Variance Approach Result After De-Anomalies (2014.07–2020.04)

Considering the negative impact of the negative price of crude oil on the portfolio simulation, this study takes into account the generalized scenario and removes the extreme values of crude oil return, and again the results of the analysis more clearly highlight the improvement of the portfolio performance by the addition of crypto assets.

Only the CRIX may lie on the top left of the effective frontier, while none of the other assets are on and above the effective frontier, especially crude oil, which is the least positioned and most risky (Fig. 20.2).

Figure 20.3 shows the risk-return characteristics of a portfolio containing crypto assets. The horizontal axis of the table shows the volatility, and the vertical axis shows the return. The red dots in the figure indicate the portfolio with the highest Sharpe ratio. Within this portfolio, crypto assets have the largest weight of 29.64%. These results indicate that crypto assets may be contributing to the improvement of the risk-return characteristics of the portfolio.

20.5.5 CVaR Approach Result

Next, since the data distribution of all types of assets, especially digital currencies, deviates from the normal distribution, this study does a CVaR analysis of the corrected distribution through Cornish-fisher expansion. Comparing to the result of the analysis without crypto assets and excluding outliers, the minimum CVaR value for the smallest CVaR portfolio is 0.046 with an annualized return of −0.034. The highest returning portfolio has a CVaR of 0.22 with only 7.2% annualized return, the result of the analysis with CRIX, the maximum annualized return portfolio reaches a return of 54% or more and corresponds to a CVaR value of no more than 0.20, while

Table 20.4 Portfolio performance with and without CRIX in 2020

Without CRIX									
Allocation	S&P500 (%)	Gold (%)	Oil (%)	GSCI (%)	REITs (%)	PE (%)	CRIX (%)	Return (%)	Volatility (%)
Max sharpe ratio	37.4	48.6	0.2	0.9	5.7	7.3	0.0	−8.0	35.0
Min volatility	21.7	39.9	0.1	31.1	4.3	2.9	0.0	−64.0	32.0
With CRIX									
Allocation	S&P500 (%)	Gold (%)	Oil (%)	GSCI (%)	REITs (%)	PE (%)	CRIX (%)	Return (%)	Volatility (%)
Max sharpe ratio	0.7	39.3	0.0	1.5	14.9	6.4	37.2	21.0	42.0
Min volatility	3.4	43.6	0.2	22.9	1.5	12.3	16.1	−38.0	31.0

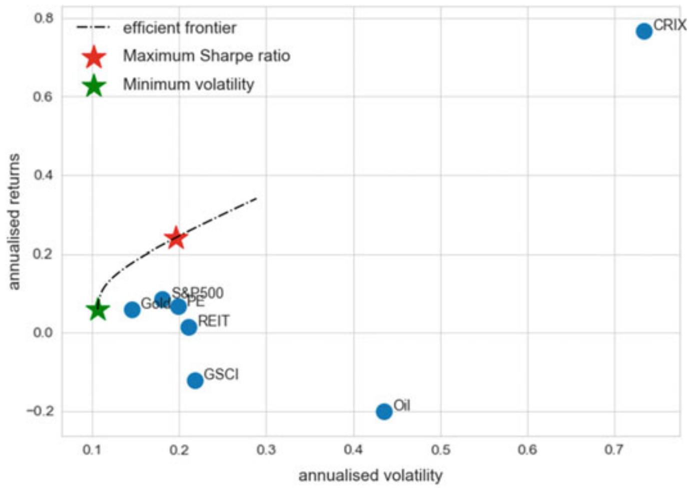

Fig. 20.2 Efficient frontier line with individual assets

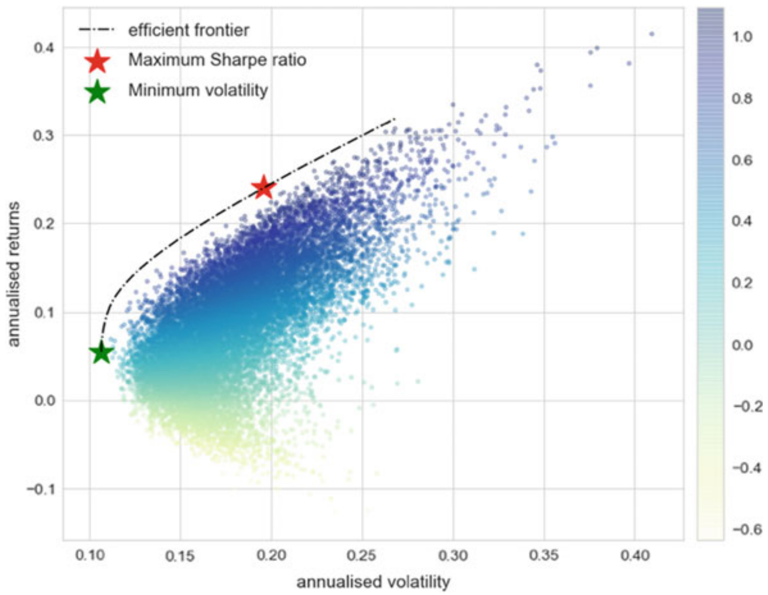

Fig. 20.3 Efficient frontier (2014–2020 including CRIX after removing crude oil minus return)

there is also an effective portfolio with a CVaR of 0.15 and an annualized return of 47%. Both recommend more than 60% allocation at CRIX. With close to the same level of conditional value-at-risk, it is believed that more investors will choose those portfolios with crypto assets included.

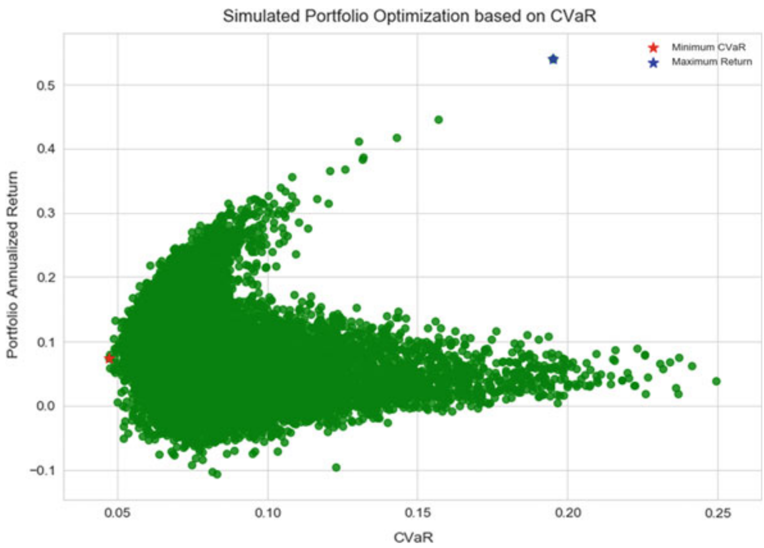

Fig. 20.4 CVaR approach analysis with crude oil minus return outlier removed

Also, with or without the removal of the crude oil price outlier, both studies suggest that the potential exists for including crypto assets to improve the risk-return characteristics of traditional portfolios (Fig. 20.4).

Next, since the return of the minimum CVaR portfolio is so low that it is not very helpful for investors, this study sets a return of at least 10% as a constraint on the target return and runs 50,000 Monte Carlo simulations to find the minimum CVaR portfolio and the portfolio with the highest annualized return portfolios were obtained.

The results show that the minimum CVaR portfolio has a CVaR value of 0.05 and an annualized return of 13.96%, with a 15.85% investment weighting in crypto assets, and the highest investment weighting remains in gold, at 51.22%. The highest annualized return portfolio had a CVaR of 0.157 and an annualized return of 47.2%. Of these, crypto index CRIX remained the top investment weighing at 60.5% (Fig. 20.5).

To confirm the reliability of the analysis results, this study also adopted a T-copula approach to adjust the data return distribution and compared the difference in the weight of each asset in the portfolio in the adjusted CVaR approach and the mean–variance approach for the effective frontier. The comparison finds that the t-copula approach adjusted mean portfolio return-CVaR efficient frontier lies slightly to the upper left of the mean–variance efficient frontier, as expected.

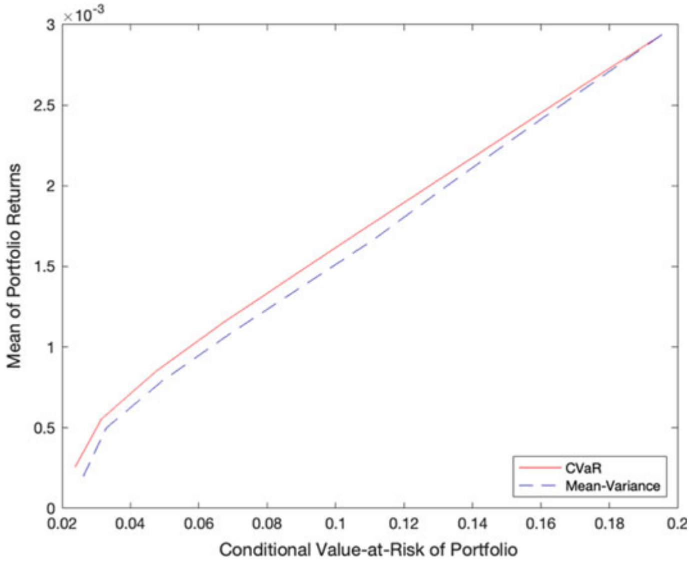

Fig. 20.5 Efficient frontiers (CVaR versus Mean–Variance)

20.6 Conclusion

In this study, the characteristics of crypto assets and traditional asset classes and their correlations were analyzed. The low correlations and the efficient frontier analysis under the mean–variance model and CVaR through both the Cornish-fisher expansion and the T-copula approach with or without the outlier of Crude Oil's negative yield indicate that the inclusion of CRIX can significantly expand the effective frontier of the traditional mainstream asset portfolio even during COVID-19 period, a sharply volatile market situation, suggesting that crypto assets have the potential to improve the risk-return performance of the portfolio.

Whether the conclusions based on the analysis of historical data can be applied to future investments for the highly volatile digital currency assets, and the specific design of a portfolio strategy that includes digital currency assets, become future topics.

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Chapter 21
A Customer Experience Mapping Model for Business Case Description of Innovation and Value Co-creation

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Abstract We propose a mapping model for describing transition processes of customer experiences in business innovation cases. Named as System Experience Boundaries Map (SEBM), this mapping model mainly focuses on boundaries that constrain the customer latent experiences. SEBM also represents a customer-side process of business innovation as a resolution of those restrictions. Used with the Managerial Decision-Making Description Model previously presented, SEBM describes value co-creation processes between firms and customers, which involve user innovation in actual business cases. We are going to apply SEBM for log-analysis in business gaming facilitation.

21.1 Introduction

The various studies on product innovation introduce thinking frameworks (e.g. Disruptive Innovation [1], Design Thinking [2], Design Driven Innovation [3], User Innovation [4], etc.) explaining how to understand and interpret the innovation. These frameworks are tightly related their own viewpoints. On the other hand, UX (user experiences) studies various mapping methods [5]. These mappings are oriented to develop innovative UX design. It is difficult to describe and compare the business innovation cases across those frameworks especially from the user experiences sides.

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This paper presents the System Experience Boundary Map (SEBM) as an experience-mapping model for formally describing the changes in customer experience due to new products and services in the case of business innovation. Also, in combination with the Managerial Decision-Making Description Model (MDDM) [6–8], SEBM and MDDM describe business innovation as an alignment-diagram [5], which illustrates a process of both in the organization and the individuals. SEBM and MDDM also provide a common way to visualize the process of value co-creation in business gaming, similar to the business case.

SEBM describes business innovation cases from the customer side, and MDDM describes business innovation cases from the manufacture side. Here, business innovation means that on the customer side, new products and services are being introduced with qualitative changes in the customer's experience in usage and consumption. On another side, business innovation in the manufacture's side means the change of objectives-resources combination in organizational business processes for new products and services.

In addition, this paper uses "customer experience" which means a sequence that is segmented into several stages of a script of usage and consumption behaviors of a customer regarding a certain good or service. On the other hand, we use "qualitative change of the customer experience" that a new good or a service resolves the existing limitations/boundary of customer's behavior at a certain stage of the customer experience and redefines customer's script of behavior.

To compare with the methods experience mapping method [5, 9], including User Experience Map [10], Customer Journey Map [11], and Mental Model Diagram [12], SEBM is close to mapping models that pay attention to changes in the user interface. Meanwhile, SEBM extracts latent limits and restrictions of the customer behavior from the existing user experience and focuses on the change of the customer behavior due to the introduction of new goods and services. SEBM enables us to visualize the business innovation case including before and after situations and innovative factors from the customer side.

SEBM describes the case of business innovation on the customer side by focusing on the behavior change of the customer. MDDM describes the case of business innovation on the enterprise side as a change in the combination of management objectives and management resources. By combining them, it is possible to express them in parallel with the process of business structure change on the company side. It is an implementation of alignment-diagram [5], which makes it possible to describe value co-creation [13] in service science as a process of interaction between changes in the business structure of a company and behavior changes on the customer side.

21.2 Methodologies

SEBM is a novel table form model that describes the transition of customer experiences from bounded experience for existing goods and services to new behavior due to the emergence of goods and services (Fig. 21.1). SEBM unfolds the customer expe-

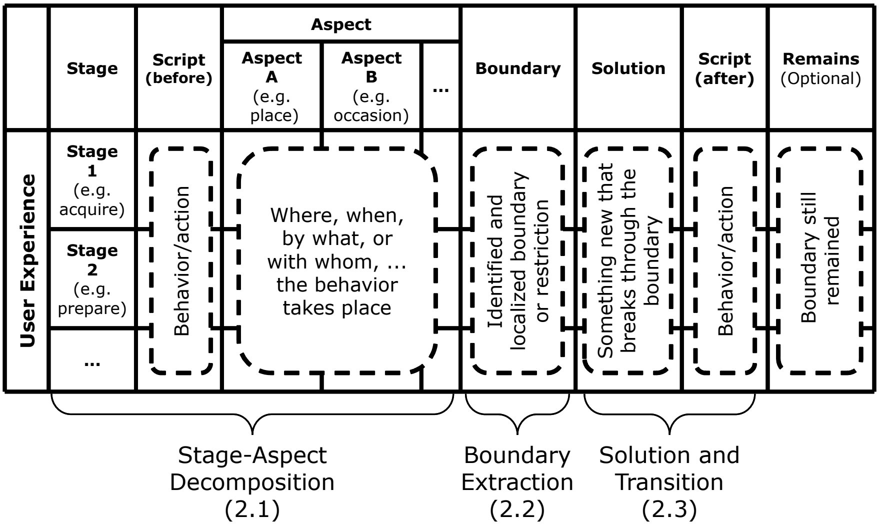

Fig. 21.1 System experience boundary map (SEBM)

riences of the following three-step procedure: (1) decomposing the characteristics of the experience into two axes of stage and aspect (Stage-Aspect Decomposition), (2) extracting each decomposed stage, and latent restrictions/constraints of the experience in each aspect (Boundary Extraction), and (3) describing new behavior by solutions to the restrictions/constraints of the experience (Solution and Transition).

SEBM describes the transition of customer experiences as a table decomposed from a certain viewpoint by these procedures. This experience map enables us to describe when, where, and what kind of constraint exists for a customer, and what kind of experience is generated by eliminating the constraint.

21.2.1 Stage-Aspect Decomposition

First of all, the characteristics of the customer experience of goods and services are decomposed and arrayed into a table format with two axes: the "Stage" and "Aspect" of realizing the experience. Here the stage is a division according to the order in which the experience is realized, such as "Acquire," "Prepare," "Enjoy," "Keep," etc. The aspect is a classification according to the nature of the experience, such as "Occasion," "Place," "Device," "Subject/Object" of the action, etc., that the experience realizes in each stage. Each category is selected by the map author based on the contents of the case (Fig. 21.1, left).

21.2.2 Boundary Extraction

Regarding the characteristics of the experience decomposed at the stage, the boundaries/constraints under the existing goods/services are described based on the contents of the case and the viewpoint of the map author. The boundary is a factor that restricts the potentiality for the customer's experiences, which corresponds to the "pain point" in other experience mappings [5]. This enables to explicitly describe which boundary is latent in the customer behavior of existing goods/services related to the characteristics of the stage or aspect of the experience (Fig. 21.1, middle).

In SEBM, the experience is decomposed into stages and aspects, so that even when there are multiple boundaries/constraints, or when the perspectives of the case writer and the map writer are different, each latent location can be identified and delineated.

21.2.3 Solution and Transition

Describe the changes of the latent experiences under the identified existing goods and services as relaxations of the boundaries/constraints by introducing new goods and services. Furthermore, the new experiences made possible by the new goods and services are described as scripts. (Fig. 21.1, right).

In this way, in case of multiple boundaries relaxations, or the different viewpoints of the case author and the map author, it is possible to identify and draw each change.

Even when only some of the multiple boundaries have been solved, the remaining latent boundaries are identified in the same format. For this reason, it is possible to describe and compare innovation chains using the SEBMs sequence.

21.2.4 Connection with MDDM

When combined, SEBM and MDDM are able to describe innovation and value co-creation by customers and firms formally. Business innovation is described in SEBM as a change to a new script by relaxing the boundaries of the customer experience, whereas MDDM describes as a change in the combination of objectives and resources in a company's hierarchical business structure (Fig. 21.2 upper half). Therefore, SEBM and MDDM are complementary as a case description model for business innovation. It is also the implementation of alignment-diagram [5], which is a bilateral description of value co-creation between organizations and individuals.

When connecting MDDM and SEBM, the customer's experience and its changes are regarded as changes in the external environment for the firm. Then, SEBM is connected through the environmental components of MDDM as part of the market landscape. The interaction between the market and management decision-making

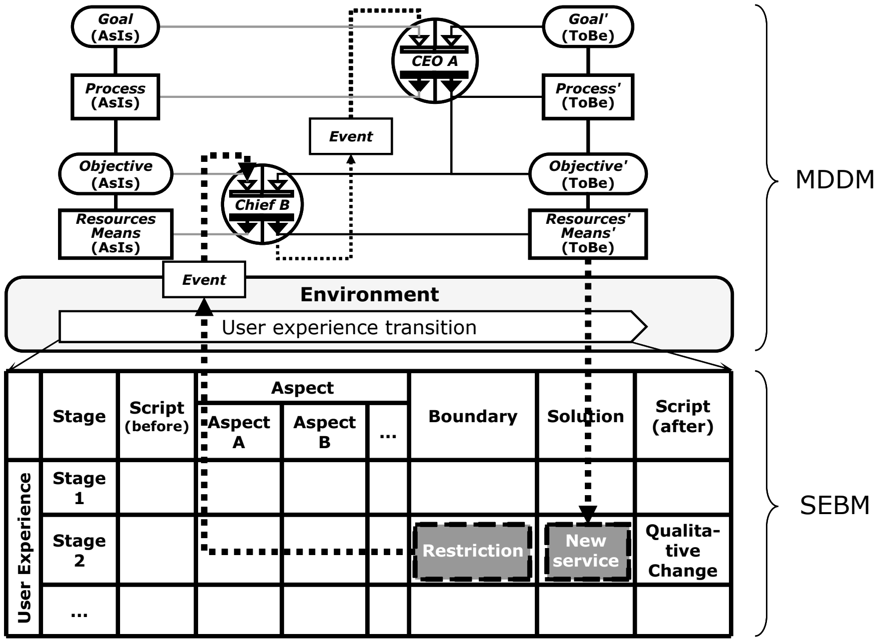

Fig. 21.2 Description of business innovation by connecting MDDM (upper-half) and SEBM (lower-half). The thick dotted lines represent the interactions that occur between corporate decision-making and changes in the customer experience

is expressed by the connection of events from the environmental component to the in-firm agent, which is the trigger of decision-making, or the connection of the event to the environmental component from the agent's decision-making (Fig. 21.2).

Following possible patterns are possible for the connection:

- The existence of boundary at a particular stage/aspect in SEBM is a trigger event for organizational decision-making in MDDM.
- New goods and services resulting from MDDM management decision-making is an event that provides them as solutions in SEBM.
- The change in customers' behavior script by the boundary relaxation in SEBM is a trigger event change in the market environment for the decision-maker in MDDM.

Such a connection between SEBM and MDDM suggests that a formal description of value co-creation is possible. It indicates that the coupling of SEBM and MDDM is a potential tool for extracting stylized facts of the value co-creation process.

21.3 Application to Actual Business Cases

For the example, we show SEBM and MDDM description of the case of Honda's entry into the North American motorcycle market. This is a classic case in Christensen's work [1], but the information from Honda's website [14, 15] is also taken into account to describe from the customer's perspective.

The outline of the case [1] by Christensen is as follows:

- Honda was looking to enter the market for large high-speed highway bikes like Harley Davidson which was popular in the North American market with the advantage of low cost.
- While Kawashima, the manager of American Honda Motors at that time, was developing a local dealer, Honda's large motorcycle was not accepted in the North American market.
- Whereas the Super Cub, which Kawashima brought in for business delivery aroused consumer interest and demand when he ran off-road for recreation.
- Kawashima convinced the Tokyo head office to introduce a lightweight recreational bike to the North American market.
- Honda changed its strategy and created a new market in North America.

Here we show the combination of SEBM and MDDM in the Honda case of the Super Cub (Fig. 21.3). In the upper-half of Fig. 21.3, MDDM describes that the finding latent demand for off-road riding by some customers triggered a bottom-up decision to develop the market for lightweight recreational bikes in North America.

In the lower-half of Fig. 21.3, the SEBM describes the changes in consumer experience before and after the introduction of Super Cub. For simplicity, the experience stage is divided into two parts: "purchase" and "usage," and aspect is divided into "place" and "atmosphere." According to Honda's website [14, 15], the limitations/constraints of the potential North American customer's experience were that the large bikes of the time had a very bad impression from society as a defective vehicle with a leather jacket, covered with oil. A store like a garage was not the place that the general public would want to visit. Small products other than large bikes for highways were undeveloped (Fig. 21.3, Boundary column).

In a market with such potential boundaries/constraints, the Super Cub gained popularity due to its toy-like ease. Some customers took the Super Cub to a camp or picnic with a pickup truck and ran through the forest. Such usage was not expected at the Japanese head office. Kawashima focused on this and reported it to the head office, and expanded the sales channels to be an inexpensive lightweight recreational bike other than specialized dealers. He launched the "Nicest people on Honda" campaign. As a result, he was able to offer the Super Cub as a vehicle for citizens, such as students and women, different from the conventional motorcycle customers (Fig. 21.3, Solution column).

As a result, at the purchase stage, customer behaviors such as easily purchasing Super Cubs at sports equipment stores and making them a Christmas present for

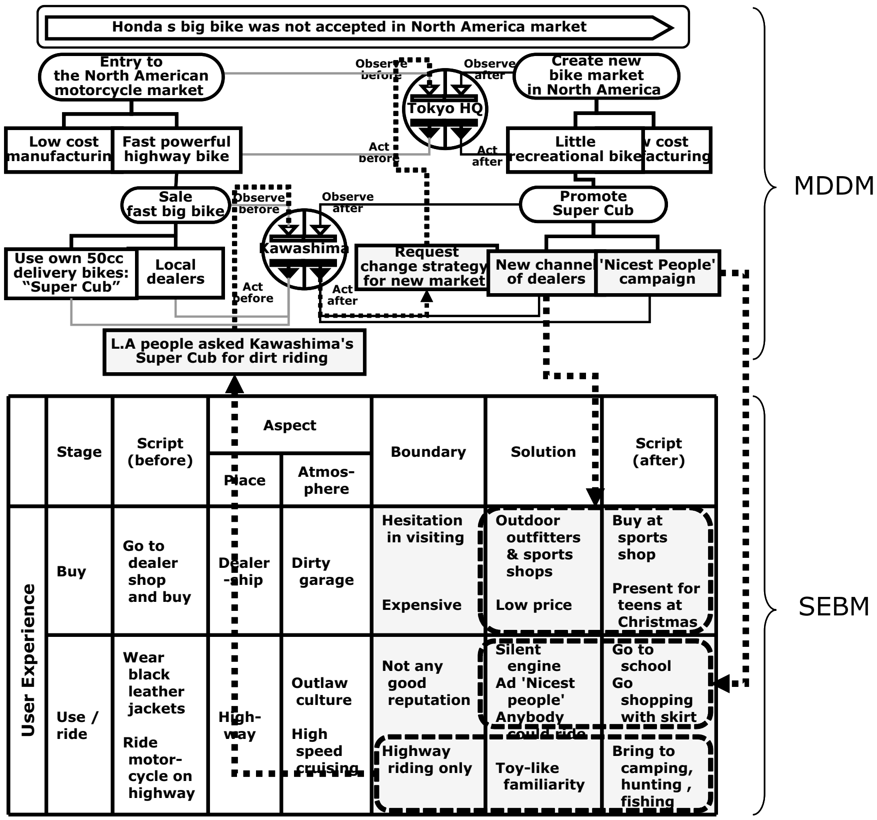

Fig. 21.3 Alignment diagram of Honda's managerial decision making (MDDM: upper-half) and customer experience transition (SEBM: lower-half) in Honda's case

teenagers were added. At the use stage, customer behaviors such as running off-roads, and students and women moving casually and fashionably when going to school or going out were added (Fig. 21.3 Script (after) column).

21.4 Application to User Innovation Case Description

Here, we consider here the application to the description of innovation caused by users themselves. It has been reported that product innovation is not necessarily caused only by firms, but also by users themselves who have knowledge and skills, which is called "User-Innovation" [4]. This kind of innovation can also be described by combining SEBM, which describes changes in user experience, and MDDM, which describes changes in the combination of objectives and resources by users themselves.

A famous example is the case of innovation in mountain biking. According to Hippel's work [4], mountain bikes, which appeared in the 1970s and later, were designed for riding on rough off-road terrain such as mountain trails. From the early days, users modified existing commercial bicycles themselves. Eventually, major manufactures grew out of the cottage industry that emerged from some users, and the mountain bike market became the majority of the US market in the 2000s. However, mountain bike enthusiasts continue to innovate product technology for their own sport riding techniques.

Luthje [16] reports the following examples of innovations in mountain biking by skilled users.

Stunt: A user encountered a problem when doing a trick feet off the pedal in mid-air, but the pedal would spin and led difficulty landing. The user improved the pedals by attaching foam to the axle to increase friction.

Extreme conditions: Another user encountered problems with losing traction and spinning or falling when riding on ice. The user got a tire with large tread blocks and put an automotive stud in each block.

Racing: Yet another user encountered the problem of comparing tryout times on different lines of the track for a race. The user attached a thumb-activated stopwatch to his handlebar.

Figure 21.4 describes the user innovation of mountain bikes [16] as an alignment diagram combining SEBM and MDDM. For the boundaries and solutions described by SEBM, MDDM can describe the changes in the combination of objectives and resources in the user-innovator.

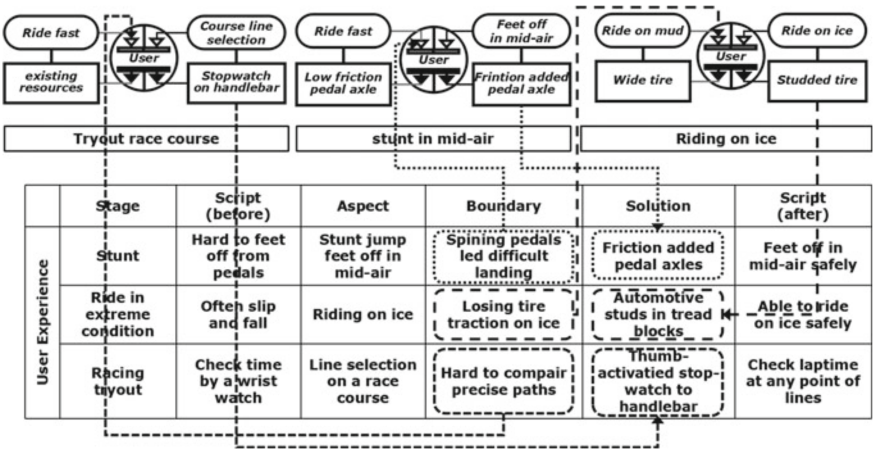

Fig. 21.4 Alignment diagram of user innovation of mountain bike [16], innovators' decision making (MDDM: upper-half) and customer experience transition (SEBM: lower-half)

21.5 Considerations

Regarding combining SEBM and MDDM, we consider the possibility of application in business case learning and business gaming learning from the facilitation support and learning log-analysis viewpoints.

In learning with business case or gaming about business innovation, it is desirable to consider both the organizational decision-making of a company and the change of ownership value, value in use, or consumption behavior change in the customer from both sides. However, the content of the teaching material and viewpoint of the learner do not always include both in a well-balanced manner. For example, for teaching materials and learners who pay too much attention to the decision-making process within the firm, preparing MDDM together with SEBM may be effective in reducing the load on the facilitator in correcting bias and deviation in learning. On the other hand, it may be effective to combine SEBM with MDDM in order to reflect on the decision-making process in a company when too much attention is paid to marketing and product design.

In business case learning or gaming, it is difficult to record the log in a form that can be compared between learners. However, if it becomes easy to formally describe the changes in the business structure and customer experience, it will be possible to look back on the learners' decision at the time of after-review and to compare them with the records of past learners. The description including useful findings in such inter-comparison can be regarded as "stylized facts" extracted from the case or gaming. Then, such formalization can be a "generator" of those useful stylized facts.

21.6 Summary and Remarks

This paper proposes a System Experience Boundary Map (SEBM) that formally describes the changes in customer experience due to new products and services in business innovation cases. The SEBM, when combined with the MDDM, can describe the process of business structure change on the company side and the change in the customer experience in parallel. Furthermore, SEBM and MDDM can be used to formally describe value co-creation as a process of interaction of firm-driven and user-driven innovation.

The application of SEBM to business case learning and business gaming learning is promising and will be discussed further in the future.

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Chapter 22
The Visualization of Innovation Pathway Based on Patent Data—Comparison Between Japan and America

Zhiyan Chen, Yusuke Matsumoto, Aiko Suge, and Hiroshi Takahashi

Abstract Innovation trends are a crucial factor in determining one country's industrial development, and with the progress of modern machine learning technology, many are studying patent document analysis. People consider patents to contain important information for analyzing the innovation process, but patents contain much complicated jargon, and the methods for extracting information were limited. The authors applied the document analysis and visualization method newly proposed in the previous research and tried to compare the innovation process for patent documents as a whole within a certain period between Japan and the United States. As a result, we realized that in the 15 years, the topic vibration in Japan is more stable than in the US, and the contents in US patents are more concentrated than those in Japan.

22.1 Introduction

Patent data contains an abundance of information, which is key to the technology innovation process. In recent years, with the development and application of machine learning, there have been a series of reports that analyze patent data text information after cluster classification. With these big data and various innovations in tools, the authors believe that it has become possible to observe each country's patent characteristics from a macro perspective. However, although many studies study technological innovation by industries and fields, few studies process all patents in one country utilizing by machine learning. Reference to those studies, this study attempted to apply several analytical methods presented for single technology and extend the range to national and monthly data for countries. For the period, the authors decided to focus on observing how Japan's leading-edge area has changed after the bubble economy burst.

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In studying trends in the technical field, the authors selected to visualize text data to summarize vast amounts of data and express trends. Regarding the visualization of patents, few tools can decipher time series without human elements, and there are precedents for research such as applying the calculation of turning points applied in specific field technology and newspaper documents to all patents. Since there is a high possibility that the decoding of the resulting diagram will be subjective, this study will compare the two countries of Japan and the United States. Therefore, since we analyzed the patents filed database trends in the past, we can grasp the global trends by analyzing and returning patent information to observe technological change to be visited next and even potential signs. It is also the initial purpose of visualizing patent trends.

22.2 Data and Methods

22.2.1 Preparation for Materials

In this paper, we used the data of American patents provided by DWPI (2001–2015, total 4,386,715) and Japanese patents completed SCDV classification in the previous research (2001–2015, total 5,244,890). This DWPI (Derwent World Patents Index) database contains information such as patent filing date, registration date, applicant, inventor, right holder, citation information, and international patent classification. First, we checked the DWPI data and extracted the required information by year. Then, we converted the extracted data to lowercase and numbers, got rid of periods (Punctuation), English idiomatic words (and, the, /s, English stop-word), and extra spaces. Each item was confirmed and extracted necessary items (publication date, IPC classification, vector length from 1 to 200 dimensions of 60 topics) from the SCDV data [1, 2].

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22.2.2 Document Vectorization and Cluster Classification

The document part (title, summary, and text) of the patent data was vectorized based on the skim-gram model (word2vec) and classify those words into multiple clusters [3, 4]. Nest we specified 60 types of topics and classified them by year. Then, we calculated the multidimensional patent numerical values by multiplying the numerical values vectorized by each patent and the cluster classification information.

22.2.3 Calculate the Weight of Topics

This subsection describes how to calculate topic weights. Equation 22.1 shows the formula for calculating the weights.

$$\mathrm{weight}(z_k, TS_i) = \frac{\sum_{j=1}^{d_i} n_{jk}}{\sum_{j=1}^{d_i} N_j}. \tag{22.1}$$

With the data classified by SCDV, the possibility of each topic z_k is added to the monthly and yearly (i), and each topic (z) is the possibility of all 60 topics within the time zone (TS_i). "Σn_{jk}" represents the weight of kth topic in the period (TS_i), and "ΣN_j" represents the total weight of 60 topics in the period. We calculated the topic's weight in the month/year as a percentage of the total value monthly.

Specifically, with one month as the unit of measure, each SCDV value are squared for all patent topics published this month, summing up the squared value for each topic and the monthly "importance" of that topic. Then, we added the "importance index" of 60 topics and calculated the weight that the "importance index" of each topic occupies in the total of the "importance index" of all topics.

22.2.4 Identify the Turning Point[1]

The turning point is the order of the month in which the change is larger than that of the previous and subsequent months, and it is specified by using the turning point in the route squeeze (Eq. 22.2) of Jensen Shannon divergence. Σn_{jk} in the equation represents the sum of weight belonging to one topic. A_{zk} represents the average weight (z_k, t) and weight (z_k, $t+1$). Then compare $TV(t, t+1)$ with the previous $TV(t-1, t)$ and following $TV(t+1, t+2)$. If one is larger than both 1.5 times of the adjacent points, define it as a candidate for turning points.

$$TV(t, t+1) = \sqrt{\frac{1}{2}\sum_{k=1}^{K} \mathrm{weight}(z_k, t) \log \frac{\mathrm{weight}(z_k, t)}{A_{zk}} + \frac{1}{2}\sum_{k=1}^{K} \mathrm{weight}(z_k, t+1) \log \frac{\mathrm{weight}(z_k, t+1)}{A_{zk}}} \tag{22.2}$$

[1]The following Sects. 22.2.4 and 22.2.5 refer to the research method of Miao et al. [4].

22.2.5 Visualization of Topic Changes and Identification of Important Topics

Based on the topic weight calculated in Sect. 22.2.3 (Eq. 22.1), we visualize the weight change by stream graph.[2] Then, we consider the topic changes that occurred before and after each month: the turning point and inductively pattern. Besides, we use the time point calculated in Sect. 22.2.4 as a delimiter and consider the pattern's change for each period.

22.2.6 Analysis for Weights and Visualized Diagrams

The scale of the topic weight is determined by the 200-dimensional numerical value included in each patent topic, so first, calculate the sum of squares in the same way as in Sect. 22.2.3. Then, instead of the sum within the time zone, the patent itself calculates the ratio (individual weight) to the sum of 60 topics. Set a time zone and identify the top 100 patents with the highest individual weights for topics # 1 to # 60 within this time zone. Extract the IPC subclasses of the 100 representative topics identified and select the virtual subclasses for the topic. Then, it is combined with the actual outline and deciphered to reveal the details.

22.3 Results

22.3.1 Stream Graph by Year

Figures 22.1 and 22.2, represent the variations of 60 topics in these 15 years. The horizontal axis of the figures shows time (December 2000–December 2015), and the vertical axis shows topic weight. Due to the characteristics of the sparse composite document vector method used in Sect. 22.2.2, revealed as lots of dimensions and low densities, many topics' weights turned out to be zero. From the figures, we can observe the high similarity between Japanese and American patterns from an overall structural perspective. The weights (ratio) of priority topics are also similar. The difference is that the weight change of each topic in Japan is small and stable.

[2] This analysis used R for visualization.

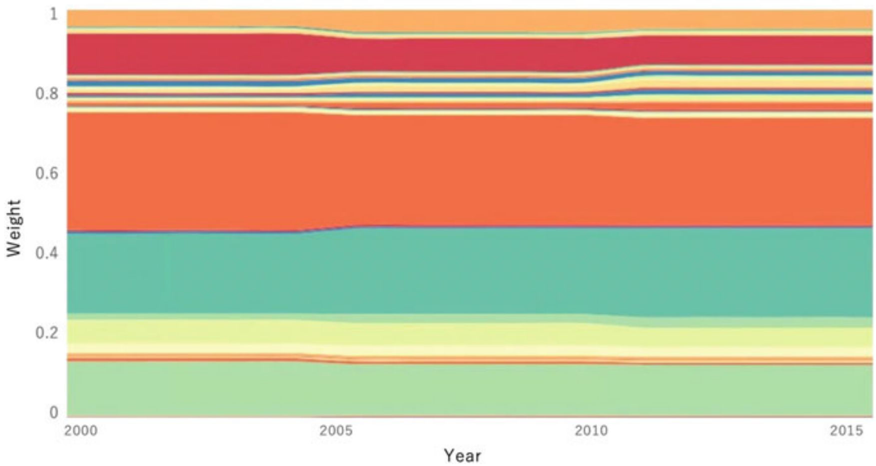

Fig. 22.1 Stream graph by year for Japanese patent topics (2001–2015)

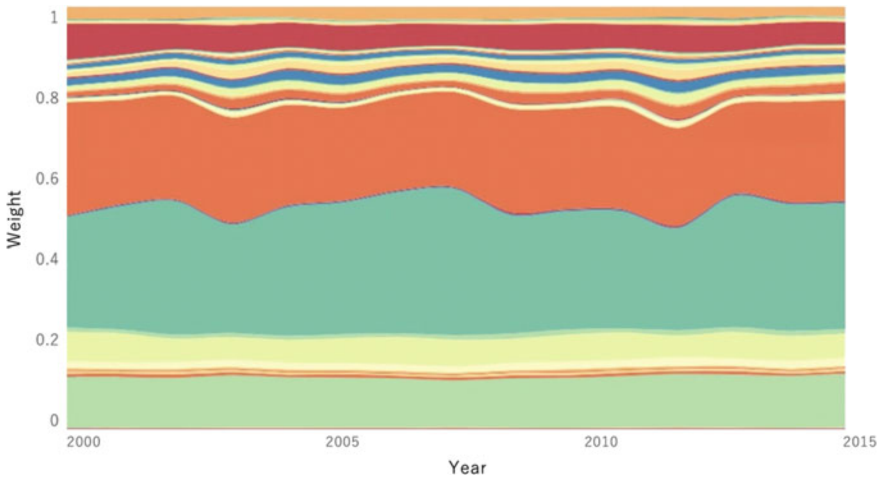

Fig. 22.2 Stream graph by year for American patent topics (2001–2015)

22.3.2 Details for Important Topics

The important subclasses and outlines that Japan and the United States have in common over the last 15 years are G06F (Electrical Digital Data Processing), H04N (Image Communication), H01L (Semiconductor Devices, Unique Electrical Solid Devices), H04L (Transmission of digital information). One subclass and outline that is not common is the American A61K (dental or cosmetic preparation). This result partially overlaps with the primary subclass pointed out in the study on cross-industry in the United States [5]. These fields explain that the absolute amount in the United States is higher than that in Japan and show essential fields in cooperation between industries.

22.3.3 Changes Between Time Periods Separated by Turning Points

This analysis analyzed monthly patent data of all Japanese and American industries from 2001 to 2015. The result of the turning point candidate is as follows:

For Japan, significant changes were discovered in January 2001, July 2004, October 2004, January 2006, July 2006, May 2007, February 2011, July 2012, and January 2014. For the United States, the candidates are January 2002, January 2003, January 2004, January 2005, August 2005, January 2006, January 2007, July 2007, January 2008, January 2009. For America, significant changes happened in January 2010, January 2011, January 2012, January 2013, January 2014, and January 2015.

Then the authors distinguished those turning points from candidates by that their main compositions of topics before and after the moment are different in figures of stream graph by months (Figs. 22.3, 22.4, 22.5, 22.6, 22.7, and 22.8). The turning points were January 2001, January 2006, May 2007, and February 2011 in Japan, January 2003, January 2006, January 2008, and January 2011 in the United States. In the cases of other candidate points of Japan and the United States, the topic differences in those months were not significant between before and after. They were those moments where a numerical fluctuation happened. For example, let us compare the time points, January 2001 and July 2004, which are the months first meet juncture's conditions. Figure 22.3 is a stream graph of 2001–2005, the horizontal axis

Fig. 22.3 Stream graph by month for Japanese patent topics (2001–2005)

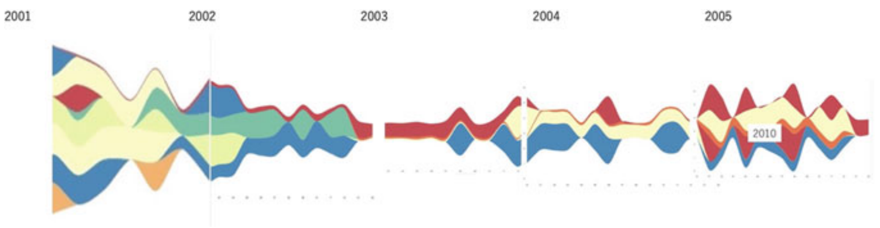

Fig. 22.4 Stream graph by month for American patent topics (2001–2005)

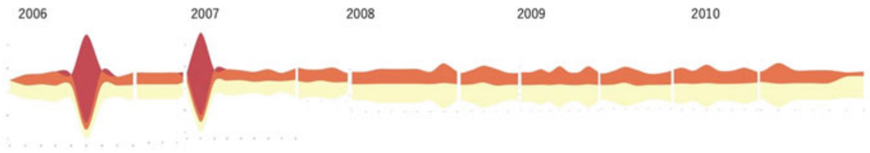

Fig. 22.5 Stream graph by month for Japanese patent topics (2005–2010)

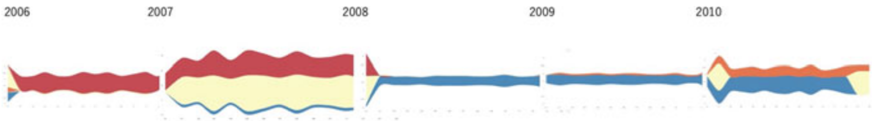

Fig. 22.6 Stream graph by month for American patent topics (2005–2010)

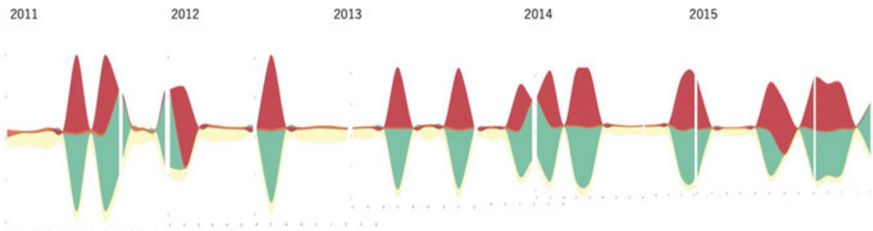

Fig. 22.7 Stream graph by month for Japanese patent topics (2010–2015)

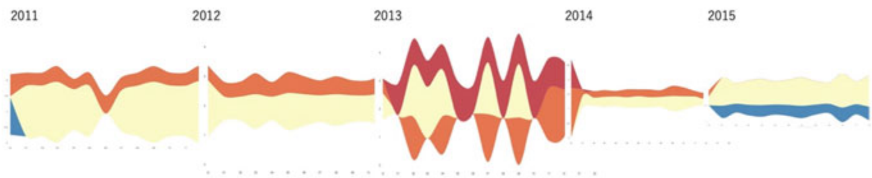

Fig. 22.8 Stream graph by month for American patent topics (2010–2015)

presents the time in units of month, and the vertical axis presents the sum of each topic's weight in each patent in that months. Differing from the stream graphs by year (Figs. 22.1 and 22.2), the widths of vertical axes are easily affected by the number of patents. In Fig. 22.3, as of January 2001, the change in the main topic from orange to yellow can be confirmed, but there is no difference in colors (topics) in July 2004. The authors identified time points as turning points and candidate points according to Figs. 22.3, 22.4, 22.5, 22.6, 22.7, and 22.8 based on the above considerations.

The number of patent data in each month is various, such as the first 3 months in 2001 of the United States has a small amount in the database. Compared to the scales of other topic weights, it shows relatively more topics, and the weights of individual themes are enormous. Moreover, for the same reason, the data for December 2003 is minimal so that the error could be too large to be a turning point. Excluding these anomalous phenomena, the results show that Japan and the United States have undergone four significant changes in the structure of critical topics in 15 years. Additionally, Fig. 22.6 shows seasonal patterns. The authors consider this phenomenon as the outcome of topic-condensed patents. Maybe it is caused by a developmental upsurge, but further research is needed on defining this specific incident.

22.4 Discussion

In this research, by visualizing the results from the SCDV approach, the authors defined the significant industrial changes in countries and compared the front-line technical innovation between Japan and the US. From the 15-year data, Japan shows no signs of following the United States in the pathway of technological innovation. As a remarkable feature, the US results revealed a more significant number in absolute amount and trans-industrial applications than Japan. WIPO (World High Ownership Organization) Research Organization (2013) America Quantity Actual innovation output is overwhelming worldwide. The authors comprehend that the document analysis of patents verifies the depth of research and development and the strength of cooperation in the United States from the aspect.

Next, regarding future applications, as a result of collating turning points with the monthly stream graph, it became possible to determine whether the topic weight change would significantly affect the future by two months before the last observation. If the topic's weight fluctuation is 1.5 times larger than the previous and next months and the main topics that make up the "stream" are different as of two months ago from now, it can present that structural reform of technological innovation may appear from this month. However, there is a possibility that the four structural changes are accidental, and there are still questions about whether they can be applied to other countries or in an era when technological innovation is very early; therefore, further in-depth examination for this method will be required.

22.5 Conclusion

Innovation is one of the most critical factors for a country's economic development these days. This study conducted innovative text-mining tools, visualized technical topics changes, and identified turning points through patent document analysis. From those results, we could identify the differences in topic weight patterns between Japan and the US. The yearly graphs show in Japan, the distribution of patent topics is stable. Moreover, the detailed subclass analysis shows American patents have strongly concentrated technique topics, and the applications of those techniques are more significant than in Japan by showing linkages between different fields. As a whole, the results show that this analyzing process could be a possible system to predict the time point for future technique field turnover. However, we conducted this analysis targeting only two countries; therefore, the analysis including other countries would be a choice for the future. Furthermore, detailed analysis with an extended analysis period will also be required for robustness confirmation.

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Chapter 23
Constructing a Decision-Making System Using Patent Document Analysis

Takashi Yonemura, Yusuke Matsumoto, Aiko Suge, and Hiroshi Takahashi

Abstract In this study, we propose a new system to support corporate decision-making using patent documents. For R&D-oriented pharmaceutical companies, the creation of new drugs is indispensable for survival, and patents, the source of R&D, are an important factor in the creation of new drugs. In this study, we attempted to clarify the quantification of technical information in pharmaceutical companies by vectorizing the patent database DWPI using Sparse Composite Document Vectors (SCDV) for pharmaceutical companies in Japan. As a result of the analysis, we found the possibility of considering the strategy of pharmaceutical companies by visualizing patent documents.

23.1 Introduction

If pharmaceutical companies, especially new drug manufacturers, do not develop and sell new drugs in rapid succession, they will not be able to increase their corporate value and will go into decline. The price of prescription drugs in Japan is determined by the Japanese government, so manufacturers have no right to set prices. According to Japan's Ministry of Health, Labor and Welfare, there is a lot of noise about the 2025 problem, when the percentage of Japan's population over 65 years old will exceed 30%, and beyond that, by 2040, healthcare costs are expected to exceed 65

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trillion yen and account for more than 8% of GDP [11, 13]. As one of the measures to solve this national problem, policies to lower drug costs have always been a topic of discussion. However, in recent years, drug costs have been ballooning due to the successive launch of new expensive drugs such as biopharmaceuticals. The government also wants to see the release of innovative drugs in order to improve the welfare of the people and the quality of medical care, as well as to promote innovation, and the NHI price revision system is structured with this in mind.

Despite this major change in the external environment, pharmaceutical companies still need to invest a large amount of time and money in the research and development of new drugs. It takes 9–17 years from basic research to marketing, the amount of money involved is tens to hundreds of billions of yen, and the probability of success is extremely low, so multiple pipelines are important to form a portfolio [12]. Compared to 5 or 10 years ago, the need to improve the efficiency of R&D in new drug development is increasing at an accelerated pace, and the creation of innovation is an urgent issue for pharmaceutical companies today in order to survive.

One of the keys to creating new drugs, or innovation, is patents. Patents, which are intellectual property rights, are the lifeline for pharmaceutical companies and are an important factor in determining the guidelines for future research and development. The purpose of this study is to construct a decision-making system that can provide suggestions for the strategies of pharmaceutical companies by analyzing patent documents and measuring the changes in patent strategies on an annual basis.

23.2 Previous Studies

23.2.1 The Value of Patent

Patents on pharmaceutical products There are four types of patents granted to brand-name drugs [6]:

Substance patent: Protects the substance (compound) itself. It is the most important patent and allows for the exclusive manufacture and sale of the developed drug.

Application patent: A patent that can be obtained when a new efficacy effect is discovered for the same substance (compound) during non-clinical testing.

Formulation patent: A patent that can be obtained for innovations in the formulation of a drug (stability, absorption, safety, etc.).

Process patent: A patent that can be obtained based on an idea that emerges during the manufacturing process of the active ingredient of a pharmaceutical product.

In addition to the above, there are other types of patents such as “combination drug patents.” In addition to the life cycle patents, there are formulation patents and process patents, and some pharmaceutical companies strategically apply for patents as a countermeasure against generics.

As a previous study on the value of patents, Zvi [3] published a study on the positive impact of intangible assets such as patents on corporate value. Some studies have shown that patents are also effective in pharmaceuticals as a means of monopolizing the benefits of innovation [7]. Uenishi and Isada (2015) sought a correlation between the results of network analysis and financial-related data assuming that multiple owners or assignees of a patent form a partnership. This suggests that partnerships will become more important. Previous studies have shown that patents, which are intangible assets, affect corporate value and financial data. Patents are a key success factor for pharmaceutical companies and have a significant impact on whether they succeed or not in terms of corporate strategy.

23.2.2 Similarity of Technology

Jaffe [2] proposed a method that utilizes technological distance by means of vectors to measure the degree of technological similarity between companies. Onishi (2010) found that the R&D expenditures of firms increase only in the case of mergers between homogeneous firms, while they act to reduce the number of patent applications and patents held, suggesting that this has a pro-competitive effect. Ida (2011) applied the calculation of technological distance based on drug sales by efficacy to distinguish between homogeneous and heterogeneous product portfolios in mergers in the pharmaceutical industry.

23.3 Data

In this study, we will use Japanese patent data obtained from the Derwent World Patents Index (DWPI) of Clarivate Analytics Japan [10]. According to Matsutani et al. [8], DPWI is an important database in patent search that contains patents from all over the world, and its features are the title, abstract, and index. It is characterized by its titles, abstracts, and indexes. Since the titles and third-party abstracts are prepared by experts in each technical field, highly accurate and efficient patent searches can be performed. Among the patent data, we will use the IPC classification of each patent and the four abstracts that describe the novelty, detailed description, use, and advantage of the patent in the abstract. The application dates are 1971–2015, and the total number of patents is 9,003,426. As data to confirm the patent transition, 901 patents applied for by Japanese pharmaceutical companies Hisamitsu Pharmaceutical Co., Inc. and 1,791 patents applied for by Japanese pharmaceutical companies Shionogi & Co., Ltd. were searched and extracted from the applicant/assignee code for each patent.

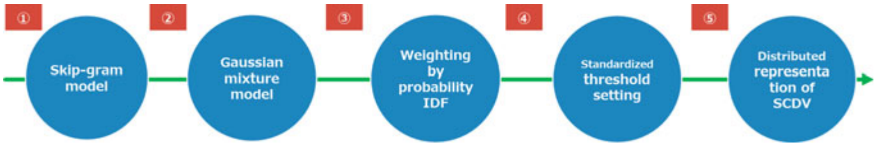

Fig. 23.1 SCDV procedure

23.4 Algorithm

23.4.1 Vectorization of Patent Documents

In this study, we use the Sparse Composite Document Vector (SCDV) method to obtain the document vectors of patents and compare the technological similarity of the companies. Following Fujiwara [4, 5], we integrate the above data and then perform a stemming process. The number of dimensions and other values is set according to Dheeraj-Vivek-Bhargavi-Harish [1] and Matsumoto, Suga, and Takahashi [9]. A 200-dimensional Skip-Gram model is then used to obtain a d-dimensional word vector. Secondly, using the mixture distribution model, the word vectors obtained by 60 clusters and 3% sparse region value are classified into clusters and each cluster is weighted by assigning a probability ($w\overrightarrow{cv}_{ik}$). Thirdly, the obtained $w\overrightarrow{cv}_{ik}$ is combined ($\oplus_{(1-k)}$) with the number of clusters (K) and weighted by the inverse document frequency IDF (where N is all documents and dft is the number of sentences in which a word t appears) to obtain $\mathrm{w}\overrightarrow{\mathrm{t}}\,v_i$ is obtained. The following (23.1), (23.2), and (23.3) show the equations by SCDV (Fig. 23.1):

$$w\overrightarrow{cv}_{ik} = wv_i \times P(C_k|w_i) \tag{23.1}$$

$$IDF_t = \log\frac{N}{df_t} + 1 \tag{23.2}$$

$$\mathrm{W}\overrightarrow{\mathrm{t}}\,v_i = IDF_t \times \oplus_{(1-k)} w\overrightarrow{cv}_{ik} \tag{23.3}$$

23.4.2 Patent Transition Visualization System

We applied multi-dimensional scaling (MDS) to Hisamitsu Pharmaceutical's patent data. MDS is a method of transforming the distance matrix for each individual (in this case, each patent) to a lower dimension. Relationships between patents within each company are calculated (23.4):

$$z_{ij} = -\frac{1}{2}\left(d_{ij}^2 - \sum_{i=1}^{n}\frac{d_{ij}^2}{n} - \sum_{j=1}^{n}\frac{d_{ij}^2}{n} + \sum_{i=1}^{n}\sum_{j=1}^{n}\frac{d_{ij}^2}{n^2}\right) \tag{23.4}$$

d_{ij}^2 is the distance between patent i and patent j. Cosine distance is adopted as the distance calculation method to calculate the similarity for each text. n is the number of features for patent i, and z_{ij} is the eigenvector transformed by the multi-dimensional scaling method. The first major axis is the horizontal axis and the second major axis is the vertical axis, and each patent is visualized by its application year. The images visualized for each year of application were converted into a simple movie using Graphics Interchange Format (GIF). Shionogi & Co., Ltd. used the same procedure to convert the images into a simple animation. By placing Hisamitsu Pharmaceutical Co., Inc. and Shionogi & Co., Ltd. side-by-side, we were able to compare the changes in patents between the two companies.

23.5 Result

23.5.1 Visualization of Patent Vectors

We visualized the patent vector of Daiichi Sankyo Company, Limited, a Japanese pharmaceutical company (Fig. 23.2). The visualization was done by compressing the 12,000-dimensional patent vector into two dimensions using the t-SNE method. The dots represent the patents owned by Daiichi Sankyo, and the legend (year) shows the patents owned by Daiichi Sankyo by year of publication in different colors. In

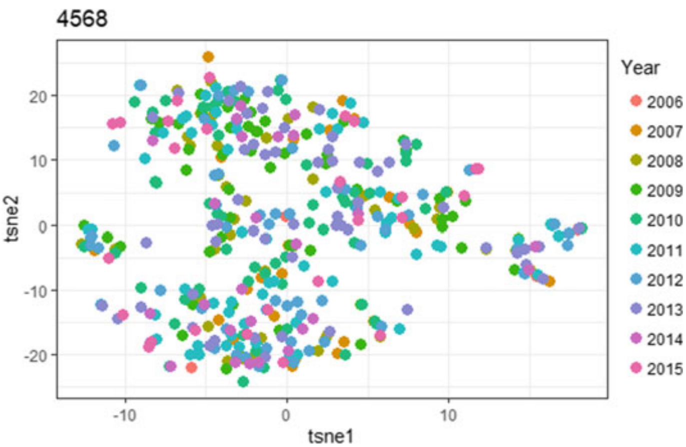

Fig. 23.2 Patent visualization (t-SNE) of Daiichi Sankyo Co., Ltd.

total, 4568 is the securities code of Daiichi Sankyo. The securities code in Japan is a four-digit number assigned to identify listed stocks and listed investment trusts.

