Smart Innovation, Systems and Technologies 306

Gordan Jezic ·
Yun-Heh Jessica Chen-Burger ·
Mario Kusek · Roman Šperka ·
Robert J. Howlett ·
Lakhmi C. Jain *Editors*



Agents and Multi-Agent Systems: Technologies and Applications 2022

Proceedings of 16th KES International Conference, KES-AMSTA 2022, June 2022

KES International

Springer

Smart Innovation, Systems and Technologies

Volume 306

The Smart Innovation, Systems and Technologies book series encompasses the topics of knowledge, intelligence, innovation and sustainability. The aim of the series is to make available a platform for the publication of books on all aspects of single and multi-disciplinary research on these themes in order to make the latest results available in a readily-accessible form. Volumes on interdisciplinary research combining two or more of these areas is particularly sought.

The series covers systems and paradigms that employ knowledge and intelligence in a broad sense. Its scope is systems having embedded knowledge and intelligence, which may be applied to the solution of world problems in industry, the environment and the community. It also focusses on the knowledge-transfer methodologies and innovation strategies employed to make this happen effectively. The combination of intelligent systems tools and a broad range of applications introduces a need for a synergy of disciplines from science, technology, business and the humanities. The series will include conference proceedings, edited collections, monographs, handbooks, reference books, and other relevant types of book in areas of science and technology where smart systems and technologies can offer innovative solutions.

High quality content is an essential feature for all book proposals accepted for the series. It is expected that editors of all accepted volumes will ensure that contributions are subjected to an appropriate level of reviewing process and adhere to KES quality principles.

Indexed by SCOPUS, EI Compendex, INSPEC, WTI Frankfurt eG, zbMATH, Japanese Science and Technology Agency (JST), SCImago, DBLP.

All books published in the series are submitted for consideration in Web of Science.

Gordan Jezic · Yun-Heh Jessica Chen-Burger ·
Mario Kusek · Roman Šperka · Robert J. Howlett ·
Lakhmi C. Jain
Editors

Agents and Multi-Agent Systems: Technologies and Applications 2022

Proceedings of 16th KES International Conference, KES-AMSTA 2022, June 2022

Springer

Editors
Gordan Jezic
Faculty of Electrical Engineering
and Computing
University of Zagreb
Zagreb, Croatia

Yun-Heh Jessica Chen-Burger
School of Mathematical and Computer
Sciences
The Heriot-Watt University
Scotland, UK

Mario Kusek
Faculty of Electrical Engineering
and Computing
University of Zagreb
Zagreb, Croatia

Roman Šperka
Department of Business Economics
and Management
Silesian University in Opava
Opava, Czech Republic

Robert J. Howlett
KES International Research
Shoreham-by-sea, UK

Aurel Vlaicu University of Arad
Arad, Romania

Bournemouth University
Poole, UK

Lakhmi C. Jain
KES International
Selby, UK

Liverpool Hope University
Liverpool, UK

ISSN 2190-3018 ISSN 2190-3026 (electronic)
Smart Innovation, Systems and Technologies
ISBN 978-981-19-3358-5 ISBN 978-981-19-3359-2 (eBook)
https://doi.org/10.1007/978-981-19-3359-2

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

KES-AMSTA-2022 Conference Organization

KES-AMSTA-2022 was organized by KES International—Innovation in Knowledge-Based and Intelligent Engineering Systems.