By visualizing patent data, it becomes easier to understand which patents were filed in which years, and the possibility of clarifying a company's research strategy on a yearly basis becomes apparent. For example, the areas that Daiichi Sankyo is developing are digestive system diseases, cardiovascular diseases, lifestyle-related diseases, central nervous system, infectious diseases, and anti-cancer, and we will be able to understand the status of patents acquired in each of these areas.

In the future, by vectorizing the patent literature, it will be possible to judge the pros and cons of a company's diversification strategy by linking the patent deviation value with financial indicators and corporate value.

23.5.2 Visualization of Patent Changes

This section shows examples of visualization of Patent Year Trends (1971–2015) of Hisamitsu Pharmaceutical Co., Inc. and Shionogi & Co., Ltd. (Figs. 23.3, 23.4, 23.5).

From the figure, it can be confirmed that Shionogi is diversifying at an earlier stage than Hisamitsu Pharmaceutical. This implies that Shionogi is diversifying at

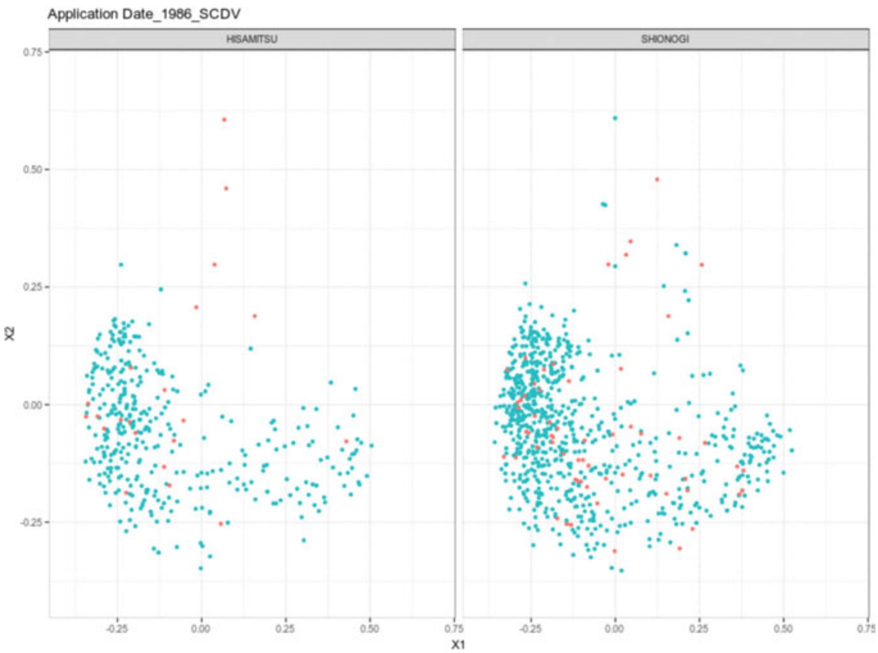

Fig. 23.3 Visualization of patent vectors at 1986 (Hisamitsu (left), Shionogi)

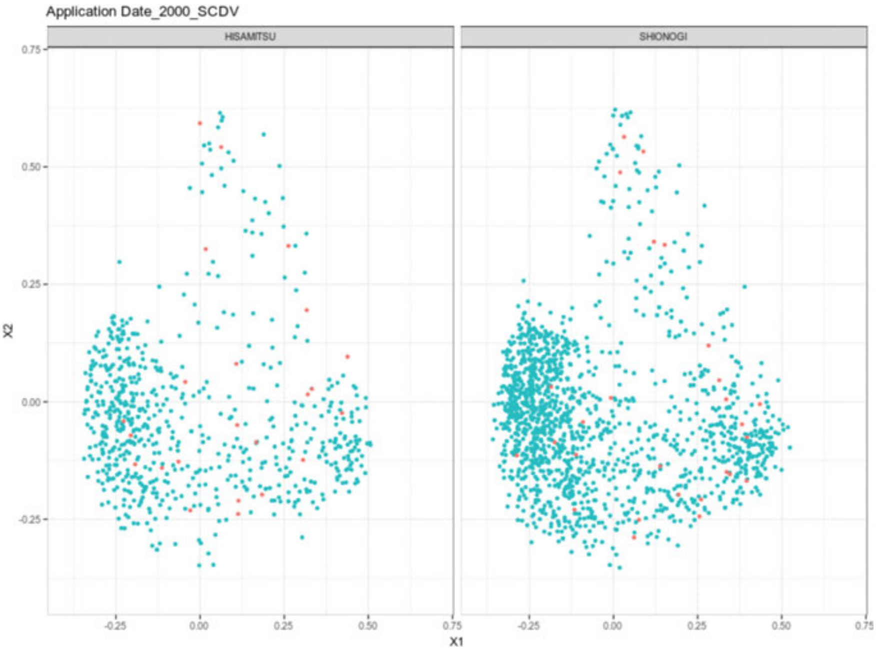

Fig. 23.4 Visualization of patent vectors at 2000 (Hisamitsu (left), Shionogi)

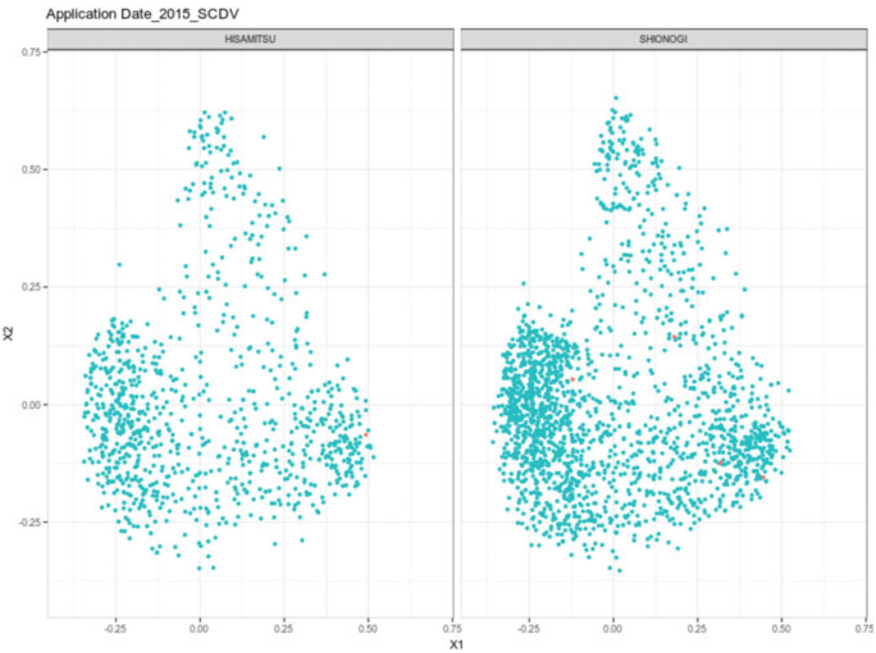

Fig. 23.5 Visualization of patent vectors at 2015 (Hisamitsu (left), Shionogi)

an early stage. Diversification of pharmaceutical companies' patents can also be seen as a domain strategy, and we can see that Shionogi is working on various disease areas.

Shionogi's domain strategy was that from 1970 to 1980, the company was a pharmaceutical company specializing in antibiotics. However, in the 2000s, the company expanded into other areas such as cancer pain treatment and hypercholesterolemia treatment. Hisamitsu Pharmaceutical, on the other hand, was a pharmaceutical manufacturing company specializing in patches, especially topical analgesics, and anti-inflammatory drugs, and has consistently followed this strategy from 1980 to 2010, resulting in a small patent spread. in 2015, the company began to expand its business into cancer pain treatment and overactive bladder treatment, resulting in a larger patent spread. In 2015, the company started to expand its business to cancer pain treatment and overactive bladder treatment, and the patent spread became larger. The numbers indicated by the patents analyzed in this study show a certain degree of consistency with the strategies actually taken.

By vectorizing the patent literature in this way, it will be possible to quantitatively analyze the patent strategy of pharmaceutical companies. For example, by examining the relationship between the degree of patent dispersion between two companies and their corporate value, it is possible to determine the certainty of their patent strategy. Furthermore, by analyzing the relationship between this index and financial indicators, it will be possible to determine the pros and cons of domain expansion. It also has great potential as a decision-making system, such as examining M&A and alliance strategies using this patent vector index. Analysis from these economic perspectives will be a future task.

23.6 Conclusion

In this study, we used DWPI, which is a patent database, and SCDV, which is one of the methods of natural language processing, to obtain the vectors of patent documents and succeeded in quantifying the technical information of pharmaceutical companies. By quantifying and visualizing the patents among several companies, we were able to construct a system that supports decision-making on patent strategy, and we found the possibility of analyzing the research strategy or patent strategy of companies. Detailed analysis is a future task.

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Chapter 24
Policy Simulation for Retirement Planning Based on Clusters Generated from Questionnaire Data

Takamasa Kikuchi and Hiroshi Takahashi

Abstract In Japan, there is significant interest in life planning for generations before and after retirement, and various policy simulations are being conducted. However, there is room to improve the diversity and representativeness of individual attributes in conventional simulations. Thus, in this paper, we set up a possible person cluster by categorizing the asset status and investment status of the generation before and after retirement using individual questionnaire data. We also discuss computer simulations related to asset formation and withdrawal based on those clusters, and we examine measures to be taken to avoid asset depletion.

24.1 Introduction

In Japan, asset formation and reversal of generations before and after retirement are problems of interest [1]. Various measures, for example, increasing retirement age, asset formation from a young age, and curbing spending, are being discussed as national, individual, and social measures. However, there has been little discussion about the withdrawal of assets, and there is room to expand and modernize basic research and analysis to better consider current issues.

Regarding asset depletion, many studies have analyzed macro-statistical data, for example, the amount of financial assets and disposable income [2]. In addition, the effect of price fluctuations on owned assets and asset depletion based on market data has been analyzed [3]. However, these previous studies only expressed some of the attributes of individuals using actual data. In practice, simulations based on individual case studies are common, and these have high individual specificity; however, there is room to improve the generality and representativeness of the individual attributes set as samples.

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Therefore, in this paper, we propose an improvement to the analysis method in policy simulation related to asset formation and withdrawal for the generation before and after retirement. To set the attributes of the assumed person cluster, it is required that (a) the cluster could be set in a realistic and diverse manner and (b) the cluster could be set in a low arbitrariness and representative form. In addition, the simulation framework attempts to express various attributes and decisions based on these attributes. Specifically, feature analysis is performed on large-scale individual questionnaire data, and we classify survey respondents into several clusters. In addition, based on those clusters, we perform computer simulations of asset formation and withdrawal that consider asset succession and the price fluctuations of risk assets. We also examine possible actions to mitigate asset depletion for each cluster.

24.2 Related Work

24.2.1 Policy Simulation on Retirement Planning

Several studies have considered sustainable withdrawals from retirement personal portfolios [4]. In the United States, a fixed withdrawal rate of 4% for initial assets is a rule-of-thumb benchmark [5]. However, it has been stated that fixed withdrawal rates are inefficient [6] and that "rules" changing the withdrawal rate and amount should be set [7, 8]. However, the complexity of such rules when operated by an individual is an issue.

In Japan, there is a policy simulation related to asset formation on an actual amount basis using macro data, for example, stock data and flow data [2]. In addition, focusing on investment strategies in asset formation, some studies have estimated the depletion probability using the annual timeseries path of asset prices using computer simulations [3]. However, various attributes of individuals are not considered explicitly. In addition, many case study-based life plan simulations are performed by determining the specific attributes of individuals; however, while individual specificity is high, there is room to improve the generality and representativeness of individual attributes set as samples.

24.2.2 Clustering Individual Questionnaire Data

Numerous reports have attempted to categorize decision-making from theoretical models and sample data using various methods, for example, statistics and machine learning [9, 10]. For example, in the social sciences (specifically marketing) and in response to the diversification of customer lifestyles and values, the provision of services suitable for each category was considered broadly after categorizing according to individual characteristics. In this paper, we categorize the respondents to a questionnaire using feature analysis of individual data.

24.2.3 Behavior Clustering and Computer Simulation

Yamada et al. [11] proposed a method that utilizes actual data and agent simulation to solve problems in business and industry. They categorized multiple types of behavior at an airport based on real-world data, and they reproduced congestion conditions when new equipment was introduced to Fukuoka Airport in Japan via agent simulation [12]. Such detailed analyses that can withstand onsite decision-making will greatly contribute to efficient decision-making in both social and economic activities. In addition, many analyses, for example, corporate behavior and analysis by modeling based on finance theory, have been reported [13, 14]. In this paper, based on the clustering results of individual questionnaire data, we perform policy simulation on retirement planning in consideration of asset succession and risk asset price fluctuations.

24.3 Datasets

24.3.1 Asset Class and Cash-In, Cash-Out

In this study, data from the Ministry of Internal Affairs and Communications are used for the income and expenditure of each individual asset class (Table 24.1) in our simulation [15]. In the simulation (Sect. 24.5.2), we analyze the effect of curbing spending on the depletion rate, depending on the asset class. In this paper, "the average value of the amount of expenditure in the asset class to which one belongs and the amount of expenditure in the next lower class" is defined as the "curbing of expenditure".

24.3.2 Various Attributes of Individuals

We use the individual questionnaire data from the "Awareness Survey on Life in Old Age for Before and After Retirement Generations" conducted by the MUFG Financial Education Institute [16]. The survey period was January 22–25, 2019, and the survey target was men and women aged 50 and over. The survey area was nationwide, and the number of valid responses was 6,192 samples. This questionnaire comprehensively investigated the asset status of each individual (current asset balance

Table 24.1 Income and expenditure of each asset class

Asset class [m yen]	(1) Income [10 thousand yen/month]	(2) Expenditure [10 thousand yen/month]	(3) Net cash flow ((1) − (2)) * 12
Less than 150	18.2	18.6	−5.1
150–300	18.8	20.1	−15.9
300–450	19.8	21.3	−17.7
450–600	20.6	22.5	−22.9
600–750	21.5	23.1	−18.9
750–900	21.9	24.7	−33.8
900–1,200	22.0	24.8	−33.8
1,200–1,500	22.4	25.5	−37.4
1,500–2,000	22.6	27.7	−61.5
2,000–3,000	24.4	29.8	−64.9
3,000–4,000	25.7	31.4	−68.4
Over 4,000	28.6	36.1	−90.8

and expected income/expenditure in old age), the planned asset succession amount, stance on investment, and outlook for old age, etc.

24.4 Methodologies

24.4.1 Clustering Method for Individual Questionnaire Data

We categorize individual questionnaire data using the k-means method [9, 10, 17], which is a widely used non-hierarchical clustering method.

24.4.2 Simulation Model of Asset Formation and Withdrawal

We construct a computer simulation model that expresses asset formation and withdrawal before and after retirement (Fig. 24.1). This model is based on a model previously proposed by the authors [18].

The actors in the model have a specific asset balance at a certain age. Actors also have regular income and expenditure (cash inflow and outflow) and sudden income and expenditure (depending on life events) according to the actor's own status (before and after retirement). The attributes of the actors can be grounded to statistical data. In addition, by manipulating the attributes of the actors, what-if analysis can be performed when a policy is implemented.

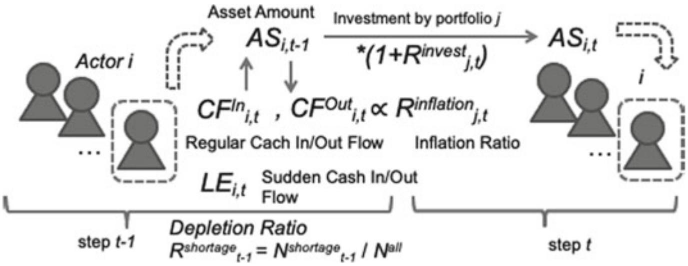

Fig. 24.1 Conceptual diagram of simulation model

Next, the assets held by actors include cash, deposits, and risk assets. Risk assets are fully invested in a portfolio of traditional assets and provide returns according to the risk of the portfolio. In addition, the regular income and expenditure fluctuate according to the inflation rate. Here, the risk-return of the portfolio, inflation rate, and their variances are given as the external environment, as will be described later.

24.4.2.1 Actor

Let A be the set of actors and let $\#A = N^{all}$. Actor i has the following attributes in step t of the simulation: age $age_{i,t}$, retirement age $age_i^{retired}$, cash and deposit balance $CA_{i,t}$, risk asset balance $RA_{i,t}$, cash inflow $CF^{In}{}_{i,t}$, cash outflow $CF^{Out}{}_{i,t}$, cash flow from life event $LE_{i,t}$, and total asset balance $AS_{i,t}$ $(= CA_{i,t} + RA_{i,t})$:

$$A = \left\{a_i = \left(i, age_{i,t}, age_i^{retired}, CA_{i,t}, RA_{i,t}, CF_{i,t}^{In}, CF_{i,t}^{Out}, AS_{i,t}, LE_{i,t}\right)\right\}.$$

Here, age is expressed as follows:

$$age_i \in \{age_{i,0}, age_{i,0} + 1, \ldots, age_i^{retired}, \ldots\}.$$

24.4.2.2 Simulation Time Steps

For the simulation time step, a single step represents one year in real time.

24.4.2.3 External Environment

The return and inflation rate of portfolio j are generated in time series by Monte Carlo simulation as follows (where the number of trials is K).

The portfolio return (annual) is expressed as follows:

$$R_{j,t}^{invest} = X_{1,t}\sigma_j + \mu_j.$$

The inflation rate (annual) is given as follows:

$$R_{j,t}^{inflation} = \left(\rho_j X_{1,t} + \sqrt{\left(1-\rho_j^2\right)} X_{2,t}\right)\sigma_{inflation} + \mu_{inflation}.$$

Here, σ_j is the risk of portfolio j, μ_j is the expected return rate of portfolio j, $\sigma_{inflation}$ is the standard deviation of the inflation rate, $\mu_{inflation}$ is the expected inflation rate, ρ_j is a correlation coefficient between portfolio j and the inflation rate, $X_1, X_2 \sim N(0, 1)$, and cov $[X_1, X_2] = 0$.

The cumulative value of the inflation rate (referred to as cumulative inflation rate) is expressed as follows:

$$IRC_{j,t} = IRC_{j,t-1}\left(1 + R_{j,t}^{inflation}\right), IRC_{j,0} = 1.$$

24.4.2.4 Cash Inflow/Outflow

Retirement cash inflows and outflows in step t are determined by considering the asset class to which actor i belongs and the cumulative inflation rate as follows:

$$CF_{i,t}^{In} = CF_i^{In}\left(1 + IRC_{j,t}\right)$$
$$CF_{i,t}^{Out} = CF_i^{Out}\left(1 + IRC_{j,t}\right)$$

In addition, to conservatively estimate the possibility of withdrawal, the net cash flow before retirement is set to zero.

24.4.2.5 Asset Formation and Withdrawal Rules

The cash and deposit balance and risk asset balance in each simulation step are varied according to the following rules. This expresses the preferential withdrawal of highly liquid cash and deposits at the asset withdrawal stage:

if $CA_{i,t} + CF^{In}{}_{i,t} - CF^{Out}{}_{i,t} >= 0$

$CA_{i,t+1} = CA_{i,t} + CF^{In}{}_{i,t} - CF^{Out}{}_{i,t} + LE_{i,t}$

$RA_{i,t+1} = RA_{i,t}\,(1 + R^{invest}{}_{j,t})$

else

$CA_{i,t+1} = CA_{i,t} + LE_{i,t}$

$RA_{i,t+1} = RA_{i,t}\,(1 + R^{invest}{}_{j,t}) + CF^{In}{}_{i,t} - CF^{Out}{}_{i,t}$

24.4.2.6 Asset Depletion Rate

For the K trials, the number of times the asset balance becomes negative at age τ is denoted $K^{shortage}$, and the asset depletion rate is expressed as follows (hereafter referred to as depletion rate):

$$R_{i,\tau}^{shortage} = K_{i,\tau}^{shortage} / K$$

24.5 Analysis and Simulation

24.5.1 Feature Analysis of Individual Questionnaire Data

For the individual questionnaire data (Sect. 24.3.2), the following items were targeted (Table 24.2), and clustering was performed using the k-means method. Here, the number of clusters was set to five based on the results of the elbow chart and silhouette analysis that are often used to determine the number of clusters. The data available for all items included 4,592 samples.

From the obtained clustering results (clusters #1 to #5), Fig. 24.2a–d show the distribution of the answers to typical questionnaire items for each cluster as a box plot.

The median age group *age* was 55–59 years for clusters #1 and #4, 65–69 years for cluster #3, and 70–74 years for clusters #2 and #5, as shown in Fig. 24.2a.

The median holding ratio of risk assets R^{risk} was 0% for clusters #2 and #3, 0 to 10% for cluster #4, 20 to 30% for cluster #1, and 40 to 50% for cluster #5, as shown in Fig. 24.2b.

The median current balances of financial assets FA^{now} was 2–3 million yen for cluster #3, 15–20 million yen for clusters #2 and #4, and 30–50 million yen for clusters #1 and #5, as shown in Fig. 24.2c.

The median balance of financial assets to be succeeded FA^{future} was zero for clusters #2 to #5 and 20–30 million yen for cluster #1, as shown in Fig. 24.2d.

Table 24.2 Questionnaire items used for feature analysis

Item	Question matters
Attributes	Age, sex, household composition, etc.
Financial status	Stock data: asset balance current/to be inherited, etc. Flow data: regular cash in/out flow, etc.
Risk preference	Investment experience, risk asset holding ratio, etc.

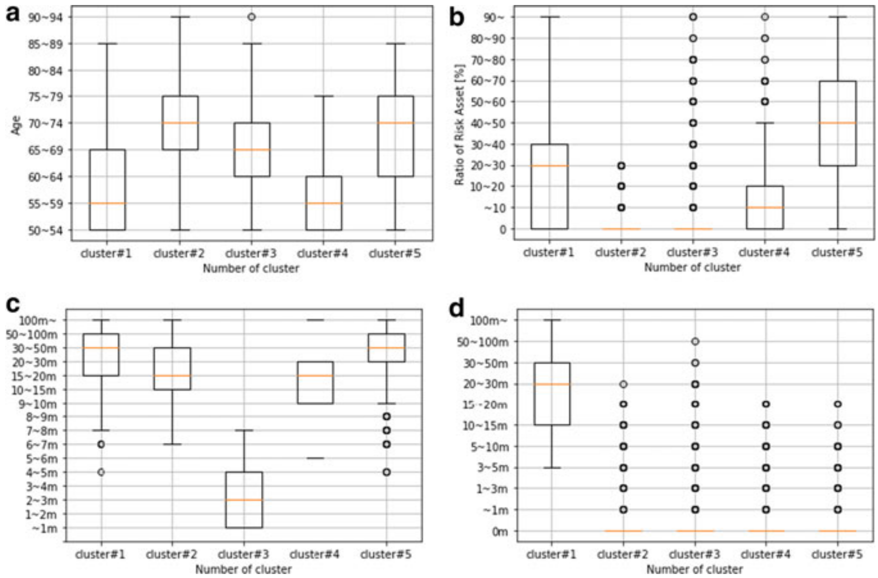

Fig. 24.2 **a** Distribution of age groups for each cluster (left). **b** Distribution of risk assets holding ratio (right) for each cluster. **c** Distribution of current financial asset balances for each cluster (left). **d** Distribution of financial assets to be inherited (right) for each cluster

These results are summarized in Table 24.3. Note that the age group is roughly divided into relatively young people (median 55–59 years, assumed before retirement) and elderly people (median 65–69 years, 70–74 years old, assumed after retirement). The holding ratio of risk assets can be classified into zero, low (0–10%), middle (20–30%), and high (40–50%) classes. The current balances of financial assets are divided into three layers, that is, 2–3 million yen, 15–20 million yen, and 30–50 million yen (each number represents the median). Here, there are two layers of financial assets to inherit, with and without asset inheritance.

Table 24.3 Summary of clustering results

# of cluster	Age group	Asset balance current	Asset balance to be inherited	Risk preference
#4	Relatively young	Middle	Without	Low
#1	Relatively young	High	With	Middle
#3	Relatively elderly	Low	Without	Zero
#2	Relatively elderly	Middle	Without	Zero
#5	Relatively elderly	High	Without	High

24.5.2 Asset Formation and Withdrawal Simulation

24.5.2.1 Depletion Rate Based on Individual Questionnaire Data

We performed computer simulations of asset formation and withdrawal based on the cluster set described in Sect. 24.5.1 (Table 24.4).

Here, the annual income and expenditure CF^{net} for each asset class was set from Sect. 24.3.1 (Table 24.1) according to the current balance of financial assets (without curbing of expenditure cases). The correspondence with the model described in Sect. 24.4.2 is expressed as follows:

$$N^{all} = 5\,(cluster\#1 \sim \#5), CA_{i,0} = FA_i^{now} * \left(1 - R_i^{risk}\right),$$
$$RA_{i,0} = FA_i^{now} * R_i^{risk}, CF_{i,0}^{Out} - CF_{i,0}^{In} = CF_i^{net}$$

We also define the parameters as follows: $age_i^{retired} = 60$, the actor's age at which a life event occurs: $age_{i,t'} = 70$, $LE_{i,\,t'} = FA^{future}{}_i * R^{future}$. Here, R^{future} is the ratio of asset succession (representing the ratio of actual balance of financial assets to be succeeded). In this paper, the above parameters are called "Case of Making Basic Decisions."

Other parameter settings, for example, the portfolio risk-return and inflation rate, are shown in Table 24.5. Note that the risk-return of the portfolio was set assuming

Table 24.4 Setting attributes for each cluster

# of cluster	Attributes			
	Age	FA^{now}	FA^{future}	R^{risk} (%)
#4	57	17.5 m yen	None	5
#1	57	40.0 m yen	25.0 m yen	25
#3	67	2.5 m yen	None	0
#2	72	17.5 m yen	None	0
#5	72	40.0 m yen	None	45

Table 24.5 Simulation parameter settings: case of making basic decisions

Item	Value
Curbing of expenditure	Without
$age^{retired}$	60
R^{future}	100%
μ_j, σ_j	(6.37%, 18.0%)
$\mu_{inflation}$	{0.0%, 0.53%, 2.0%}
$\sigma_{inflation}$	1.26%
K	10,000

Table 24.6 Depletion rates by cluster and inflation scenario

# of cluster	Depletion rates by inflation scenario					
	(1) No inflation		(2) Moderate inflation		(3) 2% inflation	
	Age: 90 (%)	Age: 100 (%)	Age: 90 (%)	Age: 100 (%)	Age: 90 (%)	Age: 100 (%)
#4	34	75	60	86	93	98
#1	0	0	0	0	0	0
#3	100	100	100	100	100	100
#2	0	34	0	94	0	100
#5	0	0	0	1	0	5

a portfolio comprising foreign stocks and bonds. The expected inflation rates were according to three patterns, that is, (1) no inflation (0%), (2) moderate inflation (actual results for the past 30 years in Japan [19]: 0.53%), and (3) 2% inflation (monetary easing target). Here, the standard deviation of the inflation rate was the same as a pattern (2), which is the actual result for the past 30 years in Japan.

The depletion rate at age 90 and age 100 by cluster and inflation scenario is shown in Table 24.6.

The depletion rate of cluster #4 increases according to the high inflation scenario, and the depletion rate of cluster #1 is zero in all scenarios. However, note that the simulation was under the assumption that financial assets are inherited as expected. The depletion rate of cluster #3 was 100% in all scenarios. Similar to cluster #4, cluster #2 shows a high depletion rate in a high inflation scenario. For cluster #5, asset depletion was observed with a low probability in the limited case of high inflation at the age of 100.

24.5.2.2 Analysis of Impact of Various Decisions on Depletion Rates

Here, we analyze decisions that have a large effect on the depletion rate for the clusters set shown in Table 24.4. Here, we consider the following decisions: (1) portfolio risk-return, (2) retirement age, (3) curbing of expenditure, and (4) asset succession.

The parameter settings are shown in Table 24.7. Here, the assumed decision-making patterns are as follows. The annual income and expenditure CF^{net} by asset class has two patterns, that is, with and without curbing of expenditure. The retirement ages are 60, 65, and 70 years. There are three of asset succession patterns, that is, 100%, 50%, and 0%, and four portfolio risk setting patterns, that is, 18%, 12%, 6%, and 0% (returns are set according to the corresponding figures, that is, 6.37%, 4.68% 2.87%, and 0.01%; see Ref. [18]). For each cluster set shown in Table 24.4, 72 decision-making patterns were generated. Note that the other parameters were the same as those shown in Table 24.5. In this paper, the above parameters are called "Case of Making Various Decisions."

Table 24.7 Simulation parameter settings: case of making various decisions

Item	Value
Curbing of expenditure	{Without, **With**}
$age^{retired}$	{60, **65**, **70**}
R^{future}	{100%, **50%**, **0%**}
μ_j, σ_j	{(6.37%, 18.0%), (**4.68%**, **12.0%**), (**2.87%**, **6.0%**), (**0.01%**, **0.0%**)}
$\mu_{inflation}$	{0.0%, 0.53%, 2.0%}
$\sigma_{inflation}$	1.26%
K	10,000

Here, we focused on the status of asset depletion and non-depletion at the specific age for each cluster. The importance of variables that classify depletion and non-depletion for each cluster was calculated using the random forest [20] method (Fig. 24.3).

For cluster #4, the importance of the portfolio risk setting was relatively high. Cluster #1 showed the highest importance in order of asset succession ratio, portfolio risk settings, and curbing of expenditure. For clusters #3 and #2, the importance of curbing of expenditure was extremely high. In addition, cluster #5 had the highest importance in order of portfolio risk setting and curbing of expenditure.

24.5.2.3 Possible Actions for Each Cluster

In this section, from the results shown in Table 24.6 and Fig. 24.3, we consider measures each individual can take to reduce the depletion rate.

Cluster #4: High depletion rate in high inflation scenario (Table 24.6). Appropriate risk taking for inflation hedging and increasing retirement age could be effective measures (Fig. 24.3a).

Cluster #1: The depletion rate is low in all scenarios (Table 24.6). However, this simulation assumed that financial assets are inherited as expected. Regarding variable importance, the ratio of asset succession was the highest (Fig. 24.3b), and appropriate and steady asset succession is important.

Cluster #3: The depletion rate was extremely high in all scenarios (Table 24.6). Note that curbing expenditure was the only option among the decisions compared in this paper (Fig. 24.3c). For cluster #3, drastic measures are required, for example, curbing expenditure and expanding social security.

Cluster #2: The depletion rate was high in the moderate and high inflation scenario at age 100 (Table 24.6). Here, curbing expenditure is considered an effective action (Fig. 24.3d).

Cluster #5: Here, the depletion rate was high in a limited scenario (Table 24.6). As a countermeasure, it is conceivable to take appropriate risks (Fig. 24.3e). This cluster showed a high proportion of risk assets (Table 24.4), and it is important to avoid excessive risk to prevent price fluctuations (decreases) of the held risk assets.

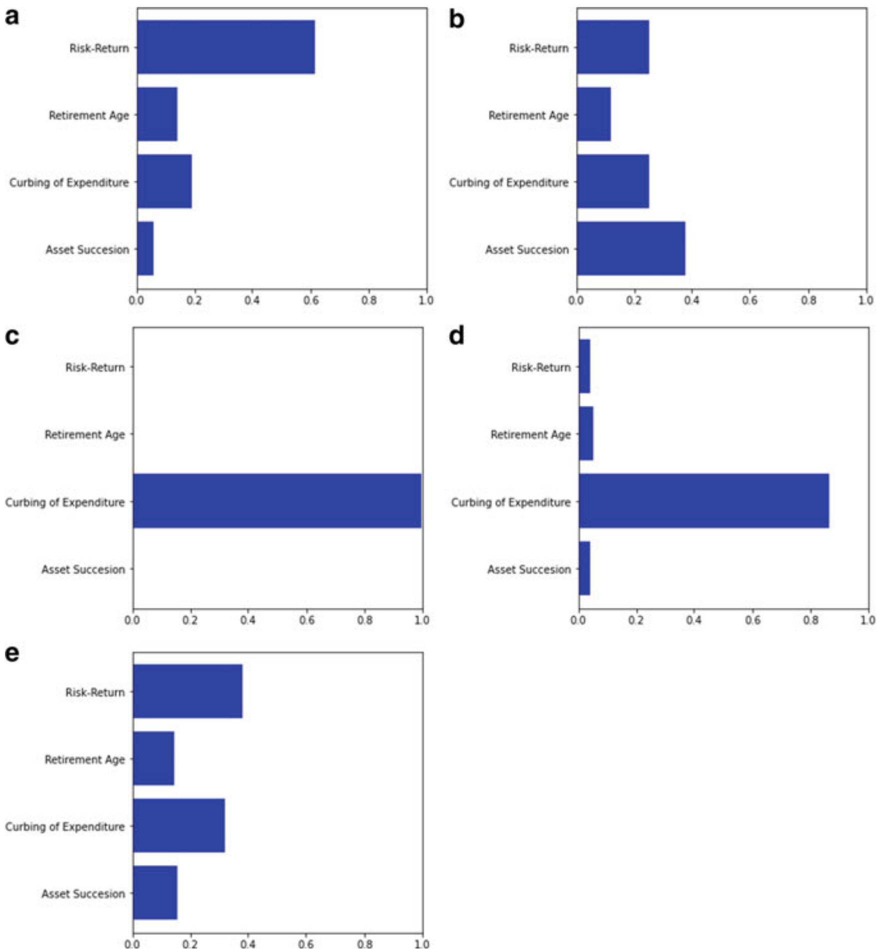

Fig. 24.3 **a, b** Variable importance for each cluster (#4, 1). **c, d** Variable importance for each cluster (#3, 2). **e** Variable importance for each cluster (#5)

Table 24.8 summarizes examples of actions each cluster could take to reduce the depletion rate.

24.6 Concluding Remark

In this paper, we have proposed an improvement to the analysis method in policy simulation of asset formation and withdrawal for the generations before and after retirement.

Table 24.8 Assumed countermeasures for each cluster

# of cluster	Countermeasures (example)
#4	Appropriate risk taking for inflation hedging, increase retirement age
#1	Appropriate and steady asset succession
#3	Curbing expenditure, expanding social security
#2	Curbing expenditure
#5	Avoid excessive risk to prevent price fluctuations

Focusing on the diversity and representativeness of the individual attributes set as the simulation target, we performed a simulation based on feature analysis of individual questionnaire data. In addition to the financial asset's balance and income and expenditure of the individual, it is now possible to consider more diverse attributes, for exmaple, financial assets to be inherited and investment preferences, which, to the best of our knowledge, are not commonly considered in conventional research. Clustering questionnaire data has made it possible to categorize survey respondents with low arbitrariness and ensure a certain degree of representativeness. In addition, based on the clusters, we conducted a simulation that considered asset succession and the price fluctuations of risk assets, and we examined actions that could be taken to avoid asset depletion for each cluster.

Future work is as follows: (1) survey of other attributes that affect asset depletion by questionnaire analysis and (2) diversify the decision making of actors in simulation.

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Chapter 25
Relationship Between Performance and Work Style Extracted from Location Data

Shohei Yada and Setsuya Kurahashi

Abstract In this research, we extract features of various work styles from the employee location data for companies that have introduced the free-address system, and we explore the relationship between these features and work performance. To achieve this, we consider the models that increase both freedom in the work environment and employee performance. Least-squares regression is adopted to model the relationship between the work style and performance using satisfaction data synthesized via sparse principal component analysis. Results prove the validity of the initial hypothesis that the performance of employees who work in a face-to-face environment with many other employees is excellent in quick-meeting areas regardless of the department. In addition, communication that occurs in a quick-meeting area affects employee performance more than that occurring in planned meetings held in conference rooms. With respect to the employees who have performed similar tasks, it was found that the performance of employees who bridge between different groups is higher than that of employees who have a lot of face-to-face communication among employees.

25.1 Introduction

In recent years, balancing employee work style diversity and performance has become an organizational management issue. Still, from the perspective of office space design, some companies have attempted to resolve these issues by introducing a free-address system [1, 2]. Herein, for the efficient use of office spaces and ease of communication, office layouts with high degrees of freedom that intentionally exclude fixed seating arrangements and partitions are collectively referred to as "free

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address." The term "free-address office" is Japanese-made English, and in Western countries, the concept of "nonterritorial office" or "open-plan office" generally exists.

This study aims to understand the effects of the degrees of freedom in the working style on the performance of employees in a free-address environment by examining the employee location data.

25.2 Background and Related Work

25.2.1 Effect of Free Address

According to Inamizu (2013), the effects of free address measures can be broadly divided into two types: improvement of space utilization efficiency and ease of communication [3]. The concept of free address in Japan originated from the background of improving the space utilization efficiency and eventually improving employee productivity amid a shortage of offices in urban areas during high-growth periods [4, 5]. Conversely, the concept of nonterritorial offices and open-plan offices in Western countries aimed to eliminate physical obstacles and distances that constrain communication. There is a background of achieving both openness without walls and partitions and unreserved seats with fixed seats as shared seats. However, it has been suggested that the introduction of free addresses and their effects are both positive and negative depending on the conditions [6–10]. Inamizu (2008) clarified that it is difficult for employees to communicate when the office space is small and that efficiently reducing the office area and achieving ease of communication are not always compatible [11].

Based on this background, we use the location data of employees in an office to detect their working areas in a free-address environment. In addition, we extract features such as the type of network formed by face-to-face communication between employees and analyze how such differences in work styles are related to the performance of individual employees.

25.2.2 Previous Research Using Location Data

Yamashita et al. (2020) developed a method for detecting offline meetings in an office using Wi-Fi connection data. In this method, they first created nonmoving time zone information for each employee to detect the occurrence of a meeting. To extract this nonmoving time zone information, the data at all-time points every 5 min were arranged in chronological order for each MAC address of the terminal lent to the employee. If the current coordinates and the coordinates of the previous time were the same, a nonmovement flag was set for the data at the present and previous time points, and the part where the nonmoving flags are continuous was extracted as the nonmoving time zone. Then, it sets an arbitrary radius distance and clusters a set of nonmoving time zones having the same start time and end time within that range [12]. This research is a development of the previous research by Yamashita et al. The potential for development, herein, follows two primary points.

Area attributes. All location data are assigned attributes that match the actual usage of the office.

Network centrality. The detected meeting is regarded as a network between employees, and the network centrality is extracted as a feature.

25.2.3 Hypothesis Setting

The hypothesis setting, herein, states the following two points.

Hypothesis 1 Employees who make good use of the free-address system and actively communicate with employees in other departments perform well.

Hypothesis 2 Communication in a quick-meeting area improves employee performance more than communication in a standard meeting room.

25.3 Preferences and Data Definition

25.3.1 Acquisition of Location Data

The target environment of this study is an office floor of the head office building of Yahoo Japan Corporation, and it is basically assumed that the free-address system is introduced on all floors. To acquire the location information of employees, we use the location data of the location information system "pozzy" in the office, which Yahoo has independently introduced for the company. Using the connection information between the provided device and Wi-Fi, the position information data of the two-dimensional coordinate system in the office are acquired. Information devices such as notebook PCs and smartphones are provided to all employees, and it is standard to work in the office using a Wi-Fi connection.

25.3.2 Data Definition

The classification of the data used, herein, is shown in Table 25.1, including 65 variables in total.

The objective variable, herein, is the performance data, which is a multifaceted evaluation index. Conversely, the main explanatory variables are the work location

Table 25.1 Classification of the data used in this research

Classification	Explanation
Attribute data	・Obtained from personnel registration data e.g., employee gender, age, and job title
Satisfaction data	・Obtained from employee satisfaction survey e.g., satisfaction with work, boss, and company
Work location data	・Feature extraction from location information data ・Percentage of staying time by area attributes in the office
Network centrality data	・Feature extraction from location information data ・Calculated by detecting the occurrence of employee meetings
Performance data	・Obtained from personnel registration data e.g., performance evaluation and value evaluation

data extracted from the location information system in the office and the network centrality data.

Furthermore, using employee attribute data, such as age, gender, and job title, and satisfaction data obtained from satisfaction surveys, we will examine the relationship between employee status, working style, and performance.

25.4 Research Method

25.4.1 Addition of Area Attributes

The core of this research is the location data of employees in the office acquired from Wi-Fi connection information and the detection method of "how to work" using it. To extract this "how to work" data, we used the location data and network centrality data with area attributes assigned according to the usage status in the office.

We define the four patterns for the area attributes, as shown in Fig. 25.1.

Formal meeting area. Closed standard meeting room area. Reservation is required to use this area. There is a tendency for closed and planned conversations to occur.

Informal meeting area. An open and quick-meeting area. No reservation is required for using this area. There is a tendency for open and sudden conversations to occur.

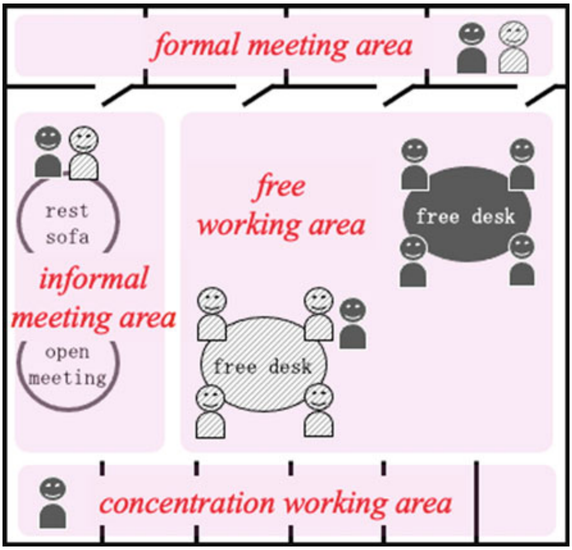

Fig. 25.1 Area attributes definition

Concentration working area. Concentrated seats with partitions. The conversation is basically prohibited. It tends to be used when you want to work intensively by blocking the line of sight of the surroundings.

Free working area. Working area other than the above. This is the basic free-address area in this office environment.

25.4.2 Extracting Network Centrality Data

Based on these definitions, we will add area attributes to the work location data and network centrality data. To extract network centrality data, we decompose all the meeting clusters of multiple people detected by Yamashita et al. (2020) into one-to-one employee pairs. To create an adjacency matrix by considering the pair of each decomposed employee as a node, the following two network centralities were extracted.

Degree centrality. An index that prioritizes nodes that are often adjacent to other nodes. In other words, it is an index that highly evaluates people who have face-to-face connections with many people.

Betweenness centrality. An index that considers nodes that frequently appear in the shortest path connecting groups of other nodes is important. In other words, it is an index that highly evaluates people who are often in a bridging position between different groups.

Herein, these two types of network centrality are subdivided and analyzed through area attributes and department where the meeting has occurred. Thus, we will examine the effects of open and sudden conversations, not just meetings held in the conference room, and the effects of communication that transcends not only employees in their own department but also organizations.

25.5 Modeling

25.5.1 Examination of Dimension Reduction Method

A total of 65 variables were considered. From these, “value_rank” was set as the objective variable. This field is a multifaceted contribution evaluation by multiple evaluators such as superiors, colleagues, and subordinates at the end of the evaluation period. Therefore, it is assumed that the manner of working during the evaluation period of the evaluated person is directly reflected.

Upon confirming the correlation of all variables, there was a high correlation among the 34 satisfaction data variables. Therefore, when creating the model, the first consideration was how to address multicollinearity.

25.5.2 Sparse Principal Component Analysis

As a result of comparing several dimensionality reductions, from the viewpoint of interpretability and model prediction accuracy, we adopted the least-squares regression model using satisfaction data synthesized via sparse principal component analysis. Sparse principal component analysis (SPCA) is a method of estimating most of the principal components to exactly 0 using the sparse estimation method.

In SPCA proposed by Hui Zou et al. (2006), $A = (\alpha_1, \ldots, \alpha_K)$, which is the matrix data of the principal components, is estimated collectively [13]. Here, if A reflects both the orthogonal constraint and the L1 regularization, it becomes difficult to construct an efficient algorithm for finding the solution. Therefore, we propose another parameter $B = (b_1, \ldots, b_K)$ to solve the following optimization problem.

$$\min_{A,B} \|X - XBA^T\|_F^2 + \lambda\|B\|_F^2 + \sum_{k=1}^{K} \lambda_k \|b_k\|_1 \text{subjectto} A^T A = I_{K.} \tag{25.1}$$

In the above formula, $A^T A = I_K$ represents the orthogonal constraint on A. L1-norm constraint and L2-norm constraint are assigned to$B$. Therefore, rather than optimizing A and B simultaneously by minimizing them alternately, the estimated values of $\widehat{A}$ and $\widehat{B}$ are obtained, and finally, the matrix $\widehat{Z} = (\hat{z}_1, \ldots, \hat{z}_K)$ is the output [14].

This approach is used to perform SPCA on 34 variables of satisfaction data. Figure 25.2 plots the eigenvectors of the variance–covariance matrix, which represent

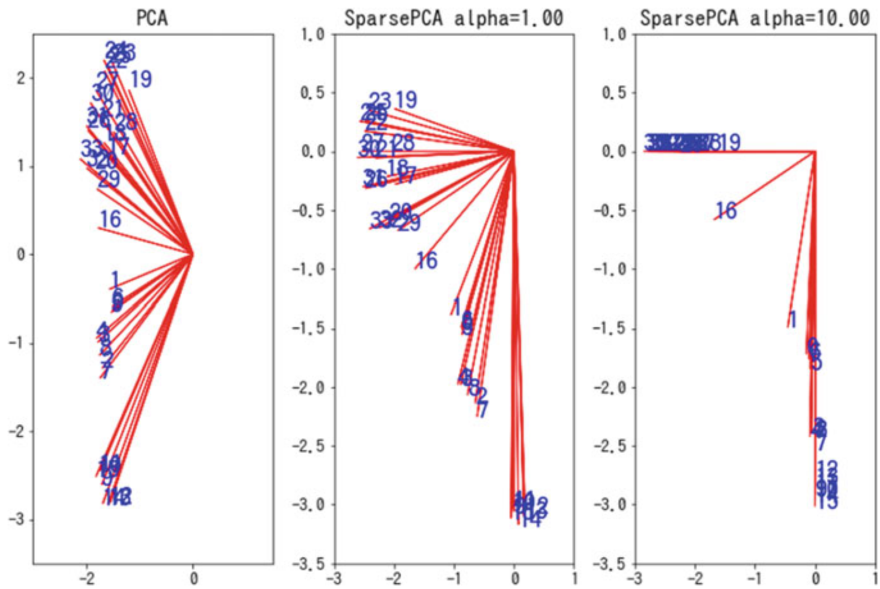

Fig. 25.2 Eigenvector of the variance–covariance matrix of the principal components

the weights of each principal component. The left side of Fig. 25.2 is the result of normal principal component analysis, and the middle and right sides are the results of SPCA with the regularization parameter set to 1 and 10, respectively.

In SPCA, the regularization is strengthened by increasing the regularization parameter alpha. As a result, the model becomes more concise with more parameters estimated to be zero. On the right side of Fig. 25.2, many principal components are equal to zero, which shows that the effect of SPCA makes it easier to interpret the results.

Considering the eigenvectors of the variance–covariance matrix, which represents the weight of each principal component, most of the satisfaction items for work and boss are zero for the first principal component. In the second principal component, most of the satisfaction items for the company are zero. From this result, it can be interpreted that the first principal component represents the overall satisfaction with the entire company, and the second principal component represents the satisfaction with the work and the boss.

Table 25.2 shows the results of the least-squares regression model using satisfaction data synthesized via SPCA. Only variables for which statistically significant results were obtained are displayed.

Table 25.2 Results of least-squares regression model using SPCA

Classification	Variable	Coef	P-value
Attribute data	age_details	−0.106	0.000
	position_type	−0.040	0.003
Satisfaction data	PC1	−0.029	0.043
Network centrality data	informal_degree_centrality	0.090	0.001
	same_informal_degree_centrality	−0.051	0.005
	same_informal_betweenness_centrality	0.038	0.006
	other_informal_betweenness_centrality	−0.036	0.033
Performance data	value_point	0.762	0.000

25.6 Conclusions

25.6.1 Hypothesis Verification

The "informal_degree_centrality," which is a network that occurs in the quick meeting area regardless of department, has the highest positive coefficient among network centrality data, this fact proved the beginning of two hypotheses. It can be interpreted that the performance of employees who have face-to-face connections with many employees regardless of department tends to be high in a quick meeting area.

Furthermore, based on the information in Table 25.2 can be used to draw two important conclusions, as shown in 6.2 and 6.3 below.

25.6.2 Area Attribute Perspective

All network centralities that affected performance had an informal area attribute. Therefore, from the viewpoint of area attributes, it can be said that it is not the so-called planned meetings held in the meeting room but the conversations that occur in the quick-meeting area that affect the performance of employees.

This is also a useful discovery in office space management. In short, employee performance can be improved by properly designing spaces that are open and subject to sudden communication rather than having ample meeting rooms to encourage planned meetings.

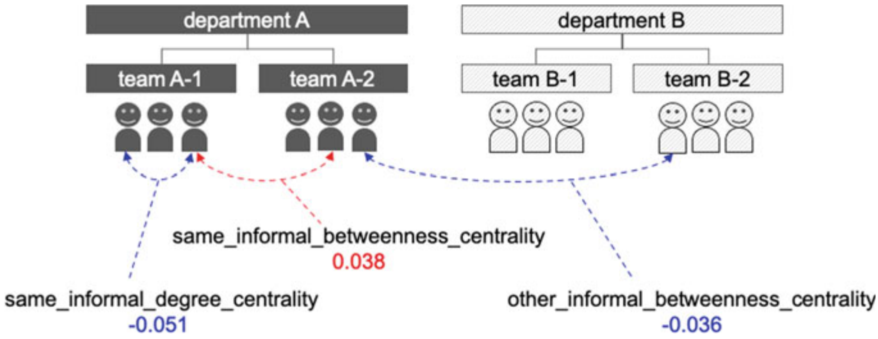

Fig. 25.3 Performance effect on network type

25.6.3 Network Type Perspective

The "same_informal_degree_centrality" attribute, which is the degree of centrality between employees in the same department, is a negative coefficient, and "same_informal_betweenness_centrality," which is the mediation centrality between employees in the same department, is a positive coefficient.

As a premise, only two layers, the upper layer "department" and the lower layer "team", were separated herein and analyzed from the organizational hierarchy of the research target. Therefore, in this research environment, the content of work (sales, planning, and engineers) may change if the upper "departments" are different. However, even if the "teams" are different in the same department, the work content would be the same.

A general interpretation of this result is that among employees with similar tasks, the performance of employees who bridge between different groups is higher than that of employees who have a lot of face-to-face communication.

Conversely, it was also found that "other_informal_betweenness_centrality," which is the mediation centrality between employees in different departments, becomes a negative coefficient. A general interpretation of this is that for employees with different jobs, a network that bridges between groups does not improve employee performance. This result is presented in Fig. 25.3.

25.7 Future Work

25.7.1 Model Improvement

As this study is conducted for employees of all occupations, it also includes employees of occupations such as development staff and customer service staff who are not of the type where communication with employees in other departments is not important. Therefore, the betweenness centrality among different departments can have a negative effect on performance.

In the future, we will consider improving the model in consideration of differences and combinations of occupations.

25.7.2 Agent-Based Model

Herein, we investigated how individual work styles are related to individual performance.

However, by adding a performance evaluation of the organization to which it belongs, it is possible to investigate how individual working styles improve the performance at an organizational level.

Assuming that these are in an interactive relationship, it is possible to design the agent-based simulation by hierarchically grasping the way individuals work as "microbehavior patterns" and the performance of organizations as "macrosocial phenomena [15, 16]."

By doing so, we will conduct hypothesis-generating research on how the type of employee behavior and organizational performance can improve based on the office layout.

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Chapter 26
Potentials of Digital Business Models in Tourism—A Quantitative Study

Ralf-Christian Härting, Marcel Bäuerle, Kevin Bilge, Lisa Fleischer, Nadja Landgraf, and Marcel Wicher

Abstract The megatrend digitization is one of the most discussed topics of the last years. It has opened up new opportunities for companies and does not stop at traditional business models. Digital technologies, especially the Internet, have been examined in the existing business models or completely new models have been created to replace analog models. The target of this research project is to identify potential digital business models in tourism. For this purpose, the authors have conducted a theoretically grounded empirical study. The hypothesis framework is partly derived from a qualitative study and partly from literature research. The following business models for tourism have been identified: sharing economy, personalized offers, customer reviews, social media and process costs. The results of this study show that social media, sharing economy and customer reviews have a positive and significant influence on the research question. Personalized offers and process costs have a positive impact and could become potential in the future. However, they have no significant influence on this study.

26.1 Introduction

Digitization as a megatrend has and will continue to change tourism, the distribution of roles between providers and guests is in a state of upheaval. On the supplier side, digitization offers a variety of information and communication media, which provide the tourism supplier with many new opportunities. In the age of digitization, tour operators are faced with the challenge of reaching their customers on all digital channels and offer as many individualized trips as possible. But digitization also provides opportunities on the consumer side. Today's traveler is always networked, mobile and informed. This means that they cannot only consult but also help to shape and develop their journeys [1]. Technological developments mean that business

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processes are subject to numerous changes, but at the same time, the digital structural change also offers new opportunities that companies can use for themselves [2].

According to the German Travel Association (DRV), a total of 25.9 billion Euros were generated in 2017 with travel booked via the Internet. The offline pendent accounted for 38.8 billion Euros, so the difference is already limited. Today, 30% of all travel bookings are made online [3]. This can be an example of not only how important it can be for companies to adapt to digital change and how business processes or models can shift to an Internet-based concept but also how important and, moreover, vital it can be the tourism industry. At present, not enough research has been carried out to determine what benefits tourism companies can derive from digital business models for their operations. The results for the described research project try to close the gap. For this purpose, hypotheses were established in advance, which were tested by means of a quantitative study.

The document is structured as follows: The next chapter deals with the definition of digital business models and tourism. The third chapter gives an insight into the research design. Chapter 4 explains the systematic approach of the research. Finally, Chap. 5 presents the results of the research, which is followed by the conclusion with the most important results.

26.2 Digital Business Models and Tourism

Basically, the term digitization refers to the change in communication technologies from analog to digital. This change makes it possible to translate all information into a binary code with the numbers 0 and 1, whereas in analog communication, one value within a range can contain innumerable intermediate values. Analog information such as photos and sounds are converted into digital units during digitization, which enables improved transmission quality through error checking and a lower frequency and power consumption [4].

However, this definition only covers the technical aspect. In the course of time, the term digitization has expanded so it can be "*[…] understood as the digital conversion and representation or implementation of information and communication. […] the digital modification of instruments, devices and vehicles as well as the digital revolution […]*" [5]. The term not only stands for digital change in technologies but also for intelligent business and value-added processes under powerful information and communication technologies such as Big Data, Cloud Computing, Mobile Computing, Internet of Things or Social Software. Digitization is, therefore, not only the provision of information but also the partial representation of value-added processes in electronic form [6].

A business model is a simplified representation of the reality of product or service groups. It consists of essential elements. The following definition can be used: "*A business model is the basic logic of an enterprise, which describes which benefits are created in which way for customers and partners*" [7]. A business process is defined as "*a series of logically related tasks that are performed to achieve a defined business result*" [8]. It is the consequence of value-added activities in which inputs create a customer-beneficial output. They can be considered at various levels of aggregation, such as individual divisions, functional areas or the company as a whole [9]. In contrast to a classic business model, information technology in a digital business model is not only part of the value creation but also shapes all areas of the business model. In this context, a business model can, therefore, be gradually restructured into a digital business model, the more components of the model based on digital technologies exist. Thereby, intelligent business processes with new technology concepts like Big Data, Cloud-Computing, Mobile Computing, etc. are used. It is important that a digital business model necessarily uses information technologies [10]. This definition will serve as a basis in the further course of the paper and create a uniform understanding of the term "Digital Business Models" among the readers.

Finally, the concept of tourism is described. It defines the movement of people to a place for a certain period of time where they have not yet spent their daily lives and the activities they carry out in this new area [11].

26.3 Background and Research Design

Based on a qualitative study "*Potentials of digital business models in tourism*" and an additional literature review, this SEM approach investigates the developed model on the potential of digital business models in tourism. This first approach was conducted as an internal qualitative study and builds the foundation for the current work.

In the model shown above, six determinants were established in the qualitative study before [12]. They provide the foundation for this quantitative study. All determinants have a positive influence on digital business models in tourism. The hypotheses will be explained in the following.

Customer Reviews Portals

Positive reviews encourage guest bookings. Customer reviews are consulted by many potential customers before booking. Poor reviews can also identify the potential for improvement. Based on the qualitative study, it might be that customer evaluation portals have a great influence on booking behavior [12]. Besides the fact that customer evaluation portals are authentic content, it is easier to get access to customer experiences while reading through customer evaluation portals. Customers call it electronic word of mouth with access from all over the world [13, 14]. One hypothesis indicates that customer evaluations have a positive influence on booking behavior. It is said that in terms of credibility, customers place a high value on the reviews and hotels or companies should pay attention to this. People attach more importance to the experiences than to promises of companies or hotels [14]. In summary, customer evaluation portals generally lead to competitive advantages through a positive influence on booking behavior due to their high credibility and easy access.

Sharing Economy

Sharing economy allows private customers to share their homes with other people. Due to changing customer needs in recent years, people pay attention to a familiar and cozy atmosphere. Sharing economy is predestined to combine these aspects. It also leads to different offers on the market [12]. Further, a reduction of overcapacity can be realized, leading to an increase in the use of underutilized resources. Other important aspects are the reduction of prices, the need for an individual property, pollution or the reduction of problems in public services. This ultimately leads to more money in the pockets of customers [15].

Personalized Offers

Digitization can be used for targeted advertising with a positive effect on individualized offers. Tourism suppliers will easily be able to contact travelers through wearable devices. This leads to an easier preparation of offers [16, 17]. New technologies play an important role in personalized offerings. As a result, processes can be implemented much faster. In addition, personalized offers facilitate customer loyalty to the company, as customer satisfaction increases [12, 18]. Because of the individualization of personalized offers, hotels or other providers have the possibility to attract more travelers. It is possible to address them more easily and quickly through new technologies [19].

Social Media

"*Consumers said they trusted earned media, which includes recommendations from friends and family members, more than any other form of advertising*." Social media offers new possibilities. The power of social media channels is growing. An account on social media platforms could provide strong advantages [20]. The customer can research actively and can be inspired by social media, which is reflected in their behavior [22]. Through social media, the level of popularity of the company is increased, which generally has a positive effect on the company [23].

Process Costs

As a result, an enormous amount of time can be saved through process costs by mapping all processes digitally. The experts see a chance that personnel can be saved by the use of digital processes. Digital technologies allow guests to do many things themselves, such as checking into a room or booking a room. A recommended course of action is to ensure all processes are implemented digitally in the future [12]. The digital reproduction of processes saves companies a lot of time. Less day-to-day business and better communication with customers. The speed of information exchange that digital technologies contain and the potential for increasing sales can be fully exploited [12]. Digital business models make the processes faster and thus increase the efficiency of products. "*The combination of enhancements in processing and flexibility of processing capability allows organizations to use their resources more wisely and profitably*" [21]. By making processes more effective and competitive, digital business models offer significant advantages in communication by increasing the speed of information [21]. Processes can be more effective and competitive with digitization. Process costs can save a lot of time by mapping processes digitally.

Increase in Sales and Profit

Digital markets offer many opportunities for the tourism industry. This has created new business models that represent a major competition for traditional providers, e.g., sharing economy [21]. Internet technology makes industry faster, more individualized and cheaper to get information. The customer can get information anytime and anywhere. This helps to increase sales. The processes in the company become more effective and bring opportunities for a wide range of processes such as brand building, customer acquisition and retention, product development and quality assurance [21]. Used potential can lead to increase turnover and business success. Companies must be able to recognize this potential in good time and deal with it [21].

These hypotheses in the form of questions were answered by participants on a Likert scale. This allows a quantitative review of the previous qualitative study. In the first questionnaire, block participants answered questions on customer evaluation portals. Afterward, they evaluated questions on sharing economy and personalized offers. Furthermore, they dealt with social media and processes. The questions used in the questionnaire were designed according to the general guidelines of a quantitative survey design.

26.4 Research Methods and Data Collection

The authors examined the hypotheses using a quantitative research approach including an online survey. The survey was conducted using the software LimeSurvey. The main study started in January and ended in February 2020, collecting a sample of $n = 111$ usable responses from tourism experts. Over 88% of the interviewed professionals work in a German company. About 8% of the participants work for an Austrian or Swiss company. The remaining 4% did not give any information about this.

With 68% of the interviewed tourism professionals, the clear majority works in a small company with less than 50 employees. 14% is the second-largest number of the participant works in an SME with between 50 and 250 employees. Only 12 respondents (11%) work in a large company with over 250 employees. 7% did not want to answer the question.

14% responds a company's turnover up to 0.5 million Euros. Another 38% has a turnover up to 10 mio Euros. Similar to the relatively low number of participants in medium-sized enterprises, only 11 of the respondents work in a company with a turnover of more than 10 and up to 50 million Euros. About 9 people took part in the survey, which is working in a large company with a turnover over 50 mio Euros.

Figure 26.2 shows how long the respondents have been working in tourism. Approximately 16% of the surveyed said that they had been working in tourism for less than 3 years. A further 27% stated, they had been working in tourism for between 3 and 10 years. In contrast, the majority with 53% has been working in tourism for more than 10 years. The remaining 4% did not want to give any personal information.

Figure 26.3 deals with the time, the interviewees are already engaged with digital business models in the tourism sector. The respondents were asked about their activity in this area in years. In this context, 12% stated, they had only been working on this topic for less than a year. The majority (51%) reported that they had already spent between 1 and 5 years working on digital business models in tourism. Over 5 years, and thus the longest time on this scale, 29% confirmed dealing with this issue for a correspondingly long time. In the survey, 5% stated, they had not yet dealt with digital business models in this area at all. With 4%, similar number of responses, did not want to give any information.

A comparison between Figs. 26.1 and 26.2 concludes that digitization has recently begun to occupy the tourism industry. It can be concluded that, although 50% of the

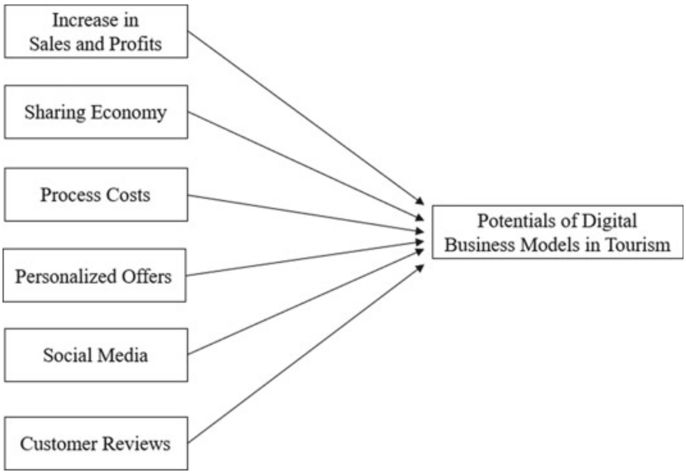

Fig. 26.1 Hypothesis model

Fig. 26.2 Personal activity in tourism or in the tourism sector of the respondents by years in percent

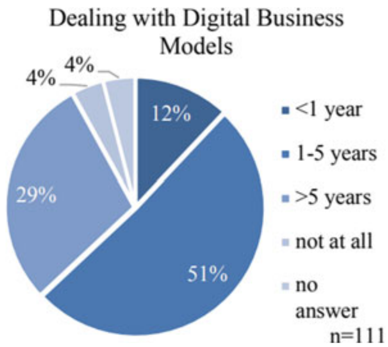

Fig. 26.3 Dealing with digital business models in tourism or in the tourism sector of the respondents by years in percent

respondents have been working in tourism for more than 10 years, over two third of the interviewed tourism professionals have a maximum experience of 5 years.

26.5 Results

To analyze the theoretical causal model (Fig. 26.1) with empirical data, structural equation modeling using software SmartPLS was chosen. The relationships between different variables can be calculated with SEM [24]. SEM is regarded as the second generation of multivariate analysis to gain a deeper insight into the analysis of the different relationships. The measurement model validates the latent variables, while the structural equation model analyzes the different relationships between the research model and the determinants [25]. The following results were obtained after evaluating the data sets of the empirical sample with SmartPLS (Fig. 26.4).

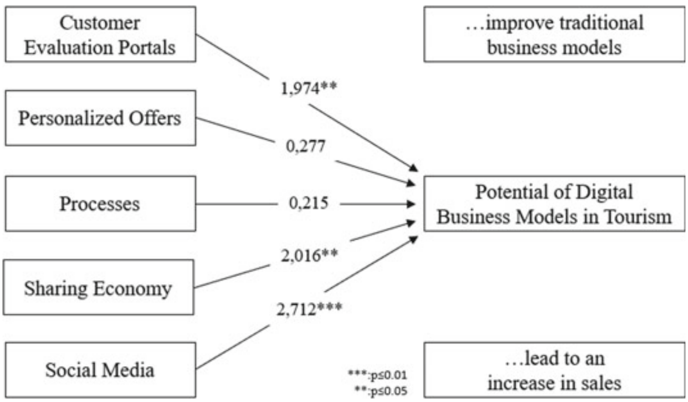

Fig. 26.4 Structural equation model with constructs

According to the analysis with SmartPLS, a significant potential for changing customer needs in a digital world in tourism is found in four of seven evaluated determinants ($p < 0.05$). In summary, the determinants Customer Evaluation Portals (1,974), Sharing Economy (2,016) and Single Item I are significant potentials ($p <$ 0.05) with high positive impact. With a p-value below 0.01, social media even have a highly significant influence on the research question. Social media platforms have the potential to improve communication with customers and have a positive influence on consumer behavior. They offer great opportunities with regard to the potential of digital business models. Overcapacities can be reduced through Sharing Economy. In addition, the range of products and services can be expanded and made more attractive for customers in terms of price. Customer Rating Portals give customers a direct impression, which can have a positive effect on the booking process and facilitate access to customer experiences. Single Item I states that digital business models improve traditional business models. The determinants Personalized Offers (0.277) and Processes (0.215) are missing a high level of significance in the results. Detailed information about the structural equation model and the influence of the determinants are presented in the following Table 26.1.

In summary, the study revealed that customer evaluation portals, sharing economy and social media can be verified as determinants with a significant influence. In addition, Single Item 1 “Digital Business Models improve traditional business models” can also be verified and confirmed.

In order to have a consistent model, it is important to take a look at the quality criteria. Regarding the quality criteria according to Homburg, the structural equation model achieves good values [25]. The examined determinants, personalized offers, process costs, sharing economy and social media show excellent values across all three quality criteria, which can be attributed to the high quality of the model. Only customer reviews weaken the model somewhat—with regard to the values of the

Table 26.1 Results of the structural equation model

Determinants	Original sample	Average sample value	Standard deviation	T-statistics	*P*-value
Customer evaluation portals	0.189	0.178	0.096	1.974	0.049
Personalized offers	−0.027	0.008	0.096	0.277	0.782
Processes	0.022	0.087	0.104	0.215	0.830
Sharing economy	0.233	0.203	0.115	2.016	0.044
Social media	0.278	0.237	0.103	2.712	0.007
…Improve traditional business models	0.239	0.239	0.106	2.261	0.024
…Lead to an increase in sales	−0.093	−0.082	0.089	1.047	0.296

Table 26.2 Quality criteria of the SEM

Determinants	Composite reliability (CR)	Cronbachs alpha (CA)	Average variance extracted (AVE)
Customer evaluation portals	0.739	0.632	0.430
Personalized offers	0.859	0.801	0.608
Processes	0.833	0.749	0.506
Sharing economy	0.837	0.759	0.570
Social media	0.911	0.856	0.733

Cronbachs alpha and the recorded average variance extracted. The values confirm the good quality of the SEM. Further information can be found in Table 26.2.

A total of 111 persons were interviewed. Of the surveyed participants, over 95% stated that digital business models in general offer potential for companies in tourism. Only three people denied this statement, while two people were undecided.

26.6 Conclusion

A structural equation model was built to investigate the potential of digital business models in tourism. The examination shows five constructs and two single items, which directly affect the research question as the potential of digital business models in tourism. It is significantly impacted by influencing factors "*sharing economy*" and "*social media*". Both factors, "*improve traditional business models*" and "*increase in sales and profits*" have a positive influence on the potential of digital business models. Other examined factors such as "*customer rating portals*", "*personalized offers*" and "*processes*" evidently have an influence on the research question. Due to the fact that the survey included only tourism experts, it was limited not only in terms of location but also in terms of sample size and time period. Only seven influencing factors for the potentials of digital business models in tourism were detected and analyzed, which is another limitation.

The authors of this paper recommend a detailed focus on the limitations, as the aspects may be relevant for further research in this area. Country selection, duration of the survey and sample size can have a significant influence on the results of the study. A qualitative research design can help to get further insights into factors influencing the potential of digital business models in tourism. The use of digital business models increases not only the profitability of the company but also the competitiveness. Therefore, elaborating and developing digital business models will be an increasingly important tool for the success of companies within the tourism business. The authors expect that digital business models will become even more important for tourism businesses as the empirical study shows. As the respondents showed, the potential is not reached yet.

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Chapter 27
Collecting Diversified Opinions from Business Meetings: A Study Based on the Faultline Perspective

Fumiko Kumada and Setsuya Kurahashi

Abstract This study aims to clarify which communication factor generates diverse opinions using the faultline perspective in diversity management: the faultline is a hypothetical dividing line that splits a group into subgroups according to one or more individual attributes. Text data of business meetings are analyzed for two objects. The first is to check the transition of topics identified by a co-occurrence network of words and the PageRank algorithm to rank pages on websites. The second is to measure participant remarks' diversity by the faultline strength and the number of subgroups. Therefore, this paper shows the relationship between the transition of topics and diversity of remarks and the facilitator's role in eliciting various remarks. It became clear that the transition of topics and the diversity of participant remarks are affected by the facilitating style.

27.1 Introduction

Japanese business organizations are diversifying due to a declining birthrate and an aging population. In the field of diversity management, diversity can positively or negatively affect organizational performance. The positive perspective is information and decision-making theory, which holds that diversity increases knowledge and information types, consequently, providing an organization with positive effects.

Moreover, communication methods that create various ideas are built on the Osborn [1] brainstorming method. Subsequently, several studies were conducted on methods for creating ideas. In a diversified organization, clarifying the factors that produce different opinions and ideas is crucial to generating the intended positive effects of diversity.

Therefore, this study aims to clarify the factors in a discussion that create diverse opinions and the role of a facilitator in eliciting various remarks.

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27.2 Previous Studies

27.2.1 Faultline Perspective

Lau and Murnighan [2] proposed the concept of faultlines, which are hypothetical dividing lines that split a group into subgroups according to one or more individual attributes; faultlines explain the causality of diversity based on organizational members' attributes and organizational conflicts. Previous studies proposed more than 10 faultline measurement methods. Thus, this study adopted the Meyer and Glenz [3] rating scale for cluster analysis, Average of Silhouette Width (ASW). ASW divides target organizations into subgroups. Kumada and Kurahashi [4] reported that the faultline strength, the number of subgroups, and the deviation of subgroups' size affect organizational performance.

27.2.2 Text Mining Keywords

Text mining of meeting notes extracts keywords and topics and visualizes the discussion flow. As an index for determining keywords, Salton et al.'s [5] tf·idf focuses on the frequency of words. In addition, Hassan et al. [6] proposed a method using PageRank, which is one of the centrality in graph theory. Brin and Page [7] proposed the PageRank algorithm that ranks pages on websites connected by hyperrings.

27.2.3 Review of Previous Studies

Previous text mining studies focused on words to visualize transitions. This paper focuses on remarks to analyze text data from actual business meetings. By adopting the faultlines perspective, this paper attempts to identify the factors of discussion that create diverse opinions and to consider the role of a facilitator in eliciting a diversity of remarks.

The faultlines perspective is a theory that measures the diversity of organizational members. However, this study applies this perspective as a measurement for the diversity of discussion remarks.

27.3 Analytical Procedures

This section outlines three business meetings that form the basis for the research and explains the analytical procedures.

27.3.1 Outlines of the Three Business Meetings

These meetings were held as events for business people in the period between April 2019 and January 2020 at Tokyo. Each 90-min meeting included at least one facilitator and 13–14 participants. Each facilitator decided the theme and how to facilitate the meeting. Then, business people interested in the theme participated in the meeting. Table 27.1 lists the information about the participants, facilitator, and remarks.

Meeting A was led by two facilitators, and one speaker, who was a Japanese culture expert and held an expository role. Thus, meeting A was named "the divided role style." In this meeting, facilitators affected the discussion process and the rate of facilitator remarks was high and the rate of participant remarks was low. Meeting B was led by one facilitator who designed the process in which participants speak on their own initiative. Therefore, the number of participant remarks was higher than the others. Hence, this meeting was named "the self-propelled style." Meeting C was led by one facilitator, who was a contemporary art expert. The facilitator held one-on-one discussions with every participant. This meeting was named "the one-on-one style." Meeting C featured a low dispersion of participant remarks.

Table 27.1 Outlines of the three meetings

Meeting	A	B	C
Date	January 2020	April 2019	September 2019
Theme	Japanese luxury	New learning	Contemporary Art
Facilitation style	Divided role	Self-propelled	One-on-one
Facilitator	Two facilitators one speaker	One facilitator	One facilitator
Number of participants	14	13	14
Total number of remarks	164	151	95
Participants			
Number of remarks	71	124	54
Rate of remarks (%)	43	82	57
Range of remarks	1–10	2~28	2~7

27.3.2 Analytical Procedures

This section explains the analytical procedures in this study. Text data of the three meetings were analyzed following these three steps:

1. Selection of featured words
   First, we separated the text data by words. Second, we consolidated participant remarks and calculated tf·idf for each participant. Third, we selected the top 10 noun words of tf·idf for each participant. Fourth, we determined the featured words by excluding duplicated words.
2. Visualization of the discussion transition
   First, we converted each remark into a vector with the tf·idf of the featured words. Second, we grouped 10 consecutive remarks and calculate the faultline strength and the number of subgroups with ASW. Third, we applied the moving average method and repeated the calculation while moving one remark at a time. This process visualized the discussion transition through the faultline strength and the number of subgroups.
3. Visualization of keyword transition.

As in step 2, we created a group of 10 consecutive remarks. While moving one remark at a time, we created a co-occurrence network of the featured words weighed by the Jaccard Coefficient. Then, we calculated the PageRank value and checked the number of featured words for which the PageRank value was generated. This process visualized the transition of keywords through PageRank.

27.4 Results

Table 27.2 below presents the text data analysis results of the three meetings according to the procedures above. The table shows the number of featured words calculated in step 1 and the number of words with the top PageRank value in each co-occurrence network. The results of the text data of the meetings are as follows:

Table 27.2 Number of featured words of the three meetings

Meeting	A	B	C
Number of featured words	82	97	107
Number of featured words with the top PageRank value	12	23	8

27.4.1 Meeting A

Meeting A contained four sections: self-introductions, problem presentation, discussion, and closing. Only the third section (with 113 remarks) was analyzed.

The red line in Fig. 27.1 describes the faultline strength with characteristic points from A1 to A4. The upper left chart shows the number of remarks of each subgroup. The orange, gray, yellow, and blue bars show, respectively, the first, second, third, and fourth subgroups in the chart. The upper right chart shows the PageRank values of each featured word, and the words in the chart are to have the top PageRank value. The lower chart shows the number of featured words that generated the PageRank value. Each characteristic point is explained below.

A1 occurred in the 79th remark with high heterogeneity sharply increasing the faultline strength. Additionally, the number of featured words decreased abruptly. The topic consolidated around the featured word "luxury." The 79th remark had such high heterogeneity that the subgroups were divided into the 79th remarks and the other nine remarks. Then, the faultline strength was decreased, as the number of featured words increased.

A2 comprised plural remarks with low heterogeneity. The faultline strength was increasing gradually, and the topic consolidated around the featured word "Europe." Then, more than two subgroups were generated due to the absence of words with high heterogeneity. The faultline strength is decreased.

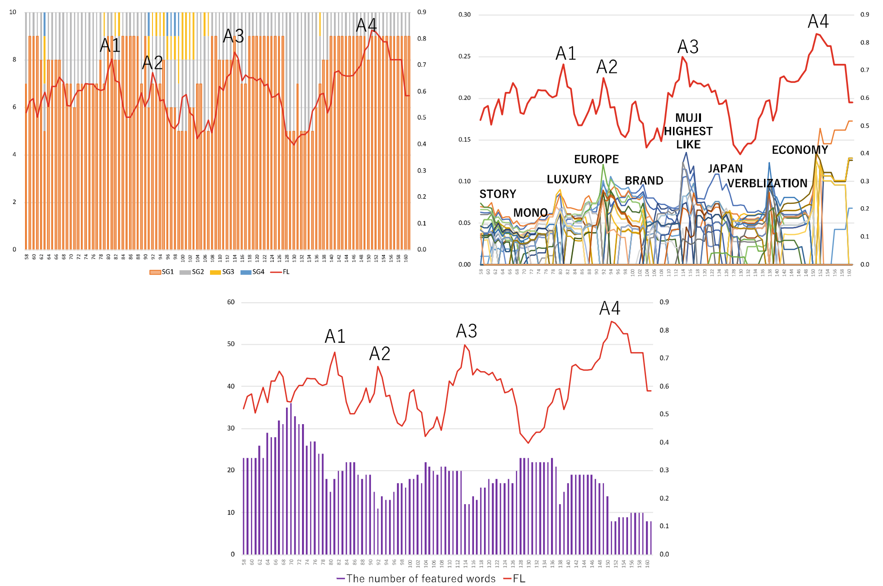

Fig. 27.1 The result of the discussion transition (meeting A)

The faultline in A3 occurred in the 108th remark, which did not have as high heterogeneity as A1's 79th remark but it did have an influence. This 108th remark contained a word with the top PageRank value. In this case, the featured word was "MUJI." Gradually, the 108th remark increased the faultline strength, whereas the number of featured words was decreased. Then, the topic consolidated around the featured word "MUJI." Next, the breakaway of the 108th remark abruptly decreased the faultline strength. The heterogeneity of the 118th remark divided the subgroups unevenly into two, specifically, the 118th remark and the other nine remarks. The faultline strength is gradually decreased.

A4 consisted of the 141st remark, which did not have heterogeneity but had a high influence on the featured word "economy," which had the top PageRank value. The 141st remark increased the faultline strength, and the topic consolidated around the featured word "economy."

Finally, the facilitators elicited remarks with high heterogeneity. For example, the 79th remark blended the facilitator's 78th remark with a new question, and the 141st remark combined the facilitator's 140th remark with a new viewpoint. The 108th remark belonged to the facilitator but represented a new point of view. Additionally, the facilitators prompted participants' remarks to converge and diffuse.

27.4.2 Meeting B

This section describes the result of meeting B, which had 151 remarks. All remarks were targeted in the analysis because the discussion began immediately. Figure 27.2 presents the analysis result of meeting B.

The red line in Fig. 27.2 described the faultline strength with characteristic points from B1 to B4. The upper left chart shows the number of remarks of each subgroup. The orange, gray, yellow, and blue bars show the first, second, third, and fourth subgroups in the chart. The upper right chart shows the PageRank values of each featured word, and the words in the chart are to have the top PageRank value. The lower chart shows the number of featured words that generated the PageRank value.

Meeting B's facilitator aimed to develop a self-propelled style. Therefore, the facilitator was not involved in the discussion. The participants spoke on their own initiative. There were fewer remarks with heterogeneity than in meeting A, where the facilitators were actively involved. As a result, meeting B had two features. First, in comparison to meeting A, there were fewer cases in which the first subgroup's number of remarks was extremely biased. Second, the number of featured words with the top PageRank value was larger (23 words) than the other two meetings. Each characteristic point is explained:

The fluctuation of the faultline strength around B1 was small. The first half was stagnant, where short remarks occurred continuously. This situation, in which the number of featured words decreased without an increase of the faultline strength, was not observed in meeting A.

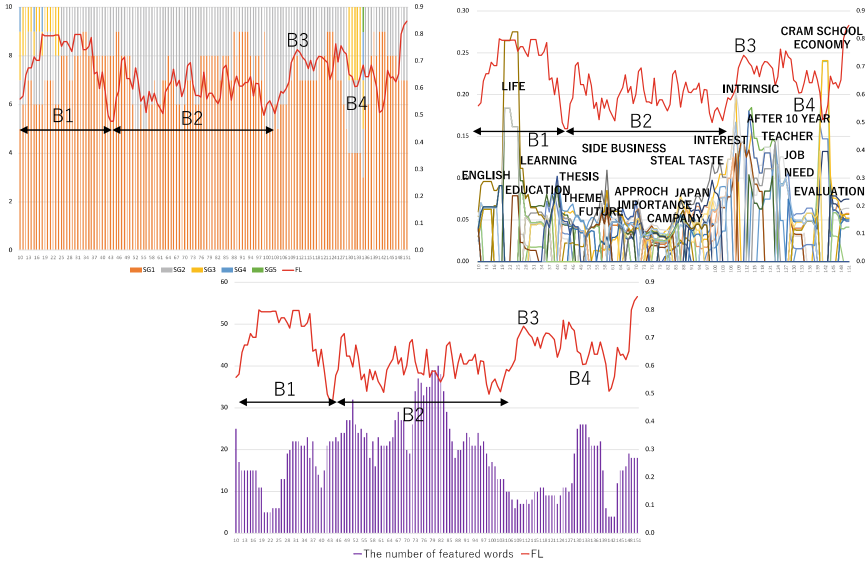

Fig. 27.2 The result of the discussion transition (meeting B)

The faultline strength is increased and decreased gradually around B2. Certain featured words in the upper right chart, such as "side business" and "steal a taste," had the top PageRank value. Small convergence and diffusion were repeated, which reflects a jabber situation.

The faultline strength was increasing at B3, as the featured words decreased, and the topic consolidated around the feature word "intrinsic."

The faultline strength was decreasing around B4, as the number of featured words increased to center on "education." This was the situation of diffusion in the discussion around "education". Then, the faultline strength increased as the number of featured words decreased; the topic consolidated around the featured word "education."

Finally, the effect of the facilitator's remarks was observed. The facilitator conducted progress in B1 period. However, in B2, without the facilitator's remarks, only the participants conversed, resulting in jabbering. Then, the topic consolidated around the featured word "intrinsic." In this process, the facilitator's 60th and the 123rd remarks summarized the discussions. The facilitator asked new questions. The 60th remarks generated one of the top values in B2. The 123rd remark triggered a movement to the top of B3.

27.4.3 Meeting C

Finally, this section described the result of meeting C, which comprised 95 remarks and was progressed with the one-on-one style. Although the facilitator did not plan this style, the participants' self-introductions and explanation of motivations took longer than expected. Remarks after the 80th remark were not the target of the analysis because they occurred after break time and the participants' feedback. Then, Fig. 27.3 illustrated the analysis result of meeting C.

The red line in Fig. 27.3 below described the faultline strength and separated by several participants. Numbers 1–14 indicate each participant. The upper left chart shows each subgroup's number of remarks. The orange, gray, yellow, blue, green, and navy bars show the first, second, third, fourth, fifth, and sixth subgroups in the chart. The upper right chart shows the PageRank values of each featured word, and the words in the chart are to have the top PageRank value. The lower chart shows the number of featured words that generated the PageRank value. The number of dialogues differed according to participants. Thus, the conversations were approximately divided into dialogues: (1) where the faultline strength was shifting and (2) where the faultline strength was monotonous. Then, the facilitator's remarks increased the number of featured words to 107. Conversely, only eight featured words had the highest PageRank values.

The C1-5 period comprised dialogues of five participants, as well as two or three dialogues between the facilitator and each participant. This dialogue remained constant in the faultline strength, and the discussions were stagnant.

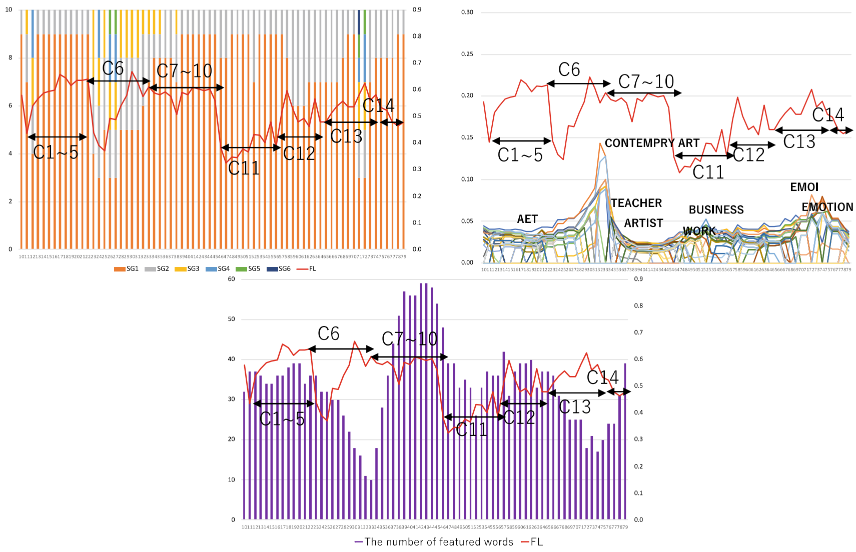

Fig. 27.3 The result of the discussion transition (meeting C)

C6 contained dialogues between the sixth participant and the facilitator with 12 remarks. The topic was consolidated around the featured word “modern art.” The repetition of the participant and facilitator’s short remarks resulted in diverse remarks.

The C7-10 period contained dialogues with four participants and the facilitator. However, the facilitator explained each participant’s remarks, and each dialogue ended only once. Although the number of featured words increased due to the explanation, the fluctuation of the faultline strength was small: the discussion was stagnant.

C11–C13 contained dialogues with three participants. Each conversation consolidated the topic around the featured words: “business,” “emoi,” and “emotion” to have the top PageRank value.

Finally, the effect of the facilitator’s remarks was observed. Convergence occurred while creating diversity: six subgroups were formed in the period of C6, by repeating the dialogues between the facilitator and the participant. This finding was one of the characteristics of the one-on-one style.

27.4.4 Summary of the Results

This study analyzed the discussion process of the text data from three meetings. The results showed that when the topic was consolidated, the faultline strength increased. When the topic was diffused, the faultline strength decreased. Therefore, the slope of the faultline strength was calculated in Eq. (27.1) below. Table 27.3 presents the results.

Table 27.3 The length of the slope

	Convergence				Diffusion			
	N of R	G of FL	L of S	G of PR	N of R	G of FL	L of S	G of PR
A1	2	0.113	0.114	0.007	5	0.219	0.223	0.013
A2	2	0.130	0.131	0.046	6	0.213	0.220	0.059
A3	6	0.304	0.308	0.086	16	0.352	0.379	0.124
A4	10	0.158	0.181	0.071	-	-	-	-
B1	-	-	-	-	4	0.182	0.184	0.054
B3	8	0.235	0.241	0.076	-	-	-	-
B4	3	0.081	0.084	0.007	5	0.151	0.155	0.043
C6	5	0.296	0.303	0.033	-	-	-	-
C11	5	0.105	0.123	0.027	-	-	-	-
C12	2	0.212	0.213	0.007	4	0.135	0.144	0.005
C13	2	0.089	0.093	0.025	-	-	-	-
C14	-	-	-	-	4	0.160	0.168	0.035

*The red words were the highest length of the slope in the data of each meeting.
N of R: The number of relevant remarks during the convergence or the diffusion.
G of FL: Tha gap of the strength of faultlines.
L of S: The length of the slope.
G of PR: The gap of PageRank.

$$\text{Slopelength} = \sqrt{G^2 + (\frac{R}{T})^2} \tag{27.1}$$

G: the gap of the faultline strength between the beginning and the end of the convergence or the diffusion;

T: the total number of remarks for analysis; and.

R: the number of relevant remarks during the convergence or the diffusion.

The convergence indicated the increasing faultline strength and the decreasing number of featured words. Then, the diffusion indicated the decreasing faultline strength and the increasing number of featured words. Table 27.3 shows that the convergence was large when the slope length was long in each meeting because of the increase in the PageRank value associated with the slope length. Also, the diffusion was large when the slope length was long in each meeting. Based on the data of this study, the convergence and the diffusion of a discussion may be effective when the increase and decrease of the faultline strength are drawn continuously over an extended period of time.

27.5 Discussion

This study aimed to clarify the factors in a discussion that create diverse opinions. Also, this research sought to clarify the roles of a facilitator in eliciting diverse remarks during a group discussion. This study analyzed text data of actual meetings. The analysis applied the faulctline perspective in the field of diversity management and used remarks as a unit.

First, the research methods were explained. Text mining focuses on words and analyzes the transition of topics. This study focused on remarks, applied the faultline perspective in the field of diversity management, and analyzed the topic transition factors. The simultaneous analysis of words and remarks showed that discussions were effectively developed along the two patterns described below, which explain the relationship between the transition of topical words and remarks that caused the transition, within the range of analytical data.

1. If the faultline strength increases with the decrease in featured words, then one feature word exists as an axis and the discussion is consolidated around this word. The longer the faultline strength draws the slope, the higher its increase in the PageRank value, and more effectively the topic is consolidated.
2. If the faultline strength decreases with an increase in featured words, then one featured word exists as an axis and the discussion is diffused. Then, the longer the faultline strength draws a slope, the higher its decrease in the PageRank value, and more effectively the topic is diffused

Thus, if the faultline strength can draw a long and high slope or a long and deep slope, then the convergence and diffusion continuously occurred on one topic word, leading to a deep discussion. Therefore, remarks that trigger it are important to examine: such remarks were led by the facilitator. This study analyzed three sets of text data for different progress styles. The facilitator roles are summarized in three points as follows:

1. Provides remarks that generate a "new question" and "new perspective" to lead participants to offer diverse remarks.
2. Provides remarks that generate "new information" to create new ideas.
3. Provides remarks that encourage participants to speak and to avoid stagnation in discussion flow.

Additionally, the analytic method in this study clarified the characteristics of the three different progress styles:

1. The divided role style creates highly heterogeneous remarks by significantly affecting the discussion progress. Thus, creating long slopes is easy.
2. The self-propelled style has a risk of stagnation because the progress is wholly assigned to the participants. However, many featured words may occur simultaneously.
3. The one-on-one style allows deep discussion between a participant and a facilitator. Then, the facilitator's keen questions allow convergence, while evoking diverse remarks.

Each style has unique characteristics. Thus, it is important to select a style properly according to the purpose of discussion, participants' characteristics, and the facilitator's individuality.

Finally, the meetings analyzed in this study were transient, but their organization is premised on the continuous discussion. Therefore, a facilitator should decide how to progress and facilitate according to the purpose of the discussion.

27.6 Conclusion

This study analyzed the text data of business meetings by combining the text mining method and the faultline perspective of diversity management. Academically and practically, this study contributed to the field by proposing the method that clarifies the factors of the relationship between the transition of topics and remarks, and the role of a facilitator in a discussion.

This study was limited to the results of the study data. Thus, future studies should clarify a causal relationship. Furthermore, the facilitator's role should be practically applied to engage effective discussion. For example, effective discussion can be modeled by using an agent-based simulation model.

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Part IV
Intelligent Agents in Health, Wellness and Human Development Environments Applied to Health and Medicine

Chapter 28
Intelligent System for the Evaluation of Implicit Memory with Semantic Emotional Stimuli (IS-EimSeS)

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Abstract This article shows the analysis and design of the model and methodology of an Intelligent System for the Evaluation of Implicit Memory with Semantic Emotional Stimuli, the learning agent will be implemented on a mobile device, which will perform two tests (called phases) for girls who have suffered child victimization, taking into account the implicit memory in child victims of Child Sexual Abuse.

28.1 Introduction

Child sexual abuse (CSA) is a common problem, especially in female victims [1]. The CSA experience has been associated with health and psychosocial consequences, linked to the emotional, cognitive, physiological and neuroanatomical fields [2, 3].

Multiple studies have focused on conducting psychological and neuropsychological evaluations of victims; the latter has focused on the measurement of Executive

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Functions (EF), Explicit Memory and Working Memory. However, few studies have studied implicit memory in victims of CSA. Considering that CSA is a potentially stressful event and that a large percentage of its victims trigger post-traumatic stress disorder (PTSD), the objective of this project is to characterize the performance of 8- to 12-year-old girls with PTSD-CSA in a semantic priming task with emotional and neutral stimuli.

The use of artificial intelligence techniques, the use of artificial intelligence, in particular, the agent paradigm, to support the measurement of EF, Explicit Memory and Working Memory, is a technique to try to support the characterization of the performance of 8- to 12-year-old girls with PTSD-CAS, with a learning agent who is in charge of analyzing and evaluating the task called semantic priming with emotional and neutral stimuli, this agent was implemented for mobile platforms in the Android operating system.

28.2 Intelligent Agents

Nowadays, more and more are used in most of the problems within the medical field, especially those related to the monitoring of patients or users, since they can be modeled using the paradigm of intelligent agents or a multi-agent system (MAS) [4].

An agent is a system capable of perceiving its environment through the use of sensors and the performance of actions by using actuators [5].

The architecture of intelligent agents is mainly used for patient or user monitoring, due to the adaptability of knowledge-based systems, whose architectures tend to be a hybrid.

It has been suggested that intelligent agents can be an option to consider when designing a patient monitoring system due to its basic properties (autonomy, proactivity, social character), which promote the management of distributed information, communication and coordination between autonomous entities [4].

For some researchers particularly those in AI, the term agent has a stronger meaning.

These researchers generally mean an agent to be a computer system that, in addition to having the properties identified above, is either conceptualized or implemented using concepts usually applied to people [5]:

- mentalistic notions (belief, desire, obligation, choice, …).
- rationality.
- Veracity.
- adaptability/learning.

28.3 Proposal

In Mexico, comprehensive care for girls, boys and adolescents has been sought since the beginning of the twentieth century; however, until now it has not been possible to decrease the percentages of child victimization [6]. For example, the Network for the Rights of the Child in Mexico mentioned that child sexual abuse is the fourth type of victimization that is most attended in the corresponding instances for its proper orientation and monitoring in the northwestern region of the Mexican Republic. Likewise, they make it clear that there is a marked difference between boys and girls based on the reports of different types of victimization, in which girls are the most vulnerable to these situations [7].

In more recent data, it has been reported through the National Report on Violence and Health of the Ministry of Health [8] that between 55 and 62% of boys and girls say they have had some form of physical, emotional or sexual abuse, in settings such as family, school, community, workplaces or institutions. On the other hand, in 2012, the National Survey of Health and Nutrition [9] reported that 10.3% of women aged 10–19 years suffered sexual assault. This agrees with data from the Organization for Economic Cooperation and Development (OECD) where it is mentioned that Mexico occupies the first place worldwide in CSA [10].

It is known that there are direct medical consequences for CSA victims such as wounds, bruises, tears in the external genitalia or in the vaginal or anal areas, vaginal discharge, chronic genital pain, recurrent urinary tract infections, enuresis, encopresis, abdominal pain [11], unwanted pregnancies [12], sexually transmitted diseases, like syphilis, gonorrhea, and trichomoniasis presenting the highest incidence [11, 13] and HIV [14].

Although the medical consequences are usually more evident, a CSA victim often experiences a severe impact on the emotional, behavioral and cognitive spheres that are usually expressed through poor academic performance, attention and concentration problems, memory deficits and EF [15] and PTSD. This is associated with anatomic-functional changes in different brain structures. These alterations are due to the participation of glucocorticoids in the basal activity of structures such as the amygdala, the hippocampus and the medial prefrontal cortex [16, 17].

In this sense, various investigations have focused on the study of autobiographical memory and verbal memory in subjects with a history of child victimization [18, 19]. However, little is known about implicit memory in minor victims of CSA.

Implicit memory is a type of long-term memory that involves the unintentional recovery of previously presented material [20]. For their study, multiple experimental designs have been used, as well as tests and tasks where the intention and the conscious effort of the subject to retrieve previously studied information are not usually considered [21]; such as perceptual priming or semantic priming [20]. Priming is defined as a helper in the execution of a task induced by previous exposure to its elements or components [22], which takes place without it being necessary for the subject to remember or recognize such elements [23].

It is imperative to mention that a large part of the memory evaluation studies, specifically implicit memory, have been carried out using pencil and paper techniques. In this sense, tests that are based on the exclusive use of this technique have several important differences from their computerized counterparts. Although, the time to answer the test is similar and the grade obtained is identical. The accessibility, the qualification time and the percentage of error are very low in the computerized one [24].

The following describes the model of the Intelligent System for the Evaluation of Implicit Memory with Semantic Emotional Stimuli (IS-EimSeS), which will be implemented on a mobile device, the model is designed to identify and process the evaluation of implicit memory with semantic emotional stimuli in girls and adolescents with sexual victimization, as shown in Fig. 28.1 (this design has been using resources from [25]).

To determine the words with emotional content, public schools in the municipality of Tijuana, Baja California, were used. With a total of 408 students from 6 to 17 years old ($\bar{x} = 12.04$), four coexistence sessions were held at each educational level. In the last session, individually, each of the minors was asked about the words that caused them joy and words that caused fear. Based on the children's response, a list of words was developed that evoked joy and fear.

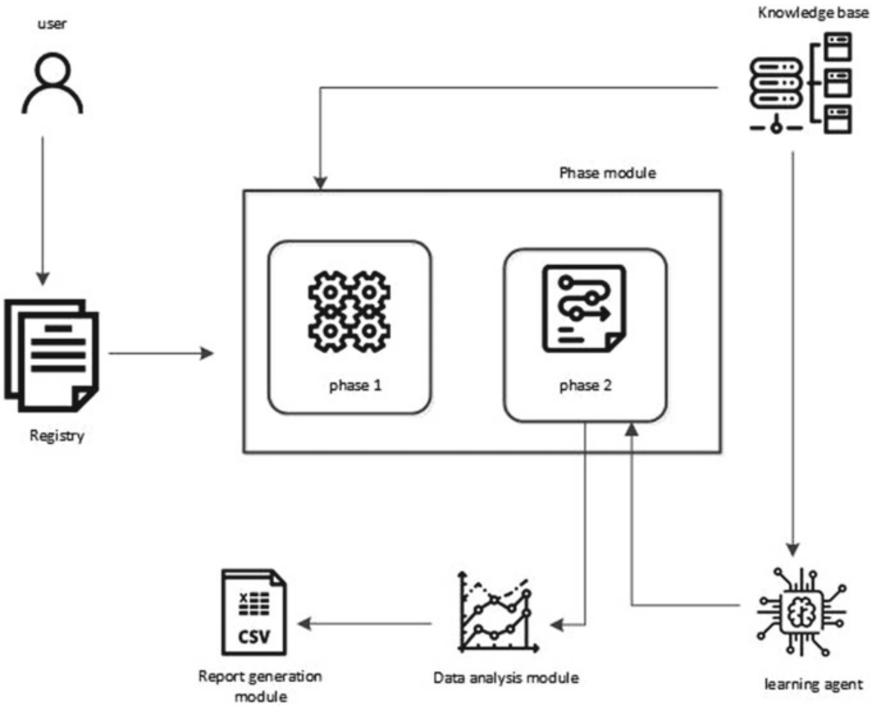

Fig. 28.1 Proposed model of the intelligent system IS-EimSeS

On the other hand, words with a neutral content were obtained from Neuropsi Attention and Memory [26], TAVEC [27] and Infant Neuropsychological Assessment-2 [28].

After preparing the list of affective words obtained by the minors of the different educational levels, four coexistence sessions were carried out with 17 minors aged 6 to 15 years old ($\bar{x} = 10.47$) who resided in foster homes in the municipality of Tijuana.

In the last session, the Self-Assessment Manikin (SAM) [29] test and the word order test were applied. For the latter, the minors were given the cards with the affective words with the instruction that they should organize the cards in descending order, the first word being the one that made them feel each emotion the most (fear and joy respectively).

In the SAM test, the minors rated a set of 180 words (fear, joy and neutral) individually, based on a valence scale (pleasant–unpleasant) and another of activation (relaxed–activated).

Finally, to obtain the two distracting stimuli, words were selected based on the following criteria: the same number of syllables, that the initial and final letters of each word were the same as the selected word with emotional content.

In this sense, the IS-EimSeS Intelligent System processes the information, which will be entered by the user, starting with a record.

At the end of the registration, we proceed to the module, which will contain two phases, which will be called phase 1 or study phase and phase 2 or test phase and will be followed by a focus point, the study phase has a knowledge base of 60 words, 20 positive, 20 neutral and 20 negative, which are displayed randomly, below the word there will be five Likert scale circles [30] (from one to five) where the user will select their range of familiarity and when clicking on an option, where one represents the minimum and five represents the maximum.

At the end of phase 1, the instructions of phase 2 will be shown, the test is carried out by the training agent, the agent has a knowledge base of 120 words, the 60 shown in the first task and the other 60 will be new words, being a total of 40 positive, 40 neutral and 40 negative displayed randomly. The screen will have the word centered in large and legible type and a certain number of letters will be missing from this.

Below this word, there will be three options that can be selected by the user by pressing on any of them, the three options must have the same number of syllables and must start with the same letter.

When the user presses the button, it will change to sky blue and the next word will be displayed. After responding to each stimulus, there will be a transition time of 3000 ms before moving on to the next word.

The data indicated by phases 1 and 2 are sent to the data analysis module, which is in charge of calculating the results, which will be displayed in the form of a graph, once the data are generated, these are sent to the model called result generator, in this module, the data are saved in CSV format, to facilitate further analysis.

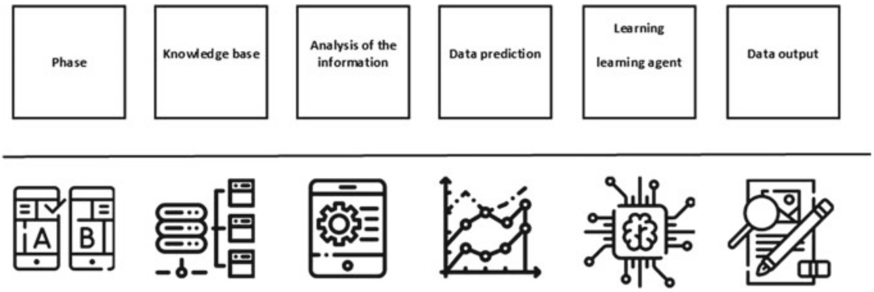

Fig. 28.2 Proposed methodology of the intelligent system IS-EimSeS

28.4 Design of the Proposal

To achieve the evaluation of the intelligent system, IS-EimSeS contextual study was carried out with users to verify the effectiveness and efficiency of the proposed model, a mobile application was developed, in the Android operating system, which is named Evaluation of Cognitive Semantic Perception (EPerSC).

The study was carried out with three control users from 9 to 14 years old, not users to whom the study is focused; this is due to the pandemic that we are currently experiencing (COVID-19).

The proposed methodology, for this study, is carried out in six stages: the first one is the realization of the phases by the user (two phases will be realized), with these data of the user, in the second stage, we proceed to the acquisition of the knowledge, in the third stage, we analyze the data, with these data, in the fourth stage, we proceed to the prediction of the data, Having these values, the system is intended to learn and grow their learning, this is done in stage 5, and performed by the Learning Agent (LAp), finally in stage 6 is generated the file for the display of data, as shown in Fig. 28.2 (this design has been using resources from [25]).

28.5 Learning Agent (LAp)

The Learning Agent (LAp) will be responsible for analyzing the structure of the words to be displayed in phase 2, in addition, this agent will be in charge of coordinating the other actors in the system. The agent has the role of learning and generating knowledge, this learning is generated from the data available from the information analysis modules and the prediction module.

28.5.1 Conversation Control

A FIPA ACL message contains a set of one or more message parameters. Precisely which parameters are needed for effective agent communication will vary according to the situation; the only parameter that is mandatory in all ACL messages is performative, although it is expected that most ACL messages will also contain sender, receiver and content parameters.

If an agent does not recognize or is unable to process one or more of the parameters or parameter values, it can reply with the appropriate not-understood message.

Specific implementations are free to include user-defined message parameters other than the FIPA ACL message parameters. The semantics of these user-defined parameters is not defined by FIPA, and FIPA compliance does not require any particular interpretation of these parameters. The prefatory string (X) must be used for the names of these non-FIPA standard additional parameters.

Some parameters of the message might be omitted when their value can be deduced by the context of the conversation. However, FIPA does not specify any mechanism to handle such conditions, therefore those implementations that omit some message parameters are not guaranteed to interoperate with each other.

The full set of FIPA ACL message parameters without regard to their specific encodings in an implementation. FIPA-approved encodings and parameter orderings for ACL messages are given in other specifications. Each ACL message representation specification contains precise syntax descriptions for ACL message encodings based on XML, text strings and several other schemes [31].

This section describes the control of the conversation between the learning agent and the decision-maker. Table 28.1 shows the conversation identifiers of the learning agent, with its three variables.

Table 28.1 Learning Agent conversation identifiers

Element	Description	Reserved values
LApi.F2.STATE = (i), where i can have 2 states (exists, does not exist) LApj.F2.OBJ = (j) where j can have 2 states (correct, not correct) LApk.F2.STATE = (k) where k can have 2 states (in time, out of time)	Introduces an expression (a conversation identifier) that is used to identify the ongoing sequence of communicative acts that together form a conversation	• True • False • Exists • Does not exist • Correct • Not correct • In time • Out of time

28.6 Evaluation of Cognitive Semantic Perception (EPerSC)

The EPerSC application was analyzed and developed for mobile devices with Android [32] version 5.1 “Lolipop”.

EPerSC is the software development instrument for measuring and characterizing the performance of 8- to 12-year-old girls with PTSD-CSA in a semantic priming task with emotional (fear and joy) and neutral stimuli that support the performance of the said measurement.

28.7 Results

28.7.1 Evaluations of: Functionality, Usability, Feasibility

When starting with the evaluations of functionality, usability, feasibility of the application EPerSC, to verify the stability of the intelligent system IS-EimSeS, as well as the learning of the agent with users, the following conclusions are reached.

The learning agent efficiently performs its functionality, so the IS-EimSeS system has an adequate functionality.

Five quality components were considered:

- Learnability: How easy is it for users to accomplish basic tasks the first time they encounter the design?
- Efficiency: Once users have learned the design; how quickly can they perform tasks?
- Memorability: When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- Errors: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- Satisfaction: How pleasant is it to use the design? [33].

The following aspects were considered for the usability test:

- Functional testing (functional testing), the following questions were considered:
- Can it be easily installed and uninstalled?
- Do all contents work as intended?
- Can it continue to be used without any problems after it has been minimized?
- Does the application crash and crash?
- Does the user receive a corresponding notification when an error occurs?

Usability test, the following questions are considered in a usability test:

- Can its operation be understood in an obvious way? Are explanations provided in the case of more complex functions?

- Is the content placed in such a way that the user can access the most important functions without hindrance?
- Do the placement of content and the composition of the interface follow a coherent concept that is recognizable in all aspects of the application and intuitively intelligible?
- Are the buttons well positioned and designed in the right size? Users with reduced mobility should not be forgotten.
- Is the wording of the texts sufficiently precise and formatted in terms of readability? [34].

The sample size for evaluation was 20 users, and each user analyzed the application in at least 20 interactions, which could be considered small, but given the current conditions of COVID-19, it is a sample that can be a starting point.

After applying the tests, the results obtained by the users indicate an easy and accessible use of the application.

28.8 Conclusions

The objective of this proposal has been to analyze and design an intelligent system, based on the agent paradigm, to support the Evaluation of Implicit Memory with Semantic Emotional Stimuli, which is implemented in mobile platforms in the Android operating system. This application supports researchers to support the evidence-based study of implicit memory and emotional processing in CSA victims.

In the same way, it contributes to the field of neuropsychological tests through technology, reducing the errors of false positives or false negatives that may exist when the tests are done with pencil and paper. In addition to the above, it systematizes the application of the task and provides certainty of the results to the researchers. Finally, it proposes a new scenario for the neuropsychological assessment at a distance, which responds to the research needs derived from the COVID-19 pandemic.

28.9 Future Work

Currently, the process is being analyzed to determine those skills expressed by the girls when performing the two phases, and a measurement protocol is being considered to support the data analysis since when the tests are performed in person (after COVID-19) a considerable number of evaluations will be generated.

It is also analyzed, getting to have a system with more than one agent, for the classification of data, is more efficient, although the results needed are direct not discrete, you can visualize the use, fuzzy logic, this could give a different perceptive of data analysis.

The design of a dashboard that could be used to support research may also be considered.

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Chapter 29
Multiagent System for Home Appliances on Internet of Things (MAS-HAIoT)

Carlos Alberto Carrisosa Camacho, Arnulfo Alanis, Javier Sotelo, Karina Romero, and Samantha Jimenez

Abstract Currently, there are various smart devices for homes, which have different functions that support domestic tasks such as keeping the pantry always full, accessing recipes, and creating shopping list. These devices have a high cost, for this reason, it arises in creating a low-cost smart device, which contains the options described above. In addition to having a module called "nutrition", with which you can keep a record of meal plans and a diet provided by a nutritionist at a cost minor, for this, a mobile application was created called: Mobile application for smart appliances (MoASa) given the current situation due to the COVID-19 pandemic. It has resulted in many people taking shelter in their homes and taking care measures such as avoiding going out to non-essential situations, this pretends to be a support to carry out grocery shopping and avoid going out as little as possible. The analysis and design of the device contain several agents, this article described the nutrition agent, the food ontology, its semantic network, hardware, and software for communication with multiple applications that support the user.

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29.1 Introduction

With the development of mobile technologies, many situations are at hand, such as a smartphone or a tablet, and with these devices obtain applications that allow you to do a large number of things such as those proposed in this project, a mobile application installed on an Android operating system tablet [1], embedded in the refrigerator.

The multiagent system that is presented in this proposal is composed of a set of agents, who will be in charge of several processes, such as: mailing list, orders, user profile, inventory, supplier, and nutrition, the latter agent will be in charge to carry a food plan, designed by a nutritionist for which data such as: eating habits, weight, body mass index (BMI) are taken into account, these data are provided through the application and the expert, from this point decides what type of diet the user needs, for this, it assigns him a food plan to follow with a maximum of daily calories that he must consume; with the aforementioned food plan, a list of products to be consumed are obtained with which the order is made from the mobile application for smart appliances (MoASa).

On the other hand, cloud services are used to manage the databases, it is also contemplated with the use of a Raspberry Pi that will contain several sensors, all of them together, it is intended to make a refrigerator convectional, a device smart internet of things.

This article presents the analysis and design of a prototype, which includes software and hardware, which has frequent use in homes and is in the home automation category. In addition to the above, it will use the intelligent agent paradigm, this prototype will communicate with multiple applications with which they are obtained: food organization, supply record, nutritional plans, and monitoring of the same together will generate satisfaction for the user who currently wants to have practicality and speed in each of the daily activities, such as: reminders of the products to be added to the shopping list, consult the inventory of the products in the refrigerator and in the pantry as well as take into account entertainment for children while the user cooks, to be able to check the weather, to listen to music, etc.

29.2 Internet of Things

Internet of things (IoT) is a global infrastructure for the information society, which allows advanced services through the interconnection of things (physical and virtual) based on existing ones and on the evolution of interoperable information and communication technologies [2].

This architecture allows intercommunication between different elements, equipment, and objects on the network and exchange information and specific data of the world that surrounds them. Today a large number of smart devices communicate with each other and with other control systems, in addition to communicating with people. This concept is known as M2P (Machine-to-Person Communications) [3].

The internet of things can find on almost anywhere exist smart devices that help with different tasks thanks to the capacity of communication that occur among sensors, the cloud, and devices, which we can find in the homes, industries, schools, etc.

We can find the internet of things almost anywhere, there are smart devices that help in different tasks thanks to the communication capacity that exists between sensors, the cloud and devices, which we can find in homes, industries, schools, etc.,

It is an area of computing that aims to have technologically enriched spaces that proactively support people in their daily lives. Among the main characteristics that are presented in (AmI) systems are being able to detect information from the environment, reason with the accumulated data, and select the actions to take in order to benefit its users [4]. Among the fields of application found, the following stand out: smart homes, health services (hospitals, assistance, and emergency services), workspaces, and educational environments.

When the concept of IoT is introduced to the smart home application, this covers a much wider range of control. For example, smart home involves security, energy management, thermostat temperature control, family entertainment, and family businesses [5].