Honorary Co-Chairs

I. Lovrek, University of Zagreb, Croatia
L. C. Jain, Liverpool Hope University, UK

General Co-Chairs

G. Jezic, University of Zagreb, Croatia
Yun-Heh Jessica Chen-Burger, Heriot-Watt University, Scotland, UK

Executive Chair

R. J. Howlett, Aurel Vlaicu University of Arad, Romania and Bournemouth University, UK

Programme Co-Chairs

M. Kusek, University of Zagreb, Croatia
R. Sperka, Silesian University in Opava, Czechia

Publicity Co-Chairs

P. Skocir, University of Zagreb, Croatia
M. Halaska, Silesian University in Opava, Czechia

International Program Committee

Prof. Arnulfo Alanis Garza, Tecnológico Nacional de México/campus Tijuana, México
Dr. Veljko Aleksic, University of Kragujevac, Faculty of Technical Sciences Cacak, Serbia
Assoc Prof. Patricia Anthony, Lincoln University, New Zealand
Prof. Koichi Asakura, Daido University, Japan
Prof. Ahmad Taher Azar, Prince Sultan University, Saudi Arabia
Assist. Prof. Marina Bagić Babac, University of Zagreb, Croatia
Prof. Rosario Baltazar Flores, Tecnológico Nacional de México/campus León, México
Prof. Dariusz Barbucha, Gdynia Maritime University, Poland
Prof. Monica Bianchini, University of Siena, Italy
Assoc. Prof. Bruno Blaskovic, University of Zagreb, Croatia
Dr. Gloria Bordogna, CNR, Italy
Dr. Yun-Heh Jessica Chen-Burger, Heriot-Watt University, UK
Dr. Angela Consoli, Department of Defence, Australia
Prof. Ireneusz Czarnowski, Gdynia Maritime University, Poland
Dr. Trong Hai, Duong, hSchool, hSpace LLC, Vietnam
Prof. Margarita Favorskaya, Reshetnev Siberian State University of Science and Technology, Russia
Dr. Michal Halaška, Silesian University in Opava, Czech Republic
Prof. Tzung-Pei Hong, National University of Kaohsiung, Taiwan
Prof. Dragan Jevtic, University of Zagreb, Croatia
Prof. Arkadiusz Kawa, Łukasiewicz Research Network - Institute of Logistics and Warehousing, Poland
Prof. Petros Kefalas, CITY College, University of York Europe Campus, UK
Dr. Adrianna Kozierkiewicz, Wrocław University of Science and Technology, Poland
Prof. Konrad Kulakowski, AGH University of Science and technology, Poland
Prof. Setsuya Kurahashi, University of Tsukuba, Tokyo
Prof. Kazuhiro Kuwabara, Ritsumeikan University, Japan
Dr. Marin Lujak, Universidad Rey Juan Carlos, Madrid, Spain
Prof. René Mandiau, University Polytechnique Hauts-de-France (UPHF) / France
Prof. José M. Molina, Computer Science Department, University Carlos III de Madrid, Spain
Prof. Radu-Emil Precup, Politehnica University of Timisoara, Romania

Dr. Ewa Ratajczak-Ropel, Gdynia Maritime University, Poland
Prof. Pavle Skocir, University of Zagreb Faculty of Electrical Engineering and Computing, Croatia
Dr. Katerina Slaninova, School of Business Administration in Karvina, Silesian University of Opava, Czech Republic
Assoc. Prof. Dr Roman ŠPERKA, Ph.D., Silesian University in Opava, Czech Republic
Prof. Ryszard Tadeusiewicz, AGH University of Science and Technology, Poland
Prof. Hiroshi Takahashi, Keio University, Japan
Prof. Masakazu Takahashi, Yamaguchi University, Japan
Prof. Takao Terano, Chiba University of Commerce, Japan
Prof. Taketoshi Ushiama, Kyushu University, Japan
Assoc. Prof. Bay Vo, Ho Chi Minh City University of Technology (HUTECH), Ho Chi Minh City, Vietnam
Dr. Mahdi Zargayouna, Université Gustave Eiffel, France

Invited Session Chairs

Business Economics and Agent-Based Modelling

Prof. Hiroshi Takahashi, Keio University, Japan
Prof. Setsuya Kurahashi, University of Tsukuba, Japan
Prof. Takao Terano, Chiba University of Commerce, Japan

Agent-Based Modelling and Simulation (ABMS)

Assoc. Prof. Roman Šperka, Silesian University in Opava, Czechia

Multi-Agent Systems in Transportation Systems

Dr. Mahdi Zargayouna, Université Gustave Eiffel, France

Intelligent Agents in health, wellness and human development environments applied to health and medicine

Prof. Rosario Baltazar Flores, Tecnologico Nacional de Mexico—Campus Leon, Mexico
Prof. Arnulfo Alanis Garza, Tecnologico Nacional de Mexico—Campus Tijuana, Mexico

Preface

This volume contains the proceedings of the 16th KES Conference on Agent and Multi-Agent Systems—Technologies and Applications (KES-AMSTA 2022) held as a hybrid conference between June 20 and 22, 2022. 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 and smart environments, etc. Special attention is paid on the feature topics: multi-agent systems and architectures, modelling and simulation of agents, business process management, agent negotiation and optimization, 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 four invited sessions on specific topics within the field. Submissions came from 12 countries. Each paper was peer reviewed by at least two members of the International Programme Committee and International Reviewer Board. 26 papers were selected for presentation and publication in the volume of the KES-AMSTA 2022 proceedings.