29.3 Nutrition

Nutrition involves processes by which the body transforms and incorporates nutrients obtained from food and fulfills the functions of supplying energy, providing materials for the formation, renewal and repair of body structures, and supplying substances to regulate metabolism, in addition to supplying the necessary energy for the maintenance of the organism and its functions [6].

The study of the origin of diseases from the components of the diet and the state of health provides knowledge with which eating plans can be made; however, the eating habits of users do not allow such plans to be taken into account food, all this due to the great variety of foods available, especially in ultra-processed products (with high energy content, sugars, fat, and salt) with a low purchasing value, and with abundant advertising to promote consumption [7].

29.4 Intelligent Agent

They are programs that help users to perform certain actions, for example, fill out forms, choose products, find a certain thing, etc., they are also called softbot (robot software). There are also other chat applications that companies use to resolve user doubts, intelligent agents use software tools and services based on people’s behavior [8].

29.5 Development Tools

29.5.1 Software

Android Studio is the official Integrated Development Environment (IDE) for Android app development, based on IntelliJ IDEA. In addition to IntelliJ's powerful code editor and developer tools, Android Studio offers even more features that increase your productivity when developing Android apps [9].

DB Browser for SQLite (DB4S) is a high-quality, visual, open-source tool for creating, designing, and editing SQLite-compliant database files.

DB4S is for users and developers who want to create, search, and edit databases. DB4S uses a familiar spreadsheet-like interface and complicated SQL commands do not need to be learned [10].

29.5.2 Hardware

The Raspberry Pi 3 Model B + is the latest product in the Raspberry Pi 3 range, with a 64-bit quad-core processor running at 1.4, 2.4, and 5 GHz dual-band wireless LAN, Bluetooth 4.2/BLE, Faster Ethernet, and PoE Capability through a separate PoE HAT Dual-band wireless LAN comes with modular compliance certification, allowing the board to be designed into end products with significantly reduced wireless LAN compliance testing, improving both the cost as the time to market [11].

29.6 Ontology

The design of the MAS-HAIoT is based on the paradigm of intelligent agents, for its development, an analysis of the information based on ontologies was carried out, said ontology was carried out on the basis of food to define the concepts of the different domains and the relationships between them.

Ontology is a form of representation of knowledge that results from selecting a domain or field of knowledge, in which types, properties, and relationships between entities are defined.

Ontologies, through the semantic web, allow information to be organized in such a way that it can be searched, extracted, processed, and drawn conclusions, with terminology easy to understand by the actors involved: computers, users, and companies.

In computer science, an ontology is a model where specific knowledge is represented in the most real way possible, where individuals (instances), classes (concepts), attributes, and relationships intervene [12].

29.7 Proposal

In total, according to figures from the UN [13] fund for Food and Agriculture Organization (FAO) [14] for October 2017, 1.3 billion tons of foods produced for human consumption are lost, a third of total world production. While in America and the Caribbean, it is estimated that 6% of the world's food loss is wasted [15], in México, according to SEDESOL [16] figures, 10,431,000 tons of food are wasted, 37% of the country's production [17].

The MAS-HAIoT system model describes the operation of how the user uses an intelligent device (Tablet), to access the system and obtain the information about the products in the refrigerator. Once this process is done, the device called Raspberry Pi (module sensors) generates the capture information elements (food) in two ways, first stored in a database which is hosted in the cloud, second Raspberry Pi device sends the data to the nutrition agent or vision agent, to their identification. These data are classified by means of neural network, and finally, the food control module is responsive for maintaining the food in the pantry with the requirements generated by the nutrition agent, for this process, a list is generated, so that, in the next task, to make the purchase and payment, after all this process, the Raspberry Pi returns the information to the database, as shown in Fig. 29.1.

Nutrition is one of the main determinants of chronic diseases, and if important changes were made in the style of diet, there could be benefits in the health of the population [7].

For this particular article, the nutrition agent is presented and developed, which will support users who can carry out nutritional control with which they will be able to: register eating plans, weight, body mass index, in addition to creating lists of products not only those included in their diet but also the products for the home and

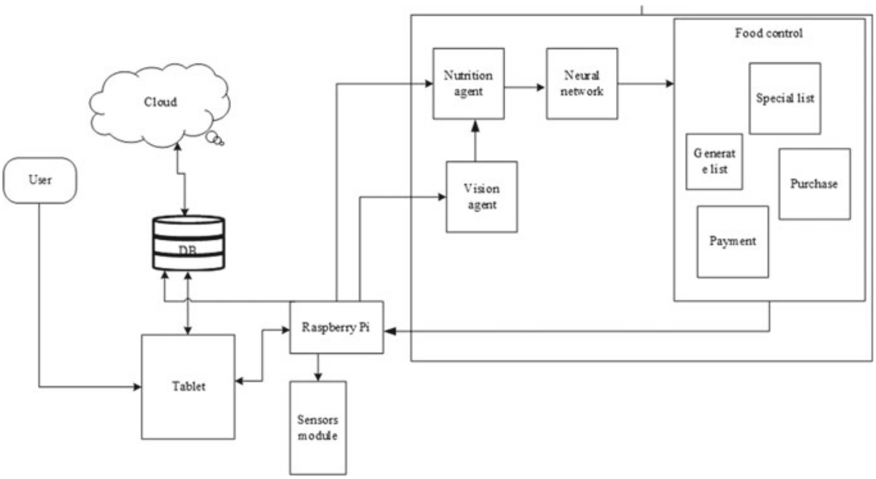

Fig. 29.1 MAS-HAIoT model

later make the purchase from the mobile application, Thus the paper list would be replaced by a digital list, the semantic network analysis would be carried out, then the ontology and after the analysis in PAMA [18].

In the current situation, developments such as this proposal must have a vision of growth, and with the passage of time wait for it to have greater acceptance by the end user, whether it is consumer users and service providers.

The semantic network of the Nutrition Agent was initially brainstormed, for this, there are several points of reference such as: nutrition, users, file, food plan, application, and order list that together make up the nutrition module of the MAS-HAIoT. For this, the mobile application for smart home appliances MoASa was developed, which is briefly described below.

The design of the food ontology is built, taking into consideration the nutrition classes (which is divided into the following categories: diets, nutritionist, and user) and foods in which it is made up of the categories: cereal seeds and derivatives, seeds of legumes and derivatives, other seeds, algae and fungi, fruits, vegetables, tubers, bulbs and roots, milk and derivatives, egg, meat, organ meats and derivatives, fish and shellfish, sugars, honey and sweets, baby foods, dressings, drinks alcoholic and non-alcoholic and miscellaneous. Data were collected from the document tables of composition of food and food products (condensed version 2015), INCMNSZ [19]. In addition, information was obtained from visits to supermarket websites such as Sam's Club [20], Soriana [21] and Chedraui [22], which have online shopping services.

For the analysis and design of the semantic nutrition network, it is contemplated that the user on the platform is registered and therefore has a file, in the latter, the medical questionnaire applied to the user, initial weight, final weight, and index will be recorded of body mass, the nutrients required for the eating plan are selected, a type of diet is selected and the user is assigned the meal plan according to calories and portions for 21 days, the user uses the application creates shopping lists and generates orders as shown in Fig. 29.2.

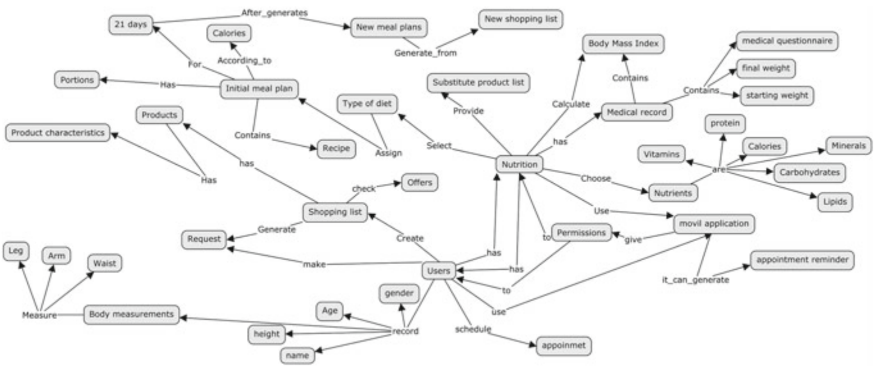

Fig. 29.2 Semantic network agent nutrition

Fig. 29.3 Food and nutrition ontology

Next, the pantry classification ontology designed in the Ontology Web Language (OWL) and the Protégé tool [23], is described, as shown in Fig. 29.3.

29.8 PAMA

Before starting the analysis and development of the agent, it is necessary to have the set of elements that intervene in the system such as: perception and actions are all the things that are involved in the system, the goals that you want to obtain from each component and the environment where the agent will operate, all these data are gathered in a matrix like the one shown in Table 29.1, and it is known as the PAMA matrix [18].

The development of the nutrition agent based on the PAMA specifications (some of the elements considered are listed) is shown in Table 29.1.

Table 29.1 PAMA—nutrition agent

Agent	Perceptions	Actions	Goals	Environment
Nutrition	– Calories – Initial weight – Portions – Initial meal plan – Recipe – Quotes – User types – List of substitute products – New meal plan – Final weight – Types of diet – Preferences – Proceedings – Nutritionist – Body mass index	– View calories – Record starting weight – View menu – View/register recipes – Record appointments – Change plan (21 days) – Notification of appointment – Record final weight (21 days) – Hypocaloric, Mediterranean, DASH, Flexitarian – Calories, carbohydrates, minerals, proteins, vitamins, lipids – Digital nutritional file – Nutritionist record – Underweight, normal, obese, morbidly obese, severely obese, overweight	– Control daily consumption – Know the progress – Maintain a balanced diet – Learn what to eat – Make healthy dishes – Nutrition monitoring – Validate application use with restrictions of each user – Buy necessary products – Consume equivalent products – Buy products – Number of products	– User – Nutritionist – Meal plan – Foods – Application – Supermarket – Mobile app – Cell phone – Tablet – Database – Weighing machine – Proceedings – House

29.9 Mobile App for Smart Appliance MoASa

For the implementation of some of the MAS-HAIoT system models, an application was developed for mobile devices; this application allows the user to keep a record of the food in their home, allowing them to control what they consume, since these records have information such as the expiration date of the food, the calories, the quantity, etc.

Among other features are recipes, shopping lists, a health module where users who have a particular diet and have a follow-up with a nutritionist can keep track of their diet with a shopping list, adapted to their style of life, and a calendar with the right foods and portions according to your case, as shown in Figs. 29.4 and 29.5.

Fig. 29.4 Screen with lists of orders of a user

29.10 Results

The analysis of the intelligent system, MAS-HAIoT with the support of the mobile application for smart appliances—MoASa, starts before the COVID-19 pandemic, without imagining that the current situation would completely change the way we interact as a society, taking account into the recommendations made by governments and the WHO, on the points that people stay in their homes and avoid going out if they do not have essential activities. By virtue of the above in the month of April 2020, a survey was conducted online from which a sample of 100 people from different parts of Mexico and the USA was obtained, this survey generated results that quantitatively show the interest of people's in making purchases of their errands

Fig. 29.5 Main screen

through an application, given the above, it strengthened the confidence to continue with the development.

This analysis, currently, has a strategic ally (which observes a good development and visualizes a medium-term growth), so that once the system is finished, a test can be carried out.

29.11 Conclusions

The development of an intelligent platform that ranges from software and hardware, in the home automation category, sets the standard for the prototype to communicate with multiple applications with which it is obtained: food organization, supply record, nutritional plans, and monitoring of the same together will generate satisfaction to the user who currently wants to have practicality and speed in each of the daily activities.

Also support to users to be able to take a purchasing plan in their homes with the supporting technology, while online shopping is not new if a new scenario for users is presented, which given the needs arising from the COVID-19 pandemic.

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Chapter 30
Multiagent Emergency Triage Classification System for Health Monitoring

Fabiola Hernandez-Leal, Arnulfo Alanis, Efraín Patiño, and Samantha Jimenez

Abstract In this paper, a multiagent classification system is proposed for the detection of cardiorespiratory abnormalities. The system takes as inputs, the blood oxygen saturation and heart rate and classifies the vital signs using the emergency triage used in Mexico. The complete system has two agents who are responsible for obtaining and classifying the information following the emergency triage. During the classification stage, the system integrates fuzzy logic that helps generate the categorization of the data; linguistic rules were generated for both the input values (oxygen saturation and heart rate) and for the output values (data classification according to the triage). The results obtained were subjected to validation by using metrics in classification systems.

30.1 Introduction

The new challenge in the health field is to monitor a patient's physiological parameters continuously, under natural physiological conditions, and in any environment. These systems will provide an increasing number of solutions for post-operative rehabilitation, to expedite recovery, and for independent living for the elderly [1].

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The Internet of Health Things (IoHT) occurs when objects exchange and process data to monitor a patient's health status. The concept of IoHT is closely related to the idea of using information and communication technologies in the health field, usually referred to as mobile health, it is also related to ubiquitous health, allowing the use of mobile computing to monitor patient's health anywhere, anytime [2].

Activity monitoring systems have the power to offer a higher life for older adults [3], as they are used to maintain an up-to-date visualization of the person's physiological parameters. Diagnostic devices may monitor the patient's vitals continuously through portable biomedical sensors, along with applications that capture and interpret data.

One of the most commons and useful tools for monitoring a patient's health is pulse oximetry. Oximetry is the spectrophotometric determination of hemoglobin oxygen saturation. Pulse oximeter is a completely non-invasive technique and provides continuous real-time estimates of arterial oxygen saturation [4].

In this paper, we present a multiagent classification system that analyses the blood oxygen saturation (SpO2) and heart rate (HR) to assess the risk of a patient based on Mexico's emergency triage. The information is obtained through a data collection agent and a classification agent based on fuzzy logic's proper categorization. As an output, the system gives the triage category from oxygen saturation and heart rate.

30.1.1 Emergency Triage

The term triage refers to selection, categorization, and prioritization. In the medical field, it is a process in which the order of care priorities is determined, allowing patients to be rapidly evaluated and selected according to their clinical and prognostic statuses [5].

The objectives of triage systems are to (1) identify patients in life-threatening situations, (2) ensure prioritization based on a classification level, (3) decide the most appropriate area for patient care, (4) provide information on the care process, and (5) improve patient flow and service congestion [6]. Depending on the emergency that is being presented, it will be the type of triage to be used.

In this work, we use the emergency triage by the Mexican Institute of Social Security (IMSS), shown in Table 30.1, it is worth mentioning that each category indicates the valid parameters of SpO2 and HR that are used to give care to the

Table 30.1 Emergency triage

	Red	Orange	Yellow	Green
Situation	Resuscitation	Very serious	Serious	Not serious
Attention	Immediate	<10 min	<30 min	120 min
SpO2 (%)	<80	80–89	90–94	>95%
HR (BPM)	>130 bpm	120–130 or <40	111–120 or 40–49	50–120

person who is in the hospital or clinic as well as the time in which the person must be cared for, the label for the category and the color assigned to it.

30.1.2 Pulse Oximeter

Pulse oximetry is a technique used to measure oxygen saturation (SpO2) and heart rate non-invasively. It is a method commonly used clinically, either in intensive care or in outpatient clinics.

The use of pulse oximetry has helped reduce the need for invasive arterial blood gas tests and increases the detection of hypoxemia [7, 8].

30.1.3 Oxygen Saturation

A hemoglobin molecule can carry up to four oxygen molecules, which is described as "saturated" with oxygen. If all binding sites in the hemoglobin molecule carry oxygen, hemoglobin is said to have a saturation of 100%.

Oxygen saturation is commonly represented as SpO2. A healthy person with normal lungs, breathing air at sea level, would have an arterial oxygen saturation of 95–100% [9].

30.1.4 Heart Rate

Heart rate (HR) is an easily accessible vital sign that contains important forecast information. Several studies indicate that normal resting HR values in adults are between 60 and 90 beats per minute (bpm), the American Heart Association defines the normal sinus heart rate between 60 and 100 bpm. However, these commonly accepted standards are derived from the HR recorded at the clinic that may not be representative of the real world [10].

30.2 Fuzzy Systems

Fuzzy systems have been used in different areas, from those oriented to computer vision using autonomous robots [11] to medicine through the implementation of systems that detect anomalies by analyzing medical images [12], giving the opportunity to make use of these techniques for implementing classification systems.

Broadly speaking, a membership function (MF) is a continuous curve that defines the degree of any variable belonging to a linguistic variable [13]. A fuzzy logic-based system analyses the membership of the rules that are being generated to analyze the system within a range of 0–1. So, if the rule to be analyzed is closer to 1, then that value belongs more in the range, otherwise, there is less membership.

A fuzzy set is represented by:

$$A = \{(x,\ \mu_A) \mid (x \in X)\} \tag{30.1}$$

where μ_A is the membership function of the fuzzy set A, which maps each element of x to a degree of membership; set X refers to the universe of discourse and can be a discrete or continuous space [11].

Fuzzy logic is a widely used technique due to its practicality, computational efficiency, certainty, and easy integration with other techniques by providing a decision-making mechanism as it can be implemented to perform mathematical analyses and approximations for linear, non-linear, or dynamic problems as well as build models of inference to solve problems [14].

Fuzzy logic has been implemented in classification systems that are geared towards predicting diseases such as hypertension [14, 15], diabetes [16, 17], heart problems [18, 19] breast cancer [13, 20], to name a few. The systems analyze different ways to add fuzzy logic with some other machine learning techniques and aim to support the diagnosis of these diseases, providing improvements in both intervention time and the use of adequate resources.

30.3 Methodology

It is proposed to create an intelligent system to help classify the vital signs of oxygen saturation and heart rate. The system has four stages, in the first stage, a body sensing is performed by using a pulse oximeter, which is placed on the finger. The data are saved in a CSV file that will be analyzed by the system. In the end, it will give us as output the category of the emergency triage.

It is important to mention that the system is divided into two intelligent agents, which help to collect the data (data collection agent) and classify it (classification agent), as shown in Fig. 30.1.

For the data categorization, a set of linguistic rules were created, as shown in Table 30.2, which were analyzed from the information obtained from the triage. The rules were adjusted as the experiments were conducted, as it is intended to obtain a customizable classification system.

In this work, we have considered a combination of two types of MF, which are Triangular MF and a Trapezoidal MF, shown in Figs. 30.2, 30.3 and 30.4.

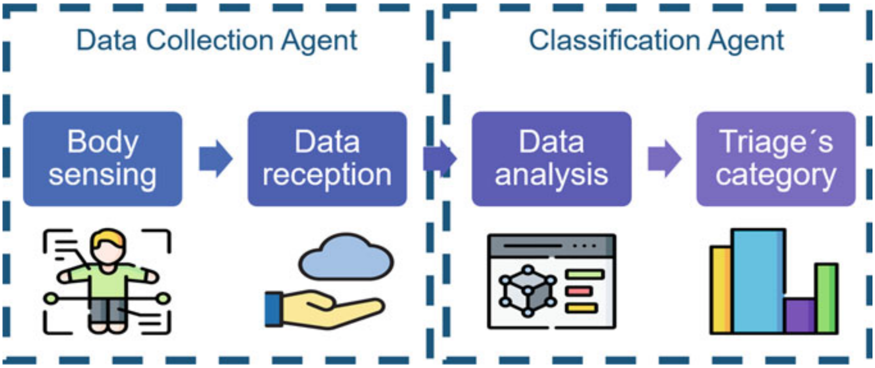

Fig. 30.1 Methodology

Table 30.2 Linguistic rules

HR	SpO2			
	<80%	80–89%	90–95%	>95%
<50 bpm	Resuscitation	Very serious	Serious	Serious
50–110 bpm	Very serious	Very serious	Serious	Not serious
111–120 bpm	Very serious	Very serious	Serious	Not serious
>120 bpm	Resuscitation	Very serious	Very serious	Serious

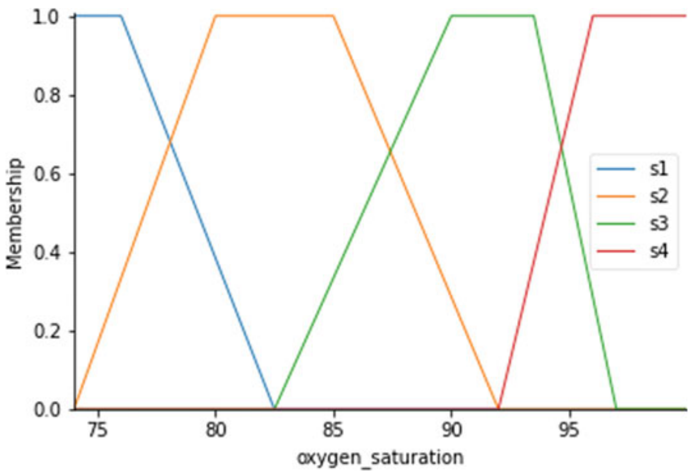

Fig. 30.2 Input membership function for oxygen saturation

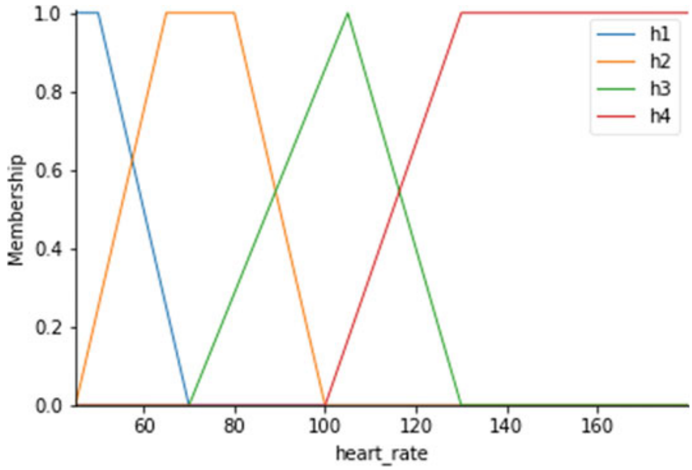

Fig. 30.3 Input membership function for heart rate

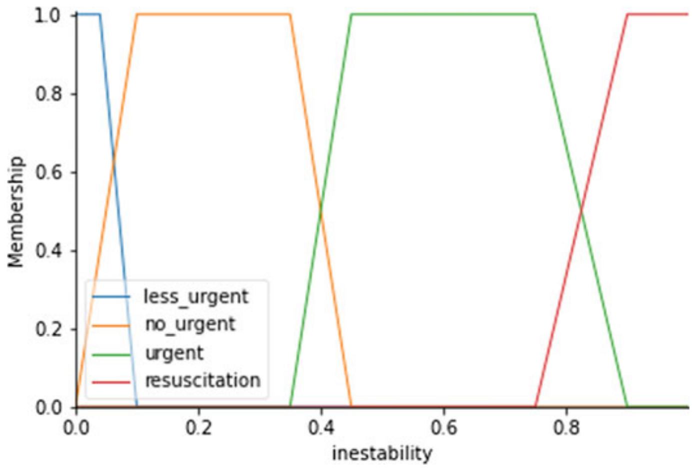

Fig. 30.4 Output membership function for classification state

30.4 Experimental Stage

For SpO2 and HR pattern recognition experiments, four people participated who had their readings taken by using the pulse oximeter for 30 min, which gives 1781 readings from de pulse oximeter approximately 1 reading per second during 7 consecutive days in a resting scenario, i.e., participants were watching television or listening to music. At the end of the 7 days, each person provided 12 467 readings, that is 49 868 readings in total. The participants have the following characteristics:

1. A healthy 32-year-old female.
2. An overweight 25-year-old female.
3. A 58-year-old female with morbid obesity, diabetes, and kidney disease.
4. A 58-year-old male with morbid obesity and hypertension.

The 32-year-old female served as a reference as she has no previous diseases of any kind. The readings obtained were tested and was established that regardless of characteristics, all participants had SpO2 and HR readings within the ranges accepted by medical organizations. Once the body signals were obtained, the development of algorithms that simulated the behavior of SpO2 and HR was continued to generate various scenarios to analyze it.

Using the information of the patients, the rest values for the vital signs and the information in the emergency triage and an algorithm to simulate the data were developed. The algorithm is as follows:

1. First, a possible scenario from the emergency triage was selected.
2. For this scenario, a random value for SpO2 and HR, S_i, and H_i, are selected based on the distribution for each one of the triage scenarios.
3. At each time *t*, the values for each vital sign are updated and stored based on:

$$V_{t+1} = V_t + r(-1, 1) * s \tag{30.2}$$

where V_{t+1} is the next value of the vital sign, V_t is the current value, $r(-1, 1)$ is a random binomial number with output $\{-1, 1\}$, and σ is a random increment based on the current value. The increment σ is calculated using the statistical data from the experiments.

4. The process will continue until the size of the vector is met.

For the experiments, we simulated vectors of 250, 500, 1000, and 2000 (each step indicates a second). The data were made with different durations with the intention of validating the certainty of the system because it must grant similar responses regardless of the sample size. From these vectors, the average of SpO2 and HR was used for the analysis. In total, there were 10 experiments with each of the vectors and for each triage category; therefore, a total of 37 500 data per category were handled.

The confusion matrix was used for data validation, which allows data accuracy to be obtained through various metrics [21, 22]. From the confusion matrix, accuracy, precision, and recall were calculated.

30.5 Results

The performance of the proposed system was tested using the accuracy, precision, and recall metrics. The results of this analysis are shown in Tables 30.3 and 30.4. The calculated metrics show a good performance of the proposed system, with an

Table 30.3 Metrics per category

Category	Precision	Recall	Accuracy
Green	0.9459	0.8750	0.9563
Yellow	0.8605	0.9250	0.9438
Orange	0.9048	0.9500	0.9625
Red	0.9737	0.9250	0.9750

Table 30.4 Metrics considering all the categories

Total	Precision	Recall	Accuracy
TP = 147	0.9188	0.9188	0.9594
TN = 467			
FP = 13			
FN = 13			

Table 30.5 Metrics per category: physician analysis

Total	Precision	Recall	Accuracy
TP = 16	0.5333	0.5333	0.8108
TN = 104			
FP = 14			
FN = 14			

accuracy of 0.9594 and a recall value of 0.911 when classifying the correct scenario. The stability in each category allows for an adequate classification system.

Experiments were also conducted where they underwent the analysis through the experience of an emergency physician, who was given a list of SpO_2 and HR values. The physician had to classify these values taking into consideration his experience in the medical field, once the list was analyzed by him, the same list was analyzed using the classification system developed, providing adequate results. For this, the physician had a set of 30 data, and it was also analyzed by a confusion matrix, shown in Table 30.5. The calculated metrics show an accuracy of 0.8108 although the positive observations (precision and recall) were as low as 0.5333, it does not mean the system failed, but the opportunity to implement more experiments.

30.6 Conclusions and Discussions

In general, the classification system gives favorable results and shows potential for further testing with real data. This system brings the opportunity to analyze physiological parameters maintaining an adequate level of certainty regardless of the sample size used, which gives the opportunity to reduce waiting times for the patients and provides a tool for medical workers when evaluating and assigning a patient at a triage category.

It is important to add that the system still has enough scalability capacity to add other physiological parameters such as temperature, age, gender, and body mass index, so that these parameters help further personalize the classification system. For this to be possible, the fuzzy system must be modified; therefore, the linguistic rules must undergo changes and the system needs to be readjusted.

The system can serve as a rapid analysis alternative for medical centers and even at home, since it has an easy-to-use infrastructure, which allows it to be reproducible. This system will only serve as support, it is not intended to be a system that determines an official diagnosis that decision must be granted by a health provider.

Future work includes adjusting the fuzzy system and adding new vital signs to the overall system. Additionally, we are working on an UI, so the system can be operated remotely.

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Chapter 31
Traveling Agents and Indirect Epidemic Transmission

Rajesh Kumar Pandey and M. V. Panduranga Rao

Abstract Indirect spread of infection at a physical location, which might be through the fomite or airborne route, has been studied on dynamic contact networks. We report a framework and some results that uses individual or agent-based simulations. We study this primarily in the context of agents traveling across locations, leaving "droplets" of infection when leaving a location. We abstract out technical details of diffusion dynamics to arrive at a simple tool that facilitates easy what-if analysis.

Keywords Indirect transmission of disease · Agent-based systems · Epidemics

31.1 Introduction

Mathematical study of epidemics is now almost a century old. Starting with compartmental models, and modeling of disease dynamics in a population through differential equations [11], the field of smathematical and computational epidemiology grew with the advent of (powerful) computers. One of the most prevalent approaches is to model populations as contact networks and epidemic dynamics as stochastic diffusion processes over such networks [10, 15, 17]. A contact network is essentially an undirected graph, where the nodes represent individuals in a population and the edges, physical proximity between them.

For the most part, contact networks were used for capturing the transmission of infection between neighbors. However, contact networks have to be dynamic in general—adjacency keeps changing between individuals. Transmission can happen when and only when a susceptible individual is adjacent to at least one infected individual. This models what is called "direct transmission". However, this has an obvious shortcoming while modeling diseases like influenza and various hospital

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acquired infections. Many pathogens can be transmitted to a healthy individual even if s/he is not adjacent to an infected individual. This can, for instance, be through airborne transmission or fomite transmission (cf, resp. [12, 16]). Fomite transmission is defined as transmission via contaminated surfaces, whereas airborne transmission happens primarily through bio-aerosols or small droplets.

With the realization that contact graphs can change with time, came a body of work on disease transmission in dynamic contact networks [5]. Subsequently, these approaches were also investigated for "same place different time" situations, where the contagion can infect susceptible individuals after an infected individual has left the neighborhood, say because of airborne or fomite transmission [19].

Another, relatively new technique is to study epidemic dynamics through Agent-Based Modeling and Simulation. In this approach, individuals of a population are modeled as agents in a computer simulation. Pertinent attributes of the agents, their behavior, and their interaction among themselves and with the environment determine the evolution of the system. The evolution of the system is realized through simulations and analyzed [6, 18]. This provides an attractive alternative when closed form analytical solutions are not easily achievable. There have been several efforts in this direction in the past [9]. The next section briefly discusses example literature in this area. Indeed, even fomite transmission has been studied in this framework [21]. This important work considered a localized scenario—the spread of SARS in a hospital in Hong Kong—through, direct transmission, fomite and aerosol transmission [21]. To the best of our knowledge, there is scant work on the agent-based approach that looks at indirect transmission in the context of agent mobility between geographical locations.

In this paper, we focus on agent-based modeling, with mobility as the central feature, to study indirect transmission. Agents travel between cities and intra-city locations. There are distinct dynamics for direct and indirect disease transmission at a given location. We abstract out the actual diffusion dynamics, since the objective is to construct a tool that enables what-if analyses. Further, realistic diffusion dynamics and data-driven approaches can be plugged into this framework.

Intuitively speaking, our approach is as follows. We model a geographical area (say, a country) as a graph, with the vertices representing locations (both cities and intra-city localities) and the edges, one-hop connectivity. In the absence of indirect transmission, the probability of a susceptible individual getting infected is directly proportional to the infected individuals sharing the same location. To model indirect transmission of infection, we use the following abstraction. When an infected agent (individual) leaves a location, it leaves a "viral load" that decays with time. Susceptible agents at that location, therefore, continue to stay exposed to infection for some time after the infected agent has left. This is in addition to the exposure due to infected individuals who are still present at the location. As mentioned earlier, parameters for simulation can be set that approximates an actual diffusion model. We discuss our approach in detail in Sect. 31.3. We show some interesting what-if analysis in a synthetic setting in Sect. 31.4, and finally conclude with some remarks on future direction in Sect. 31.5.

31.2 Agent-Based Approaches for Study of Epidemics

Agent-based modeling and analysis of epidemic spread is useful when it is cumbersome to adopt analytical approaches for complicated scenarios. Although agent-based modeling and simulation can be computationally expensive, the advent of high performance computation has mitigated this hurdle. Consequently, there has been a huge spurt of efforts in this area [1, 6, 14, 20]. This approach essentially models individuals as agents between whom infection is transmitted. To realistically model proximity that varies with time, localities like home, work, educational, and market places are also modeled. The agents travel among these locations as per pre-defined mobility models. Naturally, transmission of infection happens when agents are close to each other at various times of the day. Parameters like transmissibility, reproduction number, and individual immunity decide the probability that an agent catches the infection. Similarly, recovery is specific to the diseases and individual health. An important advantage of these techniques is the ability to perform powerful what-if analyses, that can then lead to crucial policy decisions [7, 13]. Indeed, several tools have also been developed and used based on this idea [2, 3, 6]. Topically, it has been used to study and predict the epidemic curves for Covid-19 [4, 8, 9] in various contexts.

Of particular relevance to the present paper is the work of Xiao et al. [21], which investigates the role of fomite and bio-aerosol-based spread of the SARS-CoV infection in a ward of a Hong Kong hospital in 2003. They do an extensive analysis of the incident using agent-based modeling and simulations. However, given the nature of the problem they were addressing, they restricted the study to the spread within the hospital only. How can one take into account indirect transmission when modeling travel between distant locations? This paper attempts to provide a simple solution to this question.

31.3 Movement and Indirect Transmission

Our emphasis is on the effect of mobility on indirect transmissions. Toward this, we adopt the strategy of modeling individuals as agents moving along the edges of an undirected graph, where the nodes stand for locations and edges stand for connectivity between two locations. We now discuss these in detail.

31.3.1 The Geography

A *mobility graph* is a directed graph whose vertices are partitioned into N partitions called *cities*. Within a city, there are M vertices that are called *localities*. Each locality can hold a bounded number of *agents*. In this work, we use an Erdos-Renyi graph for both cities and localities within a city, but this is not sacrosanct.

31.3.2 The Agents

We discuss the list of attributes that an agent has, along a justification:

– Home city and home locality: Since we model the geography as cities and localities, we assign to each agent a home city and locality. Wherever the agent is, it has a higher probability of returning to its home locality.
– Itinerary subgraph: The underlying assumption is that an agent has a fixed set of places it visits—workplace, home, and market place.
– Health status with respect to the epidemic. Since we are considering an SIR model, the health values will either be "S", "I" or "R". Additionally, if an agent is infected, it is either "symptomatic" with some probability (or "asymptomatic").

The following "rules" modify the attributes of an agent.

– A stochastic transition matrix that governs the movement of the agent. If the agent's itinerary subgraph consists of k nodes, this matrix is a $k \times k$ matrix. For small itinerary subgraphs, which is typical, this is a small matrix. As mentioned previously, it makes modeling sense for an agent to return to or stay at its home location. Thus, for an agent A whose home location is i, the movement probability in decreasing order is:
  – $p_{i,i}$: probability of staying at the home location (highest)
  – $p_{j,i}$: probability of returning from another *city* j.
  – $p_{j,i}$: probability of returning from another *locality* j.
  – $p_{i,j}$: probability of going to another *locality* in the same city.
  – $p_{i,j}$: probability of going to another *city*.

  Needless to say, this is our modeling intuition and can be changed.
– The health status update rule, as specified in the next subsection.

In this work, agents are initially uniformly spread over different cities at the predetermined nodes of the city. The itinerary is fixed as follows. Each agent is associated with a home city and can move over maximum three nodes within the city and these nodes are connected in a triangle. Apart from the home city, an agent can move to other two other cities which are predetermined for each agent and the agent moves at the three predetermined nodes (which are connected in triangle) in these two cities.

31.3.3 The Infection and Recovery Model

We use the SIR compartmental model, in which agents move from Susceptible to Infected, and finally to Recovered. Once an agent reaches the Recovered state, it stays there. In this work, we devise and use a transmission model that captures direct and indirect transmission in an abstract and conceptual sense. This can be replaced by any other reasonable, biologically sound transmission model [19].

At an instant t, let there be $n(t)$ people in a particular locality, of which $m(t)$ are infectious. Further, let an agent have left t_1 time units ago, another at t_2 time units ago and so on. Then, the probability of a susceptible agent getting infected is modeled as

$$\begin{aligned} p(t) &= \frac{m(t) + \frac{1}{2}^{t_1} + \frac{1}{2}^{t_2} + \ldots + \frac{1}{2}^{t_k}}{n(t) - 1} \quad \text{if} m(t) < n(t) - 1 \\ &= 1 \quad \text{otherwise} \end{aligned} \tag{31.1}$$

with a moving window of k. The first line in the equation holds if there is at least one noninfectious agent. The first term in the numerator signifies direct transmission component, since we consider direct transmission probability to be proportional to the number of co-located infected agents. The rest of the terms denote the decaying indirect transmission through fomite and airborne routes. For example, the agent who has left t_k time steps ago, contributes only $(\frac{1}{2})^{t_k}$. On the other hand, if $m(t) = n(t) - 1$, it means that every other co-located agent is infected, and the susceptible agent is infected with certainty. With probability $1 - p(t)$, the agent does not get infected at the tth time step. Note that within a locality, we assume a complete contact network. Further, an infected agent deterministically recovers in some time steps. The recovered agents get the state of immunity and remain in state R, they never go back to state S or I again. Like in the transmission model, other realistic (e.g., disease specific) recovery models can also be used instead.

31.3.4 The Simulation Algorithm

We implemented our approach in Python. The pseudocode is listed in Algorithm 1. We report simulation results with the following parameters. We create a network of 50 cities and 40 localities with 10000 agents distributed uniformly across them in the beginning. Each agent has an itinerary of three cities, and within each city, three localities. The total population, K, is chosen to be 10000. Initially, a fraction of population (0.05*K) is infected, and the rest are susceptible. At every step of the simulation, the location, city (lines 6–9), and the health status (lines 21–27 if *Infected*, lines 28–39 if *Susceptible*) of every agent is updated as per the rules described in the previous subsection. The probability of an agent remaining in the home city is 0.95, and the remaining 0.05 is equally distributed among other destination cities. Within a city, the probability of staying at the home location is 0.90, while the remaining 0.1 is equally distributed to traveling to other localities within the city (lines 5–8). A detailed description of some functions like $measure_{vl}$ that calculates the viral load (the trailing entries in Eq. (1)) are omitted in the interest of space. Depending on the kind of what-if analyses to be performed, additional steps would need to be updated. For example, we report results on various testing and vaccination scenarios. The testing strategy followed is that at each step, all symptomatic agents, and the co-located agents are tested. We remark here that every infected agent is symptomatic with a certain probability. The number of test kits are limited, and testing one agent involves expenditure of one test kit. We explored two replenishment strategies:

- T_1: The test kits are replenished after a certain number time steps (we use 7 time steps).
- T_2: The test kits are replenished when their number drops to a certain fraction (we use 1/100th of the original number). Note that this can translate to very rapid replenishment of test kits.

The vaccination algorithm, which is triggered if the vaccination flag is set, is straightforward: an agent gets vaccinated when it moves from its home location. This simple procedure is not listed in interest of space.

This simulation is continued either until a fixed period of time, or until some criteria is met, for example, until the number of infected agents goes below a threshold. This constitutes one run of the simulation, which may be repeated to achieve desired confidence. The code can be accessed at https://github.com/rajeshkpandey/networkepidemics/blob/main/Network_epidemics_ABM.ipynb.

31.4 Some Results

We ran the simulations (100 times for each experiment), the initial settings of which is given below

Input, Output and Configurations for the Algorithm 1

- $N = |Cities| \leftarrow 50$, $M = |Nodes| \leftarrow 40$, $p \leftarrow 0.3$, $K = |Agents| \leftarrow 10000$
  $Agent\_Dict \leftarrow \{Agent\_Id : [Node, State, Symptom, H, C1, C2]\}$
  $Node\_Dict \leftarrow \{Node\_Id : [Viral\_Load, Agents \subset Agent\_Dict]\}$
  $State \leftarrow (S, I, R)$, $Symptom \leftarrow (0,1)$
  $Viral\_Load \leftarrow 0$, $Viral\_Flag \leftarrow 0$
  $H \leftarrow \{Home : [Node1, Node2, Node3]\}$
  $C1 \leftarrow \{City1 : [Node1, Node2, Node3]\}$
  $C2 \leftarrow \{City2 : [Node1, Node2, Node3]\}$
  $|S| \leftarrow K * 95/100$, $|I| \leftarrow K * 5/100$, $|R| \leftarrow 0$
  $Test\_Flag \leftarrow 0$, $Vaccination\_Flag \leftarrow 0$, $Steps\_count \leftarrow 0$
- $|S|, |I|, |R|$ dynamics at different time steps of simulation.

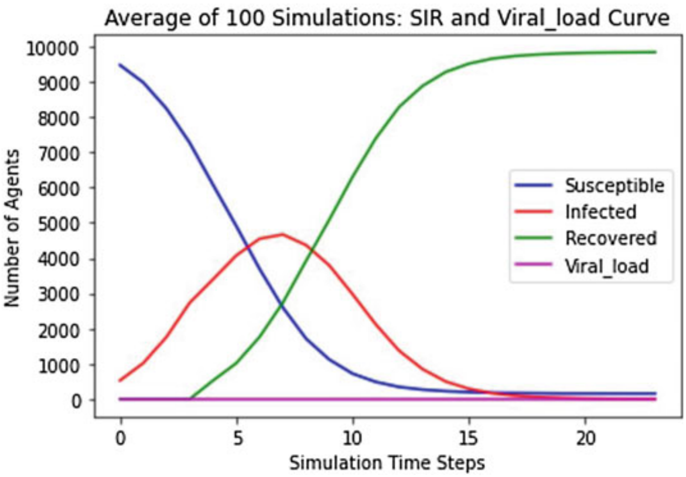

Fig. 31.1 Epidemic curve without indirect transmission

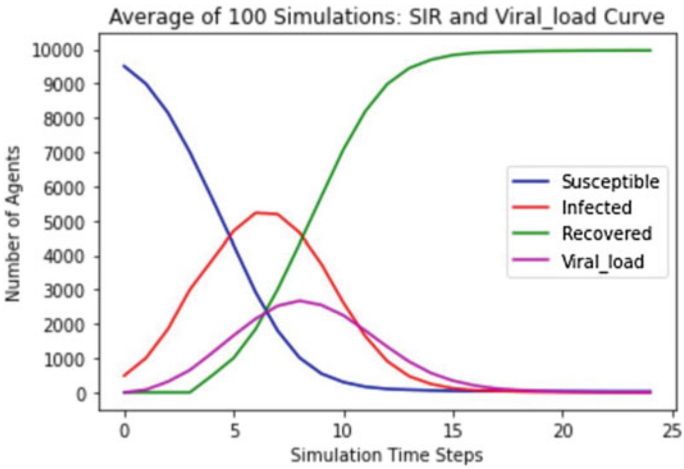

Fig. 31.2 Epidemic curve with indirect transmission

Figure 31.1 shows the cumulative epidemic curve with no indirect transmission. It can be seen from Fig. 31.2 that in case of indirect transmission, the "Infected" peak occurs earlier and is higher. Figure 31.3 shows the epidemic curve for replenishment strategy T_1, but with no indirect transmission. Assuming that agents who test positive no longer infect others due to precaution, effective testing strategy is seen to significantly reduce peak infection. Figure 31.4 shows that the curve remains small, even for

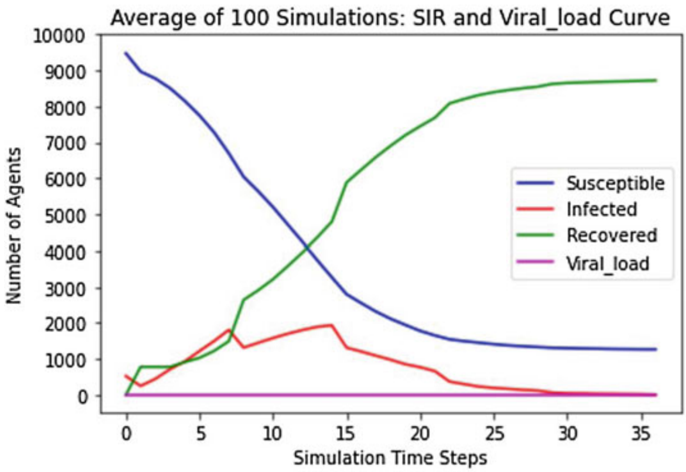

Fig. 31.3 $T1$ with no indirect transmission

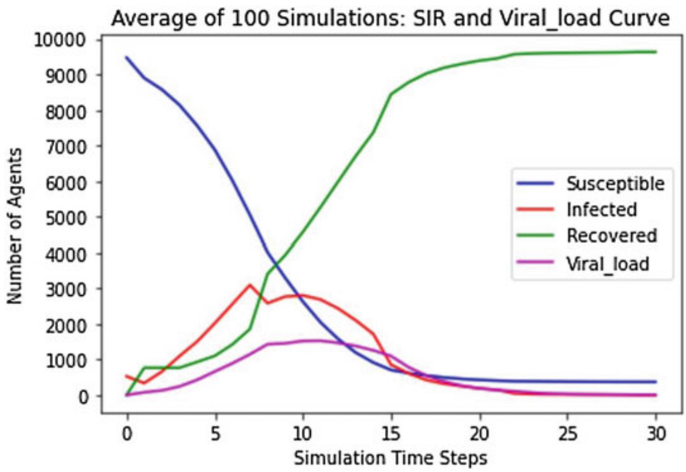

Fig. 31.4 $T1$ with indirect transmission

infections that are capable of indirect transmission. Figures 31.5 and 31.6 show that when test kits are rapidly replenished, there is a remarkable flattening of the epidemic peak both regardless of whether indirect transmission is happening or not. Finally, Fig. 31.7 shows that a combination of testing and vaccination works best, if both are available. Clearly, this is the best scenario.

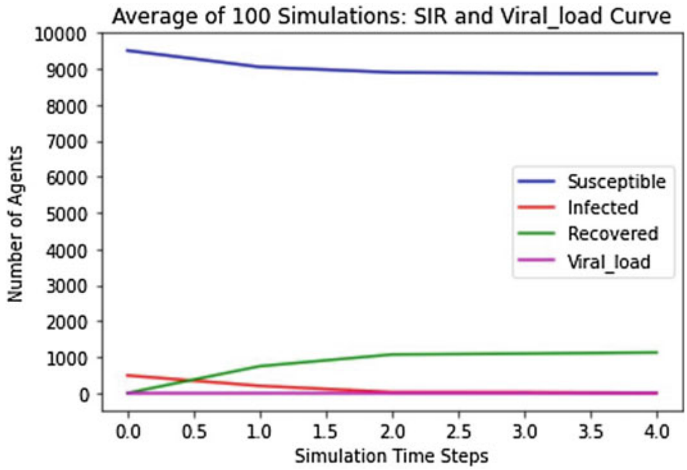

Fig. 31.5 $T2$, with no indirect transmission

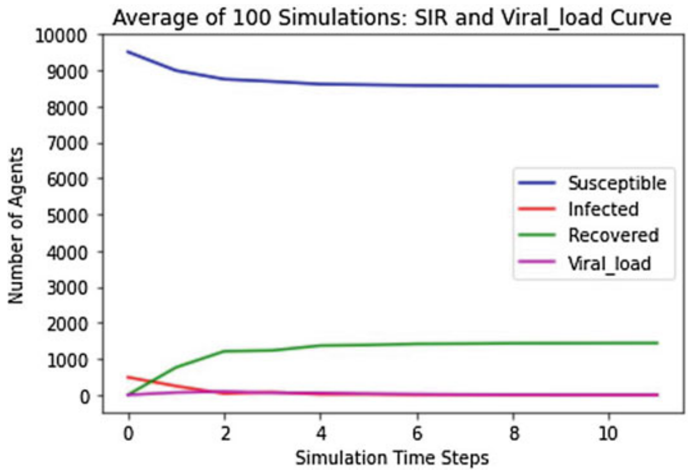

Fig. 31.6 $T2$, with indirect transmission

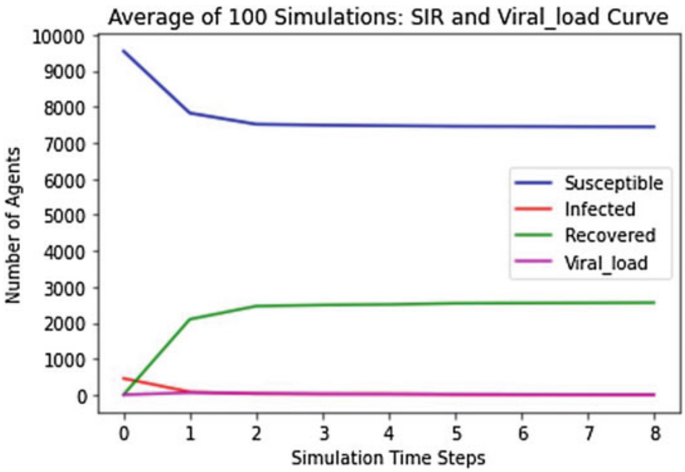

Fig. 31.7 With both testing and vaccination

31.5 Future Work

The experiments detailed in this work illustrate the idea of combining human mobility across cities into fomate and aerosol-based infection disease transmission, through synthetic examples. Porting of realistic data and transmission models would require a manual effort at the moment. An immediate goal would be to extend the tool to plug-in realistic data and models automatically for such experiments. Subsequently, the tool would be applied to studied outbreaks like covid-19.

Algorithm 1: Virus Diffusion on Erdos-Renyi Graph

```
while |I| > 0 or |Viral_Load| >= 1 do
    Steps_count = Steps_count + 1
    for node in Node_Dict do
        for agent in Agents do
            PC1 = 2.5, PC2 = 2.5, PH = 95
            City=select([Home,City1,City2] with weights (PH,PC1,PC2))
            P1 = 90, P2 = 5, P3 = 5
            Node=select([N1,N2,N3] with weights(P1,P2,P3))
            move_agent(agent,City,Node)
            update_dict(Agent_Dict,Node_Dict)
            if Node! = node and Viral_Flag == 1 then
                Node_Dict[Agent_Dict[agent][Node]][Viral_Load]+=1
            end
            if Node! = node and Vaccination_Flag == 1 then
                Vaccination_Algorithm
            end
            Node_Dict[Agent_Dict[agent][node]][Viral_load]/ = 2
            if Agent_Dict[agent][State] == R then
                do nothing
            end
            else if Agent_Dict[agent][State] == I then
                count_steps[Agent_Dict[agent]]+ = 1
                if count_steps[Agent_Dict[agent]] == 4 then
                    agent gets recovered
                    update_dict(Agent_Dict,Node_Dict)
                end
            end
            else if Agent_Dict[agent][State] == S then
                ic, sc, rc = count_sir(node)
                vl = measure_vl(node)
                w1 = |ic + vl|/|sc + ic + rc − 1|
                w2 = |sc + rc − 1|/|sc + ic + rc − 1|
                state = select([I,S] with weights(w1,w2))
                if state == I then
                    Agent_Dict[agent][State] ← I
                    count_steps[Agent_Dict[agent]] ← 0
                    update_dict(Agent_Dict,Node_Dict)
                end
            end
        end
    end
    if Test_Flag == 1 then
        Testing_Algorithm
    end
    return Agent_Dict,Node_Dict
end
```

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Chapter 32
The Role Neuromarketing Emotion as Key to Defining Consumer Behavior

Alma Casas-Frausto, Bogart Yail Márquez, Rosana Gutiérrez, and José Sergio Magdaleno-Palencia

Abstract Currently we can notice a high interest in identifying and satisfying the needs of consumers, to achieve this, companies use various techniques such as market research, surveys, product testing to name a few, today to obtain a more precise technique and tools they have evolved considerably. Neuromarketing is one of those advances which helps us to determine preferences more accurately and in-depth because the methods used are focused on in knowing conscious behavior, while consumer buying behavior is fundamentally unconscious. Currently, with the help of new technologies, there has been a greater interest in applying the methods of neurology in various different areas of medicine, which are related to human behavior, with Neuromarketing being one of the ways to investigate and understand behavior of consumer and purchasing decision making supporting us in this way to better understand psychological behavior and dictate more precise marketing actions based on knowledge of brain reactions.

32.1 Introduction

Marketing supports companies to obtain optimal results. Their main techniques for gathering information carry out market studies through the development of surveys, verbal questions and questionnaires, all of them focused on the conscious behavior of the consumer, being that the buying behavior occurs from unconscious form and

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to be applied In these tests, consumers commonly have difficulties to express their preferences in an adequate way, sometimes they lie or do not really know the answer, therefore they answer incorrectly [1]. The development of new technologies has developed an interest in applying neuroscience methods in various areas other than medical ones, being neuromarketing a new form of investigation for the behavior of the potential customer or consumer which helps us to define emotions and make decisions in the purchase process [1].

32.2 The Nervous System

The nervous system is defined as the system through which the human being receives information about its environment, its senses, processing said information, and issuing responses [2]. There are methods to measure emotions in the processes of consumer purchasing decisions [2].

32.2.1 Consumer Behavior

The brain is the one that governs the consumer behavior at the time of purchase (functions as a control center); Although it only uses 20 %, its functionality has been the subject of study for Neurosciences since their knowledge is essential to focus people's attention towards a product or service at the time of purchase [3]. The emotions are very important within neuromarketing as they guide purchasing decisions [3].

It is very important to analyze consumer behavior, since it benefits marketing in decision-making, the development of theoretical foundations to know the consumer or type of market, which allows us to help the consumer make a decision when acquiring a good or service properly [4].

32.2.2 Neurosciences

Braidot defines Neurosciences as the study of the functioning of the brain and neuron in the nervous system; and provides us with the essential knowledge and tools to understand the diseases of the Nervous System. Braidot defines neuroscience as the study of the functioning of the brain and neurons in the nervous system; which provides us with the essential knowledge and tools to understand diseases of the Nervous System. Braidot determines that this type of discipline seeks to understand how the brain's sensory systems encode information from the outside world, that is, how the nervous system does to translate the enormous amount of stimuli in which a person is exposed to the language of the brain: activation and neuron deactivation, communication between neurons, information transport and neuroplasticity phenomena [2].

32.2.3 Neuromarketing

Neuromarketing studies the functioning of the brain before a stimulus [2]. And consists of the employ research techniques from neuroscience to study traditional marketing. The techniques used in neuromarketing are of a wide variety, such as EEG Electroencephalography, fMRI Functional Magnetic Resonance Imaging, and Positron Emission Tomography [5].

32.2.4 Application of Neuromarketing Techniques

Applications are somewhat limited and certain areas of the brain involved in reward processes were activated when the participants learned that they were drinking Coca-Cola. In 2004, Montague took the Pepsi challenge a step further by using brain scans to see if individuals chosen Coke or Pepsi. The individuals were connected to fMRI (magnetic resonance imaging) and were analyzed for neuronal activity. While half of the participants, not knowing what drink they were drinking, preferred Pepsi, once they were told that they had actually had Coca-Cola, 75 chose the flavor of Coca-Cola. Looking to the fMRI, neural activity was observed changed once the individual is aware of the brand [6]. The application of fMRI technique revealed that the exposure of the subjects to the advertisements activated eight of the nine brain regions investigated. In other words, the brain of individuals reacts in a particular way to the content of advertisements. Another interesting result is the fact that, unlike previously assumed, most purchasing decisions are made instantaneously, randomly, and inadvertently (probably due to a large number of stimuli at the point of sale [6].

32.2.5 Method to Measure an Emotion

By means of an encephalogram, it is possible to determine an emotion, since three parameters can be measured which are linked to brain activity, attention, emotion, and memory [2].

32.2.6 The Encephalogram and Its Function

The Electroencephalogram (EEG) is a functional brain process, which helps us to determine the electrical activity of the cerebral cortex and gives us the possibility to identify any anomaly in its proper functioning [7]. Determines and typifies the different types of epilepsies. Convulsive or non-convulsive status epilepticus. Some types of dementia and it determines brain death [7].

32.2.7 Neural Network

Artificial neural networks (RN) are a model of processing and machine learning inspired by the way the nervous system processes. It is a system of linkage of neurons that participate among themselves to execute an output stimulus. In artificial intelligence, it is common to address them as neural networks [8]. They are learning systems based on the human brain. They simulate and imitate systems, allow to establish nonlinear iterations between the input and output variables [9].

The advantages of using neural networks for the classification of emotions are the following:

Biological Structure They are based on the structure of the nervous system, primarily the brain, so the analysis of bioelectrical signals through encephalogram facilitates excessive data collection [8].

Learning Neural networks have the ability to learn through a phase, which is called the learning stage. This consists of providing the RN with data as input, in turn, indicating which is the desired output [8].

Self Organization One A neural network creates its own representation of the information inside it, avoiding this task for the user [8].

Fault Tolerance Due Because a neural network stores information in excess, it may continue to respond acceptably even if it is partially damaged [8].

Flexibility One A neural network can handle minor changes in the input information, such as noisy signals or other changes in the input (for example, if the input information is the stimulus of a certain image of an object, the corresponding response does not change if the picture changes a bit). or if the matrix is not fed correctly within a pattern, the neural network may be accessible to information that is not necessarily genuine [8].