The Programme Committee defined the following main tracks: Intelligent Software Agents and Optimization, and Multi-Agent Systems. In addition to the main tracks of the conference there were the following invited sessions: Agent-based Modelling and Simulation, Intelligent Agents in health, wellness and human development environments applied to health and medicine, Business Economics and Agent-based Modelling, 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, Chiba University of Commerce, 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.

Zagreb, Croatia — Gordan Jezic
Scotland, UK — Yun-Heh Jessica Chen-Burger
Zagreb, Croatia — Mario Kusek
Opava, Czech Republic — Roman Šperka
Shoreham-by-sea, UK — Robert J. Howlett
Selby, UK — Lakhmi C. Jain
April 2022

Contents

About the Editors

Gordan Jezic is a Professor at the University of Zagreb, Croatia. His research interest includes telecommunication networks and services focusing particularly on parallel and distributed systems, Machine-to-Machine (M2M) and Internet of Things (IoT) systems, communication networks and protocols, mobile software agents and multi-agent systems. He actively participates in numerous international conferences as a paper author, speaker, member of organizing and program committees or reviewer. He co-authored over 100 scientific and professional papers, book chapters and articles in journals and conference proceedings.

Yun-Heh Jessica Chen-Burger is an Assistant Professor, Computer Science, Heriot-Watt University. She was Research Fellow, Informatics, University of Edinburgh. Her research interests include enterprise modelling, process modelling, execution and mining technologies and how they may interact with agent technologies to solve complex real-world problems. She is committee member of several international conferences, journals and chair of conference and conference sessions. She is PI to several research and commercial projects.

Mario Kusek is Professor at the University of Zagreb, Croatia. He holds Ph.D. (2005) in electrical engineering, from the University of Zagreb. He is currently a lecturer of 9 courses and has supervised over 130 students at B.Sc., M.Sc. and Ph.D. studies. He participated in numerous projects local and internationals. He has co-authored over 80 papers in journals, conferences and books in the area of distributed systems, multi-agent systems, self-organized systems and machine-to-machine (M2M) Communications. Prof. Kušek is a member of IEEE, KES International and the European Telecommunications Standards Institute (ETSI). He serves as a program co-chair on two international conferences.

Roman Šperka is an Associate Professor and Head of Department of Business Economics and Management at Silesian University in Opava, School of Business Administration in Karvina, Czech Republic. He holds Ph.D. title in "Business economics and management" and Dr. title in "Applied informatics" since 2013. He has been participating as a head researcher or research team member in several projects funded by Silesian University Grant System or EU funds. His field of expertise is business process management, process mining, implementation and deployment of information systems and software frameworks; the use of agent-based technology in social sciences; modeling and simulation in economic systems and financial markets.

Robert J. Howlett is the Executive Chair of KES International, a non-profit organization that facilitates knowledge transfer and the dissemination of research results in areas including Intelligent Systems, Sustainability, and Knowledge Transfer. He is a Visiting Professor at Bournemouth University in the UK. His technical expertise is in the use of intelligent systems to solve industrial problems. He has been successful in applying artificial intelligence, machine learning and related technologies to sustainability and renewable energy systems; condition monitoring, diagnostic tools and systems; and automotive electronics and engine management systems. His current research work is focussed on the use of smart microgrids to achieve reduced energy costs and lower carbon emissions in areas such as housing and protected horticulture.

Lakhmi C. Jain Ph.D., Dr. H.C., ME, BE (Hons), Fellow (Engineers Australia), is with the Liverpool Hope University and the University of Arad. He was formerly with the University of Technology Sydney, the University of Canberra and Bournemouth University. Professor Jain founded 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 world-wide, KES facilitates international cooperation and generate 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
Agent and Multi-Agent Systems

Chapter 1
Temporal Logic in Multi-agent Environment

Vladimir V. Rybakov

Abstract This paper studies temporal multi-agent's relational models with distinct time accessibility relations for agents. Distinct valuations of truth values for agents' are also allowed, and a global valuation is the one which in a sense summarizes the opinion of agents. Some illustrating examples are provided (cf. displayed in paper below formulas (1.2), (1.3)). From mathematical point of view, we deal with satisfiability problem for formulas, and we construct a mathematical algorithm (cf. Theorem 1.3) verifying satisfiability. Also we prove that the problem of admissibility for inference rules in some such logics is decidable. Open problems from the area are proposed.