Real Time The structure of a neural network is parallel, so if this is implemented with computers or special electronic devices, responses can be obtained in real time. This should only be mentioned where the rules are already generalized for the classification study [8].

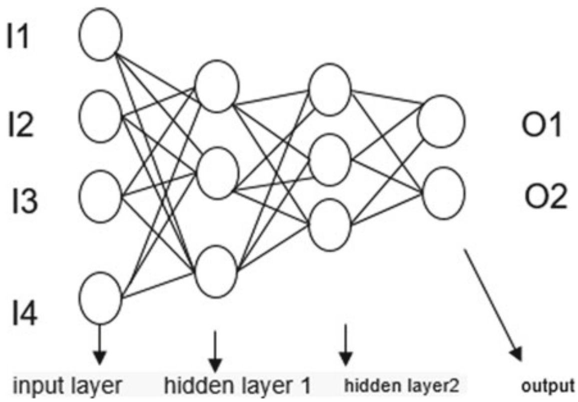

Fig. 32.1 Multilayer perceptron

32.2.8 How a Neural Network Works

In a neural network, the nodes are connected through the synapse, this connection structure defines the behavior of the network. The most widely used neural network is the Multilayer Perceptron [9]. Figure 32.1 shows such a structure with two hidden layers where I1 represent the inputs and O1 the outputs. The input layers depend on the information available to be classified, while in the output layers, there is a number of nodes equal to the number of variables response to the output medium. Neurons in one layer connect to those in the next layer through synapses, whose value is different for each of the connections and is determined through the training process [9].

32.3 Materials

The MUSE headband is a device that provides the ability to measure brain signals like a heart rate monitor detects the heartbeat. It has seven finely calibrated sensors that determine the brain activity, two of them located in the forehead, two behind the ears, and three as reference sensors [10]. Broadband MUSE is a headband, which helps us to perform an encephalogram and obtain bioelectrical signals from the brain. It has seven dry sensors, four input channels, and five output channels. Diadem makes it easier to access and use brain wave data [11].

32.3.1 Protocol to Perform Encephalography

The procedure is carried out as follows: through electrodes, surface or needle, the electrical activity of the cerebral cortex. The signal obtained is so small that it is necessary to use several amplification systems. The amplifiers used are differential, that is, they receive the electrical impulse of 2 points and magnify the potential difference between them. The position to place the electrodes on the scalp is subjected to an international system or 10-20 system [7].

Preparation for encephalography

– The patient should be relaxed.
– Record the level of alertness or confusion before, during, and after the test.
– Write down personal data of the patient, as well as pathological history.
– Explain the dynamics and the process of the test and ask for their cooperation at all times.
– Inform the patient that the EEG is not contraindicated in any case, nor does it have any side effects, so it is not necessary to sign any type of consent and authorization.
– It is highly recommended to clean the hair and the absence of foams, gummies, etc.
– Place the headband or cap having as a reference that the frontopolar electrodes are located on the frontal part so that the occipital electrodes rest on the occipital region and not on the cerebellum.
– Introduce conductive gel on each electrode, fixing them as much as possible, to avoid movement artifacts.
– Ensure good conductivity at the registration point, between the electrode and the skin, and leave them registered for later review.
– Use the appropriate filters, both high and low frequency, seeking to obtain a good signal for later interpretation.
– The test is performed with eyes closed [7].

32.3.2 Methodology to Classify Emotions

The classification process consists of 4 inputs, 5 outputs, and the weights for each input. The inputs are captured using electrodes capturing the bioelectrical signals in which it consists of collecting by electrodes, the electrical activity of the cerebral cortex. The signal obtained at the moment is averaged. The amplifiers used are differential, that is, they take in the electrical signal from 2 points and amplify the capacity difference among them [8]. Recognition of brain operation is calculated using generated potentials, said encephalogram components arising in response to a optical impulse of 3 s per picture and 4 s of counteraction each three images, utilization the internationally standardized 10-20 positioning method [8] (Fig. 32.2).

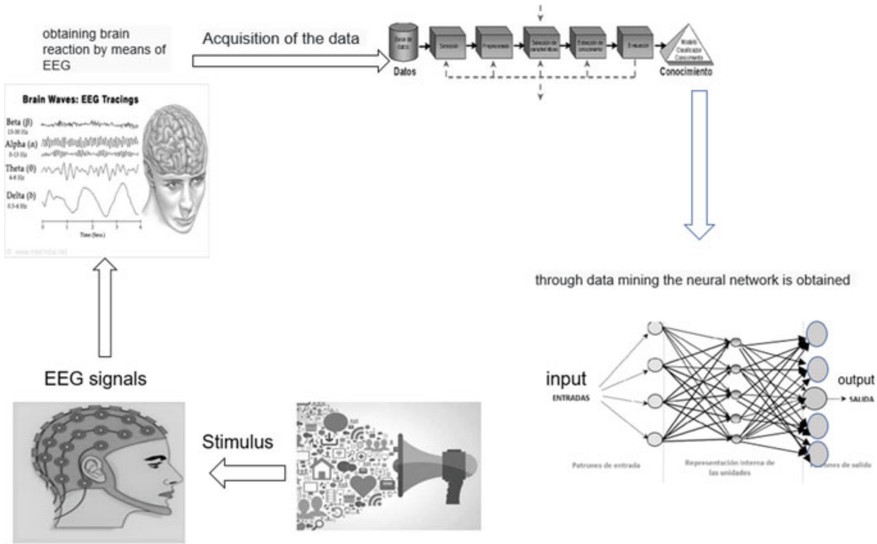

Fig. 32.2 The diagram shows the process for obtaining brain reactions, to classify emotion

32.3.3 Synaptic Weights

The weight

$$w^{l,l-1}_{i_l,i_{l-1}} \tag{32.1}$$

they are the intensity of the synapse that connects two neurons; both signals and weights are real values [12]. Type fuzzy neural model allows a better representation as it is a dynamic system [8].

The entry signals to an artificial neuron

$$a^{l-1}_{i_{l-1}} \tag{32.2}$$

They are continuous variables rather than discrete pulses, as in a biological neuron, input signals go per weight gain, which is called synaptic weight, its functionality is analogous to the synaptic function of a biological neuron [8].

The weights can be positive (excitatory) or negative (inhibitory), the summation node accumulates all the input signals multiplied by the weights or weighted, and passes them to the output through a transfer or activation function [8]. The net entry to apiece unit is distinct by the next equation

$$n_{i_l}^{l} = \sum_{i_{l-1}=1}^{N_l-1} W_{i_l,i_{l-1}}^{l,l-1} a_{i_{l-11}}^{t-1} + b_{i_l}^{l} = \sum_{i_{l-1}=1}^{N_l-1} W_{i_l,i_{l-1}}^{l,l-1} f_{l-1}\left(n_{i_{l-1}}^{l-1}\right) + b_{i_l}^{l} \tag{32.3}$$

The value of n belongs to the sum of the product of the weights by the inputs plus the threshold function [12]

$$a_{i_l}^{l} = f_l\left(n_{i_l}^{l}\right) = f_l\left(\sum_{i_{l-1}=1}^{N_{l-1}} w_{i_l,i_{l-1}}^{l,l-1} a_{il-1}^{l-1} + b_{i_l}^{l}\right) = f$$
$$f = f_l\left(\sum_{i_{l-1}=1}^{N_{l-1}} w_{i_l,i_{l-1}}^{l,l-1} f_{l-1}\left(n_{il-1}^{l-1}\right) + b_{i_l}^{l}\right) \tag{32.4}$$

where

$$f_l\left(n_{i_l}^{l}\right) \tag{32.5}$$

represents the activation function for that unit, which corresponds to the function chosen to transform the input [12]

$$n_{i_l}^{l} \tag{32.6}$$

in the output value

$$a_{i_l}^{l} \tag{32.7}$$

and that depends on the characteristics generated by the network, on the other hand it is the threshold function [8].

$$b_{i_l}^{l} \tag{32.8}$$

that the neuron must overshoot to activate [12]. The advantages of this model are learning, generalization, and robustness against sound in the data. It is known that there is a noise of 0.7 mv RMS de 1–50 Hz. In the model in this first part the data is entered directly without any type of filter. The obtaining of information is given from the knowledge of the internal architecture of the data, those that have connections or weights between the different ones constitute a neural network where knowledge is maintained. It is very important to note that there is no a priori specific definition of the form of cognizance, the algorithm itself is iterative of the estimation of unknown parameters or weights, so it is in charge of acquire the presence of regularities in the data, in order to be able to find the ideal weights for apiece input, that is, how important and what the input is related to

$$a_{i_{l-1}}^{l-1} \tag{32.9}$$

with the emotion that you want to evaluate [12].

32.4 Conclusions

With the use of neurosciences we can undoubtedly obtain optimal results for marketing and that is why neuromarketing gives us the possibility of obtaining true answers that are not obtained in a verbal or written questionnaire, because it enters the mind of the consumer and This is how you can decipher the emotions of the potential customer when purchasing a product or service. It is certainly an advantage with the ability to obtain information that could not be obtained otherwise. The encephalogram is a method most used in research to define behavior with the help of neuromarketing, it will be possible to obtain in depth the behaviors and stimuli that will help us to obtain the marked patterns of behavior of the human being, since it studies the functioning of the brain in decision-making. Advances in Neuromarketing will allow choosing the format that best suits the market study, given that what the consumer says and thinks does not always coincide, therefore, if artificial neurons are applied in neuromarketing for market research, this will generate results that are highly reliable. The use of neural networks in the field of neuromarketing has been very effective.

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Chapter 33
Intelligent Agent for Actuator Control in a Robot (IA-ACR)

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Abstract This article presents the analysis and design of the intelligent agent model “IA-ACR”, which has the objective of monitoring movements, which are carried out in a coordinated and intelligent way in a robot, which will have the task of performing routines of physical exercises and dance, these routines will then be imitated by children with neurodevelopmental disorders (NDD), in order to capture their attention so that therapies are more effective, which will be evaluated by the specialist (psychologist). Due to the current situation of the pandemic that is being experienced due to COVID-19, health protocols were established, such as avoiding contact between people, given this restriction, a digital platform was developed that serves as support for children in order to receive their sessions, where the robot appears through videos, this being an advantage of telehealth.

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33.1 Introduction

Neurodevelopment occurs through a dynamic process of interaction between the infant and the environment that surrounds it, resulting in the maturation of the nervous system with the consequent development of brain functions, and with it the development of personality [1]. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM in its fourth edition), generalized developmental disorders "are characterized by a serious and generalized disturbance of several areas of development: skills for social interaction, skills for communication or presence of stereotyped behaviors, interests, and activities [2].

Neurodevelopmental disorders (NDD) comprise a number of clinical moments, which are evidenced in the early stages of life and affect the trajectory of cognitive development, language, and behavior [3]. They are characterized by the presence of cognitive, neurological or psychiatric dysfunctions associated with an alteration or variation in the development and growth of the brain [4].

The objective of this article is the proposal of is the integration of an algorithm based on the intelligent agent's paradigms, which will then implemented in a robot. This robot will have the purpose of supporting assisted therapies in children with neurodevelopmental disorders in their warm-up sessions with physical movements and dance. The agent will be in charge of monitoring all the movements to be performed during a session; it should be noted that it is intended to increase motivation and reduce fatigue in their class or therapies.

This proposal was developed prior to the pandemic when observing that during several sessions in person before the pandemic, there was not enough motivation to carry out many of these tasks, as well as a deficit in the imitation of movements proposed by the psychologist, these situations affect children to be able to carry out their exercise routines, having repercussions in the low participation in their classes or therapies. During these in person sessions, the children were more active and engaged with their therapy than were without the assistance of the robot. The development of the agent (IA-ACR), aims to have interventions that are generated in a more pleasant and motivational way, while generating information of how to increase and promote imitation in therapies in children with neurodevelopmental disorders, through an intelligent agent for the control of actions in robots that are used in the sessions.

33.2 Intelligent Agents

Intelligent agents are considered anything capable of perceiving an environment or environment through sensors and acting on it through actuators [5], they also have the ability to communicate with other agents. The agent role for an agent specifies the action to be taken by it in response to any perceived sequence.

In these types of algorithms, the sensors adapt to be able to perceive what the environment is generating, as well as the actuators that allow certain specific actions to be carried out, for example, in a human agent [6]: the eyes, ears, and other organs function as sensors; hands, legs, and other body parts serve as actuators.

The most relevant characteristics of intelligent agents are: autonomy, rationality, proactivity, and benevolence, it is pertinent to clarify that the agents obtain only those characteristics that the programmer grants them [7].

These agents have the ability to retrieve information by design, specifically to perform activities such as processing queries, processing capacity, and generating knowledge of the environment where the agent moves and information from a domain [8].

33.2.1 Classifications

Perceptron

The Perceptron is an Artificial Neural Network (ANN) that has the ability to correctly detect and classify the behavior of a series of data, with some type of relationship between them, leveling various magnitudes to "predict" its behavior [9].

Bayesian Networks

Bayesian networks are a probabilistic functions by means of which it is feasible to construct a graph between the causes of an event (independent variables) and its consequences (dependent variables) [10]. Bayesian classifiers facilitate the classification of discrete and limited events (independent variables) in a certain number of classes, defining a statistical function for each class. In defining these statistical functions, they take as a reference a training database. Based on these defined functions, the system will be able to classify a new set of independent variables (test data) and establish the class to which they belong, based on the statistical function that generates the highest value [11].

Telehealth

This term comes from the Greek τελε (tele) which means "distance", to which it is added to health to have more scope in the health services carried out in the distance. Related to this area can be found multiple terms [12], sometimes they are used interchangeably to refer to the same thing: telemedicine, e-Health, health 2.0, ubiquitous health, personal health, connected health, ICT in health, digital health, mHealth, and all the Anglo-Saxon translations. Specifically, the terms e-Health, health 2.0 are used to more broadly address any form of health care that interacts through the INTERNET and other instruments of the new digital era, while telehealth or telemedicine are specifically focused on the use of ICTs to provide health services at a distance through the following applications [13]:

- Remote diagnosis: Remote sending of data, signals and images, for diagnostic purposes.
- Telemonitoring: Remote monitoring of vital parameters, to provide automatic or semi-automatic surveillance or alarm services.
- Teletherapy: Remote equipment control.
- Tele Didactics: Application of Telematics networks in Health Education.
- Social Telephony: Application of modern conventional telephony resources to dynamic assistance, telecommunication for people with limited disabilities such as the deaf, blind, mute and motor limitations, support for preventive medicine, and teleshopping.

33.2.2 What Opportunities Does Telehealth Offer to Society?

Presenting these types of services related to the health sector based on telehealth has many advantages such as optimizing care resources, improving demand management, reducing hospital stays, reducing the repetition of acts or consultations, reducing travel, improving communication between professionals, and improving patient accessibility to these aforementioned services.

A relevant aspect is that telehealth represents a structure that helps in improving the management of health services. Health management aims to improve the health of the population by providing high-quality, accessible, and economically sustainable health care [12]. In this way, telehealth is positioned as an effective strategy for the sustainability of health systems. While this has been true for a number of years, it has been more widely adopted since the pandemic has changed the way we access health services worldwide.

33.2.3 Neurodevelopmental Disorders

The neurodevelopmental process occurs through a process of interaction between the infant and the entire environment that surrounds it, resulting in the maturation of the nervous system, also developing brain functions, and with it the formation of personality [1]. The brain stops through a complex and precise process that begins in the early stages of life and this lasts for several years after birth.

In the Diagnostic and Statistical Manual of Mental Disorders (DSM) in its fourth version, generalized developmental disorders "are characterized by a serious and generalized affectation of several areas of development: skills for social interaction, skills for communication or communication presence of stereotyped behaviors, interests, and activities" [2]. This category, which was first included in DSM IV within childhood-onset disorders, includes:

- Autistic Disorder.
- Rett's disorder.

- Childhood Disintegrative Disorder.
- Asperger's disorder [1].

Neurodevelopmental disorders (ND) comprise a number of clinical pictures, which are evidenced in the early stages of life and affect the trajectory of cognitive development, language, and behavior [3]. They are characterized by the presence of cognitive, neurological or psychiatric dysfunctions associated with an alteration or variation in the development and growth of the brain [4].

33.2.4 Telehealth Program with Educational Robotics (TPER)

Telehealth Program with Educational Robotics (TPER) is a distance training mode of intervention that uses Information and Communication Technologies so that through devices, such as a tablet, smart cell phone or a computer, parents can implement individualized programs when and how where they advance in the therapy process of their children.

Due to COVID-19 [4], the way in which these types of face-to-face sessions were received in order to comply with the health standards recommended by the government and health officials has come to change, this generates new ways of being able to offer therapies within the recommendations given.

With the TPER, a virtual space has been generated with the intention of functioning as a repository of resources and recommendations in order to help both psychologists and those who specialize in health in their interventions, while also giving parents additional resources to help their children. While not being able to leave their homes, they have a virtual space so that their children can receive therapies, with the above; the importance of telehealth in this contingency is facilitated through other means.

These technological advances have left benefits for users; the advantages of the TPER are shown below:

- Motivation: Provides greater motivation to exercise and improve motor skills.
- Imitation: Allows you to learn new movements and knowledge almost in real time.
- Online access: To access the content it is only necessary to have INTERNET access and any device for its connection. It is available any time, 365 days a year.
- Accessibility: Reduces costs and problems associated with traditional methods, such as transportation, distance, and the speed with which changes and innovations occur.

33.3 Proposal

Attracting and maintaining the attention of a person at a certain time is usually difficult, for example, during a session that involves dancing becomes complex, that is, you can have their full attention and perform a routine completely and correctly. For neurotypical human beings, managing to maintain that motivation to execute routines and imitate certain movements is usually a difficult task to perform, because it requires various cognitive processes, however, technology has become a great tool in this area, but with this program you can have a robot that maintains motivation and imitation in a therapy [14], which is complex, but not impossible. To solve this scenario, the agent (IA-ACR) is created, with which it is intended to advance these investigations.

It is important to know the whole context of the problem, for example: children with neurodevelopmental disorders come to present a very dynamic clinical picture, which is shown in the early stages of life and this comes to affect the trajectory of their development cognitive, language, and behavior. Of the main characteristics that are involved, we can list the cognitive, neurological or psychiatric dysfunctions that are associated with an alteration or variation in the development and growth of the brain. It is considered that through this implementation of the robot, it can support the improvement of its motivation and coordination motor in their movements; with these qualities, they will directly support therapists and parents of children with neurodevelopmental disorders.

The agent (IA-ACR) controls a series of actuators of a robot, which is intended to be of great help for parents and educators, since all movements made by children during the session will be monitored.

In order for these movements to be carried out correctly by the actuators, which in this case are the robot's motors, the program can be adapted in order for the children to learn at their own pace, gradually improving until better coordination and motivation are obtained.

The environment where the use of the robot that will contain the agent (IA-ACR) will be implemented will be in CAOP [15], a low cost center for attending psychological problems where children with neurodevelopmental disorders are found.

Next, the AI-CAR agent model is described, which will be implemented in a mechatronic system (Robot), in which the agent will perform its functions, as shown in Fig. 33.1, said model has a process to identify all the movements that children perform and monitor, if they are performing correctly the dance and exercise routines.

The robot tries to generate motivation to fulfill each one of the routines; this in order for children to be more attentive to the movements that are carried out in the routine chosen by the psychologist, with this data, the sensors process and detect all movements, as well as the proximity with which they are carried out. It is called the process of obtaining parameters, which consists of the recording of descriptive data of the movements obtained by the sensors that allows us to visualize the outside world.

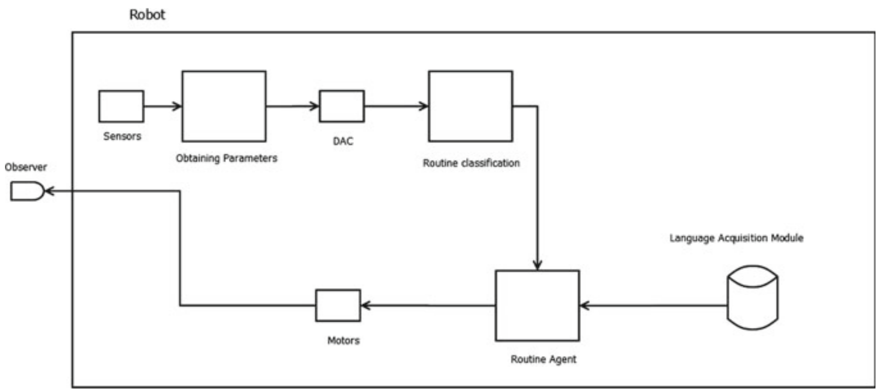

Fig. 33.1 . Proposed model of the intelligent agent (IA-ACR)

The DAC [16] is in charge of processing all the information from the sensors, its main task is to save the records obtained taking into account each of the parameters, for example, the types of movements, such as arms up, if the robot will make a turn and the distance in which this device is generated will allow us to record n movements, it is worth mentioning the limitations of the storage and processing capacity that it has, in the DAC, a routine classifier is generated which requires a log storage depending on the aforementioned parameter as the type of movement.

Upon obtaining the previous information, the routine agent has the task of planning the decisions and reviewing the obtained parameters generated by the sensor and the generated routines; contemplating the routine that is carried out by the robot, the agent makes inquiries about the amount of movements carried out correctly by the child.

It will be necessary to indicate that if the routine is not being carried out correctly, the process is that it is modified from the routine; this is supervised and planned by the psychologist.

One of the last processes to be carried out is the movement of the motors, since they generate the routines of the hands (movements) and turns of the robot that are generated within the routine agent, finally the observer (child) have the task of imitating the movements performed by the robot correctly, and thus with them, improve motivation, this process is repeated each time a new routine is started.

33.4 Conclusions

In this article, the analysis of the problem to be solved was provided, it is observed that children with ODD who have a very varied clinical picture but tend to lack motivation when performing physical exercises and dance routines. The development of the IA-ACRagent has a modular structure, which helps to be able to have scalability, this gives the possibility when the algorithm needs to be improved, new modules can be integrated or the model can be reused by adding new functionalities.

In particular, the integration of the AI-CAR agent to the control of a robot's actuators is an area of importance for the future of the following investigations, which leaves a promising advance in the autonomy and efficiency of the tasks carried out by the robot, by this need, the AI-CAR is created in the area of neurodevelopmental disorders that helps children with various clinical pictures to improve their motivation in activities such as physical warm-ups and dancing, which could be somewhat complicated but not impossible, with this work, we take steps in that direction.

This design process is very important for the correct functioning of the IA-ACR agent, in order to better understand the problem that had to be solved, we are working together with a psycho pedagogical center [15]. With this collaboration, it is possible to have a complete contextual study of the situations presented in the various sessions that are held. Throughout the development of this program, there was the opportunity to interview different psychologists, which resulted in behavioral observations of the children in their physical education class, through this process, objectives, and modules were established for the programming of the intelligent agent of the robot. This entire process was carried out with prior written consent of the parents and the institution.

A very important aspect is to know the environment where the therapy will be applied to have control of the movements that the student performs, where it will later be processed in the agent IA-ACR, an important factor to understand is the context in which it is being developed. The project is developing is the COVID-19 pandemic that prevents the sessions from being face-to-face while the contingency is controlled, the use of a platform called Telehealth Program with Educational Robotics (TPER) is being tested where therapies will be given with the robot and seeking to improve agent performance.

Understanding the problems presented in CAOP [15], was very important to have as a result the model of the agent IA-ACR, with this, the robot will be better equipped to work within the limits and opportunities provided by the particular characteristics of the children that use this program. While there was evidence that the presence of the robot during therapy increased the participation and motivation of the children, as referred by their therapists, more in person trial are recommended as soon as the proper health protocols deem it safe for all the participants. It remains to be measured in a subsequent study with a detailed observation checklist and questionnaires for the therapists how much of an advantage the assistance from the robot is compared to the prior level of functioning that the child had. Based on the preliminary interventions, there are reasons to be optimistic given the observed results that the robot has on behavior and motivations during a session.

33.5 Work Towards the Future

The works that are visualized in this research is the implementation of the algorithm in the generic mechatronic system, where it is not an easy task because a multidisciplinary team is needed, in the areas of computing, psychology, neuropsychology, and medicine to generate continuous improvements in the movement detection model generating a validity that the child really has the motivation to imitate all exercises, it is expected that in the following phases of the project, more tests will be carried out to see the precision of movement detection.

It is contemplated to develop an intervention protocol focused on these sessions for therapies with the help of specialists in the subject, this in order to measure the child's performance, to obtain better results, it is necessary to know the amount that will be taken per group.

The next phases of the project are conditioned by the global contingency that is being experienced by COVID-19, since face-to-face therapies are suspended until the health situation improves, this affects that the corresponding tests cannot be carried out, these conditions will strengthen the technological part in the health sector. This type of research seeks to generate a contribution towards that area so that future studies and implementations can be integrated within the scope of these advances.

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Chapter 34
Analysis and Prediction of EMG Signals for Interpretation of Human Communication for Individuals with Disabilities

Sergio Méndez-Mota, Bogart Yail Márquez, Samantha Jiménez, and José Nava-Nava

Abstract People with communication difficulties are characterized by having problems expressing themselves orally. Some manifestations related to these difficulties are: aphasia, dysarthria, dysphemia, dysphonia, muteness/aphonia, laryngectomy, and expressive disability. The main idea is that through electromyographic signals, they can communicate with the help of computational processing.

34.1 Introduction

Human relationships are achieved through communication. This process helps people express their ideas and enables them to understand their emotions through others. As a result, we can develop feelings of affection or hatred towards others and create positive or negative relationships, as learn and share knowledge and experiences. However, not everybody can communicate in the same way. Some individuals live with a disability and lack the opportunity to express or communicate with others in the same way that most people do. Another disability can refer to the movements made by the human body such as walking, sitting, getting up, and running, these actions are performed without difficulty for a large part of the population, but in

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people with disabilities or muscular weakness, the difficulty increases and in some cases these actions are prohibited. These kinds of problems have impulse multiple research and technological advances for the development of equipment such as prostheses, movement assistance equipment, and/or exoskeletons, which ease daily tasks and release the motor load on repetitive work or support for people with physical weaknesses. The main disadvantage of the devices and exoskeletons used today is the need to be controlled manually or employing a reaction control, that is, the device moves in reaction to the movement of the user and does not help at the beginning of the movement, resulting in its little practicality to handle.

Through the use of bioelectric signals, also known as biopotentials, it is possible to predict the user's movement intention and carry out the corresponding action before starting the action to be carried out, even that same signal can be used for communication, such as the interpretation of sign languages, but the objective is to identify the bioelectric signal and through computational processing to describe what the user wants to say [1, 2].

The objective of the project is to identify the bioelectric signal of the users with some disabilities through electromyography, and in the same way to predict and interpret it in written communication.

34.2 State of the Art

There are different ways to perform signal analysis, here we will give a very general description of each one.

34.2.1 Simple Regression Analysis

In a simple regression analysis, there is a response or dependent variable (y) an explanatory or independent variable (x). The purpose is to obtain a simple function of the explanatory variable, so that is capable of describing the variation of the dependent variable as close as possible. The explanatory variable can be formed by a vector of a single characteristic or it can be a set of n characteristics, attributes, or dimensions (multiple regression). Regression is used to predict a measure based on the knowledge of another and the final intention is that given an input vector xl + 1, the objective is to predict an output value y1 + 1 from a function generated by previously observed monitoring of an initial training set of examples (xi, yi), i = 1…l [3, 4].

34.2.2 Multiple Linear Regression in Matrix Notation

The function in which the sum of the squares of the differences between the observed and expected values is smaller corresponds to finding the regression coefficients w for which the function by which its determine said error is a minimum error, or in other words, corresponds to differentiating the equation [3, 4].

$$w = \left(X^T X\right)^{-1} X^T y \tag{34.1}$$

After getting adjusted to a model, it is important to get certain values that offer us information on how important the adjustment has been concerning the data, when analyzing the correlation between the independent variables, there are many quantitative terms that provide valuable information regarding that measuring [5, 6].

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_1 \end{bmatrix}, X = \begin{bmatrix} x_{10} & x_{11} & \cdots & x_{1n} \\ x_{20} & x_{21} & \cdots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{l0} & x_{l1} & \cdots & x_{\mathrm{ln}} \end{bmatrix}, w = \begin{bmatrix} w_0 \\ w_1 \\ \vdots \\ w_n \end{bmatrix} \tag{34.2}$$

If the relationship is not linear, the values of one or both variables can be transformed to try to linearize it. If it is not possible to convert the relation to linear, the degree of adjustment of a more complex polynomial function can be checked. The simplest polynomial function is the quadratic that describes a parable but could use a cubic function or another of an even higher order (order k) capable of achieving a near-perfect fit to the data [4–6].

$$y = w_0 + w_1 x_1 + w_2 x_2^2 \tag{34.3}$$

The Principal Component Analysis (PCA). It is a technique coming from exploratory data analysis whose objective is the synthesis of information, or reduction of the dimension (number of variables). That is, facing a data table with many variables, the objective will be to reduce them to a smaller number of transformed variables, losing the least amount of information possible. This approach is based on the fact that any set of n variables (X1, …, Xn) can be transformed to a set of n orthogonal variables (and therefore, independent of each other, without any relation). The new orthogonal variables are known as principal components (C1, …, Cn). Each variable Cj is a linear combination [4, 5].

$$C_j = v_{1j}\tilde{X}_1 + v_{2j}\tilde{X}_2 + \cdots + v_{nj}\tilde{X}_n,\ j = 1, \ldots, n \tag{34.4}$$

These new principal components or factors are calculated as a linear combination of the original normalized variables, and besides, they will also be linearly independent of each other. Technically, the PCA looks for the projection according to which the data is best represented in terms of least squares and constructs a linear transformation that chooses a new coordinate system for the original data set in which the largest variance of the data set is captured on the first axis (called the First Principal Component), the second-largest variance is the second axis, and so on. The choice of the factors is made in such a way that the first one collects the largest possible proportion of the original variability; the second factor must collect the maximum possible variability not collected by the first, and so on. From the total of factors, those that collect the percentage of variability that is considered sufficient will be chosen. These will be called main components [4, 5].

34.2.3 Elimination of Variables from the Analysis

It is the most comfortable solution since it is only necessary to eliminate those predictors correlated with others from a previous detection of them. The estimators that result has a smaller error variance. This approach is accepted for being reductionist and simplify the model, however, it reduces the range of the information matrix of independent variables and this can turn it into a technique that generates a model with less explanatory power when in front of new inputs [3, 5].

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34.2.5 Exploration of Biased Regression

The RR technique is also known as a “ridge regression” or “biased regression”. Let’s look at the two computational modalities that we have to be able to carry out this type of regression. Finding the function in which the sum of the squares of the differences together with the biased for the observed and expected values is less, will correspond to finding the regression coefficients w for which the function by which we determine such error is an error minimum, or put another way, corresponds to differentiate Eq. (34.5) in w [3, 4].

$$w = \left(X^T X + kI_n\right)^{-1} X^T y \tag{34.5}$$

A dimension identity matrix (n x n) that can always be inverted if k > 0. As we will see later, we know that there is a k (in fact, an interval of values of k), improving the error of the MCO estimator. The drawback lies in the choice of k, which should not be intuitive, since if this value is very large, overregulation occurs [3–5], which can cause loss of important information, and if k is small, a sub-regularization occurs, which can cause the solution not to be robust, that is, it is sensitive to errors in the data (k = 0 means returning to an MCO estimator). Like it happened with the case of the MCO method, where w is a linear function of the vector of the dependent response variable (y), solving the previous equation for the coefficients w, then implies solving a system of linear equations with n equations and n unknowns. Therefore, the computational complexity of this task results in N operations. Once we have the regression coefficients, w,will be the prediction function of a new input vector x [3, 5, 6].

34.3 Methodology

The information available may consists exclusively of the measurement of output signals. The objective then is to extract functions or parameters that describe the behavior, provide the possibility of monitoring, and classification of the communication.

The extracted parameters can be limited from the most basic such as RMS (root mean square) to sensitive peaks. The functions that describe the behavior can be correlation functions, spectral density, etc., and even parameters directly based on these functions. In other situations, both disturbances and responses are measured. The objective may be to identify the system or just some parameters of the model. Disturbances can be controlled, such as modal structural tests, or consist of single disturbances in the place, such as wind forces acting on real structures. The identification of the results may consists of the form of the described function (frequency response function), an impulse response, or even a structure model [7, 8].

In the physiological part, the striated muscles are the effectors of voluntary mobility. Striated muscle fibers (MFs) are elongated cells with alternating white and dark bands (striations) due to the longitudinal and parallel arrangement of contractile proteins within them. The contraction is verified by the sliding of these proteins against each other. The central nervous system encodes the degree of contraction of the MFs according to the frequency of nerve impulses from the alpha motor neurons, whose bodies are located in the anterior horns of the spinal cord. Nerve impulses are motor neuron action potentials (APs) that are transmitted to muscle cells along their axons, their terminal ramifications end, and neuromuscular junctions [6, 8, 9].

A basic property of MFs and neurons is the possibility that the membrane potential, under certain circumstances, changes and becomes momentarily positive on the inside. This reversal of the potential or depolarization is called PA and is triggered by the sudden opening of the sodium channels present in the membrane, with the consequent increase in the permeability of that ion. Changes in ionic flows associated with AP are transmitted to adjacent points of the membrane, driving along the muscle fiber at a speed of between 3 and 5 m/s. In a weak voluntary contraction, only a small number of motor Units (MUs) are activated, which discharge action potentials at low frequencies (around 5 per second). Increasing the force of contraction implies a progressive increase in the frequency of discharge and the recruitment or activation of more MUs [6–8].

All EGM instrumentation is aimed at obtaining an intelligible representation of muscle APs. For this, the systems must be sufficiently sensitive because the bioelectric magnitudes are very small, being necessary to amplify the signal between 50 and 250,000 times. The amplified signals are between 1 and 10 V, which is the range in which the electronic circuits of the microprocessors operate. A problem in the signals is the noise, whether of technical or biological origin, invariably accompanies the signal to be recorded and generally exceeds its magnitude by several orders. Differential amplifiers can neutralize much of the noise because they measure the potential difference between the active and reference electrodes and only magnify the difference between them. If the two electrodes are very close, as in the case of the concentric electrode, the disturbances that affect both electrodes equally (common inputs) are canceled [6–8].

In order to purge or eliminate the noise, filtering is applied, the FO (Frequency Oscillation) of the MUAP's (Motor Unit Action Potential) is a two-dimensional representation of voltage versus time, but the MUAP can also be represented as a sum of sinusoidal waves of different frequency, amplitude and phase through a mathematical procedure called Fourier transformation analysis. Rapid voltage fluctuations indicate the presence of high frequencies and low-level fluctuations indicates low frequencies. The System Registration possesses filters that remove high or lower frequency spikes of those owned by the physiological signal. It is recommended to eliminate frequencies below 2–5 Hz and above 10 kHz, this is due to the MUAPs low-level needle variation and rapid oscillations of the signal, and in part to its technical origin. Likewise, the oscillation of the signal at 50 Hz (60 in the American continent) due to the alternating current of the electrical network must be eliminated by means of a specific notch (notch filter). Filters can be analog (circuits with resistors and capacitors) or digital (algorithms executed on the signal after digitization). In any case, the effects on the signal depend on the cutoff frequency, order and filter type. Depending on the values of these parameters, filters eliminate noise, but they can also distort the frequency oscillation of physiological signals [6–9].

In the first equipment, the signal appeared in oscilloscopes (cathode ray tubes). To analyze the frequency in a more comprehensive way, we had to screen shot the oscilloscopes. On today's video monitors, multiple curves can be displayed with sensitivity ranges between 0.01 mV/cm and 100 mV/cm and ranges of 0.5 ms/cm at 100 s/cm. Two basic functions to facilitate acquisition (already implemented in the first analog equipment) are the threshold or trigger, which allows to hold the signal on the screen when it exceeds a certain amplitude value set by the user, and the delay line, the preceding signal is kept locked on memory at the moment it reached the threshold value [6, 8, 9].

The voltage variations inherent to EMG (electromyography) signals can be transferred to a loudspeaker. The frequency components of the signals are converted into vibrations, that is, into sounds, the perception of which is essential to guide the placement of the needle and to recognize certain phenomena such as different types of spontaneous activity [8, 10].

Analog systems operate on the signal as a continuous variation of voltage. Digitization, carried out in analog–digital converters, consists of obtaining measurements (samples) at regular intervals of time. The sample rate of the converter must be high enough not to miss significant changes in voltage. As established by the Nyquist theorem, the sampling frequency must be at least twice the highest frequency component (maximum frequency) of the oscillation occurrence to be recorded (3–5 kHz in the case of MUAPs). Modern equipment works with sampling frequencies greater than 20 kHz (intervals less than 50 μs). The resolution in the voltage measurement depends on the number of bits (binary digits) of the converter. With 12 bits, the amplifier gain is divided into 4,096 (212) discrete amplitude values. Most of the current equipment has 16-bit converters, which allows to attain measurements of the nanovolt order. The signals are converted into series of numbers that can be mathematically handled by a processing unit (CPU) in order to control the waves of the signals and are reflected on the screen, as well as the data storage, wave analysis, and data management in general [6, 8–10].

Today's equipment incorporates algorithms for the automatic calculation of parameters. The activity during the maximum effort can be quantitatively analyzed by measuring the number and amplitude of the peaks (turns) present in the signal with different algorithms, some already implemented in the first modular systems, such as the Willison analyzer. With regard to the analysis of the oscillation frequency of the MUAP, conventional devices have algorithms to determine the initial and final points of the wave (and the duration as the time difference between the two), the maximum amplitude (difference between the samples of lowest and highest value), the area under the curve, the number of phases (parts of the waves on either side of the baseline), and the number of turns (changes in the direction of the wave). These parameters inform about the size and structure of the MUs. The size parameters (duration, amplitude, area) express the number of MFs in the MU [6, 8, 9, 11].

In myopathic diseases, the UMs lose MFs, resulting in a reduction in the amplitude and duration of the MUAPs. On the contrary, in neurogenic processes, the number of MUs is reduced, but surviving MUs increase the number of MFs due to collateral reinnervation. In these circumstances, the MUAPs show increased amplitude [2, 6, 11].

34.3.1 MUAPS Extraction

During the extraction, a continuous (raw) signal is acquired that includes the successive discharges of the MUAPs but also contains noise of different origins, which is breakdown as follows: from the equipment itself, from the alternating current, electromagnetic interference from the environment, biological signals (electrocardiogram, activity of distant MUs), needle movements, etc. Filters remove some of the noise but are insufficient, so new procedures have been introduced such as independent component analysis (ICA) and TW, which are particularly robust against high-frequency Gaussian noise [1, 6, 11].

Conceptually, the EMG signal is considered as an isoelectric baseline (BL) (zero value) on which the discharges of the MUAPs are placed. But in real records, the baseline always shows slow fluctuations produced by the activity of distant MUs and electrode movements. The high-pass filter does not completely eliminate the vague yet low fluctuation, but it does raise excessively its cutoff frequency, the frequency oscillation of the MUAPs may be distorted, with artifactual appearance of a negative phase in its final part. The conventional criteria for considering the baseline as a straight line entails imbalances in the subsequent management of MUAPs, especially in the duration of automatic measurement. Standard methods such as adaptive filters did not perform satisfactorily, requiring the sequential application of several processing techniques [2, 6, 11].

34.3.2 Potentials Recognition

To analyze the frequency oscillations of the MUAPs, the discharges present in the raw signal must first be identified. This process can be done manually or semi-automatically using trigger or delay line. Both procedures are time-consuming. In order to automate the extraction of discharges, in the 1980s, the first decomposition systems of the EMG signal and multipotential or multi-MUP systems began to be developed. These systems generate templates with the frequency oscillations of isolated discharges, compare them with each other by means of cross correlation and other functions, and classify them into sets according to their degree of similarity, each of these sets corresponding to discharges from the same MU. All modern equipment incorporates multi-MUP systems in which up to 6 different MUAPs can be extracted from a raw signal acquired during 5–10 s of muscle contraction. This reduces the number of insertions and the recording time required to obtain a sufficient sample of MUAPs. In addition to template matching, methods based on higher-order statistics (HOS) and Transformed of wavelet (TW) are being tested, as well as neural networks, genetic algorithms, and other artificial intelligence techniques. Expect new generations of electromyograph to incorporate more powerful multi-MUP systems [2, 11, 12].

34.3.3 Significant Waveform Extraction of the MUAPs

Once the discharges of the same MU are isolated, their curves are superimposed (generally taking the maximum peak as a reference) and the frequency oscillation of the MUAP is obtained by averaging t curves (arithmetic mean of the samples). The objective is to achieve a frequency oscillation that includes all the significant morphological details, this means, that significantly represents the physiological changes that have occurred in the system. The conventional procedure involves certain inaccuracies due to misalignment and the frequent presence of distortions that artifact the average curve. To resolve these limitations, various strategies have been designed, such as the use of the median (less sensitive than the mean to extreme artifactual values). The weighted average calculation and the selection of a fixed number of maximum similarity discharges have also been applied. We have proposed a selection procedure to establish the optimal number of similar discharges that maximizes the signal/noise ratio. We have also introduced a system for aligning the discharges by maximizing correlation, which offers an optimal degree of overlap, better than taking the maximum peak as a reference. We have also applied a sliding window method to obtain the frequency oscillation of the MUAP by selectively rejecting the distorted segments of the discharges [2, 12].

34.4 Conclusions

The purpose of using neural networks is to give a better solution to the situation to which it is applied, the characteristics that make its implementation more attractive are: the way of organizing information and adaptability when using algorithms that make it more adaptive and learn, Another is the way of the data are processing in a non-linear scheme, which increases the network to make approximations, perform command patterns and functions, as well as the ability depending on the network to perform the parallel processing, which is where its name of a neural network is taken; because it has connections called nodes that interact with each other.

In the analyzes which are made of studies with EMG, most of them are statistical and on the other hand, the signals obtained by an analog traditional way are noisy and the signal must be characterized and be conditioned for a proper manipulation for use with the systems before being digitized, in turn with the use of the neural network these data are not only statistical but can be characterized in such a way that a neural network classifies the signal inputs and as a result, we obtain a series of understandable data to work with and each data can correspond to different signals giving more flexibility to work and implement a system in assistive devices.

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Chapter 35
Speech Recognition as Assistive Technology in a Smart Closet for Visual Disability

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Abstract This paper presents the design and implementation of a speech recognition software module for a smart closet. This is a work in progress, and it is focusing on people with visual disabilities as an assistive technology for the storage, searching, and extraction of their garments. Basically, through this human–computer interface, the users use speech to make requests. These instructions are translated into commands or actions for the smart closet such as insertion of garments, search for garments by description, and/or extract their clothes from their intelligent wardrobe. The speech recognition software module has based its development on agents and is centered on Web-based environments as a user interface. The preliminary results show the proposal's potential and highlights the contributions: improving the quality of life for people with vision disabilities and integrating them into the digital age in the near future.

35.1 Introduction

In the document titled "World report for vision" presented by the World Health Organization (WHO), and according to the International Classification of Functioning, Disability and Health (ICF), "Disability" refers to the impairments, limitations, and

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restrictions that a person with an eye condition faces in the course of interacting with her or his environment—physical, social, or attitudinal [16]. Globally, at least 2.2 billion people have a vision impairment or blindness and regrettably, this number will continue increasing in the coming decades due to the population growth, aging, and changes in the lifestyle [16]. On the other hand, the work [14] defines assistive devices and technologies as those whose primary purpose is to maintain or improve the functioning and independence of an individual to facilitate participation and to enhance overall well-being. In this sense, in recent years, there has been a notable increase in research, technological development, innovation, and commercial solutions in the area of health for people with disabilities. Among the featured technologies, there is speech recognition, which is the process of converting a speech signal to a sequence of words by means of an algorithm implemented as a computer program [1]. Speech recognition is a type of human–computer interface with a big potential in this digital era due to its promising application in helping disabled people. This technology uses devices to capture spoken languages to trigger a command or action in the system. In the literature, many proposals are focusing on the improvement of the life of people with disabilities. This with the objective to facilitate their daily tasks or activities in different scenarios such as educative, sanitary, home, personal care, etc. Highlighting personal care as one of those with the greatest potential shortly. Then, motivated by the previously mentioned, this work presents a speech recognition software module composed of agents and integrated into a smart closet, which is a multi-agent system, to keep interactions with their components. Basically, an agent is a computer system or anything that can perceive its environment through its sensors and act upon that environment through its effectors [15]. This approach aims to contribute on the improvement of the quality of life for people with vision disabilities and integrate them into the digital age in the near future.

The rest of the article is as follows. Background and related work are reviewed in Sect. 35.2. The proposal of this work is presented in Sect. 35.3. The main aspects of implementation and preliminary results are shown in Sect. 35.4. Finally, this paper concludes by highlighting the preliminary results in Sect. 35.5.

35.2 Background and Related Work

The concept "assistive technology" in general is used in several fields where users require some form of assistance [3]. This technology helps people work around their challenges. The range of applications is quite wide, for example, text, speech, and typing; speech-based command interfaces; navigation; gaming and serious gaming; among others [4, 5, 13]. There are in literature some proposals that present speech recognition as an assistive technology to ease the users, both with or without a disability, into their daily tasks or activities. In reference [6] the authors propose an efficient system for arm-disabled students that allows them to interact with their computers by just giving vocal commands. The system presents an easy-to-use interface with a humanized avatar to create a user-friendly environment, which is the great interest for students. This work is focusing on educational applications. The authors in [11] present a speech recognition system whose main objective is to facilitate interactions between the user and home appliances through IoT communications based on speech commands. This approach is flexible, scalable, and adaptive to existing smart IoT devices. In [12] the authors propose the combination of augmented reality, automatic speech recognition, and audio-visual speech recognition technologies to help people with disabilities. This approach is centered on deaf and hard of hearing people and helps them to communicate with /ordinary people in different scenarios. The work presented in [2] is a tool for shopping and home control using voice commands. Its effectiveness was tested by measuring the performing tasks as well as its efficiency in recognizing user speech input. In relation to our work, it proposes to use speech recognition as an assistive technology based on agents aimed at people with visual disabilities to help them in their daily tasks or activities with relation to the management of their garments storage in a smart closet. This software module will integrate into the first smart closet Web system version, which is under construction. The Web system version is a new interface for the smart closet or intelligent closet presented in [8, 10] as a capstone project in a cross-border collaboration. The capstone project consisted of a real-size prototype of clothing, storing, and retrieving system. The software system is capable of controlling a conveyor prototype through a simple graphical interface programmed using the Java and Python languages on Raspberry Pi, which is a low-cost computer. With RFID tags and readers, the software system can manage the garments, namely, add or delete new clothes, and find these garments using filters. Our speech recognition software module integrated into the first Web system version could be employed by people with or without visual disabilities. However, for this last group of people, our focus gives them independence and self-sufficiency. Besides, to allow them to adapt to the digital age shortly.

35.3 Proposal: Speech Recognition Software Module

The proposed speech recognition software module, a facilitator agent, interacts with two components: a microphone/speaker system (agent) and a smart closet conveyor system (multi-agent system) [8, 10], such as you can see in Fig. 35.1.

The user sends a speech command (request) to the speech recognition software module through a microphone. After the software module receives the command, it realizes a query into the database. After, it translates into an operation or action that is later sent as instructions to the hardware. Next, the smart closet system conveyor will receive and execute the respective order corresponding to the storage, searching, and/or extraction of the garments. Finally, the smart closet conveyor responds to the speech recognition software module, and the latter in turn responds or gives speech comments to the user about the request made. In each stage, the software module will interact speech-to-speech with the user until attending the requests. Figure 35.2 summarizes the interaction between the main actors.

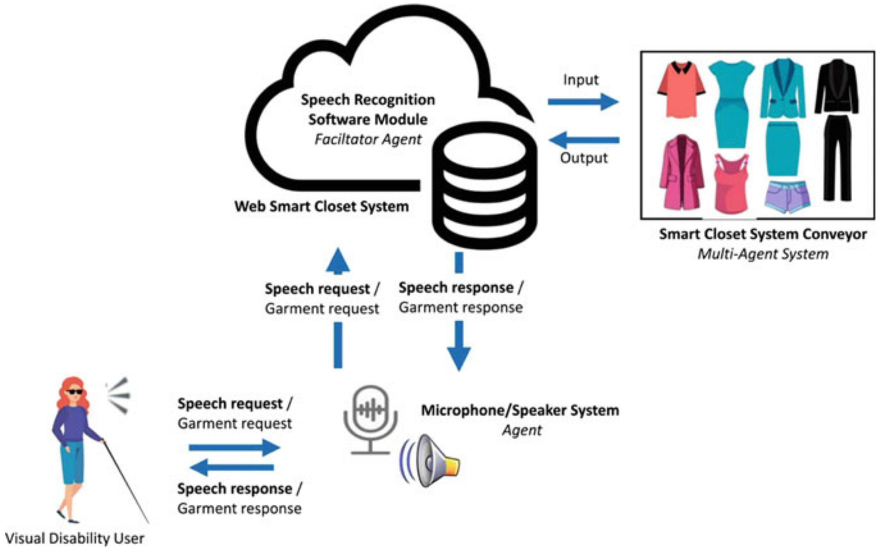

Fig. 35.1 Speech recognition software module schema

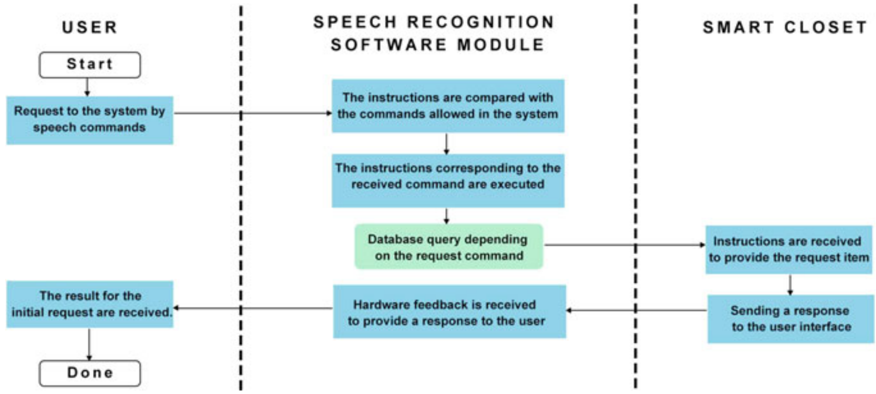

Fig. 35.2 Sequence diagram of speech recognition software module

For this work, the first version, we propose a set of basic commands as a human–computer interface between the user and the smart closet system. The first version consists of a set of six commands: “start,” “bye,” “language,” “search,” “again,” and a compound command called “out + number choice.” These commands satisfy the basic operations of the software module. Each command has a specific task that is described in Table 35.1.

Table 35.1 Description of basic command proposal for the speech recognition software module

Command	Action	
Start	Turn-on the speech recognition module for receiving the speech commands.	
Bye	Turn-off the speech recognition module.	
Language	Changes the module language for the interaction through speech commands	
Search	Search command of the clothes.	
	Category:	Man or Woman
	Color	Black, White, Blue, Red, White, Green, etc.
	Type:	Pants, Shirt, Blouse, Skirt, Jacket, Suit, etc.
	Texture:	Plaid, Stripes, Velvet, Denim, etc.
Out + "number choice"	With the Search command, the module will give the user options numbered for the selected garments. Then, the user with a speech command will indicate the number corresponding to the desired garment. Finally, with the command "Out" and "garment number," the smart closet will extract the garment.	
Again	The module repeats the last command, instructions, or options for the user.	

35.4 Implementation and Preliminary Results

The solution has been implemented and tested in Visual Studio Code using Python, JavaScript, HTML5, and CSS3 programming languages. The Web version of speech recognition software module was built with the simplest MVC (model-view-controller) framework. We use MySQL Server for storing all of the data on Windows and Workbench (MySQL) for our database modeling. Figure 35.3 deploys the database model of speech recognition software model. The libraries for speech recognition used were p5.speech and annyang. For the back-end software module, an open-source framework called Django and for front end (Web design) Bootstrap framework were used. Finally, GitHub was used as the code repository of the project.

We called Sophie to the speech recognition software module-assistant proposed and developed for this work. Sophie is modeled and implemented as an agent facilitator [7], which acts as an intermediary between the agent sending the request (microphone/speaker system) and the agent providing the service (smart closet conveyor system) such as Fig. 35.4. For simulating the sequential logic, in Fig. 35.5, Sophie is modeled as a finite-state machine. In the model, each state (which is indeed a macro-state) represents a condition in Sophie's behavior. The basic working scheme is the following: in the initial state, init, the agent waits for her name in order to be "start"; after that, Sophie enters the state in which she is able to hear the term to be searched in the database. Sophie state is able to respond to searching clothes, change to the language, and other instructions referred to in the previous section. The Sophie state is abandoned on the basis of two events: after a timeout of 30 of inactivity (in this case the state reached is once again "init"), or when the user says "language"; in the

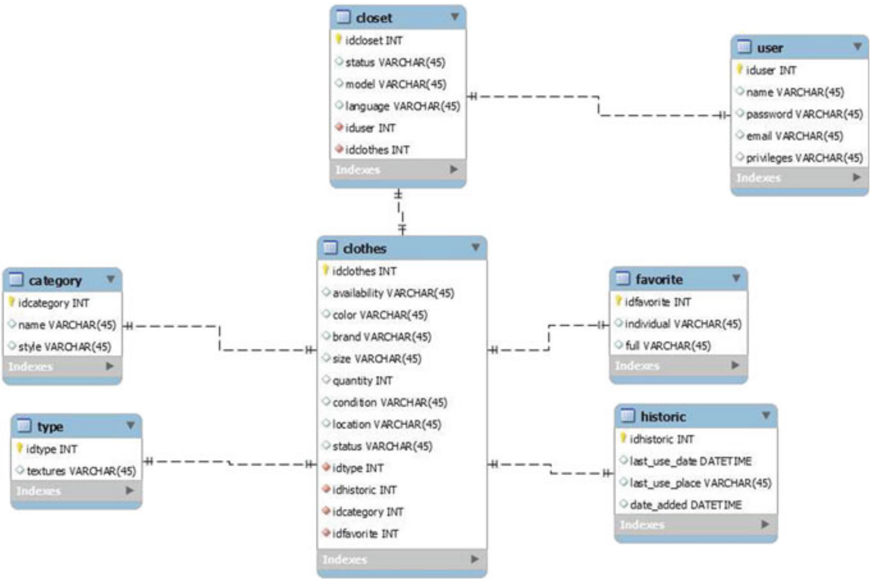

Fig. 35.3 Database design of speech recognition software module

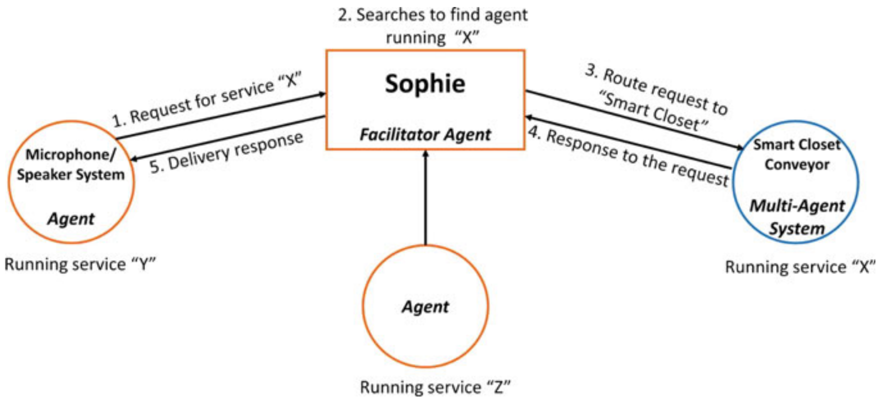

Fig. 35.4 Sophie agent model

latter case, Sophie enters in the language state asking the user for the new language desired. For this first version of Sophie, only English and Spanish languages will be available.