1.1 Introduction

Working with information, each agent updates it and checks it for reliability, safeness, truth, always being during work in some temporal environment.[1] Therefore, instrument of temporal logic is rather popular in such kind of research and usually to be combined with elements of multi-agency, parallel computing, and multi-agent logics (in a sense a multi-modal logics). It seems the first substantive example of a two-modal logic is Arthur Prior's tense logic, with two modalities, F and P, corresponding to "sometime in the future" and "sometime in the past". A logic with

[1]This paper is supported by Krasnoyarsk Mathematical Center financed by Ministry of Education Russian Federation (grant 075-02-2022-876).

V. V. Rybakov (✉)
Institute of Mathematics and Fundamental Informatics, Siberian Federal University, Krasnoyarsk, Russian Federation
e-mail: Vladimir_Rybakov@mail.ru

Institute of Informatics Systems, Siberian Branch of RAS, Novosibirsk, Russia

National Research University - High School of Economics, Moscow, Russia

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_1

infinitely many modalities is dynamic logic, introduced by Vaughan Pratt in 1976, it has a separate modal operator for every regular expression.

In multi-agents' logic, modalities are interpreted often as agent's temporal accessibility operations, or the ones oriented to model checking. They were used widely for study interaction and autonomy, effects of cooperation (cf. e.g. Babenuschev and Rybakov [1–4], Rybakov [20], Woldridge and Lomuscio [28], Woldridge [29, 30], Lomuscio et al. [10], Rybakov [23, 25]).

Working with knowledge representation also often deals with analysis of information by logical instruments (e.g., description logics) close to temporal and modal logics (cf. Horrocks, Satler et al. [14–16], Baader et al. [7–9]). Representation of agent's interaction (as a dual of common knowledge) was suggested in Rybakov [20]; using as a base agent's knowledge (S5-like) modalities. Knowledge, as a concept itself, came from multi-agency, since individual knowledge may be received only from interaction of agents, learning.

As essential feature of multi-agent environment is the observation that receiving or knowledge, interaction of agents, cooperation occur during some intervals of time, and that the length of this interval might be of great importance. To capture this observation CS often use symbolic (mathematical) temporal logic. Historically investigations of temporal logic in the framework of mathematical/philosophical logic based on modal systems, as we know, was originated by Arthur Prior in the late 1950s.

Nowadays temporal logic highly developed area in mathematical logic, information sciences, AI , and CS overall (cf. e.g.—Gabbay and Hodkinson[11–13]). One of the important cases of such logics is the linear temporal logic $\mathcal{LTL}$, which was used for analyzing protocols of computations, verification of consistency. Automaton techniques to solve satisfiability in this logic were developed by Vardi [26, 27]). Further, to evolve mathematical tools of $\mathcal{LTL}$, the solution for admissibility problem for $\mathcal{LTL}$ was found in Rybakov [17], the basis for admissible rules of $\mathcal{LTL}$ was obtained in Babenyshev and Rybakov [5]. Recently modeling multi-agency in non-transitive time assumption was studied in Rybakov [21, 22].

This paper considers temporal multi-agent's relational models with distinct linear time accessibility relations for agents. Agents as well have their own valuations for truth values of letters (notations) and formulas, and models have a global truth valuation which in a sense summarizes opinion of agents. Illustrating examples and explaining discussions are provided. From the mathematical point of view, we investigate with satisfiability problem for formulas, we find an algorithm verifying satisfiability. Also we prove that the problem of admissibility for inference rules in some such logics is decidable. Open problems from the area are proposed.

Formally this paper is structured as follows. Section 1.1—Introduction—comments on the historical state of existing research in the area and the aim of this paper; Sect. 1.2—Notation, Preliminary Facts—introduces accepted notation and briefly recall necessary for reading known facts; Sect. 1.3—Rules for computation truth values for formulas—formally and detailly describes algorithmic (mathematical) rules for computation; Sect. 1.4—Satisfiability Problem—recalls basic notation and facts concerning satisfiability problem in logics and then precisely enumerates all main obtained results formulated as mathematical theorems.