The Sophie implementation results can be seen in Fig. 35.6. The image displays the main pages of Sophie. Through the Smart Closet Web system's main screen, a visually disabled user can make a switch to the speech recognition interface screen using the "Start" voice command. Then, Sophie shows and executes a speech "Welcome" message and displays it on the screen. The screens in Figs. 35.6b and 35.6c show

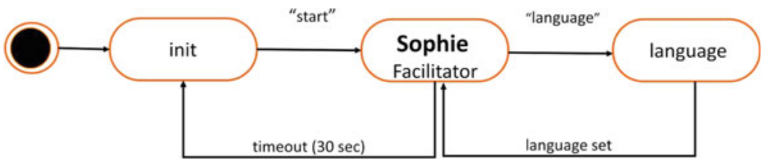

Fig. 35.5 The basic Sophie's behavior

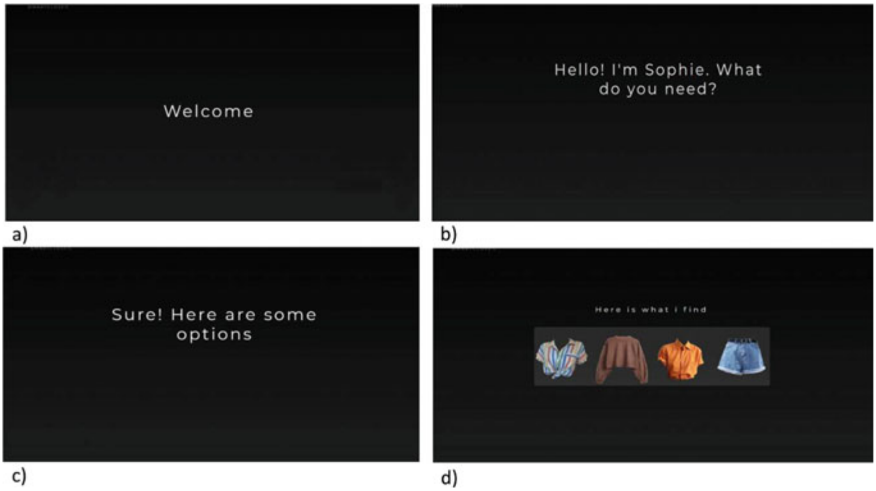

Fig. 35.6 Main interfaces of the Web-based speech recognition software module

the interactive messages between a user and Sophie. Finally, screen Fig. 35.6d shows Sophie's response to a search garment command requested by the user.

Regarding the preliminary results, in Table 35.2, we present a list of the most important test cases based on the main Sophie's functionality scenarios.

A test case is a set of actions executed to reveal if Sophie's interface or speech recognition software module works and if the functions of the software module used by its users are a success or failure. In summary, test case results identified as 1, 2, 3, 4, 6, and 8 were satisfactory. Concerning testing cases 5 and 7 corresponding to the functionality of "Search" and "Out" commands, the team continues working on their implementation. Currently, the speech recognition software module works adequately in the smart closet Web system version. However, the interactions with the conveyor are still simulating. The last stage will be to integrate and test the complete functionality of software and hardware infrastructure.

Table 35.2 Preliminary results of main Sophie's functionality test cases

Test cases #	Test case description	Expected result	Actual result	Pass/fail/not executed/suspended
1	Verify that the speech software module listens to the user	The system shows as the message the command said by the user	As expected	Pass
2	Verify that the command "Start" works	The system welcomes the user to the speech recognition interface "Sophie"	As expected	Pass
3	Verify that the command "Bye" works	The system should change from the speech interface (Sophie) to the home page (Smart Closet Web system)	As expected	Pass
4	Verify that the command "language" works	The system should indicate the current language of the speech recognition interface (Sophie)	As expected	Pass
5	Verify that the command "search + option(s)" works	The system makes a query to the database and shows the result for the request (images)	–	Not executed
6	Verify that the command "Again" works	The system should repeat the last command executed or message deployed by the system	As expected	Pass
7	Verify that the command "Out + number choice" works	The system executes/extracts the garment corresponding to the number option indicated by the user	–	Not executed
8	Verify that the user continues using the speech recognition module (Sophie).	The system should change from the speech interface (Sophie) to the home page (Smart Closet Web system) after 30 s of inactivity	As expected	Pass

35.5 Conclusions

This paper presented the design and implementation advances of a speech recognition software module based on agents and integrated into a smart closet Web system, a multi-agent system. Through this human–computer interface, users will enter garments, search garments giving their description, and/or extract the selected clothing. Preliminary results include the development of the most important interfaces and their functionalities. Moreover, the basic predefined commands were tested to verify their correct operation. This first version has considered including both Spanish and English languages. In conclusion, the main contributions of this work in progress are to provide visually disabled people with assistive technology to interact with their smart closets, to improve the quality of their life, and to integrate them into the digital age in the near future.

Acknowledgements This work was sponsored by the Tecnológico Nacional de México/Instituto Tecnológico de Matamoros (TecNM/ITM).

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Part V
Agent-Based Modeling and Simulation, Business Process Management and Multi-Agent Systems in Transportation Systems

Chapter 36
Multi-Agent-Based Framework for Resource Allocation in Cloud Computing

Safia Rabaoui, Hela Hachicha, and Ezzeddine Zagrouba

Abstract Resource allocation in computing is the first operation carried out in the execution of processes within the cloud computing. This operation consists of allocating the requested resources to the consumer. The resource can be computed and\or data storage (virtual machine, bandwidth, CPU, memory…). Cloud computing requires techniques and methods that adapt to the dynamic behaviors inherent in cloud computing environments. In this paper, we propose a multi-agent-based framework for resource allocation in cloud computing.

36.1 Introduction

The cloud computing paradigm provides different services to end users on demand with minimal costs and less overhead. The cloud platform dynamically allocates, deploys, redeploys, and cancels different services as user requirements change with the passage of time.

Resource allocation is the first operation carried out in the cloud, which consists in allocating the requested resources to consumers. Consumers of cloud services aim to leverage the resources they need to do their jobs with minimal cost [1]. Cloud service providers aim to integrate unused resources to create shared and virtualized resource pools in order to improve and maximize the use of resources and therefore

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increase their profits. Therefore, establishing a resource allocation mechanism that responds to dynamic changes in available supplier resources and consumer demands is one of the main challenges in cloud computing [1].

The technology of multi-agent system is with great interest and is fairly mature to be used to satisfy these challenges. In fact, multi-agent is a distributed system which allows the collaboration of autonomous entities. Also, in recent years, mobile agents have become an alternative and an interesting solution for the development of distributed systems. Thus, several systems benefit from the use of mobile agents, such as [2, 3].

In our research work, we propose a multi-agent-based framework for resource allocation in cloud computing. This framework aims to improve the utilization of resources and to satisfy the users' requirements by adopting the permanent publication of resources allocation/freeing which allow to improve the time and cost.

This paper is structured as follows. In Sect. 36.2, we present a description of related works. In Sect. 36.3, we discuss the main advantages of the proposed approach. In Sect. 36.4, we describe our proposed multi-agent framework, the role of different agents, and the dynamic of our system. An implementation of a proposed prototype is given in Sect. 36.5. Finally, Sect. 36.6 presents a conclusion and outlines our future works.

36.2 Related Works

Cloud computing requires techniques and methods that adapt to the dynamic behaviors inherent in cloud computing environments. Stand-alone techniques could help suppliers and users achieve this goal. Multi-agent system can manage configuration change; heterogeneity and volatility meet this requirement. The technology of multi-agent systems is of great interest, especially when combined with the technology of "Cloud Computing" which also represents a great progress in computer systems [4].

Agent-based cloud computing is an innovative discipline, its goal is to provide cloud computing solutions based on the design and development of software agents that can improve cloud resource utilization, service management and discovery, SLA negotiation, and composition of services [5, 6]. Autonomous agents could make clouds smarter in their interactions with users and more efficient in allocating resources.

In our works, we are interested to deploy multi-agent system for cloud computing challenges, especially the resource allocation challenge.

In this context, some research works have been proposed to resource allocation in cloud computing by deploying multi-agent system, among them [7]. This research work has proposed to moving toward a new discipline called "Cloud Computing based agents." The defined architecture consists of five agents who are: a cloud user agent that represents the user in the cloud environment; a cloud provider agent that represents the provider in the cloud environment; the broker agent whose role is to satisfy the user's request by finding the best offer; the data center management agent, whose role is to discover the capabilities of resources on physical nodes; and the coordinator agent acts as the coordinator between the data center management agents and controls the resources of the suppliers. In this architecture, the broker agent broadcasts the received allocation request to all cloud providers appearing in its own directory.

In [8], the authors have proposed cloud architecture based on multi-agent system exhibiting a self-adaptive behavior to address the dynamic resource allocation. This self-adaptive system acts according to QoS, cloud service information, and propagated run-time information, to detect QoS degradation and make better resource allocation decisions. The principal focus of this work is to enhance the energy consumption while satisfying the QoS demanded by users. This architecture consists of four agents who are: analyzer agent who identifies the resources and services demanded by users and build specific queries. Scheduling agent that has the responsibility to allocate resources needed by users and it makes the final decision about resource allocation. The controller agents track the status of resources in the data center. The coordinator agent supervises the whole process.

We quote also the work of [9] in which the authors have proposed an intelligent approach to allocation resources based on agents. This approach, which is distributed and scalable, can learn from previous experiences and produce better results in each resource allocation. The proposed model has been designed to address the problem of excess energy consumption by proposing solutions that consider the degree of efficiency.

This architecture defines five agents. The service monitor agent is in charge of monitoring each of the services offered by the system, collecting data regarding the requests being made and measuring parameters of their quality, performance, errors, etc., in addition to having access to the demand history. The service supervisor agent ensures that the previously established SLA agreements are being complied with, taking appropriate action in the event of detecting decencies. It is also responsible for ensuring the high availability of the service, making sure that there are at least a certain number of nodes working in independent physical teams. The local monitor agent is in charge of collecting data regarding the state of the local resources of each physical server including its virtual machines and transforming these data into adequate information for decision-making. The local supervisor agent is in charge of the control and distribution of the physical machine's computer resources, and is able to redistribute resources among the instances of execution, launch, or shut down of virtual machines. The global manager agent is in charge of making decisions about how to distribute the computer resources among several nodes of the cloud platform, and not only at a local level. The global manager agent is a specialized agent using a reasoning process in order to allocate resources at the macro-level.

36.3 Discussion

All the presented research works (in Sect. 36.2) represent interesting contributions for resources allocation; however, we note some limits. In fact, in [7], authors did not show how to choose the best data center and it did not show whether the needs of users (the requested resources) are not available how to propose an alternative solution. Also, in this work, there is not a strategy to allocate resource and the allocation request is dispatched to all existing cloud providers.

In [8], authors have proposed an architecture in which the request is delegated to one central agent who is the scheduling agent. This agent has the responsibility to allocate resources needed by users and it makes the final decision about resource allocation.

In [9], the system monitoring and decision-making-related responsibilities have been distributed throughout all the components of the platform (servers, services, etc.). Also this work is based on the reasoning process and using the BDI agent.

To overcome some challenges, we propose to distribute the allocation process and the preparation of allocation planning on many agents in order to reduce time and cost. Also, in order to minimize the network traffic, we propose to deploy mobile agent which executes the allocation process algorithm in the suppliers' destination and then uses local resources instead of having many interactions. The deployment of mobile agent offers dynamic adaption, autonomous actions, flexible maintenance, parallel processing, and is tolerant to network faults.

In addition, our proposed framework is based on permanent publication of information and this allows agents to be notified in real time with the status change of resources and then it can take the right decision and made an alternative solution.

36.4 Proposed Multi-Agent Framework

The dynamic change of resource status represents the major issue for resource allocation. In order to reach this challenge, we propose to adopt in our framework the concept of permanent publication of information. With this concept, information will be available to all entities in order to make the appropriate decisions. This can reduce essentially cost and execution time.

Our architecture is based on stationary and mobile agents and it is structured in three layers: user layer, resource allocation layer, and data center infrastructure layer. (1) The user layer provides an interface to access the cloud services and through which users specify their resource allocation needs. (2) Resource allocation layer represents an inter-layer between upper layer (users) and lower layer (data center). (3) Data center infrastructure layer provides resources as a service. It consists of a physical layer (physical machines, hosts) and a virtual layer (virtual machines, VMs). Figure 36.1 shows our proposed multi-agent architecture for cloud resource allocation.

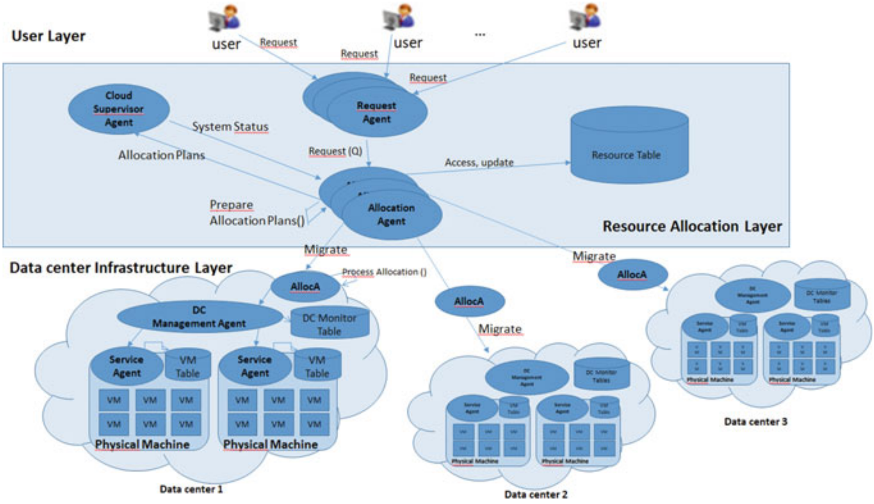

Fig. 36.1 Multi-agent architecture for cloud resource allocation

36.4.1 Agents Roles

The agents of resource allocation layer are as follows:

- *Request Agent* is a stationary agent responsible for processing user request and identifying resources and services demanded. It is also responsible to build specific queries (Request Q).
- *Allocation Agent* is a mobile agent, whose mission is to discover and search for the resources and services, specified in the request received by the Request Agent (Request Q). The allocation agent must visit the relevant suppliers offering the resources to enquire the status of VMs present in Data Center (DC) and look for the desired configuration. It is also responsible for preparing allocation plan and for applying the allocation strategy. Each allocation agent must define its itinerary and move to the cloud suppliers.
- *Cloud Supervisor Agent* is a stationary agent responsible for coordinating between all allocation agents. It checks all the allocation plans and supervises the whole process.
  The agents of data center infrastructure layer are as follows:
- *Service Agent* is a stationary agent who is responsible for maintaining the capacity of physical nodes and handling virtual machines in the data center. It is also responsible for maintaining information on the status of resources and characteristics. It has also the mission to manage resources (allocation, freeing). For each physical machine, there exists one Service Agent.
- *Data Center Management Agent (DC Management Agent)* discovery of resource capacities on physical nodes and manages virtual machines in DC. This agent has visibility into all resources in DC from the same provider. It maintains the current

state of physical machines and tracks resource status. The DC Management Agent monitors all Service Agents in data center. It supports the DC Table that stores all information about characteristics of all virtual machines.

36.4.2 Dynamic of the Proposed Multi-Agent System

The different stages of the resource allocation process are described in the following steps:

- User initiates request via graphical interface, by expressing the services and resources needed (memory, CPU, computing …).
- The Request Agent analyzes the received request; prepares the Request Q and sends it to Allocation Agent for processing.
- After the identification of requested resources, the Allocation Agent searches for most relevant suppliers of the resources specified in the Request Q from resource table. The Allocation Agent must visit the suppliers offering the resources to enquire the status of VMs present in DC and looks for the desired configuration. The Allocation Agent moves to the first data center in its itinerary.
- Upon arrival at the first data center, the Allocation Agent requests the DC Management Agent to enquire for the desired configuration. The DC Management Agent identifies the concerned physical machine and sends to the designed Service Agent to enquire about the appropriate resource. If the Allocation Agent not fined the needed configuration, it moves to the next suppliers in its itinerary.
- The Service Agent receives the request from the DC Management Agent and responds with the current status of resources and their characteristics.
- If the Allocation Agent finds the adequate resources and they are free, it must subscribe to these resources in order to be notified about their status and then execute its code in order to prepare the allocation plans. In this case, the Allocation Agent has achieved its mission and can return to its home to complete the allocation process with the Cloud Supervisor Agent. If the desired resource is not free, the agent subscribes to these resources and moves to the next suppliers in its itinerary.
- Upon arrival on its home, the allocation agent must process the status change notifications in order to update resource availability and then valid its allocation plan and sends it to the Cloud Supervisor Agent
- Finally, the Cloud Supervisor Agent sends information about state of the system and supervises the allocation process.

Figure 36.2 shows the interactions made between the different agents in the allocation process based on AUML sequence diagram [10].

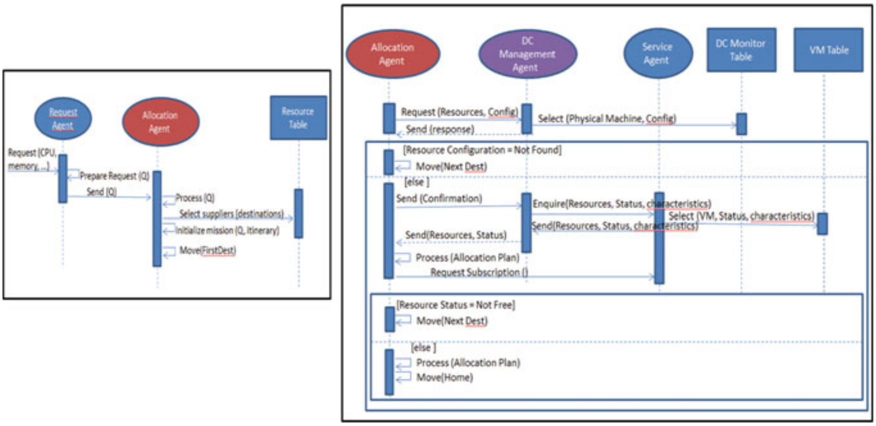

Fig. 36.2 **a** Agents interactions in home host; **b** Agents interactions in data center

36.5 Simulation

In order to implement our prototype, we decide to use the CloudSim simulator [11] to create our data center infrastructure and to use the Jade platform [12] in order to implement our multi-agent systems. The static structure of our system is a set of classes that are included into two packages: the first package CloudEnv contains the classes used for the simulation of the cloud environment. The second package MAS contains the classes used for the development of the multi-agent system. Figure 36.3 shows the structure of our project.

To illustrate the usefulness of our framework, we define an example of resource allocation scenario. In this scenario, we consider that the user aims to allocate a number of GO storage space during d period (see Fig. 36.4). We assume also that we have two data centers. Each data center has one host and each host offers a set of VMs which offer storage spaces (see Fig. 36.5).

In our prototype, we consider that we have four containers in Jade platform (Fig. 36.6). Each Data Center (DC) represents a container (container 3 and 4). The DC container contains the stationary agent (DCM Agent) responsible to monitor this data center. This agent publishes the offered services to the main container (to DF Agent) and responds to the Allocation Agent request.

The container 1 represents the cloud user level in which the user specifies his resources requirements through a graphical user interface.

The container 2 represents the allocation system which contains the Allocation Agent and it is responsible to receive the request of user, to search the cloud service providers from the main container and move to each selected provider in order to choose the best offer. Figure 36.6 illustrates the different interactions made in the JADE platform.

In our scenario, the user requests to allocate 450 GOES. The DCM Agent1 provides 450 GO with 295.211 Budget and the DCMAgent2 provides 450 GO with

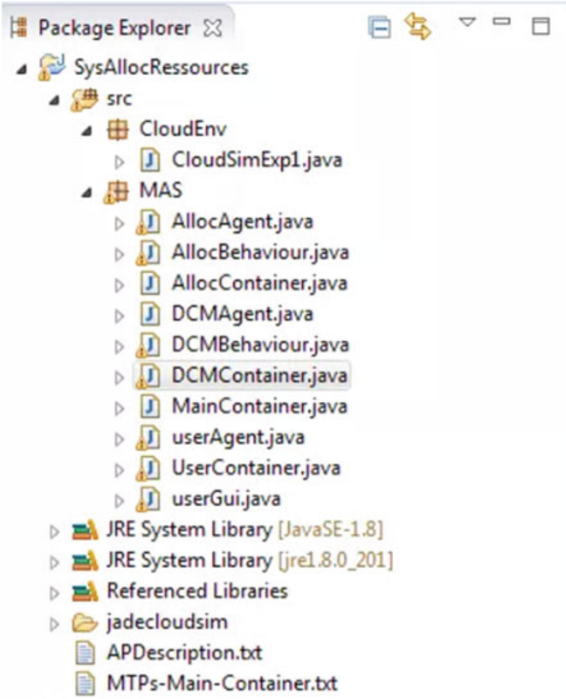

Fig. 36.3 The structure of our project

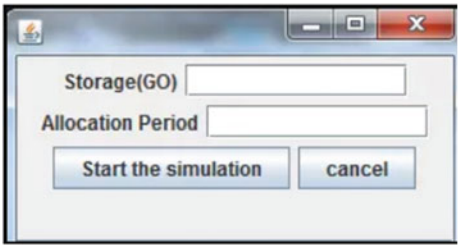

Fig. 36.4 The user request graphical interface

```
Simulation completed.

========== OUTPUT ==========
Cloudlet ID    STATUS    Data center ID    VM ID    Time    Start Time    Finish Time
    0         SUCCESS         3              0       320       0,1          320,1
    5         SUCCESS         3              0       320       0,1          320,1
    1         SUCCESS         3              1       320       0,1          320,1
    6         SUCCESS         3              1       320       0,1          320,1
    2         SUCCESS         3              2       320       0,1          320,1
    7         SUCCESS         3              2       320       0,1          320,1
    4         SUCCESS         3              4       320       0,1          320,1
    9         SUCCESS         3              4       320       0,1          320,1
    3         SUCCESS         3              3       320       0,1          320,1
    8         SUCCESS         3              3       320       0,1          320,1
```

Fig. 36.5 An extract of cloud environment configuration console

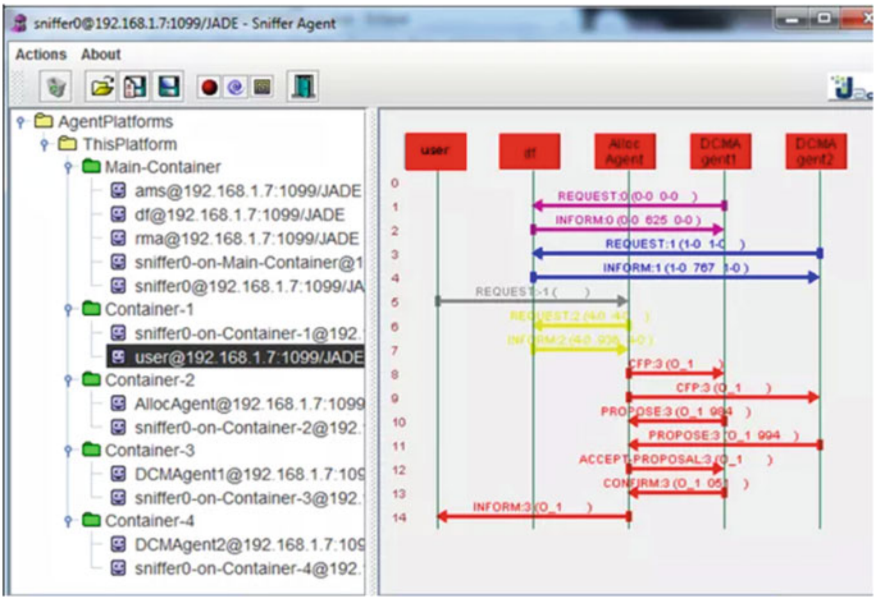

Fig. 36.6 Agents interactions in JADE Platform

306.114 Budget. Then the Allocation Agent chooses to allocate from DCMAgent2 which represents the best choice. Figure 36.7 shows the lunch console of allocation process.

36.6 Conclusion

In this paper, we have proposed a framework based on stationary and mobile agents for dynamic resource allocation in the "Cloud Computing." In our architecture, stationary agents are responsible to treat user request, manage data canter resources, and handles notifications to mobile agents. Mobile agents have the mission to discover and search for the resources specified in the user request. They are also responsible for preparing the allocation plans and implementing the allocation strategy. Our proposed framework can reduce network traffics and minimize time and cost.

In the future work, we plan to present a formal model of our approach defining the query for resource allocation, user preferences, and agent rules. We also plan to add security module for the resource allocation process.

```
-------------------------------------------
I'am the allocation agent my name is:AllocAgent@192.168.1.7:1099/JADE
Search for services...
List of datacenters found :
====DCMAgent1@192.168.1.7:1099/JADE
====DCMAgent2@192.168.1.7:1099/JADE
#########################################
VMs allocation request:
From :rma@192.168.1.7:1099/JADE
Vms : Storage= 450 GO
...........................
Sending the request....
....... In progress
**********************************
Conversation ID:transaction_Storage= 450 GO_1
Receiving the offer :
From :DCMAgent1@192.168.1.7:1099/JADE
Budget=295.21138857840117
**********************************
Conversation ID:transaction_Storage= 450 GO_1
Receiving the offer :
From :DCMAgent2@192.168.1.7:1099/JADE
Budget=306.1143080262388
----------------------------------
closing of the transaction.......
...... In progress
........................
Confirmation Receipt ...
Conversation ID:transaction_Storage= 450 GO_1
```

Fig. 36.7 Lunch console of allocation process

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Chapter 37
Characterizing the Data Basis of Parametric Computer-Aided Design Systems for Agent-Based Modeling

Paul Christoph Gembarski

Abstract Still, a central tool for mechanical engineering is the computer-aided design (CAD) system for defining product shape and production information. Until today, researchers and practitioners attempted to implement intelligent agents as decision support or synthesis and analysis tools into CAD systems. To those belong multi-agent systems that analyze CAD models regarding manufacturability and production planning or support in knowledge retrieval and (manufacturing) feature recognition. This paper raises the question of what data and information sources a parametric CAD system provide that can be used for intelligent agents and agent-based modeling, and how agents may operate these. The contribution is an analysis and characterization of trigger, perception, and actor mechanisms for the interaction of intelligent agents and CAD systems in mechanical engineering. Developers of corresponding multi-agent systems can use the resulting morphological matrix as design tool.

37.1 Introduction

The development of modern technical devices, as components of cyber-physical systems, involves both human and artificial experts collaboratively [1]. A single engineer can hardly overview a corresponding solution space, i.e., the set of all feasible solutions for a design problem, with all occurring degrees of freedom for such a component [2]. The application of computer-aided synthesis and analysis systems for the respecting design artifacts is state of the art in many disciplines. More than this, computer-aided engineering environments include product data management and collaboration support systems that allow for coordination of large teams as well as formalizing and communicating knowledge between all stakeholders [3].

Still, a central tool for mechanical engineering is the computer-aided design (CAD) system for defining product shape and production information. Meanwhile,

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CAD systems have developed to powerful parametric 3D design systems where a designer is able to modify his parts and assemblies simply by changing values of dimensions for lengths, adding, or deleting features and implement engineering knowledge to adapt designs to new or changed requirements more rapidly [4, 5].

In the last years, researchers and practitioners attempted to implement intelligent agents into such computer-aided engineering environments. Focusing on CAD systems, multi-agent systems are reported that analyze CAD models regarding manufacturability and production planning [6–8] or support in knowledge retrieval and (manufacturing) feature recognition [9, 10]. It can be observed that the interfaces and interactions between agents and CAD system are narrowly focused on the respecting modeling task. For example, Dostatni et al. [11] use data from the bill-of-materials and the physical properties from CAD part documents to check an assembly for design for recycling guidelines as these sources contain data about the components' material.

This paper raises the question of what data and information sources a parametric CAD system generally provides that can be used for intelligent agents and agent-based modeling, and how agents may operate on these. The contribution is an analysis and characterization of trigger, perception, and actor mechanisms for the interaction of intelligent agents and CAD systems in mechanical engineering. Developers of corresponding multi-agent systems can use the resulting morphological matrix as design tool.

Section 37.2 presents the theoretical background and Sect. 37.3 introduces data sources in CAD systems. Section 37.4 then relates these to agent knowledge and perception and leads toward the morphological matrix. Its application is shown in Sects. 37.5 and 37.6 concludes the contribution and outlines further research.

37.2 Theoretical Background

37.2.1 Intelligent Agents and Multi-Agent Systems in Mechanical Engineering

Agent-based modeling and simulation, as well as multi-agent systems, have been proposed for various applications since the 1980s [12–14]. The definition of "agent" is still subject to standardization, but there is widespread agreement in literature that an agent is a software entity that operates autonomously, without intervention from a human user, to accomplish a task [12]. To do this, an agent must perceive its task-relevant environment, react to changes in the environment, and be aware of consequences [7].

Since a multi-agent system implementation usually integrates more than one agent, the individual agents need the ability to communicate and collaborate with other agents or the user [15]. Figure 37.1 depicts this as a mental model. The notion "intelligent agent" outlines that an agent is self-responsible and self-capable of

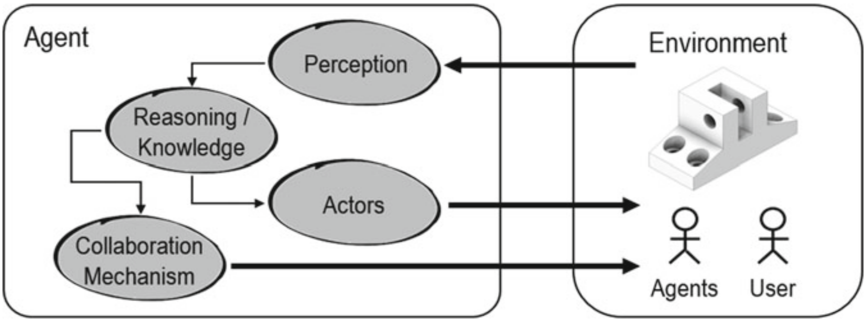


Fig. 37.1 Mental model for agents in a multi-agent system

building and adapting its knowledge base, reasoning capacities, and following adjust its goals [16].

Within mechanical engineering, different application areas for multi-agent systems and intelligent agents exist [7, 14]:

- Workflow management in collaborative engineering
- Simulation of system behavior and control circuits
- Synthesis or reengineering of design artefacts
- Analysis of product characteristics according to design guidelines.

37.2.2 Computer-Aided Design

Parametrics and constraint implementation of today's CAD systems are a basic requirement for the planned changeability of geometry and thus for the modeling of a design solution space. Both distinguish these tools from conventional modeling of rigid geometry blocks and 2D line drawing [17, 18]. Parametrics include variables for dimensions of sketch or 3D modeling elements, relations between such dimensions, geometric constraints, i.e., parallelism between two sketch lines, as well as the chronology, i.e., the modeling history, of the CAD model.

The German VDI (German Association of Engineers) guideline 2209 [19] distinguishes between two further types of CAD systems which provide additional functionalities for the creation of variable geometry models and for the representation of design knowledge (Fig. 37.2).

Feature-based CAD systems are an extension of the parametric systems. In this context, a feature represents a semantic information object usually consisting of several related geometry elements with parametrics and behavioral rules. Features can thus adapt flexibly to their environment to a limited extent. Within features, additional information can be stored, e.g., on manufacturing processes, which can be further processed in software tools for the preparation of models into NC programs for the control of manufacturing systems [3]. In addition to the parametrics, these

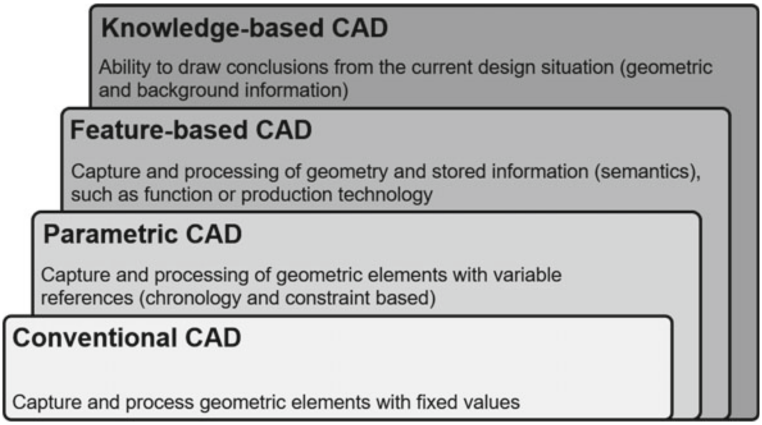


Fig. 37.2 Overview of the principles of 3D modeling [19]

models thus contain further design knowledge, which is, however, independent of the actual modeling task.

As fourth principle, VDI 2209 introduces knowledge-based CAD, which Chapman and Pinfold [20] characterize as evolutionary step in computer-aided engineering as it combines object-oriented programming, artificial intelligence, and CAD. This approach thus goes beyond the mere modeling of the design solution space: It additionally maps processes and strategies by algorithms, how this solution space is explored and how the optimal solution, satisfying all requirements and restrictions, is calculated and integrates design rules, dimensioning formulae, spreadsheets, macros, and interactive applications like configurators or generally expert systems [21–23].

37.3 Data Sources in Computer-Aided Design Systems

There are two starting points for analyzing and characterizing data sources for agents in CAD systems. First, VDI 2209 defines modeling objects (the “what”) for each of the described four principles as shown in Fig. 37.2. Second, the application programming interface (API) model of a CAD system describes background operations and the foundational data model (the “how”). To reduce abstraction, the following parts of the article are explained on the example of the CAD system Autodesk Inventor, focusing on part modeling.

37.3.1 CAD Modeling Objects

Starting from conventional CAD, the basic modeling object is the geometric model of the designed part or assembly. Standard topological representations use either boundary representation or constructive solid geometry or hybrid forms [3]. In today's CAD systems, usually surface or solid bodies, their shells, faces, edges (and edge loops) as well as single vertices may be addressed.

Regarding parametric and feature-based CAD, the model definition changes fundamentally. Besides the topological representation, the creation rule, variable parameters, and the chronology are available. Many CAD systems rely on sketches, which are 2D or 3D geometries that are processed in a basic geometric feature like extrusion, revolution, trajectory, or loft. Applicable 3D features are used to add a fillet on an edge of a solid body or applying a wall thickness on a solid body under reference of one or more faces. Parameters may be used both for dimensions in sketches and variables in features [24].

Knowledge-based CAD offers additional model elements, depending from the CAD system, from equations between parameters, design rules (if-then-else statements) over spreadsheet integration to embedded macros and automation routines [4].

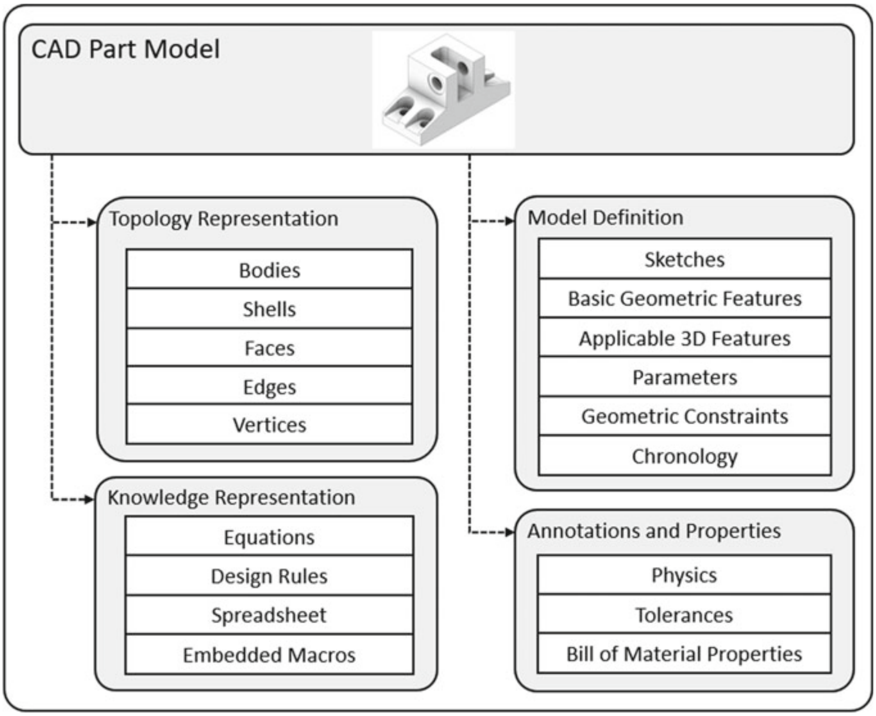


Fig. 37.3 Components of a parametric CAD part model

For all implementations, file annotations and properties are available. Parametric CAD offers the possibility to attach tolerance information to the single dimensions for further processing in manufacturing planning systems. The physics module usually calculates mass, center of gravity, and for intersections the area moment of inertia. For use in assemblies, additional bill of material properties (e.g., a project number) may be assigned. Figure 37.3 depicts these components of a parametric CAD part model.

37.3.2 CAD API Model

The API of Autodesk Inventor is a powerful tool set to create macros and automation routines. An excerpt of the API object model is shown in Fig. 37.4.

Besides the application commands, the object model offers a detailed component definition that allows the creation or modification of all features. The chronology is instantiated as browser panes (feature tree). In addition to this, the transient objects are relevant. Such are geometric or mathematical objects, which exist temporarily in some modeling situations. For example, when a component is inserted into an assembly, its coordinates need to be chosen which is done with a transient matrix. Moreover, if a working plane for an intersection is placed in the model, transient geometry comes into play.

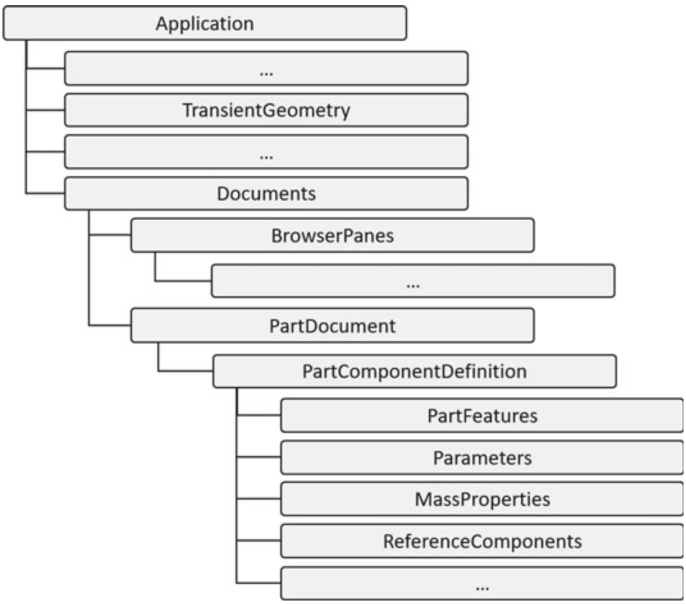


Fig. 37.4 Autodesk inventor API model (excerpt) [25]

37.4 Linking Data Sources to Agent Knowledge and Perception

According to the mental model in Fig. 37.1, agents have sensors for perceptions and actors to modify their environment. For the morphological matrix (Fig. 37.5), the trigger mechanism, which initiates the multi-agent system, is discussed separately from the sensors.

As triggers, developers of multi-agent systems can use:

- **User Action**: The user starts the multi-agent system by himself.
- **Automation Routine**: An application, either the CAD system or a remote application, starts the multi-agent system.
- **File Operation**: The multi-agent system starts operation when the user opens or saves a file.
- **Change Event**: The multi-agent system is triggered by change events in the CAD model, e.g., when the designer adds a distinct feature like fillets.

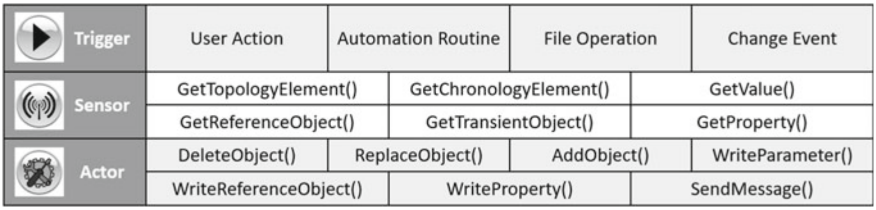
Developers can use the following sources for sensing:

- **GetTopologyElement**: The agent loads elements of the topological representation with their ID into his working memory.
- **GetChronologyElement**: An agent identifies features from the chronology for further processing.
- **GetValue**: Agents get values from parameters or parameter lists.
- **GetReferenceObject**: The agent searches for reference objects or parent–child relations of an object of the CAD model.
- **GetTransientObject**: This sensing mechanism requires an action before. As transient objects are only for temporal use, the agent defines such an object before using this for a sensory action. For example, the agent places a work plane in a CAD part model at a defined position, which it uses for the determination of a cross section for further processing.
- **GetProperty**: The agents read properties like mass or project description.

The actual reasoning then is done by comparison of the sensed objects to objects from the knowledge base.

As actors, a developer might apply:

- **DeleteObject**: The agent deletes an object from the CAD model.
- **ReplaceObject**: The agent replaces an object from the CAD model by another.
- **AddObject**: The agent adds an object to the CAD model.
- **WriteParameter**: Agents write values to parameters. Note that the assignment of a new value in this case can also mean to set equations or add references to other parameters.
- **WriteReferenceObject**: The agent adjusts the reference object of a feature.
- **WriteProperty**: The agent sets writable properties. Here it is important that some operation can result in an unwanted behavior as the user may set the mass property



Trigger	User Action	Automation Routine	File Operation	Change Event
Sensor	GetTopologyElement()	GetChronologyElement()	GetValue()	
	GetReferenceObject()	GetTransientObject()	GetProperty()	
Actor	DeleteObject()	ReplaceObject()	AddObject()	WriteParameter()
	WriteReferenceObject()	WriteProperty()	SendMessage()	

Fig. 37.5 Morphological matrix for agent triggers, sensors, and actors in a CAD system

as override for the volumetric calculation in many CAD systems. Part libraries use this with models of low level of detail.

- **SendMessage**: The agent sends a message to the user of the CAD system or other agents.

37.5 Application as Design Tool

The morphological matrix in Fig. 37.5 can be applied as design tool for agents and multi-agent systems. This section shows this for three different examples.

37.5.1 Watchdog for Sheet Metal Bending Parameters

Designers of sheet metal parts need to keep bending radii within certain limits. Using a minimum bending radius of twice the sheet metal thickness prevents the metal to defect during the forming operation. A designer now asks for a design support tool that checks the part document on save with respect to the minimum bending radius.

The trigger is already specified by the later user, as sensor the agent needs to go into each flange feature in the model chronology and check the parameter for the bending radius (combination of GetChronologyElement and GetValue). If it is too small, the agent shall change the parameter value to an equation that links the radius to the sheet metal thickness accordingly (WriteParameter). If the radius is bigger than this lower limit, the agents ignore it. In another expansion level, the agent could compare the radius to a tool database.

37.5.2 Performance Optimizer for Extrusions

The choice of reference objects affects the performance of a CAD model. For example, if a cutting extrusion is performed to an outer surface instead of doing a cut all operation, this influences the performance for loading and rebuild negatively.

An agent can perform the corresponding check. As trigger, there are multiple options: on the one hand, a file save operation, on the other hand, the change event after inserting a new cutting extrusion into the chronology may launch the agent. The sensor then has to identify if there are any topological elements used as reference object. If so, the agent changes the type of the extrusion feature to cut all. Afterward, it senses if the mass property has changed. If not, the new version of the extrusion has not affected the topological representation and the agent can approve the change.

37.5.3 Advanced Design Checker for Casting Design

Design guidelines for casting force to avoid material accumulations since such are potential points of failure like cracks and cavities as the material will shrink during cooling down. If there is no way to design the part without such an accumulation, the designer needs to arrange a pouring riser. Small accumulations may be acceptable depending on the casting material and the production process.

In such a context-dependent environment, a multi-agent system as decision support and design optimization system is generally possible. In order to detect a material accumulation, an agent needs to scan the casting part. One way to do this is to analyze cross sections and identify areas where branches join. Besides graph-based methods, deep learning image processing with heat maps is a potential technology [26]. In detail, the agent uses transient geometry to slice the geometry of the part. Afterward, each slice is analyzed regarding its topological representation and the edge loops in it. Areas with potential accumulations are saved and compared to an image library of acceptable or non-acceptable configurations. If the agent discovers a potential accumulation, the coordinates of the slice and the corresponding edge loop are stored and communicated to the designer as report.

37.6 Conclusion and Further Research

This contribution presents a morphological analysis of agent sensory and actor mechanisms in context of computer-aided design systems in mechanical engineering. The resulting morphological matrix can be used as design tool for single agents or multi-agent systems. The examples from Sect. 37.5 show how a developer transforms requested tasks into implementations. The matrix can also be used as synthetic design tool when the question is raised which functionalities are interesting, when the GetChronologyObject is chosen.

There are two avenues for extension and further research. On the one hand, the current version of the matrix focusses on mechanical CAD systems solely. In a computer-aided engineering environment, other software packages interact with each other which all host data and knowledge. Fostering these sources and integrating them into the matrix is advisable.

On the other hand, the reasoning capacities of an agent and functionalities for knowledge discovery and learning as discussed with intelligent agents are other mechanisms that could be integrated into the matrix.

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Chapter 38
Multi-Agent Path Planning Approach Using Assignment Strategy Variations in Pursuit of Moving Targets

Azizkhon Afzalov, Jun He, Ahmad Lotfi, and Mehmet Emin Aydin

Abstract This study aims to investigate the problem of assignment strategies for multiple agents. In multi-agent scenarios, agents compute a path towards the goal, while these goal destinations in some cases are predefined in advance. The topic of assignment strategies, where agents need to identify and assign goal destination at the initial position, before making any move, has not been studied sufficiently. This problem becomes even more challenging if the goal destinations change over the period of time. This study investigates for new approaches to the assignment strategy in order to improve the efficiencies introducing three novel approaches for multiple agents in multiple moving targets environments: twin-cost, cover-cost and weighted-cost criteria. These new methods have been tested against existing overall the best approach in the literature. Empirical analysis is performed on grid-based gaming benchmarks. The performance is measured for the successful completeness of the test runs and achieving the shortest distance travelled. The experimental results suggest that the new assignment strategy methods exhibit better results in comparison with the existing approaches, where even some individual cases improve approximately by 23% especially when the means are the same.

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38.1 Introduction

Pathfinding attracts a great importance in artificial intelligence (AI) research. Many search algorithms have been studied and developed to find better solutions for a long time. Such search algorithms have been applied to video and computer games, robotics, military applications [1], autonomous aircrafts or underwater vehicles [2] and warehouses [3].

There are many search algorithms that use the classical and standard scenario, where a single agent's goal is to find the shortest path, for example, A* algorithm is a well-known solution to many applications [4], MTS [5], D*Lite [6] Real-Time Adaptive A* [7], and Abstraction MTS [8].

Pathfinding problems have been developed and more complex variations of problems are introduced. The problem variation and complexity depend on the map, known or partially known environments, existence of static or moving obstacles, target or goal destinations being able to move or wait until the rescue arrives [9], number of players and combination of these. These issues have been extended to the multiple agent scenarios or multi-agent path finding (MAPF) problems [10]. A detailed literature review has been analysed for MAPF problems [11] and it is known to be a NP-hard problem [3]. Consider a scenario where five agents are present, their neighbouring nodes are not occupied and they can make a move in orthogonal directions, the possible joint actions at one time step are equal to $4^5 = 1024$ [2].

In MAPF problems, the environment is dynamic, players can move and change their positions at any time. Search algorithms need to generate a path that is adequately realistic, avoid deadlocks and finish the task successfully within a given time [12].

One of alternating approaches is use of an assignment strategy for agents. The distance measures pose a very high impact on the performance level of the strategy, while an efficient measure would help the agents approach the targets faster. This study investigates more effective distance measures encompassing multiple criteria. A variety of cost functions have been considered in this study to ascertain efficiency of each proposed composite criterion subject to various environmental configurations. Twin-cost, cover-cost and weighted-cost criteria are investigated in this paper. It is found that these criteria are more efficient than the existing best-known method, which has been commonly used in the literature.

The rest of this paper is organized as follows. Sect. 38.2 focuses on review of related work in the context of multi-agent algorithms. In Sect. 38.3, the proposed methods for assignment strategies are presented, followed by a description of the experimental setup and discussion of analysis in Sect. 38.4. Finally, Sect. 38.5 draws the conclusions from the results obtained.

38.2 Related Work

This section reviews several existing algorithms that are used in the multi-agent scenarios in the literature. Each algorithm is described briefly.

Arranging a meeting or gathering in the middle of two or more destinations is a real-life problem and it is introduced as Multi-Agent Meeting (MAM) [13]. The meeting point is optimal when the starting positions have the shortest path. To minimize the distance towards the meeting location, the sum of costs (SOC) and the maximum distance cost (makespan) are used. To overcome such problems, the Multi-Directional Meet-in-the-Middle (MM*) algorithm using the best-first search method finds the middle meeting point for several starting locations. MM* promises an optimal path for MAM problems with providing a unique priority function for both, SOC and makespan. When the solution is found for one priority function, SOC, it continues to search if any other solutions are available from another priority function, makespan.

Robotics is one of the core applications used for search algorithms and efficient path planning (e*MIP*) algorithm is one of them [14]. It uses a coordination among the robots with resource constraints, for example, path length or energy capacity. Robots monitor the environment to obtain a maximum shared information. This mutual information analyses the most informative paths. Each robot's path associates with a sum of sensing cost and travelling cost. The task is to find a path with a minimum cost and maximum information using joint effort. This is another useful method for assigning targets to the robots. The experiments are set on robotic boats in a lake.

Conflict-Based Search (CBS) is the state-of-the-art algorithm for MAPF problems [3]. It has high-level and low-level searches. These levels are the combination of centralized and decoupled pathfinding algorithms [15].

At the low level, the search is run only for the agents in the constraint tree from the collected information at the high-level search [10]. Some multi-agent pathfinding algorithms were demonstrated whose performance could change depending on the grid map, size, agents and branching factor, and there is not any global best algorithm [16]. CBS outperforms other optimal multi-agent pathfinding algorithms in the corridors and in areas with many obstacles.

38.3 Assignment Strategies

In the following section, the assignment strategies are introduced. First, the assignment strategy algorithm is described. Then, it follows current assignment strategy approaches, and finally new methods are introduced.

38.3.1 Assignment Strategy Algorithm

The success of search algorithms is when an agent occupies the same location as the target within a given time space and has a shorter distance. These types of searches are easier if it involves either one-to-one players or multiple agents to one target. The problem becomes complex when the number of players increases. The question arises how searching agents know which target they need to chase before making the first move.

Algorithm 1 outlines the Assignment Strategy algorithm [17] for multiple agents. It computes the possible distance combinations for all agents and assigns targets based on the given strategy. It works as follows: first, every player, whether agent or target, is identified and put in the lists at steps 2 and 3. Then these lists are looped through to get a distance from each agent to each target at the initial position, steps 4–8. Once all distance combinations d at step 6 are computed, it checks if d is not empty and only then computes assignments a based on the given strategy c. The currently available and new strategies will be detailed below in Sects. 38.3.2 and 38.3.3. At the final step, the algorithm returns a for all agents and targets.

At the initial position, the number of targets n is assigned to the number of agents m if the $n \leq m$. During the search, the observation continues to monitor if the target is caught or not. The optimization has been implemented to the cases when a target is captured by its initially assigned agents, then these agents will be reassigned to the next available, not caught targets. This algorithm is used during the experiments.

Algorithm 1 Assignment Strategy Algorithm

```
 1: function assign(target)
 2:    agents ← getAllAgents();
 3:    targets ← getAllTargets();
 4:    for each agents a do
 5:       for each targets t do
 6:          d ← getDistanceCombinations(a, t);
 7:       end for
 8:    end for
 9:    if d is not NULL then
10:       c ← computeAssignmentStrategy(d);
11:       a ← assignAll(c);
12:    end if
13:    return a;
```

38.3.2 Current Methods

Sum-Of-Costs. A cost is the number of movements that measures the distance from a starting location to the goal location. Every agent, at the current position, estimates a distance cost towards the goal. Sum-Of-Costs (SOC) is the sum of distances of each agent [13]. The criterion for SOC is the lowest value of the total cost of all distances for every agent. For example, in Table 38.1, where the distances are computed for three agents and three targets are displayed under *Distance* column. Based on the computation of each possible path search, there are six combinations available. *DistanceSum* is the sum of all distance costs for three agents within a combination. SOC uses the minimum value, in this case, it is the second combination which has got the shortest overall distance towards the targets for all agents.

Makespan Criterion. This is a similar criterion to the SOC described above. Makespan criterion uses distance cost but instead of a summation cost, it uses the maximum distance of all distance costs within the combination [18]. Makespan can

Table 38.1 The sample scenario of three agents versus three targets and agents' distance towards the targets

	Agent to target	Distance	DistanceSum	MaxDistance	Twin-cost	Weighted-cost 50/50
1	$A_1 \rightarrow T_1$	8	39	**16**	**624**	27.5
	$A_2 \rightarrow T_2$	15				
	$A_3 \rightarrow T_3$	16				
2	$A_1 \rightarrow T_2$	4	**37**	17	629	**27**
	$A_2 \rightarrow T_1$	17				
	$A_3 \rightarrow T_3$	16				
3	$A_1 \rightarrow T_2$	4	40	22	880	31
	$A_2 \rightarrow T_3$	22				
	$A_3 \rightarrow T_1$	14				
4	$A_1 \rightarrow T_1$	8	41	22	902	31.5
	$A_2 \rightarrow T_3$	22				
	$A_3 \rightarrow T_2$	11				
5	$A_1 \rightarrow T_3$	20	48	20	960	34
	$A_2 \rightarrow T_1$	17				
	$A_3 \rightarrow T_2$	11				
6	$A_1 \rightarrow T_3$	20	49	20	980	34.5
	$A_2 \rightarrow T_2$	15				
	$A_3 \rightarrow T_1$	14				

There are six possible combinations, and each has the sum of distances (*DistanceSum*) and maximum distance (*MaxDistance*). The twin-cost is *DistanceSum* times *MaxDistance* and weighted-cost uses a parameter value of 0.5 to *DistanceSum* and 0.5 to *MaxDistance* be called timesteps too, as each move is equal to one timestep. Consider a situation where the maximum distance cost or maximum timesteps have an important factor. For example, parcel delivery drivers might want to deliver the packages in a shorter period of time. Table 38.1 also has a column named *MaxDistance*, which is the maximum distance cost within the combination. As the table provides precomputed results for each combination, the combination-1 has the lowest value for makespan criterion.

Mixed-Cost Criterion. Mixed-cost criterion uses makespan criterion as a main component for its assignment strategy and it is overall the best criterion [18]. To assign agents to the targets it takes the best value from the *MaxDistance*, i.e. the lowest value, as shown on Table 38.1. The distance cost used in the mixed-cost criterion is the maximum time spent to reach the destination at the current position. If both *MaxDistance* values are equal, then the tie breaker uses *DistanceSum*.

38.3.3 Proposed Approaches

Twin-Cost Criterion. Similar to the previous SOC and makespan criteria, the twin-cost criterion uses distance cost to obtain the best value for its new assignment strategy. The equation for the twin-cost creation is the multiplication of two values, *DistanceSum* and *MaxDistance*. When the function *computeAssignmentStrategy*() of Algorithm 1 on line 10 is called Algorithm 2 performs the combinations on line 4–6 and returns the best result on line 7.

Consider a case where only combination-4 and combination-6 from Table 38.1 are present. For mixed-cost criterion, the *MaxDistance* with the lowest cost value of 20 would be the result. But, when the *DistanceSum* and *MaxDistance* are multiplied, the results are 902 for combination-4 and 980 for combination-6. Although the combination-6 has lower *MaxDistance* and it is the best choice for mixed-cost criterion, in the multiplication combination-4 has better result. Therefore, for the cost of two timesteps, the optimal choice is combination-4 with respect to the twin-cost criterion. In the situations, when there is a tie breaker needed, then the average of *DistanceSum* and *MaxDistance* is taken.

Algorithm 2 Twin-cost Strategy

```
1: function computeAssignmentStrategy(combinations)
2:    n ← DistanceSum combinations
3:    m ← MaxDistance combinations
4:    for each n do
5:       r ← n * m;
6:    end for
7:    return r.left < r.right;
```

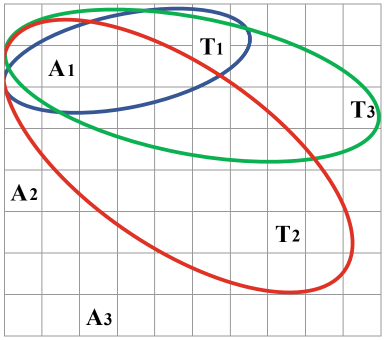

Fig. 38.1 An illustration of a sample grid map with agents A_n and targets T_n positioned in the environment with no obstacles. Coloured ovals represent possible A_1's cover area towards T_n

Cover-Cost Criterion. All previous criteria, existing ones and the new twin-cost criterion use a distance to compute the best assignment strategy for the multiple agents. This paper proposes a different approach which is not to use the cost of distances, but instead use the area of cover. Each agent computes an area that it occupies if it successfully reaches the target at the current position. The covered areas are compared for each agent, and the maximum coverage is assigned to the agent.