1.2 Notation, Preliminary Facts

Since we will use elements of multi-modal (temporal) logic we first recall necessary definitions and facts. As model theory for such logic usually to be used relational models which may be viewed as tuples $\langle W, \{R_i \mid i \in I\}, V\rangle$ with a base set W—the set of worlds (or states) in these models. A set of binary relations $\{R_i \mid i \in I\}$ on these worlds (any R_i is a subset of W x W) represent current time events in perception of agents i. Here V is a valuation of a set of propositional statements (letters) in this model.

That is, for any $p \in P$, $V(p) \subseteq W$. Then if $w \in W$ and $w \in V(p)$, we say p is true at the world w w.r.t V. As a logical language, it usually to be based on Boolean logic and uses special additional logical operations. Special rules defining computation of the truth values logical formulas are introduced, and the logic is usually defined as the set of all formulas which are true in any world of such specified models.

In order to embed the multi-agent approach, we consider individual valuations—$V_1, \ldots, V_k$ for agents in such models instead of only one unique fixed one. Then any V_i represents viewpoint of the agent i on truth of the atomic statement—propositional letters, and $w \in V_i(p)$ would mean that the agent i accepts the statement p to be true at the world w.

Besides differently from our previous works in that direction, we consider different time accessibility relations $\leq_j$ for different agents $j \in Ag$.

So, relational models of our paper look as follows; assume that a set of propositional letters $Prop$ be given.

Definition 1.1 A temporal k-model with agents' multi-valuations is the structure $\mathcal{M} := \langle \mathcal{N}, \leq_j, \text{Next}, V_1, \ldots, V_k, V_0\rangle$, where

(i) $\mathcal{N}$ is the set of all natural numbers;
(ii) Each $\leq_j$ (for $j \in Ag$) is a linear order which is a subset of usual $\leq$ on $\mathcal{N}$ (that is it is a linear order coinciding with $\leq$ on some subset of $\mathcal{N}$);
(iii) Next is the binary relation, where a Next b means that b is the number next to a;
(iv) any V_j is a valuation of $Prop$ (that is for any $p \in Prop$, $V_j(p) \subseteq \mathcal{N}$).

These models have a good range of applications, as researchers viewed earlier: they may represent (i) computational multi-agents runs (in particular—threads, as often for usual linear temporal logic), (ii) surfing via networks, internet, databases collections ($\mathcal{N}$ then will represent sequence of steps in the search), (iii) sequences of queries for relational databases, (iv) evolutions of social objects in time, etc. But now our semantics also includes different time relations for agents which give more ways for applications. To fix notation, for all $a \in \mathcal{N}$ and any $p \in Prop$ we write $[(\mathcal{M}, a) \Vdash_{V_j} p \Leftrightarrow a \in V_j(p)$, and say that the letter p is true at a w.r.t. V_j.

The valuation V_0 is a special one—global one—accepted in these models to fix objective truth relation. This valuation, in a sense, have to summarize opinions of all agents. Ways to construct V_0 out of all V_j may be different. For example, we may consider $(\mathcal{M}, a) \Vdash_{V_0} p \Leftrightarrow ||\{j \mid (\mathcal{M}, a) \Vdash_{V_j} p, j \neq 0\}|| > ||\{j(\mathcal{M}, a) \nVdash_{V_j} p, j \neq 0\}||$, This means the majority of agents believe that p is true. There are very many ways to express what means global valuation and what indeed means the dominant part of agents.

Maybe the agent's opinion may be considered with an appropriate weights prescribed, maybe depending on different states the rules to compute global valuation may be different, etc. At the very limit point, we may assume V_0 to be arbitrary, which does not depend on all V_j—it is opinion of a total dominant—the only true what V_0 think to be true. In this paper, we do not fix rigidly the rules for computation V_0 (they may be any ones chosen).

Definition 1.2 To fix language, the set of all formulas for our multi-agent logic (the set For) contains $Prop$ and is closed w.r.t. applications of Boolean logical operations $\wedge, \vee \neg, \rightarrow$, the unary operation N (next) and the binary operations U_j $j \in Ag$ (until, each one for each agent j).

The formula $N\varphi$ has meaning: φ holds in the next time point (state); $\varphi U_i \psi$ can be read: φ holds until ψ will be true in the opinion of the agent i.