Consider Fig. 38.1 with three agents A_n on left side of the grid map and three targets T_n on the right side of the map. Each A_n computes a path towards existing targets and marks the expanded nodes as agent covered. Initially, A_n has its turn and the area that it occupies is marked accordingly, then it follows to the next agent. When these areas are computed, they are compared, and the highest value is found. The area with the highest cover value towards the target is assigned to the agent. Algorithm 3 Cover-cost Strategy gives the pseudocode for these steps.

Weighted-cost Criterion. This is the criterion relevant to the problems where both *DistanceSum* and *MaxDistance* costs needed to be considered. When all distances are computed and their combination values are obtained for each agent, then the results for *DistanceSum* and *MaxDistance* will allocate a specific weight value depending on the weighted-cost criterion provided.

The overview of weighted-cost criterion approach is presented in Algorithm 4. The pseudocode provides the steps to compute the best assignment strategy for agents based on the weight inputs on line 2. The equation on line 6 returns the values which are compared to get the lowest result for this criterion.

For example, a taxi driver has a plan to drive fast to get to the goal destination quicker, makespan criterion, but needs to consider shorter routes to get there at the same time, SOC criterion. Table 38.1 displays the results for weighted-cost criterion with 0.5 for *DistanceSum* and 0.5 *MaxDistance* at the last column. In contrast to the mixed-cost criterion, where the results show the combination-1 is the best option, the weighted-cost criterion displays slightly better results for combination-2.

Algorithm 3 Cover-cost Strategy

```
function computeAssignmentStrategy(combinations)
    compute area to cover
    mark area as agent covered
    get costValue for marked area
    add costValue to coverCost list
    for each coverCost c do
        maxCoverCost ← max(c);
    end for
    return maxCoverCost;
```

Algorithm 4 Weighted-cost Strategy

```
function computeAssignmentStrategy(combinations)
initialise w1 & w2 (w is weight parameter)
n ← DistanceSum combinations
m ← MaxDistance combinations
for each n do
    r ← (n * w1) + (m * w2);
end for
return r.left < r.right;
```

38.4 Experimentation and Discussion

This section contains empirical results for the existing and the proposed approaches. The experimental setup is described first and follows with performance results for the proposed new methods.

38.4.1 Experimental Setup

The experiments are implemented on the grid-based maps from Baldur's Gate video game [19]. These are commercial game industry maps that are standardized to be used as benchmarks and suggested these testbeds are excellent for AI research [20]. Seven of them are used in this study. The selection of these maps is based on the size, existence of obstacles and difficulty of navigation. The movement direction is octile, with a cost of one for orthogonal and $\sqrt{2}$ for diagonal moves.

The initial scenario is configured with four pursuing agents versus two target agents. The number of players is increased by one for each side in the next configuration. There are five different starting positions for agents and targets. The first starting position is the same state for agents and in far distance it is the same state for targets. The second starting position is to locate all agents in the centre of the map, if possible, and spread the targets around the corners of the map. The position of agents on other sets was randomly selected on the opposite side of each other. Each set of tests runs 30 times and makes in total 12,600 individual test runs. The pursuing agents use Strategy Multiple Target A* (STMTA*) algorithm [17]. The simulation [21] is implemented using C++ and obtained results from the experiments were performed on a Linux machine with 1.9 GHz Intel® Core™ i7 and 40 GB of its RAM.

38.4.2 Performance Analysis

The results are presented as the comparison of assignment strategies for multiple agents. Performance measures the average number of steps travelled for all agents on a single map and success of completeness of the path. The timeouts are excluded from the results, instead the percentage of hit rate is provided. The results are compared for mixed-cost, twin-cost, cover-cost and weighted-cost criteria.

The evaluation of assignment strategies and their comparison is displayed on Table 38.2. All new approaches are compared against existing overall best assignment strategy, the mixed-cost criterion [18]. There is no parameter for twin-cost or cover-cost criteria, but weighted-cost criterion uses weight parameters to compute the best possible combination for agents. For the experiments in this study, the ratio of 75/25, 25/75 and 50/50 used for *DistanceSum* and *MaxDistance*, respectively. The means represent the number of steps travelled for each test set and the hit rate indicates the percentage of successful runs, meaning at least one of the agents occupying the state of the targets before the timeout. At the bottom of the table, the results are averaged for all maps. Although there is not a big difference, cover-cost and twin-cost criteria perform slightly better in four pursuers versus two targets (4vs2) scenario and only twin-cost shows positive results for five pursuers versus three targets (5vs3) scenario.

In Table 38.2, the results show that mixed-cost criterion has been outperformed in every case on each map. The overall means for number of steps travelled display that weighted-cost criterion is successful with the lowest results, although with different set of parameters for each scenario, weighted-cost 75/25 on 4vs2 and weighted-cost 25/75 on 5vs3.

AR0302SR, AR0304SR, AR0313SR and AR0607SR maps are either larger in dimensions or have more nodes to expand. These maps are more difficult to navigate and provide lower rates of success, i.e. capturing the targets before the timeout, see Fig. 38.2b. The results suggest that by increasing the number of agents from 4 to 5 increases the success rate and it never drops. The great improvement is seen on maps: AR0304SR with average hit rate from 82 to 100% and AR0607SR with average hit rate from 87 to 97%, as depicted in Fig. 38.2b. The graph illustrated on Fig. 38.2a demonstrates the improvement in number of steps, averaged per map, when compared with 4vs2 and 5vs3 players. More experiments with scenarios on 4vs3 and 5vs2 test configurations for each assignment strategies have been conducted, but due to space limitations, similarities in the output results are not outlined in this paper.

Standard deviation is taken as the third metrics alongside means and hit rate to indicate the spread of data with which the particular mean value is calculated. The lower the standard deviation, the better performance is. The results in Table 38.2

Table 38.2 The means for number of steps travelled, the ratio of successful test runs and their standard deviations for all maps in all configuration settings

	4 pursuers versus 2 targets						5 pursuers versus 3 targets					
	Mixed-cost	Twin-cost	Cover-cost	Weighted-cost 75/25	Weighted-cost 25/75	Weighted-cost 50/50	Mixed-cost	Twin-cost	Cover-cost	Weighted-cost 75/25	Weighted-cost 25/75	Weighted-cost 50/50
Map	AR0302SR											
Means	67.55	65.62	64.93	65.03	65.54	**62.84**	90.11	87.77	**73.93**	89.35	89.8	85.44
Std. dev.	9.66	10.35	5.38	9.66	9.95	9.2	14.41	12.35	10.56	12.85	15.42	15.84
Hit rate	84%	87%	90%	80%	83%	83%	93%	92%	88%	94%	91%	91%
Map	AR0304SR											
Means	51.44	52.2	52.43	**41.57**	53.13	52.61	64.92	64.11	69.73	64.24	**63.74**	64.08
Std. dev.	4.21	5.05	5.46	4.54	4.96	4.52	8.05	7.21	5.77	7.31	6.42	6.69
Hit rate	83%	84%	79%	79%	82%	83%	100%	100%	100%	100%	100%	100%
Map	AR0313SR											
Means	69.33	**68.31**	69.91	68.65	69.45	70.39	83.27	81.92	85.26	**79.77**	84.47	83.9
Std. dev.	14.65	13.09	10.15	12.61	14.21	12.63	17.65	14.19	15.87	17.09	14.13	14.4
Hit rate	89%	87%	86%	91%	87%	91%	91%	94%	93%	92%	95%	95%
Map	AR0417SR											
Means	47.1	**44.97**	46.55	49.38	47.77	48.95	63.99	64.51	58.28	60.61	56.06	**55.04**
Std. dev.	14.39	8.91	15.65	11.33	9.71	12.27	24.22	37.5	19.68	22.23	20.65	17.15
Hit rate	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Map	AR0514SR											

(continued)

Table 38.2 (continued)

	4 pursuers versus 2 targets						5 pursuers versus 3 targets					
	Mixed-cost	Twin-cost	Cover-cost	Weighted-cost 75/25	Weighted-cost 25/75	Weighted-cost 50/50	Mixed-cost	Twin-cost	Cover-cost	Weighted-cost 75/25	Weighted-cost 25/75	Weighted-cost 50/50
Means	49.27	48.47	**43.08**	49.39	48.81	47.23	46.57	48.12	49.03	46.11	**45.28**	45.79
Std. dev.	9.09	8.89	3.77	10.19	8.82	8.46	9.42	8.29	6.91	7.63	6.95	7.89
Hit rate	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Map	AR0528SR											
Means	34.75	34.91	**33.29**	36.24	35.56	34.91	40.47	38.32	46.36	42.97	**38.16**	39.9
Std. dev.	7.26	7.45	2.69	7.41	7.5	7.3	11.09	9.44	6.58	10.81	7.92	6.8
Hit rate	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Map	AR0607SR											
Means	80.78	83.14	83.82	**78**	82.88	84.95	65.42	**65.3**	80.83	73.91	65.55	71.78
Std. dev.	18.67	23.49	21.02	18.51	20.29	21.83	15.66	18.45	27	23.55	16.2	22.9
Hit rate	83%	85%	91%	89%	88%	89%	99%	100%	93%	97%	99%	95%
Means of all	57.17	56.8	56.29	**55.47**	57.59	57.41	64.97	64.29	66.2	65.28	**63.29**	63.7
Std. dev. of all	11.13	11.03	9.16	10.61	10.78	10.89	14.36	15.35	13.2	14.49	12.53	13.1
Hit rate of all	91%	92%	92%	91%	92%	92%	98%	98%	96%	98%	98%	97%

The bottom of the table is the average results of all maps

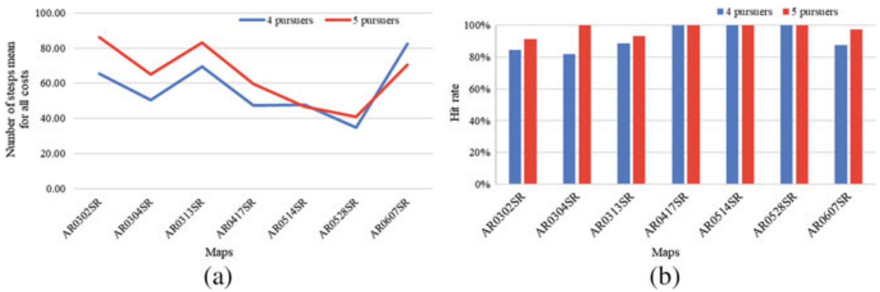

Fig. 38.2 The illustrated graphs display the number of steps mean for all assignment strategy costs per map (**a**) and the success rate of completed test runs per map (**b**)

show the standard deviation remains steady and helps differentiate the performances one another.

In overall, the experimental results show that the proposed new assignment strategies help to succeed and in some individual cases improve approximately by 23% especially when the means are the same. The reduction is seen in the number of steps, even the number of agents increase.

38.5 Conclusion and Future Work

This paper has investigated and identified more new alternative methods for assignment strategies in multi-agent scenarios in order to increase the efficiency. The proposed methods such as twin-cost, cover-cost and weighted-cost criteria have been experimented and performance analysis measures the number of steps travelled and the success of completed test runs on grid-based gaming maps. These findings highlight the potential usefulness of these methods and evaluate the strength and weaknesses during the experiments. It was suggested that the use of proposed criteria makes the algorithms more efficient than those currently used including mixed-cost criterion. The results suggest the weighted-cost criteria depending on parameters has performed the best.

Further studies should be undertaken to confirm the success of new assignment strategies with thorough experiments. Although the computation time was out of scope on this study, further work is required to identify and improve the performance.

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Chapter 39
Improving Water Distribution in a Multi-Agent System Using Fixed Multiunit First-Price Sealed-Bid Auction

Kitti Chiewchan, Patricia Anthony, K. C. Birendra, and Sandhya Samarasinghe

Abstract This paper proposes a fixed multiunit first-price sealed-bid auction that can be used to improve water distribution in a multi-agent setting that uses first-price sealed-bid auction. The proposed auction is a variation of the conventional first-price sealed-bid auction that can be used to distribute water efficiently among farmers in a community irrigation scheme during water scarcity. Our experimental result showed that the proposed auction mechanism was able to distribute more excess water to the community than first-price sealed-bid auction. In addition, the total additional profit gained in the community increased after the redistribution of excess water.

39.1 Introduction

Environmental problems associated with inefficient irrigation are common around the world. This is the case in New Zealand, where ground and surface water resources have been degraded due to nitrate leaching through drainage [1]. The Canterbury Region which is located in the South Island of New Zealand has the largest area of irrigated land and thus uses the largest proportion of water (58% of country's total water allocation); it represents 70% of the country's total irrigated land [2]. In this region, areas under irrigation have been progressively increasing over the past 13 years, from 240,778 ha in 2002 to 478,143 ha in 2017. Consequently, water use

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and water demand have steadily increased, and it has directly affected the water allocation scheme in Canterbury.

To address this, the New Zealand government implemented the water resource consent which is a water usage policy for farmers on how much water farmers can use on a daily, weekly, and monthly basis and under what minimum river flow conditions. If farmers want to use more water than the prescribed government standard, they can apply for individual water consent or buy water from water provider. The individual consent process takes a long time and is expensive. Applying for consent is only suitable for farmers who own large pieces of land and is unsuitable for farmers with smaller pieces of land. Rather than applying for individual consent, a better option for these farmers is to join a community irrigation scheme as it offers them greater financial benefits and productivity. However, to join a community irrigation scheme, farmers are still required to estimate how much water is required to irrigate their farms. This is determined based on the types of crop and the size of their farms and how much profit they intend to gain at the end of planting season. Water requirement will change if farmers choose to change their cropping strategies as crop water requirement varies from one to another. Moreover, water reduction is usually imposed by the water authority during water scarcity such as during drought season forcing the farmers to make wise decision as to which crops should be given priority to reduce their losses. As such, there is a need to manage irrigation wisely and intelligently within the farm.

In our previous work, we proposed an agent-based water management system that can be used by farmers to calculate the water requirement in the farm based on the types of crop, the soil condition, and the size of the farm that can be used to assist the farmer to make decision and to determine how much additional water is required before contacting the water provider [3]. We investigated several negotiation mechanisms that can be used to improve water allocation among farmers in a community irrigation scheme [4]. In this paper, we proposed a fixed multiunit first-price sealed-bid auction which is a modification of the first-price sealed-bid auction to improve the water distribution in a water trading scenario. We compare the performance of the first-price sealed-bid auction and the fixed multiunit first-price sealed-bid auction in terms of how much excess water is left in the community and the total additional profit gained or lost. This agent-based water management system represents individual farmer who may be negotiating with each other to sell or buy water with the aim of maximizing its profit margin. The remainder of this paper is organized as follows. Section 39.2 describes the agent-based water allocation and water allocation mechanisms. The fixed multiunit first-price sealed-bid auction and experimental design are discussed in Sect. 39.3. The experimental results and conclusion are discussed in Sects. 39.4 and 39.5, respectively.

39.2 Related Work

39.2.1 *Agent-Based Water Allocation*

Agent-based Programming (AP) is a software that uses concepts from Artificial Intelligence (AI). An agent's behavior is dependent on what it is tasked to do. AP is a microscale model that simulates operations and interacts with other agents to predict the appearance of complex phenomena [5, 6]. Moreover, the agent is able to exhibit goal-directed behavior by taking initiative while ensuring that it achieves its goal. It can learn and adapt itself to fit its environment and to fulfill the users' desires. An agent is essentially a special software component that can operate without the direct intervention of humans. Researchers can build a single or multi-agent depending on the nature of the problem. A single agent is often limited in what it can do, but these agents can work together collaboratively to solve more complex problems by way of a multi-agent system. In a multi-agent system environment, each agent is autonomous and is able to make its own decision. They are able to communicate with each other using Agent Communication Language (ACL). This allows them to negotiate and collaborate in order to achieve a common goal [7, 8]. Multi-Agent System (MAS) has been used to solve resource allocation problems. It has the potential to manifest self-organization as well as self-direction and other control paradigms and related complex behaviors to find the optimal solution [9]. MAS has been applied for water distribution based on varying water user behaviors and water restrictions [10–12].

Several researches proposed that auction mechanisms can be applied to water distribution while balancing benefit for stockholders [13–15]. Many research papers contend that MAS modeling has the potential to solve water allocation problems as it is flexible and can be modified to reflect varying user behaviors. Moreover, it is able to negotiate with other agents and the environment using auction mechanisms to find the best solution for farmer during water scarcity.

39.2.2 *Negotiation Process and Auction Mechanisms*

The negotiation process involves dialog between two or more people with the aim of reaching an agreement. The outcome of the negotiation is an important factor in determining whether the negotiations are successful [16, 17]. Negotiations are commonly used to solve labor issues, to resolve conflict and in market bargaining. A bidder can join a group and find products or services offered by a seller. A bidder may contact and negotiate with a seller who can provide compatible value and/or specialist services. Sellers and buyers can negotiate on an agreed price for services/items. A successful negotiation will result in a sale/trade [16, 18].

Negotiation between a seller and a buyer is very important. Both sellers and buyers/bidder are keen to maximize their benefits. In general, negotiations can be divided into two categories: (1) distributive negotiations and (2) integrative negotiations. Distributive negotiations operate under zero-sum conditions that one person is going to win and other bidders will lose. Integrative negotiation attempts to create total value from the course of the negotiation using "win–win negotiation." A seller is interested in obtaining a good price for the item/service that he is trying to sell; equally, the bidder is keen to receive a bargain. This form of negotiation is called an auction [19].

An auction is a process of buying and selling goods/services that involves several steps. Multiple buyers want the same item; however, they are aware that they may not win the negotiation process. Buyers need to make sure that they do not bid more than their private valuation (the maximum price they are willing to pay for the item being negotiated), and estimate the best bidding price so that they can win the auction [18]. Sellers want to sell their item at a price equal to or above their reserve price. There are four standard auction types: an ascending-bid auction, a descending-bid auction, a first-price sealed-bid auction, and a second-price sealed-bid auction [20].

An ascending-bid auction is often called an English auction. It is the most prevalent form of auction. At the beginning of the English auction, the seller sets a starting price for the item to be auctioned. Bidders compete to buy the item, with each bid being higher than the last. This process goes on until there is a single bidder left who is holding the highest bid. In the online variation, there is a fixed time: when the time is up, the winner is the one who has offered the highest bid. A bidder cannot rejoin an auction once s/he decides to quit the auction. Sometimes, in online auctions, bidders wait until the last minute before making a bid. If this happens, the time is often extended. When an auction closes, if the winning bid is lower than the reserve price, then the seller can choose not to sell the item [21, 22].

A descending-bid auction works in the opposite way. The auctioneer starts the auction with highest price. The price lowers in steps until a bidder accepts the current price. The winner pays that price for the item. This auction is called a "Dutch auction" because it is used to sell flowers in the Netherlands. Sometimes, if there are lot of the same product from the same seller, bidders call out to buy some of the available lots and the rest are reauctioned [20].

In the first-price sealed-bid auction, a bidder cannot see anyone else's bids. They can only submit one bid price. When the auction period closes, the seller opens all bids and sells their goods/services to the person who has offered the most money. The winner pays for their bid. This type of auction is used widely in the sale of artworks, real estate, and government mineral rights [19-23]. The second-price sealed-bid auction has the same rules and process as the first-bid auction. However, the winner pays the second-highest bid price. This auction is called a Vickrey auction after William Vickrey who wrote a paper on auctions [20, 21]. Sellers can use these different types of auctions to sell a single item or trade multiple units of a product. The multiunit auction is used for selling multiple units of the same item [24].

The multiunit auction is designed for people who want to sell multiple units of a particular good/service at the same time. The multiunit uniform auction is an auction where multiple units can be sold at the same price. In contrast, the multiunit discriminatory auction is an auction where multiple units can be sold with varying prices depending on the bid price.

In a multiunit uniform auction, bidders may submit single/multiple bids which specify the number of units and price per unit. These bids are sealed and are not revealed to the other bidders until the auction closes. The auctioneer serves the highest bidder as the first priority and gives them the requested number of units. The auctioneer then serves the second-highest bidder using the same process until all the items are sold. All bidders pay the same price per unit, which is the lowest winning bid. In this auction, the winners pay the highest losing bid rather than the lowest winning bid [25].

The multiunit discriminatory auction differs slightly from the multiunit uniform auction. This kind of auction is used to sell multiple homogeneous items at difference prices [26]. The bidding process is the same (bidders submit the number of units and how much s/he is willing to buy). After the auction closes, the auctioneer serves the highest bidder as the first priority. Each bidder pays the price they offered.

In summary, the multiunit uniform and multiunit discriminatory auctions have the same sequential bidding process. In a multiunit uniform price auction, the winners pay the lowest winning bid price, whereas in a multiunit discriminatory auction, the bidders pay the price they offered.

39.3 Fixed-Multiunit First-Price Sealed-Bid Auction

In an auction, typically if the auction mechanism used is first-price sealed bid, the seller will advertise the volume of water s/he wishes to sell, and bidders are free to submit a sealed bid for that volume of water being traded. At the end of the auction, the bids are opened, and the winner is the one with the highest bid. During water scarcity, farmers with excess water will be auctioning their water based on how much volume is available and farmers with water shortage are looking to bid for water which is close to the volume of water they require. Unfortunately, it is not always possible to have an exact match between what the bidder needs and what is being traded. Often, the volume of water being traded is much more than required, and so winning bidders will end up having more water than needed and ended up keeping the excess water. To optimize water distribution, it is better for farmers to buy just the right amount of water needed or close to the amount needed to reduce wastage. To solve this problem, we propose the fixed multiunit first-price sealed-bid auction which is a variation of the first-price sealed bid where the volume of water is divided into smaller volumes where the seller now can conduct multiple auctions for multiple units of water. This mean that bidders have more opportunities to bid and win while sellers have better chance of selling their excess water.

39.3.1 Algorithm Design

This auction is a variation of the single unit first-price sealed-bid auction. Instead of selling excess water as a single unit, the seller splits the water into smaller units and sells them using several auctions at the same time. This means that when the marketplace is started there are multiple units of water that are being auctioned. The seller predetermines the volume of water for each auction. Figure 39.1 shows that excess water of 100 m^3 can be split into two equal parts of 50 m^3. In this setting, bidders may bid in multiple auctions if the water needed is more than the individual lot being traded. The auction process is the same as before but this time there are more auctions in the marketplace. The winner is chosen in the same way as the first-price sealed-bid auction. However, it is possible for the same bidder to win more than one auction if s/he has bid in multiple auctions. As before, there is no auction winner if the highest bid is lower than the reserve price.

By splitting the excess water into many lots, a seller may be able to obtain higher offers from the bidder. Likewise, bidders have more opportunities to bid in more than one auction. A bidder will also be able to buy the right amount of water (or closer to the volume that they need). Hence, there is less wastage and less cost. Even though this mechanism represents an improvement on the previous one, there is still no guarantee that all the excess water can be traded, as the water volume per auction is fixed.

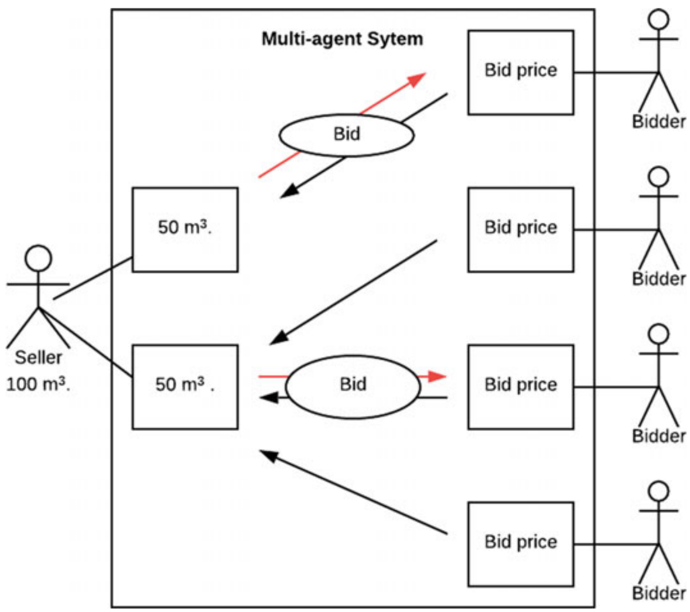

Fig. 39.1 Conceptual design for fixed multiple units first-price sealed-bid auction

Begin Get selling volume from farming information Separate the selling volume to multiple units Advertise the lots to auction market Wait for offers until the auction conclude Determine winners and reply to winner for each lot **End**	**Begin** Search lot(s) to bid Bid for the selected lot(s) Wait until the auction conclude Deal with the seller/wait for another auction **End**

Fig. 39.2 Pseudocode on seller (left) and bidder (right)

Figure 39.2 shows the auction processes for sellers and bidders. Seller starts with separating the selling volume to multiunit and advertises the volume information to all participants. When the auction time expires, seller replies with an accept message to the winner on each lot and replies with a reject message to the rest. On the other hand, bidders search for the lots that they wish to bid (they may have to bid in multiple auctions if the volume required is larger than each individual unit being traded). They then send their offers to the seller and wait for the auction to be concluded. Once concluded, they will get a message from the seller indicating whether their offer is accepted or rejected. If they win, they will proceed with the payment process, otherwise they wait for another round of auction and repeat the process again.

39.3.2 Experimental Setup

We conducted two experiments to compare the performance of using fixed multiunit first-price sealed-bid auction with the conventional first-price sealed-bid auction. For each experiment, we set up a simulated environment consisting of 55 farmers. Within this group there are 5 sellers and 50 buyers. We generated 55 farms with varying crop properties which are common in New Zealand's farm. Crop properties are randomized based on the growth stage and crop types. The farm size is fixed to 200 Ha and the water capacity to 15,000 m^3. The actual water need and water reduction is calculated using the multi-agent irrigation management and water pricing equations to set up the selling price for selling water [3, 4]. We run the auction 100 times and observed the average excess water and the total additional profit for the sellers, bidders, and community.

39.4 Result

Table 39.1 shows the comparison of excess water between first-price sealed-bid and fixed multiunit first-price sealed-bid auction. It can be seen that fixed multiunit first-price sealed-bid auction reduces the excess water more than the first-price sealed-bid for seller, bidder, and community. At the end of the auction trading, using first-price sealed-bid auction, the total excess water with sellers was reduced from 3,483.02 to

Table 39.1 The excess water after finished auction in percentage

	Seller		Bidder		Community	
	Before bidding (m^3)	After bidding (m^3)	Before bidding (m^3)	After bidding (m^3)	Before bidding (m^3)	After bidding (m^3)
First-price sealed bid	3,483.02 (100%)	768.35 (22.06%)	0 (0%)	108.75 (3.12%)	3,483.02 (100%)	**877.10 (25.18%)**
Fixed multiunit first-price sealed bid	3,483.02 (100%)	698.64 (20.06%)	0 (0%)	25.35 (0.73%)	3,483.02 (100%)	**723.99 (20.79%)**

768.35 m^3 (77.94% of the excess water was distributed). For the bidders, there was a gain of 108.75 m^3 as they have bought more water than what was needed. On the other hand, using fixed multiunit first-price sealed-bid auction, the total excess water with sellers was reduced to 698.64 (79.94% of the excess water was distributed) and there was a gain of 25.35 m^3 for the bidders. When put together, fixed multiunit first-price sealed-bid auction has less excess water in the community (723.99 m^3) compared to first-price sealed-bid auction (877.10 m^3). At the end of the auction, 79.21% of the excess water was distributed using fixed multiunit first-price sealed-bid auction. This is an improvement of 4.40% over the first-price sealed-bid auction.

The changes in additional profit is shown in Table 39.2. This result is consistent with the result obtained for excess water distribution. It can be seen that using fixed multiunit first-price sealed-bid auction sellers gained 1.26% additional profit, bidders gained 1.13%, and the community gained 1.15%. In contrast, first-price sealed-bid auction recorded a lower gain of 1.03, 0.57, and 0.63% for sellers, bidders, and community, respectively. Based on these results, we can conclude that water distribution can be improved using fixed multiunit first-price sealed-bid auction.

39.5 Conclusion and Future Work

In this paper, we describe a fixed multiunit first-price sealed-bid that is a variation of the first-price sealed-bid auction to improve water distribution in a community irrigation scheme during water scarcity. The proposed auction increases the selling chance for sellers and provides more opportunities for bidders to buy water in appropriate volume. Based on the experimental results, it can be seen that fixed multiunit first-price sealed-bid auction is useful for farmers (both sellers and buyers) as it helps to reduce the excess water and increase the total additional profit in the community. For future work, we plan to extend this work by implementing multiunit uniform auction and multiunit discriminatory auction to determine their allocative efficiency in water distribution in a farm setting. In addition, we will investigate what happens if the agents in the marketplace possess various behaviors such as greedy, generous, and neutral.

Table 39.2 The additional profit in total after finished auction in percentage

	Seller		Bidder		Community	
	Before bidding	After bidding	Before bidding	After bidding	Before bidding	After bidding
First-price sealed bid	4,069,648.46 (100%)	4,111,731.30 (+1.03%)	28,875,592.91 (100%)	29,040,002.14 (+0.57%)	32,945,241.37 (100%)	**33,151,733.44 (+0.63%)**
Fixed multiunit first-price sealed bid	4,069,648.46 (100%)	4,120,926.03 (+1.26%)	28,875,592.91 (100%)	29,201,887.11 (+1.13%)	32,945,241.37 (100%)	**33,322,813.14 (+1.15%)**

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Chapter 40
Multi-Agent Task Allocation Based on Reciprocal Trust in Distributed Environments

Koki Sato and Toshiharu Sugawara

Abstract This paper proposes a method for dynamically forming teams and assigning appropriate tasks to their members to provide services accomplished by groups of agents of different types. Task or resource allocation in multi-agent systems has drawn attention and has been applied in many areas, such as robot rescue, UAV wireless networks, and distributed computer systems. The proposed method allows agents to belong to more than one team simultaneously for efficiency based on the reciprocal trust relationship, which reflects the past performance of cooperative work, and thus allows each agent to have a queue to undertake multiple tasks. In such a setting, in addition to the communication time, the tasks in the queue can even cause processing delays, leading to instability in the observed information from the leader who selects the team members. Our experimental evaluation shows that the proposed method can efficiently enable stable team formation even in this situation. We also analyze the reasons for this efficiency.

40.1 Introduction

Services on networks, such as *service computing* and *edge computing* combined with IoT, have received a considerable attention with the recent advancement in information technologies. These services are achieved by the coordination/collaboration of multiple networked computational resources using diverse and timely data provided by sensors/smartphones to quickly respond to user demands. In general, these services are provided by performing the corresponding tasks each of which is further divided into a number of subtasks that are completed by agents that have their own functionality, data, and resources, and are often geographically distributed [1, 2, 8]. Thus, from an operational viewpoint, these subtasks have to be allocated to appropri-

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ate agents as immediately as possible, because even a delay of one subtask will result in the delay or inability of the corresponding service, which may affect subsequent services requested by other users.

These types of problems can be modeled by the team/coalition formation, in which agents with various types of resources are formed as a team and the subtasks appropriately allocated its members for each task. Several studies were conducted to appropriately select the member agents and allocate the corresponding (sub)tasks in real applications [3–6, 9–11]. For example, in the well-known *contract net protocol* (CNP) [11], a manager/leader agent initiates to form a group of agents that are appropriate to execute subtasks for the given goal. Ramchurn et al. [10] modeled the emergency management problem in the RoboCup Rescue disaster simulation platform as a coalition formation with spatial and temporal constraints to complete tasks. Hayano et al. [3] proposed a method wherein agents recognize the dependable agents through past experiences of team formation and generate tight alliance structures to execute the given tasks based on the mutual trust in a model of distributed computer systems.

However, if we consider our target applications mentioned above, they do not work well in a busy environment where such a large number of tasks are requested simultaneously. Moreover, allocating subtasks to appropriate agents is not only a combinatorial problem but is also required to consider many factors, such as communication time, their resources and computational performance, and their workloads. Furthermore, most studies do not allow the memberships of several teams simultaneously, which reduces the entire performance owing to the exclusive behaviors. Therefore, in a small-scale environment, an optimal combination of tasks and agent teams can be identified in a plausible time in a centralized way. However, we require a more flexible allocation method for agents to accept multiple subtasks from different leaders for large-scale and busy environments.

One problem in team formation when we allow for multiple memberships is the conflicts occurring when we have few high-capable agents because they are likely to be allocated many tasks, resulting in an overload. However, if we assume that such agents can decline the announced subtasks, leaders should identify the agents that are likely to undertake the subtasks to improve the success rates of forming teams for task executions.

Therefore, we propose a method for leaders to decide the agents they should work with based on *reciprocal trust* that it is derived from the good experiences of collaborations, by extending the conventional method [3]. Therefore, using our method, a leader can identify the agents they should invite as members, and conversely, member agents can identify the subtasks they should accept from among those suggested by different leaders. Such reciprocal trust reflects several factors for collaboration, such as computational capabilities, efficiency, communication latency/throughput, and average workloads based on their past achievements. In our model, each agent has the local queue for the assigned subtasks and executes them in turn. When they are not busy, they will accept almost all announced subtasks. However, when their queues are almost full, they exclusively accept subtasks from the trusted agents, unlike conventional rational agents. This can also reduce the number of messages by replying to trusted agents. Our experimental results indicate that our methods can achieve the improved performance by comparing them with those by the CNP and the rational agents that consider only past experiences but not reciprocal trust.

40.2 Problem Description

40.2.1 Agents and Tasks

We introduce the discrete time whose unit is $tick$. Let $\mathcal{A} = \{1, ..., N\}$ be the set of agents. Agent $\forall i \in \mathcal{A}$ has its capabilities or computational resources, which are described by vector $C_i = (c_i^1, ..., c_i^L)$, where $\forall c_i^l \geq 0$ is a real number and L is the number of resource types. For example, these resources correspond to the amount of CPU processing speed, memory size, data access speed, communication throughput, or available energy [7, 12]. Thus, the resources are given to agents at the time of implementation, and a high resource value means high performance or throughput, while 0 means that the agent has no corresponding capability.

We place i on (x_i, y_i) in a two-dimensional plane P, where $0 \leq x_i \leq P_x$ and $0 \leq y_i \leq P_y$, and define the communication latency between agents i and j as

$$L(i, j) = \lceil D(i, j) \cdot D_{\max}/(P_x + P_y) \rceil \quad \text{(in tick)}, \tag{40.1}$$

where $D(i, j) = |x_i - x_j| + |y_i - y_j|$ is the Manhattan distance, and $D_{\max} > 0$ is the *maximal communication latency* between agents. We adapted the Manhattan distance for the distance between agents because they operate on edge devices and base stations that are often connected by cables or optical fibers buried in a grid of roads in a city region.

Task $T = (S_T, u_T)$ is denoted by the pair of the set of subtasks $S_T = \{s_1, ..., s_m\}$, and u_T is the reward function of T, where $u_T(s_k)$ is the reward associated with subtask $s_k \in S_T$. Task T is completed when all subtasks in S_T are executed. Subtask s_k has the required resource, $R_{s_k} = (r_{s_k}^1, ..., r_{s_k}^L)$, where $\forall r_{s_k}^l \geq 0$ is the k-th resource required to execute s_k. The duration for agent i to complete s_k is $d_i(s_k) = \max_{1 \leq l \leq L} \lceil r_{s_k}^l / c_i^l \rceil$ ticks. For simplicity, we assume that $\exists l_k, r_{s_k}^{l_k} > 0$ and $r_{s_k}^l = 0$ if $l_k \neq l$. When i completes s_k, i gains the associated utility $u_T(s_k)$. Assuming that the rewards are identical to the required resources, $u_T(s_k) = \sum_{k=1}^{L} r_{s_i}^k$. *Workload* $\lambda > 0$ represents the average number of tasks requested from users per tick. The requested tasks are enqueued to the *system queue*, Q^s.

40.2.2 Task Execution by Team of Agents

Agents play two roles: *leaders* and *member*. A leader agent, who we will simply call a leader, initiates a *team* for the delegated task, i.e., selects a number of agents with enough resources to execute one of the subtasks, requests them to join the team to execute the current task, and allocates the subtasks if its requests are accepted. A member agent can belong to a number of teams and executes the allocated subtasks in turn.

The *team* formed for T is represented by (id_T, G_T, σ_T), where id_T is the team id, $\sigma_T : S_T \to G_T$ is the bijective assignment function, $G_T \subset \mathcal{A}$ is the set of agents, and $s_k \in S_T$ is assigned to $\sigma_T(s_k) \in G_T$. Because σ_T is bijective, we can define $\sigma_T^{-1} : G_T \to S_T$.

Leader i can be in an active or inactive state. When i is inactive, it tries to acquire task T from $\mathcal{Q}^s$ and becomes active; if $\mathcal{Q}^s$ is empty, i becomes inactive for a tick. Subsequently, active agent i chooses the most effectively rewarded subtask $s_\kappa \in S_T$, i.e., the utility per tick $(u_T(s_\kappa)/d_i(s_\kappa))$ is the largest, and executes it if it exists. i then initiates to form the team for the remaining subtasks. Selection of candidate member agents for a team is the main part of our proposed method and will be discussed in Sect. 40.3. Agent i sends each of those candidate agents the *solicitation message* (SM) with its team ID id_T and the suggested subtask in $\tilde{S}_T = S_T \setminus \{s_\kappa\}$ that will be allocated, and immediately starts to execute s_κ.

When i has received the responses from all candidate agents and when at least one agent has accepted each subtask, i forms team (id_T, G_T, σ_T) for T using the proposed strategy, which will be explained in Sect. 40.3. It then sends the *teaming success messages* (TSMs) to the members in $G_T \setminus \{i\}$, and sends the *regret messages* (RGMs) to the candidate agents that have accepted the SM but are not in G_T. However, if even one subtask is not accepted by any agent, i fails to form the team and sends *failure messages* (FMs) to all agents that accepted the SMs. It then returns to an inactive state.

When agent j plays a member, it also has an inactive or active state. When j is inactive, it checks the received SMs in the last one tick. If j receives no SMs, it stays inactive for another tick. Whenever j receives the SMs, it chooses a number of SMs based on our proposed strategy in Sect. 40.3, sends the *acceptance messages* (AMs) to the leaders of the selected SMs, and enters the active state. It also sends *rejection messages* (RJM) to other leaders. Agent j also has the variable $M \geq 0$ to maintain the replies from the leaders; therefore, each time j sends an AM, M is incremented by one, and M is decremented by one when it receives a reply, which is either a TSM or RGM. Whenever j receives a TSM, it adds the suggested subtask to its local execution queue Q_j^a.

An active j picks up subtask s from the head of Q_j^a if $Q_j^a \neq \emptyset$, and starts executing it. When completing s, j sends the *completion message* (CM) to the leader. j then checks the received messages and takes previously described action for each message if it exists. Subsequently, j executes one task in Q_j^a. If $Q_j^a = \emptyset$ and $M = 0$, j enters the inactive state.

When j receives a TSM, if the size of j's queue $|Q_j^a|$ already reaches the upper limit $Mq_{\max}$ (> 0), j sends the *task cancellation message* (TCM) to the corresponding leader i. Leader i then abandons the corresponding team and forwards the received TCM with team ID id_T to $G_T \setminus \{i, j\}$ to cancel the team. Other member agents receiving the TCM remove the associated subtasks from their local queues.

40.2.3 Time Required for Communication

A message from agent i to j takes in $L(i, j)$ ticks. The agent can read all received and sent messages, and obtains a subtask from Q_i^a in one tick. Therefore, the duration from the time when leader i sends the TSM for subtask s_k to member j until i receives the CM is $2L(i, j) + d_j(s_k) + w$ in ticks, where w is the delay owing to the queued tasks, that is, the time from when task s_k is queued until when it is removed from Q_j^a. Leader i cannot distinguish the breakdown of this duration.

40.3 Proposed Strategy for Team Formation

The proposed method is an extension of Hayano et al. [3] by introducing communication delays and agent queues to their model to realize efficient team formations in more realistic situations.

40.3.1 Role Evaluation

Because the appropriate ratio of the number of leaders to that of member agents depend on the structures of tasks and the degree of load, it is desirable for agents to learn appropriate roles. For this purpose, agent i has two *role evaluation* (RE) parameters, e_i^l and e_i^m, to learn the role suitable for obtaining more rewards, that is, to increase the success rate of team formation. Each RE parameter describes the degree of successful team formation when i plays a leader (e_i^l) or a member (e_i^m). After initializing these values to 0.5, they are updated by

$$e_i^l = \alpha_r \times \delta_r^l + (1 - \alpha_r) \times e_i^l \text{ and } e_i^m = \alpha_r \times \delta_r^m + (1 - \alpha_r) \times e_i^m, \qquad (40.2)$$

where $0 < \alpha_r (\ll 1)$ is the update rate. Parameters δ_r^l and δ_r^m indicate the result of team formation, that is, $\delta_r^l = 1$ if i could form a team as a leader, and $\delta_r^m = 1$ if i could join the team and execute the subtask as a member; otherwise, $\delta_r^l = 0$ or $\delta_r^m = 0$, depending on its role.

Agent i reviews its role using the RE parameters when it becomes inactive, i.e., it has no subtask to execute. Agent i chooses the leader role if $e_i^l > e_i^m$, the member role if $e_i^l < e_i^m$, or randomly if $e_i^l = e_i^m$ with ε-greedy strategy; thus, i randomly chooses one of the two roles with probability $\varepsilon \geq 0$ whatever e_i^l and e_i^m are. When member agent i is inactive for $K_r > 0$ ticks consecutively, it updates e_i^m with $\delta_r^m = 0$ and then reviews its role. Note that K_r is known as the *endurance* for a member role.

40.3.2 Degree of Trustiness

We introduce the learning parameters of *degree of trustiness* (DT), which corresponds to the degree of dependability in the previous method [3]; however, its definition is slightly different owing to the uncertainty caused by adding the condition that agents can belong to one or more teams. We assume that agent i's *trustiness* for other agent j is the expectation of j's trusted cooperative behavior toward i based on past experiences. Therefore, i tries to work with more trusting agents to increase the success rate of team formation.

Leader i has the DT $dl_{i,j}^{t(s)}$ for $\forall j \in \mathcal{A}_{-i} = \mathcal{A} \setminus \{i\}$ to express the level of trustiness in j for subtask s whose resource type is $t(s)$, where $t(s) = \arg\max_{1 \leq l \leq L} r_s^l$, i.e., the most required resource for s. Meanwhile, member agent i also has the DT $dm_{i,j}$ for $\forall j \in \mathcal{A}_{-i}$ as the leader. These DTs are updated by

$$dl_{i,j}^{t(s)} = (1 - \alpha_d) \cdot dl_{ij}^{t(s)} + \alpha_d \cdot \delta_d^l, \text{ and } dm_{i,j} = (1 - \alpha_d) \cdot dm_{i,j} + \alpha_d \cdot \delta_d^m, \tag{40.3}$$

where $0 < \alpha_d (\ll 1)$ is the learning rate, and $\delta_d^l = u_{\sigma_T^{-1}(j)} / (2L(i, j) + d_j(\sigma_T^{-1}(j)) + w)$ if leader i receives the CM from j, $\delta_d^l = 0$ if i receives the RJM, $\delta_d^l = -u_{\sigma_T^{-1}(j)}$ if i receives the TCM from j for the allocated subtask, $\delta_d^m = u_{\sigma_T^{-1}(j)} / (2L(i, j) + d_j(\sigma_T^{-1}(j)))$ if i is allocated a subtask, and $\delta_d^m = 0$ if i receives the FM or RGM. The initial values of $dl_{i,j}^{t(s)}$ and $dm_{i,j}$ are zero.

The values of the DT parameters are gradually reduced to forget the experiences that are no longer valid or to adapt to changes in the environment. This is done by

$$dl_{i,j}^{t(s)} = \max(dl_{i,j}^{t(s)} - \gamma, 0), \text{ and }, dm_{i,j} = \max(dm_{i,j} - \gamma, 0), \tag{40.4}$$

where γ is a small positive number. Note that all agents have both $dm_{i,j}$ and $dl_{i,j}^{t(s)}$ for all types of subtasks because they can choose either of the two roles.

40.3.3 Trusted Agents and Reciprocal Trust

Agent i has the sets of the trusted member agents $DL_i^{t(s)}$ as a leader and the trusted leader agents DM_i as a member, which are defined as

$$DL_i^{t(s)} = \{j \in A | dl_{i,j}^{t(s)} \geq T_L\}, \ DM_i = \{j \in A | dm_{i,j} \geq T_M\}, \tag{40.5}$$

where T_L and T_M are the threshold values to be recognized as trusted agents.

Subsequently, agents follow one of two strategies, *reciprocal trust* (RT) strategy and *reciprocal greedy* (RG) strategy, to select the member agent for each subtask as leaders and the leaders of the solicited teams as a member, respectively. Agents initially follow the RG strategy, but individually change to follow the RT strategy when $|DL_i^{t(s)}| \geq T_L^r$ for subtask s as leaders and $|DM_i| \geq T_M^r$ as members, where T_L^r and T_M^r are the thresholds to change the strategy of the agent. Note that for task T, S_T contains a number of different subtasks, and therefore the leader follows different strategies to select members depending on the types of subtasks in S_T. This is one of the major differences from the existing method [3].

40.3.4 Strategies for Leader/Member Selection

We explain how leader i selects prospective member agents for task T to which i sends the SMs with the suggested subtasks. We set the variable $X_a = \mathcal{A}_{-i}$. In the first process, i selects $s \in \tilde{S}_T$ such that $|DL_i^{t(s)}| \geq T_L^r$ and $u_T(s)$ is the largest. If it exists, i adopts the RT strategy, and chooses the agent $j \in X_a$ for s such that $dl_{i,j}^{t(s)}$ is the largest. i sends the SM with s to j and then removes s from $\tilde{S}_T$ and j from X_a. Agent i repeats the first process, while $\exists s \in \tilde{S}_T$ such that $|DL_i^{t(s)}| \geq T_L^r$. Therefore, i selects only one prospective member for each subtask in the RT strategy.

Agents adopt the RG strategy in the second process if $\tilde{S}_T \neq \varnothing$. First, agent i sorts $\tilde{S}_T$ by descending the order of the utility. It takes subtask s in $\tilde{S}_T$ in order from the top and assigns s to $j \in X_a$ whose $dl_{i,j}^{t(s)}$ is the largest. i sends the SM with s to j and removes j from X_a. Leader i repeats this second process $N_d \geq 2$ times, where N_d is an integer known as the *solicitation redundancy*. Therefore, in this process, N_d agents are assigned for each subtask. Finally, note that agents adopt the ε-greedy strategy, thus, in the selection of a prospective member in both processes, i selects a prospective member randomly from X_a with probability ε.

After receiving the responses to the SMs, if only one agent j accepted the SM for s, i assigns s to j. If multiple agents accept the SMs for subtask s, i assigns s to the accepting agent whose $d_{i,j}^{t(s)}$ is the largest, but with probability ε, i assigns it to another agent that accepted the SM. If $\exists s \in \tilde{S}_T$ such that no agents accepted, this team fails to be formed.

Conversely, member agent j chose the leader to accept its SM when it received multiple SMs. When $|DM_j| < T^r_M$, if j has at least one free space in Q^a_j, j takes the RG strategy with which the member agent replies with AMs to all received SMs. Thus, j tries to maintain its local queue full such that it pursues more utilities by executing more subtasks. In contrast, when $|DM_j| \geq T^r_M$, j takes the RT strategy, in which it sends AMs to the leaders in DM_j, and the RJMs to other leaders. This can strengthen the reciprocal trust between j and the leaders in DM_j. Further, j might select a leader that is not in DM_j with probability ε.

40.4 Experimental Evaluation and Discussion

40.4.1 Experimental Setting

We experimentally evaluated our proposed strategy by investigating the performance, including the number of executed tasks, the required time for task completions, and the communication time under various workloads specified λ in the two-dimensional plane ($P_x = P_y = 50$) when $|\mathcal{A}| = 500$. We compared them with those by the *reciprocal greedy only* (RGO) strategy in which agents always take the RG strategy and those by the modified CNP strategy in which agents do not have the DT but the RE parameters, so, therefore, they can individually select their roles. Leaders in the CNP announced all subtasks to the nearest one hundred agents, and the members received the announcement and bided the subtask s, whose utility per tick is the largest. Subsequently, leaders select the member whose bid value is the highest. Other parameter setups are listed in Tables 40.1 and 40.2. The data shown below are the averages of ten experimental runs.

Table 40.1 Experimental setting

Parameter description	Value
Types of capabilities	$L = 3$
Agent's capabilities	$c^k_i = 1$–5
Max. comm. latency	$D_{max} = 5$
Solicitation redundancy	$N_d = 2$
Endurance for member role	$K_r = 100$
Local queue size	$|Q^a_i| = 5$
Number of subtasks	$|S_T| = 3$–6
Size of system queue	$|\mathcal{Q}^s| = 1000$
Required capabilities	$r^k_i = 5$–10

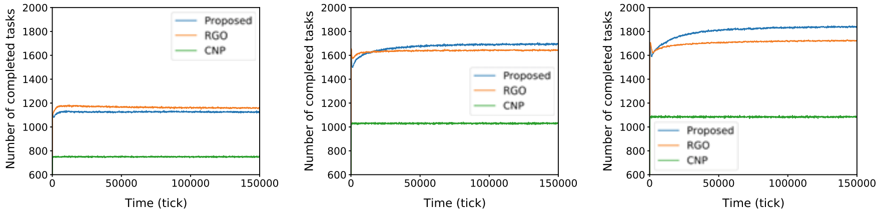
Table 40.2 Learning parameters

Parameter description	Value
Thresholds of trusted agents	$T_L, T_M = 0.7$
Threshold to change strategy as leaders	$T_L^r = 1$
Threshold to change strategy as members	$T_M^r = 3$
Learning rates	$\alpha_d, \alpha_r = 0.05$
Probability of explore in ε-greedy strategy	$\varepsilon = 0.05$
Reduction value	$\gamma = 10^{-8}$

40.4.2 Experimental Results

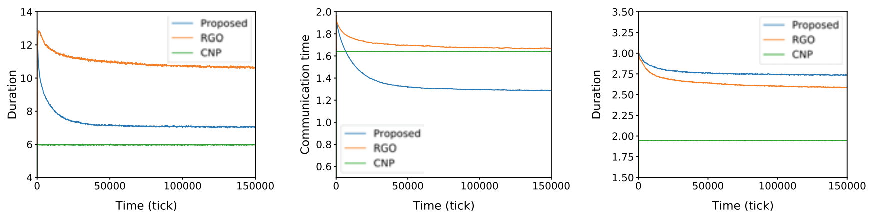
The number of executed tasks every 100 ticks when $\lambda = 12$ (light workload), $\lambda = 18$ (moderate workload), and $\lambda = 20$ (high workload) are plotted in Fig. 40.1. Note that the degree of load $\lambda = 20$ does not exceed but is very close to the upper limit of the system's capability. First, we can see that agents using the proposed strategy executed more tasks than agents using the RGO strategy or CNP except when $\lambda = 12$. When their workload is moderate or higher, multiple solicitations to members may increase the success rate of team formation, but simultaneously, the leaders tend to assign subtasks only to limited capable agents, causing overload and long delay. As Fig. 40.1 shows, this tendency becomes more pronounced as the load factor λ becomes higher. It can be safely said that reciprocity, i.e., the narrowing of task requests based on mutual trust in past actions, was effective when the workload was high. In contrast, when the load was light, such conflicts seldom occurred even if tasks were requested from multiple agents, and there was no need to narrow down member agents based on reciprocal trust. Note that the number of executed tasks reflected the success rate of team formation; thus, the rate was quite high when using the proposed method.

Next, we examined the features of the proposed method to identify the reasons for the improved performance. Figure 40.2 plots the required time of one task completion from the viewpoint of leaders (Fig. 40.2a), the average one-way communication time



(a) $\lambda = 12$ (b) $\lambda = 18$ (c) $\lambda = 20$

Fig. 40.1 Number of executed tasks



(a) Required time to complete (leaders' viewpoints) (b) Communication time per message (c) Execution time (members' viewpoints)

Fig. 40.2 Features of the proposed method ($\lambda = 20$)

between leaders and member agents (Fig. 40.2b), and the execution time per task of member agents (Fig. 40.2c). We only show the data when $\lambda = 20$ because the distinctive features of the proposed method appeared in this setting.

Figure 40.2a indicates that the agents using the proposed method could gradually reduce the time required for the task over time, compared to those using the RGO strategy and CNP. Although the execution time per task was larger with the proposed method (Fig. 40.2c), the communication time was shorter than that with other methods (Fig. 40.2b), resulting in the shortest time required for each task observed by the leaders. We can see that when agents used the RGO strategy, the time required for completion observed by the leaders was relatively long and the efficiency improvement by learning was small (Fig. 40.2a). Whereas the actual task execution time was shorter than that of the agents using the proposed method (Fig. 40.2c), the communication time was quite longer (Fig. 40.2b), and the ties between agents were weaker owing to the absence of weight on reciprocity; therefore, the member agents, especially the more capable agents, would continue to be overloaded with task requests arriving from many leaders.

Finally, Fig. 40.2a, c indicates that the required time per task was the smallest when agents used the CNP, although the communication time was relatively long (Fig. 40.2b). Thus, the CNP could assign tasks to more efficient and appropriate members, but when agents used the CNP, the success rate was quite low (Fig. 40.1a), probably because of the conflicts caused by the concentration of task solicitations.

40.4.3 Discussion

We could observe a number of important characteristics of the proposed allocation method. First, when the environment was busy, agents using the proposed strategy performed more tasks than agents using other strategies/protocols, but when the load was low ($\lambda = 12$), the RGO strategy appeared to be better. Nevertheless, we would like to emphasize the significance of our method. The potential performance of the system must be exploited when the environment is really busy, and our proposed method has this desirable property.

The results were not shown; however, we conducted an analysis when the solicitation redundancy $N_d = 1$, and we found that the performance of agents using the proposed method considerably decreased. This means that it is necessary to attempt multiple members to find good collaborators; therefore, we introduce condition $N_d \geq 2$ in Sect. 40.3.4.

We believe that the reciprocity-based trust strategy we have proposed has two benefits and could bring out the above properties. First, by connecting with specific agents by reciprocity, the acceptance rate for task solicitations increased, and thus the success rate of team formation, which is identical to the number of executed tasks, increased even if the number of SMs was limited to one. Second, these connections between agents based on reciprocal trust could reduce the length of the local queue Q_i^a. This has the effect of greatly lowering the time required for task completion from the leaders' viewpoint. Thus, the proposed method succeeded both in increasing the success rate and decreasing the time required simultaneously. Although the details are not described, we confirmed that the number of messages was also greatly reduced.

40.5 Conclusion

We first formulated our problem of task allocation in this paper. We then proposed the method for forming a team and allocating appropriate tasks to each member of the team to execute a requested task based on the reciprocal trust, which is the result of the past successful experiences of collaborations. One main feature of our model and method is that agents can belong to multiple teams simultaneously. For this extension, we assume that agents have the local queues to store the committed subtasks. We also introduce the communication delay to express the communication latency and the delay because of the executions of the queued tasks. Our experimental results indicated that the proposed method achieved a good performance, especially in a busy situation, by keeping strong connections with the trusted agents.

We would like to extend this method to improve the performance because it slightly lowered when the system was not busy.

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Chapter 41
TDABC and Estimation of Time Drivers Using Process Mining

Michal Halaška and Roman Šperka

Abstract Costing systems play a crucial role in many managerial decisions; thus, it is crucial that costing systems provide appropriate information. Time-driven activity-based costing systems (TDABC) are successors of activity-based costing systems (ABC). ABCs were created in order to address shortcomings of traditional costing systems, while TDABCs were created to address mostly implementational shortcomings of ABCs. In this research, we focus on the advantages of integration of process mining (PM) and TDABC for estimation of activity durations used as time drivers for allocation of overhead costs. Thus, we have stated two research questions: (1) Can PM be used for estimation of time drivers? and (2) What are the benefits of using PM for the estimation of time drivers? To address these questions, we present a proof of concept, where we analyze two real-world datasets representing loan application process. Firstly, we clean both datasets, and then, we use PM techniques to discover process models representing the process. We show that PM can be used for time estimation and time drivers' determination and that there are potential benefits to this approach. Furthermore, we discuss the possibility of using actual times instead of estimates.

41.1 Introduction

The difficulty inherent in choosing a proper and accurate cost allocation method for enterprises has been widely discussed by academics and practitioners. Overhead cost allocation is one of the most serious problems within cost management for companies and accurate information about costs is crucial for all businesses, such as

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manufacturing, trading, service sector, etc. [1]. In many cases, accurate cost information about products and services, customers, suppliers, and business processes can provide a competitive advantage by, e.g., elimination of non-value adding activities, elimination of lossy products, pricing of products, etc.

Traditional absorption-costing systems have several limitations, which became wildly publicized in the early 1980s. First limitation of traditional costing systems comes from the use of principles of averages, which has become obsolete due to increasing competition resulting in the need of reducing cost and more detailed information on company costs, and change in the cost structure of companies, where so-called "averagisation" can lead toward inaccurate overhead cost allocation. Popesko [2] defines averagisation as the end result of allocating a proportionally average volume of costs of any type to all cost objects. Glen and Becker [3] defined the number of fundamental limitations of traditional costing systems, e.g., significant increase in service-related costs, indirect cost of technology, etc. Traditional absorption costing provides accurate results when the company has customers similar in nature, very homogenous products, and few departments with overheads [4]. However, when the company has heterogeneous output with large amount of overhead costs or with great number of processes and activities, traditional costing systems struggle to provide accurate information [2, 5, 6].

Since then, several methods have been introduced that avoid inaccuracies of traditional costing methods like, e.g., variable costing, ABC, TDABC, etc. Variable costing helps to avoid issues related to imprecise overhead cost allocation while calculating the capacity of the company by separately measuring the company's variable and fixed costs. However, this method is unable to manage company's overheads effectively and is insufficient when it comes to producing information on total product cost [4]. Since the fixed costs are not being allocated to the cost objects at all, the variable costing is effective in short-term decision-making. However, production and other decisions are not short-term decisions and, thus, it is inappropriate to use variable costing [7]. Volume-based cost systems run into difficulty regarding operations that do not vary per unit sold like, e.g., sales order processing, which is driven by the number of sales orders placed by customers [8]. In such cases, volume-based allocation of costs based on volume drivers like, e.g., direct labor or volume, leads to distortions in cost figures.

The remainder of this paper is organized as follows. Section 2 presents an introduction to TDABC approach in cost accounting and reasoning behind its use. Section 3 briefly introduces PM, its fundamental areas, and required data. The following section presents the research methodology, and the next section presents the results of our research. Finally, we conclude and discuss our results.

41.2 Time-Driven Activity-Based Costing

Activity-based costing is based on three assumptions [9]: products require activities, activities consume resources, and resources cost money. The basic idea behind the ABC is to allocate costs to operations through the various activities in place that can be measured by cost drivers based on cost-and-effect relations. The basic idea behind the ABC is to allocate costs to operations through the various activities in place that can be measured by cost drivers based on cost-and-effect relations [1, 2]. ABC focuses on the overhead of individual activities, as well as allowing for the allocation of overhead costs to operations that brought about these costs. It firstly assigns overhead costs to activities and then to products, orders, or customers, based on consumption of individual activities [8, 10, 11]. Moreover, ABC approach can provide managers with information on how operating activities add value to outputs, and thus, as a result, be able to identify and eliminate costs related to non-value-adding activities [12, 13].

However, ABC has several difficulties related mainly to its implementation. To solve these problems, the concept of time-driven activity-based costing (TDABC) was introduced. It was specifically designed to simplify the implementation and maintenance of the ABC system [12, 14]. TDABC provides the ability to identify and report complex and specialized transactions in a simple way by using time equations that can employ multiple drivers. As shown by several researchers, TDABC can bring positive results and better representation of company's costs. According to Everaert et al. [8] the breakthrough lies in the time estimation, where the time required for performing the activity for each case is estimated. Traditional costing systems ignore the critical role of time, which can affect the expected profits inefficiencies caused by bottlenecks [6]. TDABC approach requires only two parameters to estimate that is the unit cost of supplying resources and the time required to perform an activity by this resource group [10, 15]. While time drivers are generally more accurate than transaction drivers, they are also more expensive to measure. On the other hand, this reduces the need for time-consuming interviews and surveys defining resource pools, which were one of the main problems of ABC. The first step of ABC implementation is eliminated and the first cost assigning process is eliminated while preserving the second assigning process, where the time is utilized to drive costs directly from resources to cost objects [16]. This makes the implementation of costing system easier as the design of the system itself is easier and thus, resulting in quicker and cheaper implementation and in easier software integration. TDABC also better accounts for complexities of business transactions by using time equations reflecting time involved in a particular process [17], as time drivers are easier to maintain than transaction drivers used in ABC systems [9]. The model also removes activity pools and the use of quantity-based resource-activity cost drivers [14].

41.3 Process Mining

Process mining is a group of techniques that seek to recognize patterns and other information within data produced by business information systems. The essence of process mining is to analyze business processes that are objectively represented by data, so-called event logs. This wave of digitization is one of the main reasons for the popularization of process mining techniques in connection with business processes. Information systems that record required data are increasingly appearing in medium and small companies together with raising interest in the management of business processes.

There are five fundamental areas of process mining: process discovery, conformance checking, enhancement, online support, and deviance mining. The main goal of process discovery is to find patterns in the logs, based on which a process model of the monitored process is constructed. Currently, among the most successful techniques are inductive mining and split miner [18, 19]. None of the discovery techniques guarantees that the discovered model really corresponds to the original process or if it fully represents the behavior discovered in the data. It is therefore necessary to verify that the discovered process model is of proper quality [20]. The essence of process enhancement is the extension or improvement of existing process models using information from the log of the monitored process [21]. Deviance mining is a group of techniques that attempts to discover the reasons for discrepancies in business process records and/or process models [22]. Online or operational support allows to analyze processes in real time using the combination of a premortem and postmortem data, where the premortem denotes data from pending cases and the postmortem data from terminated cases [20].

The data required for PM analysis have to be extracted from operational systems, e.g., customer relationship management systems, enterprise resource planning systems, etc., or even embedded systems. Irrespective of the type of PM analysis, the log has to contain the following minimum information:

- each event contained in the log must be unique and must be sorted, which in practice is solved almost exclusively using a timestamp,
- we must be able to distinguish between process instances,
- there has to be a function that is able to assign the activity name to each event.

Different types of PM analysis require different types of supporting attributes (e.g., construction of social network requires event log to contain resource information). The standard format for event logs was MXML format. However, due to several encountered limitations, a new standard event log format named XES was created. Nevertheless, there are other formats, e.g., CSV files, or even software-specific FXL files, etc.

41.4 Methodology

In the following section, we present data and research methodology. In our research, we deal with a complex real-life process of financial institutions, namely, the loan application process. The loan application process is represented by two event logs [23, 24]. Both logs represent the loan application process in the same company; however, one is from 2012 and the second one is from 2017. The 2012 log contains more than 13,000 cases, which are formed by 262,200 events each having 9 attributes. The 2017 log contains more than 35,000 cases, which are formed by 561,671 events each having 22 attributes. The log contains three types of events. Each event name starts either with A, O, or W. The A events are related to applications, the O events are related to offers sent to customers, and the W events are related to the processing of work items of applications. The overall workflow of the process is as follows: after applying, a small part of the applications is controlled for fraudulent behavior, the rest of them are controlled for completeness, after that the application is pre-accepted and the application is processed. Some applications are canceled and the offer is sent to the rest of the customers and the contact with customer follows. In case if the customer accepts the offer, the application is assessed and the loan is approved. In some cases, after assessment of the application, further contact with the customer might be required to complete the application.

Firstly, it is necessary to prepare the logs for the application of PM techniques. The logs of the loan application process are available in XES format. Thus, it was checked whether all events in the log contain the basic required attributes in the appropriate formats, i.e., case IDs, timestamps, and activities. Events and related cases that did not possess required attributes or did not respect necessary formats were modified to respect them if possible. Otherwise, they were excluded together with missing values. As the focus was solely on the aforementioned attributes (case ID, activity, timestamp, resources, lifecycle transition), the rest of the attributes were ignored and no cases nor events were removed from the log based on these attributes. The output is the clean event logs. These logs are then used to discover process models that are contained in the 2012 and 2017 logs. For this purpose, we used Apromore.[1] TDABC approach is highly dependent on understanding company's business processes. Process discovery in Apromore is based on split miner and the discovered model is represented in the form of a BPMN diagram (Business Process Model and Notation 2.0).[2] As already mentioned in Sect. 3, split miner performs among the best process discovery techniques [19]. Based on discovered process models time drivers are estimated using time enhancement of discovered process model. We identified several activities from logs to demonstrate estimation and determination of time drivers (e.g., repetitive occurrence of activities in trace, outcome of the process, etc.) and we focused on the specific activity "W_Afhandlelen leads." We compared different perspectives of

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[1] Apromore—process mining tool. http://apromore.org/platform/tools/, last accessed 2021/01/13.

[2] OMG—Business Process Model and Notation 2.0. https://www.omg.org/spec/BPMN/2.0/About-BPMN/, last accessed 2021/01/13.

activity durations in 2012 and 2017 to determine the factors (time drivers) behind different durations of activity "W_Afhandelen leads" (which is equivalent to activity "W_Handle leads" in the 2017 log).

41.5 Results

Figure 41.1 presents the discovered process model representing the loan application process in 2012. To discover the process model, we used the following parameters in Apromore: activity filter is equal to 100%, trace filter is equal to 60%, and parallelism filter is equal to 100%. Figure 41.2 presents the extract of black oval in Fig. 41.1. In Fig. 41.2, one can see that the process model is enhanced with averages of processing and waiting times. Waiting time refers to a time period in which a work item is waiting for further processing. Processing time refers to a time period in which a work item is being processed. For now, we are interested in processing times which determine the duration of particular activities in loan application process (see Eq. 41.1). Figure 41.2 shows just one activity as it serves to illustrative purpose. However, in Fig. 41.1, the entire process model is enhanced with processing times, which can be used as time estimates in the equations for cost calculations using TDABC approach:

Fig. 41.1 Discovered process model—2012 log

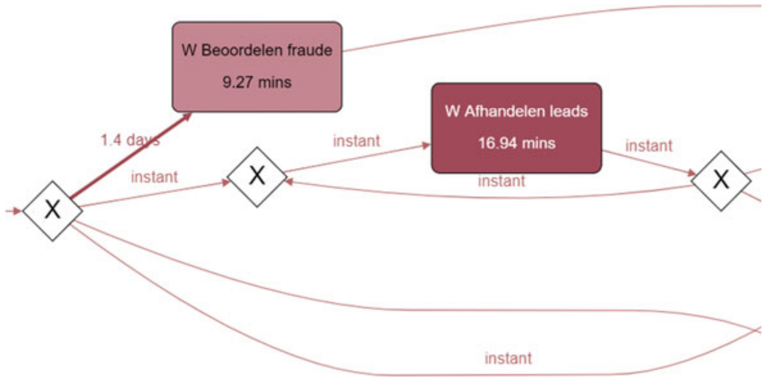

Fig. 41.2 Extract of black oval in Fig. 41.1 (activity "W_Afhandelen leads" with an average processing time of 16.94 min)

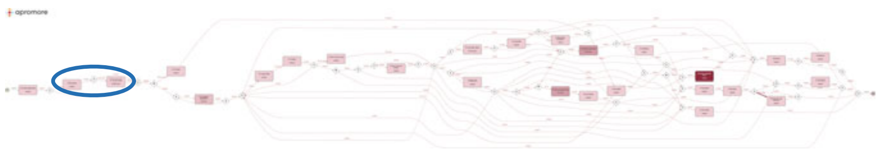

Fig. 41.3 Discovered process model—2017 log

$$t_{E,A} = \sum_{i=0}^{n-1} \beta_i x_i, \text{ where } x_0 = 1 \tag{41.1}$$

$t_{E,A}$ time required for executing event E related to activity A,

β_i time consumed per unit of time driver i, β_0 is a constant amount of time required for activity A,

x_i i-th time driver,

i number of time drivers needed to run activity A.

Similarly, Fig. 41.3 presents the discovered process model representing the loan application process in 2017. To discover the process model, we used the following parameters in Apromore: activity filter is equal to 100%, trace filter is equal to 50% and parallelism filter is equal to 100%. Figure 41.4 presents the extract of blue oval in Fig. 41.3. In Fig. 41.3, we see that the process model is enhanced with averages of processing and waiting times similar to Figs. 41.1 and 41.2.

Now let's consider activity "W_Afhandelen leads" from the 2012 log. When the activity "W_Afhandelen leads" first appears in the trace, it has an average processing time equal to 17.80 min, while in the case of its recurrence in the trace, the activity has an average processing time equal to 13.34 min ($p_{ANOVA,\alpha=5\%} = 0.6720$). In case of activity "W_Afhandelen leads," the time driver related to the first or recurrent occurrence of activity "W_Afhandelen leads" makes a difference on average 4.46 min. Especially, the activity "W_Afhandelen leads" occurs in the process within

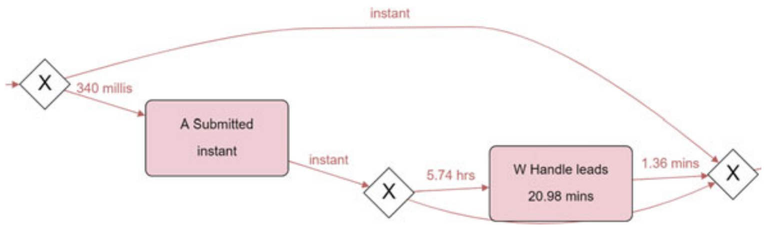

Fig. 41.4 Extract of blue oval in Fig. 41.3 (activity "W_Handle leads" with an average processing time of 20.98 min which is equivalent to activity "W_Afhandelen leads" from 2012 log)

the observed period[3] 4,755 times from which 763 were recurrent (15.48% of recurrent occurences). In case of activity “W_Afhandelen leads”, Eq. 41.1 would take the following form:

$$t_{E,W\_Afhandelen\_leads} = 17.8 - 4.46x_1 \tag{41.2}$$

where $x_1 = 1$ if event E with assigned activity name “W_Afhandelen leads” occurred a second time or more in the trace. Otherwise, if it is the first occurrence of activity “W_Afhandelen leads” in the trace then $x_1 = 0$. Equation 41.3 is then used for estimation of time required to process all events with assigned activity name “W_Afhandelen leads”:

$$T_{W\_Afhandelen\_leads} = \sum_{k=1}^{4755} t_{E_k,W\_Afhandlen\_leads} = \sum_{k=1}^{4755} 17.8 - 4.46x_1^k \tag{41.3}$$

The time required to process all events with the assigned activity name “W_Afhandelen leads” was equal to 80,549.70 min during the observed period, while the estimated time using the second of higher occurrence of activity in trace as time driver was equal to 81,236.02 min during the observed period. This is a significant improvement over ABC and TDABC. In ABC approach, time equations would be estimated using employee surveys which were in many cases inaccurate due to employees’ perception and bias. Moreover, such surveys were resource-intensive to the point where large companies had to hire the entire department just to conduct and evaluate surveys. TDABC used observations to estimate time equations, and even if there was data, understanding the underlying process is necessary to estimate time equations. In the 2017 log, we discovered that the company almost eliminated repetitive tasks and thus, this time driver would not be applicable anymore (see Figs. 41.2 and 41.4).

ABC and TDABC systems reduce specification and aggregation errors while causing the occurrence of measurement errors. PM can help to address this issue at least partially as it is a data-driven approach and it does not rely on the perception of employees, managers, etc. ABC systems were dependent on estimation of time spent on specific activities, which was traditionally done using employ surveys. Thus, high demand for input data is one of the most important disadvantages of ABC system. TDABC does not require employee surveys, however, it still requires time estimations for activities of the process. As was shown PM can be used for time estimation of process activities as well “as determination of activities” time drivers. Moreover, the determination of activity’s time drivers and time estimations is dependent on understanding the process, which is one of the main purposes of PM in the first place. Another difficulty of ABC system is updatability of such complex models. TDABC partially addresses this issue, however, it is another area, where PM can be of great use, especially in combination with deviance mining, which is the area of PM

[3]Observed period is 1/102011–14/3/2012.

focused on deviance behavior in the process, which was demonstrated in case of the 2017 log, where the repetitive tasks were almost eliminated (in 2017 there were only units of cases where the repetitive tasks occurred). Furthermore, since PM is focused on understanding business processes, it gives us the possibility to analyze costs from different perspectives, which is many times not possible through traditional costing systems.

In many cases, it is also possible to use exact durations of events instead of estimates. That is to work with costs at the event level instead of activity level. In this case, we use exact durations at the event level, we add further benefits, where there is no need for estimation of times of activities and determination of activity's time drivers. Moreover, the system itself would be easier to maintain. This approach places even higher demands on data, however, from recent trends, one can see that companies seem to value such data and that involvement of different kinds of sensors and other event capturing methods are on the rise and stay that way in the future.

41.6 Conclusions

It is expected that, in the future, the need for detailed and accurate cost information systems will increase as a result of raising competitiveness and cost efficiency of companies' processes. The difficulty inherent in choosing a proper and accurate cost allocation method for enterprises has been widely discussed by academics and practitioners. TDABC is an alternative approach towards cost allocation with several benefits over traditional costing systems, especially if the company's management already uses a process-oriented approach. To this point, we add that information systems are increasingly appearing in medium- and small-sized companies together with raising interest in the management of business processes.

In this research, we had the following two research questions: (1) Can PM be used for the estimation of time drivers? and (2) What are the benefits of using PM for estimation of time drivers? We showed that PM can be used for time estimation and time drivers' determination and that there are potential benefits to this approach. We determined time driver of activity "W_Afhandelen leads" to be a repetitive occurrence within the case and estimated time durations based on which time equation for activity "W_Afhandelen leads" was derived. The time required to process all events with assigned activity name "W_Afhandelen leads" was equal to 80,549.70 min during the observed period, while the estimated time using the second or higher occurrence of activity in trace as time driver was equal to 81,236.02 min. It shows how can be PM used in principal to estimate time equations and determine time drivers. Furthermore, we discussed the possibility of using actual times instead of estimates, which further eliminates the need for time estimation and time drivers´ determination and helps with maintenance of the TDABC system. We address the issue of using exact time durations at the event level in future research, together with several other topics regarding process discovery and other PM techniques and their use within TDABC.

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Chapter 42
Multi-Agent Activity-Based Simulation of a Future Neighborhood

Younes Delhoum, Rachid Belaroussi, Francis Dupin, and Mahdi Zargayouna

Abstract Mobility simulations are an effective tool to forecast the effects of transportation policies. They are a useful part of decision support systems for policy-makers. Big real-estate projects, aiming at creating whole new neighborhoods, for instance, need this kind of application to estimate their impacts on the surrounding environment. The potential visits of the various equipments and the public spaces of the new neighborhood can also be estimated with this kind of tools. In this context, agent-based simulation is a relevant model for the design and implementation of transportation applications, that represents travelers individually, together with their perception model of the environment and their internal decision processes. In this paper, we propose a multi-agent activity-based simulation to represent current and future mobility patterns in a city, with or without a new neighborhood. We describe the inputs of the simulation, in terms of networks and travel demand, the behaviors of the agents, and the outputs on the laVallée project (France). The first series of experiments demonstrate the potential of the simulation and its benefits for the project managers and the decision-makers in the concerned territories.

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42.1 Introduction

Large-scale and complex mobility systems could be represented by simulating the behaviors and interactions of self-interested "agents," evolving in a transportation environment, creating a multi-agent system. In [1], the authors state multiple reasons to use multiagent systems in transportation applications. The authors indicate that the solving of several transportation problems with multiagent systems is natural and intuitive. The simulation of passenger mobility is particularly suitable for an agent-based design. Indeed, the objective in these simulations is to take into account human behaviors, interacting in an open, dynamic, and complex environment [2]. This configuration obeys the general definitions of agents as entities that are situated in some environment, that are capable of autonomous action on it [3], that can perceive this environment and have a partial and incomplete perception of it [4].

Among multi-agent models, there is a class called activity-based models, that address specifically the need for a realistic representation of travel demand and the human behavior in a mobility context. The activity-based modeling (ABM) framework was originally developed in response to demands for more realistic travel demand models which are capable of analyzing a wider range of transportation policies. These models are capable of evaluating travel demand and transportation supply management strategies, such as road pricing, and behavior modification programs (flexible scheduling, ride-sharing), in a more efficient way than the previous generation of aggregate flow models, which generally focus on evaluating network capacity improvement.

In activity-based models, unlike traditional analytical trip-based models, the travel demand originates from the needs of the traveler to pursue some activities that are distributed in time and space. The understanding of the travel decisions becomes hence secondary compared to the fundamental understanding of the agent activities [5]. Based on this methodological choice, activity-based models have been proposed, such as TRANSIMS [6] and ALBATROSS [7].

The LaVallée project (Paris Area, France) is a large construction project, to be delivered in 2024, with an area of about 500 m $\times$ 400 m, and is part of a larger city called Chatenay-Malabry. It will house 6000 residents (20% of the city population), a large set of services ranging from a shopping street, a mall, schools, and office spaces for 2000 employees; and the district is designed to be fully integrated in the rest of the city. The effects of this new neighborhood on the surrounding city are complex to forecast. One of the reasons is that the new district might imply changes in the behaviors of the city users, that are difficult to model with traditional modeling paradigms. This is the reason why we have chosen to model the city, with and without the new neighborhood, with a multi-agent activity-based simulation.

The remainder of this paper is structured as follows. Section 42.2 is the related work section. Section 42.3 describes the model of the simulation. Section 42.4 provides the first results of our simulations. Finally, Sect. 42.5 concludes the paper.

42.2 Related Work

The modeling of mobility has been long dominated by the modeling approach called the four-step model. In this approach, trip origin-destination (O-D) is the principal database. However, the valid representation of underlying travel behavior in this conventional trip-based model of travel demand forecasting has never really been proved [8]. In contrast, activity-based models use a sequence of *activities* to represent the mobility behavior of the population. Transportation demand is the result of the agent need to satisfy their goals via activities taking place in different locations and times. The activity-based approach considers contextualized individual trips, making it possible to represent more realistic travel behaviors.

When representing mobility behaviors, first generations of simulations were governed by a centralized top-down process. Proactive interactions and communication between individuals were not possible. Agent-based modeling and simulation came as an answer to this limitation. Multi-agent systems are useful when studying complex and self-organizing systems [9]. The models in this category are based on the concept of autonomous entities, called agents, that are situated in a shared observable environment, that they perceive and where they can act upon, in order to achieve their own goals. Several agent-based models exist in the literature, such as AgentPolis [10], SUMO [11], Aimsun [12], SM4T [13], etc.

In this paper, we use a specific kind of multi-agent models, called activity-based models [14]. In this category, the agents plan and execute activity schedules. Each activity is of a specific type (e.g., work, school or shop) and has associated start times and durations. Trips between each pair of activities are specified by their transport mode (e.g., car or public transport). Models like SCHEDULER [15], TRANSIMS [6], CEMDAP [16], SacSim [17], actiTopp [18], the two-level dynamic model [19] or the walk-bicycle ABM [20] are examples of existing activity-based models.

42.3 The Model

42.3.1 Overview

The main idea behind our process to forecast the future impact of the new neighborhood (LaVallée) on the surrounding city is (cf. Fig. 42.1):

1. to perform a valid simulation of the current situation (without LaVallée)
2. to perform a simulation of the hypothetic future situation, by modifying the inputs.

Each one of these two simulations is performed following the process described in Fig. 42.2. The inputs of the simulation are:

1. The population of the area is synthesized, to represent the actual users of the network, notably including their activities

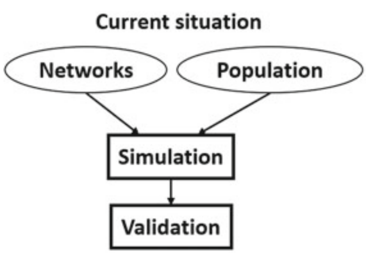

Fig. 42.1 Overview of the methodology

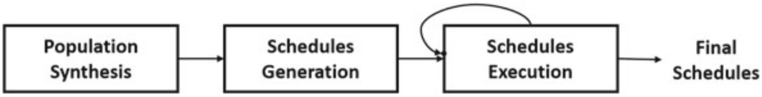

Fig. 42.2 Overview of a simulation workflow

2. Schedules are generated for the population
3. Several runs are executed to reschedule the activities of the agents until reaching convergence.

These steps are described in more detail in the following paragraphs.

42.3.2 Input Data

The input of the current situation simulation are:

1. The global survey data for transport from household census.
2. The road network: by default OpenStreetMap (OSM) files.
3. Public Transportation (PT) network: the PT (bus/train/tram) stops location and times from General Transit Feed Specification (GTFS), the PT routes were generated following the stops-sequence using the shortest path algorithm, compared and corrected manually.

The input of the future situation simulation are:

1. The current situation data, plus the population data based on a survey of the real-estate developer (see Fig. 42.3).
2. The road network: The current situation data, plus the road network and walk network of the new neighborhood.
3. The current situation data, plus a future tramway line (T10, expected in 2023).
4. The locations of a set of activities: school, work, leisure, and shopping.

The detailed process of population synthesis, together with all the used data can be found in [21].

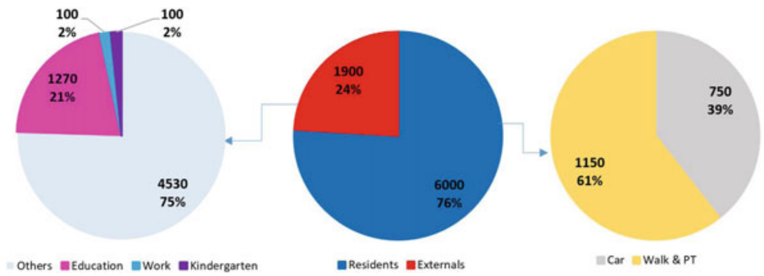

Fig. 42.3 LaVallée population data. (Left): the residents trip-purposes. (Center): the proportion of users from LaVallée distributed between residents and externals. (Right): the external workers transport mode-share5

42.3.3 Agents Behaviors

The traveler agent iteratively tries to improve a *score* associated to its current plan, until no improvement is observed. Indeed, each traveler agent has the objective of performing its sequence of activities. It tries to implement a current plan and gets a corresponding score. The score depends on the travel time of the agent and the duration of its activities. To do so, each agent has an internal scoring function, which stores the activities' start and end times, together with legs starts and ends.

The implementation of each agent's currently scheduled plan is dependent on the links dynamics. The physics of a link is determined by the free speed link travel time, its capacity, and storage capacity. These quantities are computed from the link length, the number of lanes, and the link's maximum speed. The capacity is the classic maximum number of vehicles allowed to leave the link per time step, and the storage capacity of a link is the maximum number of vehicles that can be placed on the link.

42.4 Experiments

42.4.1 Case Study

Our objective is to assess the impact of the LaVallée project on the whole city. We take into account the flow of external visitors, estimated realistically based on the pre-project movements in the areas of influence of LaVallée. We define the catchment area of LaVallée district as the area that can be reached by future potential visitors. Potential visits correspond to a need for a specific purpose (shopping, leisure, school) that are currently done outside of the district, but would be more convenient if realized in LaVallée when the real estate will be in place. Figure 42.4 indicates the location of the district of interest and the catchment area where LaVallée would attract a

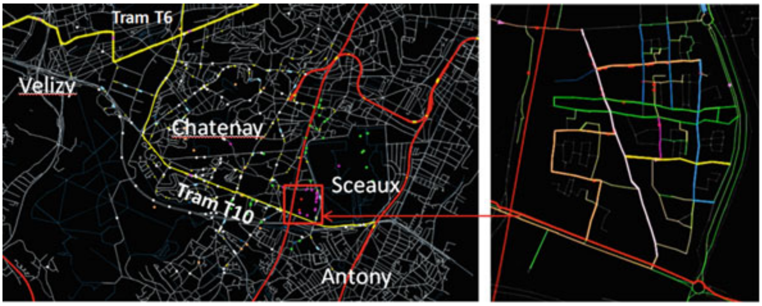

Fig. 42.4 (Left): the catchment area. (Right): LaVallée future road network (walk, bicycle and cars)

population that will use its services. This area is defined as the zone accessible in less than 15 min, by private cars or public transportation. This definition implies a rather large area.

42.4.2 Setup

The population of the catchment area, composed of 126,151 agents, is simulated. It represents around 8% of the department (Hauts-de-Seine) population.

The simulation has a set of parameters, such as the replanning (rescheduling) strategies probabilities, the focus is on two strategies: *ReRoute* and *TimeAllocation-Mutator*. By selecting the first (second) strategy, the agent has to change its travel route (start and end time of its activities) for the current iteration. A third strategy is *Best Score*, the agent plan will remain the same. Each strategy has a selection probability P, the simulation runs using the following probabilities: $P_{ReRoute}$ (20%), $P_{TimeAllocationMutator}$ (10%), $P_{BestScore}$ (70%).

All simulations were performed with the MATSim platform [22], the details about the redefining of the workflow on MATSim are in Fig. 42.5.

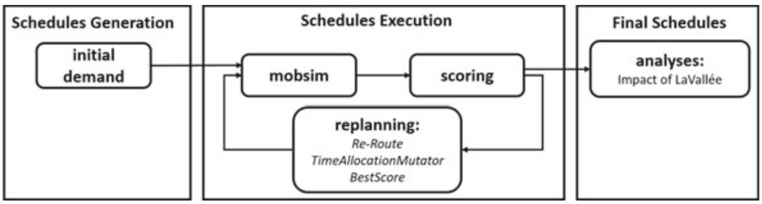

Fig. 42.5 Redefining our workflow on MATSim platform. (Left): the generated schedules are represented by the initial demand. (Center): the schedule executions are represented by the three steps: mobility simulation, scoring, and replanning with its strategies. (Right): the final schedules are analyzed to extract the impact of the new neighborhood on the whole population

42.4.3 Results

Two main scenarios were simulated: the current situation and future situation.

Current situation In the first scenario, we are interested in the current situation, without the presence of LaVallée. In this case, each agent has only one plan (original plan). The type of activity (trip-purpose) and the mode-share distributions are described in Fig. 42.6a, b.

To validate our simulation, we focus on four activities: work, education, leisure and shopping. The results show very close distributions (for these activities) with reference distributions (Enquête Globale de Transport [23]), the results are in Fig. 42.6c.

However, we notice some differences in some activities. The first is the work activity, these differences are mainly related to a large number of workplaces (workers) in other areas of the department (such as La-Defense). The education activity follows the same pattern, more schools are in the other of Hauts-de-Seine (comparing with catchment area). For the remaining activities (leisure and shopping), similar distributions were found.

Figure 42.7 shows a comparison on values of transport mode share for previous trip purposes. Four transport modes were considered: public transportation (pt), private vehicle (car), walking (walk), and cycling (bicycle).

With these results, we consider that we represent quite accurately the current situation, and can move forward with executing future scenarios.

Future situation By considering the future situation, including the new neighborhood, each traveler can alter its plans, the idea is to propose for each potential visitor (a traveler has *leisure* or *shopping* as activity), to do that activity in LaVallée. Statistically, 48% (60,084) of the agents have *leisure* as activity, 44% (56,009) have *shopping* and 68% (85,407) have *leisure* or *shopping*.

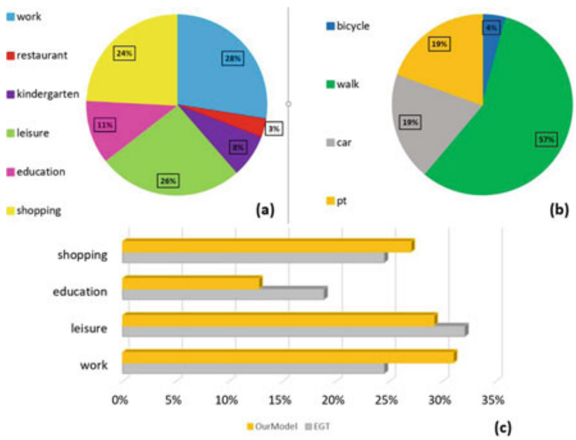

Fig. 42.6 **a** Trip purpose, **b** transport mode share in the district catchment area and **c** activity distribution (OurModel vs. EGT)

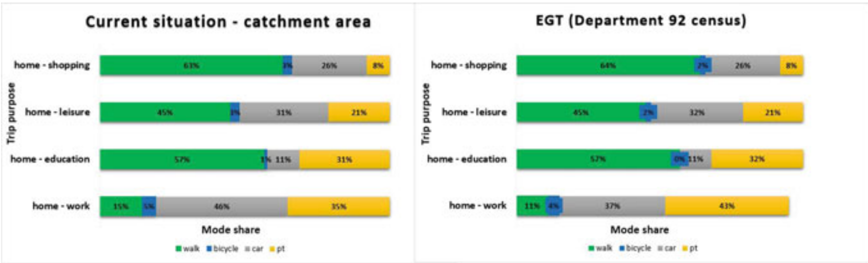

Fig. 42.7 Transportation mode share for different trip purposes. (Left): the extracted result from the current situation simulations of the catchment area. (Right): data from EGT of the whole department 92 [22]. Travel mode shares from the model are similar to the 92 census with minor differences

By using the same simulation settings of the current situation simulation, we study the proportion of potential visitors. The simulation show that: 6.61% (3,973) of the potential visitors come for *leisure* activity, 6.30% (3,531) for *shopping* and 7.92% (6,767) for *leisure* or *shopping* (see Fig. 42.8).

Another objective of this work is to study the benefits of the new neighborhood. As a measure, we consider the gain that an agent would earn from executing an activity in LaVallée (in term of score). This gain is equal to the difference in score between LaVallée selected-plan and main-plan (in the current situation). The results show that the visitors (6,767) have an average gain of 5.63 (score points) with a median gain of 2.41. At the population scale, the global gain is around 0.3, which can represent the benefit in travel time (a faster route), and time-choice (duration, start, and end time) of the activities. The quantification of the gain (in terms of score) depends on the simulation functions.

To better analyze the benefit value, the five-number summary is calculated. The results show that almost 25% of visitors have gains that are higher than the mean value (5 points), more details are in Fig. 42.9.

The proportion of visitors depends mainly on the replanning strategies, to understand better the behavior of agents, we decide to vary the selection probability P of *ReRoute* (S1) and *TimeAllocationMutator* (S2) strategies, the remaining probability is set to *BestScore* strategy.

The results show that 4.01% (3,425) of agents come to LaVallée (with P_{S1} = P_{S2} = 0%), they are whose living close to LaVallée. By increasing the probability of $S1$, the number of visitors increases very slowly, it passes from 4.01% for (P_{S1} = 0%) to 5.05% for (P_{S1} = 44%). This slow rise is due to the localization of LaValéle in the catchment area (the furthest location is at 15 min by car). By changing the route, the

Fig. 42.8 Proportion of external visitors who's switch into LaVallée

Trip-purpose	External-visitors	Frequency (activity)	(%) External-visitors
leisure	3973	60084	6.61%
shopping	3531	56009	6.30%
leisure or shopping	6767	85407	7.92%

Trip-purpose	*Mean*	*Min*	Q_1	*Median*(Q_2)	Q_3	*Max*
leisure	5.63	0.00	0.89	2.43	5.30	511.72
shopping	4.94	0.00	0.86	2.28	5.14	454.18
leisure or shopping	5.49	0.00	0.87	2.41	5.32	511.72

Fig. 42.9 Five-number summary and mean values, for the agent gain

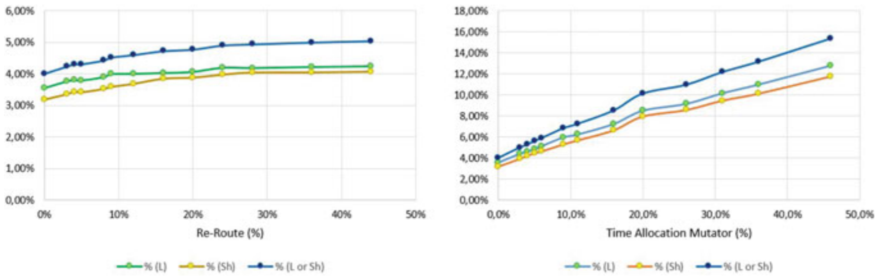

Fig. 42.10 (Left): changing the trip route (ReRoute) has a little impact on the proportion of potential visitors. (Right) the changing in the time (duration) of an activity has a large impact on the proportion of potential visitors, this proportion increases linearly with the selection probability of TimeAllocationMutator

traveler can reduce its travel time but with a little time, which is not enough to boost the score, and then selecting the LaVallee-plan.

However, the results show that $S2$ has more impact on visitors' decision, by changing the probability P_{S2}, the proportion of visitors pass from 4.01% (3,425) to 15.39% (13,142) with P_{S2} variants from 0% to 46%. The switch in the start-time and duration impact the plan (score), which promotes the neighborhood activities. LaVallée-plans become a better alternative, especially for the agents who live a little further. The potential visit for both cases is presented in Fig. 42.10. Both strategies (in particular S2) could be used to calibrate the model once the counts are realized.

42.5 Conclusion

In this paper, we describe a multi-agent activity-based simulation to forecast the impact of a future neighborhood on the mobility on the scale of a city. The activity-based modeling allows for a fine-grained description of the travelers and a flexible behavior of the system. We first implement and validate a simulation of the current situation, then we implement the simulation representing the future situation. The results show that our model represents the current situation with some minor differences, which are related mainly to the region's infrastructure. Based on the simulations, a potential part of travelers will join LaVallée for an activity, it improves their activity-plan score, the volume of travelers depends mainly on the time and duration of the activities.

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Chapter 43
Analysis of Factory Automated Guided Vehicles Systems Using Contract Net Protocol

Daimotsu Kato, Shohei Yada, and Setsuya Kurahashi

Abstract Automated Guided Vehicles (AGVs) are used in a flexible job shop production system. In this type of production system, proper scheduling of tasks is the most important issue. This issue is considered to be non-deterministic polynomial time-hard and difficult to solve in a reasonable time. Moreover, in the semiconductor manufacturing process, contamination by airborne debris and vibrations during transportation have a significant impact on the manufacturing yield because of the fine processing, so there are constraints that AGV in the factory must pass on a predetermined transportation route. This constraint causes spatial interference between AGVs, which results in congestion of AGV on the transfer task. In this paper, an analytical model is investigated by using the multi-agent system that takes into account the spatial interference model of the AGV. In addition, we applied the contract net protocol, treating the processing equipment as the task manager and the AGV as the contractor in dynamically negotiating the contract. Our analytical model in which the AGV assignment agent and the task manager agent collaborate make decisions using feedback of time-series information of traffic congestion. By using this approach, we found that traffic flow could be improved.

43.1 Introduction

In recent years, the progress of the Internet of Things (IoT) and smart factories have been considered for the purpose of improving productivity and other factors in the manufacturing industry [1–4]. Unlike conventional production systems that use conveyor belts, etc., Automated Guided Vehicles (AGVs) are used in smart factories to provide a flexible job shop production system in which products being processed to move backward and forward between multiple processes instead of one direction [5]. In this type of production system, proper scheduling of tasks is the most important issue. This is called the Flexible Job Shop Scheduling Problem (FJSSP) and it is

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studied as combinatorial optimization problems in operations research field. In terms of scheduling complexity, FJSSP is considered to be non-deterministic polynomial time-hard and difficult to guarantee an optimal solution [6]. Brucker and Schlie first treated FJSSP and various methods and algorithms have been studied to solve this class of problems over the past three decades [7, 8]. In recent years, mathematical optimization methods such as integer/linear programming that can obtain exact solutions, Tabu search, Evolutionary algorithms, Ant colony optimization, Particle swarm optimization, and hybrid method combining heuristics and meta-heuristics methods have been studied [9–16].

Moreover, in the semiconductor manufacturing process, which is the motif of this paper, contamination by airborne debris and vibrations during transportation have a significant impact on the manufacturing yield because of the fine processing, so there are constraints that AGV in the factory must pass on a predetermined transportation route and cannot overtake transportation vehicles [17–19]. This constraint causes spatial interference between AGVs and congestion of AGV on the transfer. As a result, products cannot be delivered at the appropriate time, resulting in delivery delays and other problems.

In this paper, we studied the analytical model that is investigated to takes into account the spatial interference model of the AGV by using the Multi-Agent System (MAS) simulator Netlogo [20]. There are few studies of analytical models that take into account the spatial interference of such AGVs. In addition, we applied the Contract Net Protocol (CNP) which could split the main problem into some sub-problem and feedback of traffic information to our model. We report the developed analytical model in which the AGV assignment agent and the task manager agent collaborate to make decisions using feedback of time-series information of traffic congestion.

43.2 12-Inch Semiconductor Factory

Semiconductor manufacturing factories are flexible job shop factories where multiple pieces of the same type of manufacturing equipment are placed and the processing order is variable, and AGV-based transport systems are introduced. Therefore, in this study, we used a semiconductor manufacturing process as a motif. A semiconductor manufacturing plant is a typical job shop-type plant because the substrate cleaning and photolithography processes are repeated multiple times using the same equipment to manufacture products [17–19]. In semiconductor manufacturing, contamination by airborne debris and vibrations during transportation have a significant impact on yield due to the fine processing. For this reason, in factories using 12-inch semiconductor wafers, an automated AGV transport system is installed on the ceiling to prevent atmospheric debris from adhering to the processed products. The system receives racks containing semiconductor wafers being processed from the manufacturing equipment, moves them along the transport path, and passes the products being processed to the next manufacturing facility. Since AGVs move along a predetermined transportation path for the products being processed, it is basically impossible for AGVs to overtake them. Therefore, the spatial interference of the AGVs has a significant impact on the productivity of the factory. In this study, a 12-inch semiconductor manufacturing plant is used as a motif and the traffic flow rate of the AGV is analyzed.

43.3 Traffic Flow Analysis Model Considered AGV Spatial Interference

In the AGV system, an AGV with a total length of L m, as shown in Fig. 43.1, is assumed to travel at a speed of v m/s, detect the distance L_h m from the vehicle in front, and adjust v to keep L_h constant. In the MAS, each AGV is treated as an agent. When the agent flows into the production line at a rate of n units per second, the traffic flow out of the AGV is determined by the distance between the AGVs. The analysis assumes that the incoming AGVs flow n per unit time from the inter-bay to the intra-bay and the AGVs travel counterclockwise along the transport route, assumed a part of the manufacturing line in a factory as shown in Fig. 43.2. In this study, L_h is 1, 3, 5, 7, and 9 m, and n is 0.3 and 0.4 per second.

Figure 43.3 shows the time variation of the traffic flow and vehicle number when L_h is varied from 1 to 9 where the horizontal and vertical axis is time and traffic flow, respectively. Figure 43.3a, b are the traffic flow and vehicle number at the $n =$ 0.3 and Fig. 43.3c, d are $n = 0.4$. As shown in Fig. 43.3a, c, the traffic flow peaks at about 100 s. This is thought to be due to the fact that AGVs flowing into or out of the intra-bay change their speed v in order to maintain a constant distance L_h between vehicles at the intersection of the transport routes. On the other hand, it can

Fig. 43.1 AGVs position

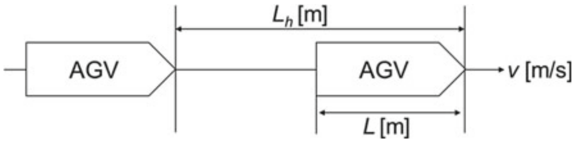
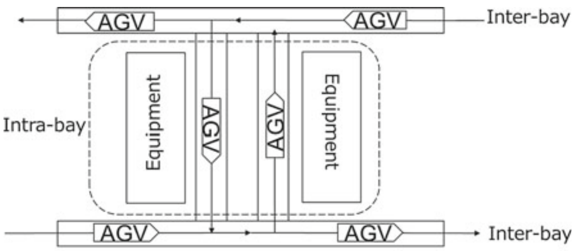


Fig. 43.2 Work area layout



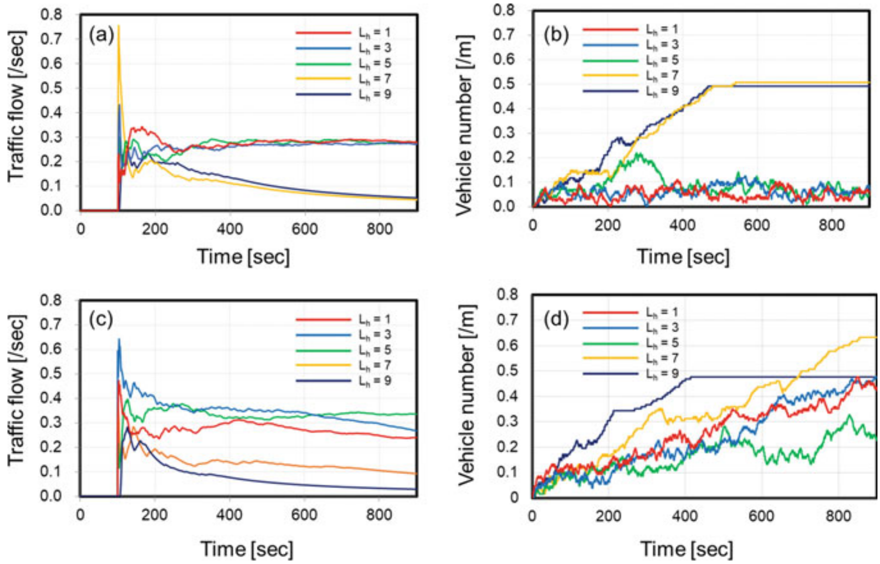


Fig. 43.3 Bidirectional traffic flow (**a**), (**c**) and vehicle number (**c**), (**d**)—time characteristic, when L_h is varied from 1 to 9 (Fig. 43.3a, b and Fig. 43.3c, d are $n = 0.3$ and $n = 0.4$, respectively)

be confirmed that the traffic flow rate, once it peaks, either shows a constant value or gradually decreases and shows a constant value.

As for the distance L_h between AGVs, Fig. 43.3a shows that the traffic flow rate is higher at $L_h = 1$, 3, and 5 than at $L_h = 7$ and 9. On the other hand, as shown in Fig. 43.3b, the total number of AGVs saturates at a rate of 0.5/s at $L_h = 7$ and 9. This value is higher than $n = 0.3$/s, which is the rate at which AGVs are flowing in. It might suggest that the margin of distance between vehicles is too wide. This causes traffic congestion on the transport road, as a result, reduced the traffic flow rate. In Fig. 43.3c, d at $n = 0.4$, although the same tendency can be seen, it can be clearly seen that the total number of AGVs increases in time for all L_h compared to $n = 0.3$, and eventually, there will be traffic jams.

Figure 43.4 shows the box-and-whisker plot about traffic flow (Fig. 43.4a, c) and vehicle number (Fig. 43.4b, d)—L_h characteristics at 800 s. L_h was varied from 1 to 9 in two increments. Here, each box-and-whisker diagram is connected by the median of the 10 calculations. As shown in Fig. 43.4a, b for $n = 0.3$, the traffic flow rate clearly decreases at $L_h = 7$ and 9, while high traffic flow rates are observed at $L_h = 1$, 3, and 5. In addition, as shown in Fig. 43.4c for $n = 0.4$, although it can be confirmed that the traffic flow rate increases than at $n = 0.3$, the amount of congestion increases. In addition, when $n = 0.4$, an increase in the number of AGVs in the transport path can be clearly observed even at $L_h = 5$.

These results indicate that it is possible to increase the traffic flow rate by increasing the number of AGVs flowing in per unit of time, but that there is an

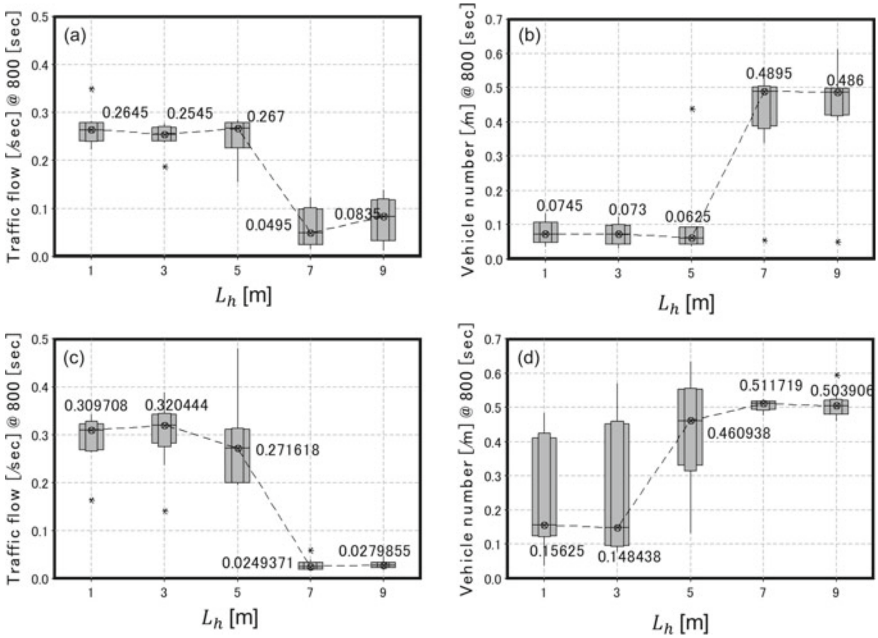


Fig. 43.4 Box-and-whisker plot about traffic flow (**a**), (**c**) and vehicle number (**c**), (**d**)—L_h characteristics at 800 s (Fig. 43.4a, b and Fig. 43.4c, d are $n = 0.3$ and $n = 0.4$, respectively)

optimum distance between vehicles, and that if the distance L_h is set too wide, congestion may occur and the traffic flow rate may decrease.

43.4 Traffic Flow Analysis Model using Contract Net Protocol

As mentioned in Sect. 43.3 focused only on the flow rate of the AGVs, it is necessary to schedule the tasks to be assigned to each AGV in FJSSP. Therefore, we considered applying CNP to our model. A contract net is a set of processing nodes that divide the problem based on CNP and allocate tasks by each node negotiating with each other [21]. Previous reports have shown that considers the reduction of computation time by dividing the problems into job order allocation and operation allocation using CNP [22, 23]. In this paper, we will also consider how to assign tasks and studied the task-allocating agent and the bidding agent by incorporating them into the model of MAS discussed in Sect. 43.3. In addition, by introducing domain information into CNP, such as the traffic information in Sect. 43.3, we believe that more robust task processing will be possible. In addition, recent studies have reported that MAS can flexibly respond to dynamic changes (e.g., failures), and in particular, a dynamic scheduling approach using CNP can be used to schedule the manufacturing system while enforcing coordination between the AGV assignment agent and the machining equipment job assignment agent. Using a dynamic scheduling approach with CNP, which enforces coordination between the AGV assignment agent and the machining equipment job assignment agent, has achieved better performance than methods such as dispatching rules [24]. For this reason, the CNP approach is considered to have a high affinity with the spatial interference model of AGVs considered.

In this paper, we gave each AGV and processing unit the function of a negotiation agent, and according to CNP, we gave each AGV the task that the processing unit has in the form of an auction. The agent that gives the task is the manager and the agent that bids is the contractor, and the processing equipment is treated as the manager and the AGV as the contractor, and the contract is dynamically negotiated. During the negotiation, messages based on the contract net protocol are exchanged between the manager and the contractor. The flow of the negotiation between the task manager and the contractor is shown in Fig. 43.5. As shown in the figure, first, the task manager sends a task to the AGV, which then decides whether to bid on the task and if so, bids on it. The task manager then selects the successful bidder from the multiple bids. The successful bidder will take into account the heterogeneity of each AGV (e.g., the distance between the AGV and the target equipment) and report the results to the winning AGV. Finally, the AGV that wins the bid for the task considers its own situation and makes a decision on whether to execute the task. If the task is not executed, the task manager will allocate the task to another contractor. In addition, as shown in Fig. 43.6, the traffic information manager changes the CNP and the L_h

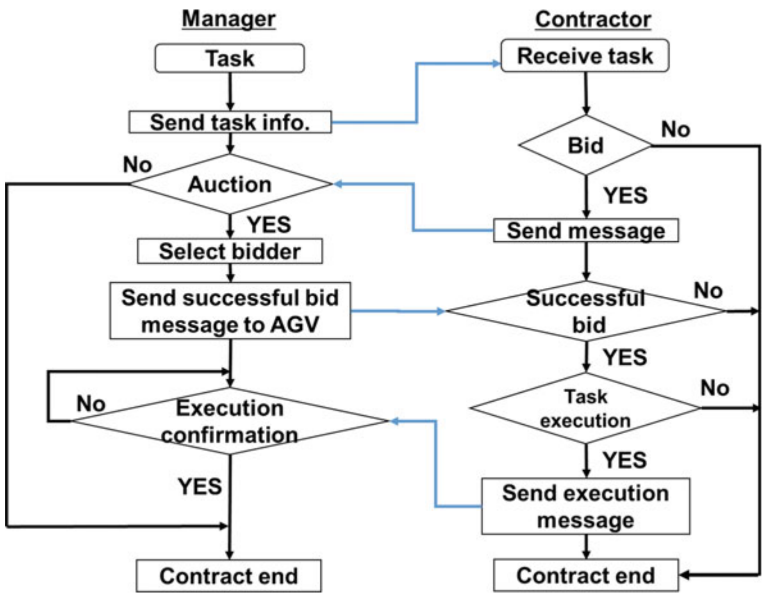


Fig. 43.5 Negotiation flow between the task manager and the contractor

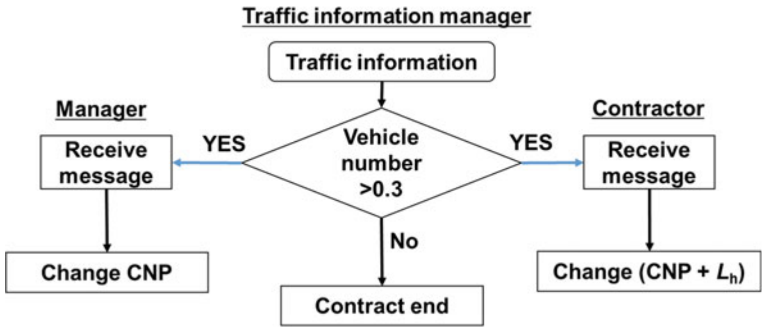


Fig. 43.6 Negotiation flow using traffic information

when vehicle number >0.3 based on the congestion information. L_h changed is set to $L_h = 3$ m based on the results of Sect. 43.3. As shown in Fig. 43.3d, the total number of AGVs on the transport path increases with time when $n = 0.4$, and congestion is expected to occur over a long period of time. For this reason, when the vehicle number ≥ 0.3, the algorithm was changed to CNP and the distance between AGVs was changed to $L_h = 3$, which is relatively free from congestion based on the results of Sect. 43.3, and the calculation results are shown in Fig. 43.7. Unlike the results in Fig. 43.3d, when the number of AGVs in the congested transfer furnace increases, the increase in the total number of AGVs in the transfer furnace can be suppressed by applying CNP and changing $L_h = 3$.

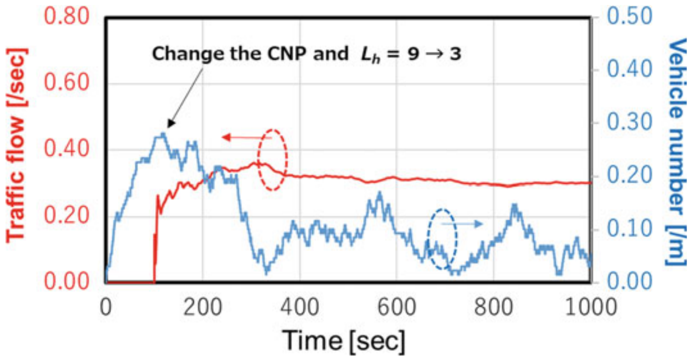


Fig. 43.7 Bidirectional traffic flow (red line) and vehicle number (blue line)—time characteristic ($n = 0.4$, (initial) $L_h = 9$)

43.5 Conclusions

We demonstrated the analytical model that takes into account the spatial interference of AGVs using MAS and CNP, in which the processing unit is treated as the task manager and the AGV as the contractor. The contract was dynamically negotiated, and the distance between AGVs was adjusted by using traffic information. Using this model, when the vehicle number ≥ 0.3, the algorithm was changed to CNP and the distance between AGVs was changed to $L_{\mathrm{h}} = 3$ m, which is relatively free from congestion based on the results in Sect. 43.3. The results of Sects. 43.3 and 43.4 show that changing the distance between AGVs to $L_{\mathrm{h}} = 3$ m, which is relatively free from congestion, can suppress the increase in the total number of AGVs on the transport path. Since our analytical model is simple, such a model is likely beneficial for suppressing the AGV congestion in the system where the spatial interference of AGVs may occur.

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