1.3 Rules for Computation Truth Values for Formulas

Rules for computation truth values at our models for compound, complected formulas are as follows. Let a temporal linear k-model with agent's multi-valuations

$$\mathcal{M} := \langle \mathcal{N}, \leq_j, j \in Ag, \text{Next}, V_1, \ldots, V_k, V_0 \rangle,$$

be given. That is, for any letter $p \in Prop$ $V_i(p) \subseteq \mathcal{N}$. If $a \in \mathcal{N}$ and $a \in V_i(p)$ we write $(\mathcal{M}, a) \Vdash_{V_i} p$ and say that p is true at a w.r.t. the valuation V_i.

Definition 1.3

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

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

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

$$(\mathcal{M}, a) \Vdash_{V_j} N_i\varphi \Leftrightarrow \forall b[(a \text{ Next } b) \Rightarrow (\mathcal{M}, b) \Vdash_{V_i} \varphi];$$

$$(\mathcal{M}, a) \Vdash_{V_j} (\varphi U_j \psi) \Leftrightarrow \exists b[(a \leq_j b) \wedge ((\mathcal{M}, b) \Vdash_{V_j} \psi) \wedge$$

$$\forall c[(a \leq_j c < b) \Rightarrow (\mathcal{M}, c) \Vdash_{V_j} \varphi]].$$

There are various ways to define other logical operations using the postulated ones. In particular, the modal operations $\Box_i$ (necessary for agent i) and $\Diamond_i$ (possible for agent i) might be defined via temporal operations as follows: $\Diamond_i p := \top U_i p$, $\Box_i p := \neg\Diamond_i\neg p$. It might be easily verified that then

$$(\mathcal{M}, a) \Vdash_{V_j} \Diamond_i\varphi \Leftrightarrow \exists b \in \mathcal{N}[(a \leq_i b) \wedge (\mathcal{M}, b) \Vdash_{V_j} \varphi];$$

$$(\mathcal{M}, a) \Vdash_{V_j} \Box_i\varphi \Leftrightarrow \forall b \in \mathcal{N}[(a \leq_i b) \Rightarrow (\mathcal{M}, b) \Vdash_{V_j} \varphi];$$

Now we pause briefly to discuss why we cannot look at it as simply a mechanical combination of k—examples of the standard linear temporal logic. That all is a consequence the fact that in our definition of rules for computation truth values of formulas, cf. above, recall:

$$(\mathcal{M}, a) \Vdash_{V_j} (\varphi U_i \psi) \Leftrightarrow \exists b[(a \leq_i b) \wedge ((\mathcal{M}, b) \Vdash_{V_j} \psi) \wedge$$

$$\forall c[(a \leq_i c < b) \Rightarrow (\mathcal{M}, c) \Vdash_{V_j} \varphi]].$$

So, we switch the valuation for temporal operations: if the valuation is some V_j and we compute truth value for a temporal operation with index i we switch j to i and use further the valuation V_i. That is seemed as very correct and well justified: if a temporal statement refers to an agent i, the opinion about truth for future to be its one.

As you may see truth values during computations are switching valuations. Therefore, the standard technique cannot be directly applied. That is in particular because the standard rule of exchanging equivalents does not work here.

Indeed if for a model $\mathcal{M}$, it may happen

$$\forall a, (\mathcal{M}, a) \Vdash_{V_0} \Box_0((p \to q) \wedge (q \to p)),$$

but it does not imply generally speaking that

$$\forall a, (\mathcal{M}, a) \Vdash_{V_0} \Box_1((p \to q) \wedge (q \to p)).$$

Assume a class $\mathcal{K}$ of described models is given. We may assume that the rules of definition of the global valuation V_0 via agent's valuations V_i, $1 \leq i \leq k$ are fixed and are the same for all models and all states of these models. Though the agent's valuations themselves may be various (that looks as the most general case) but the rules imposed on the agent's valuations are the same for all states. For example, rules for agent's valuations may be with the limitation: for all states a,

$$[||\{i \mid (\mathcal{M}, a) \Vdash_{V_i} p\}|| > k/2 + 1] \Rightarrow \tag{1.1}$$

$$[\forall i(1 \leq i \leq k \Rightarrow (\mathcal{M}, a) \Vdash_{V_i} p)].$$

This means a uniform opinion—if a majority of agents believe that a fact is true then all of them think it is true.

Definition 1.4 A formula φ is said to be satisfiable in a class of models $\mathcal{K}$ if there is a model $\mathcal{M} \in \mathcal{K}$ and a state $a \in \mathcal{M}$ such that $(\mathcal{M}, a) \Vdash_{V_j}$ for some j.

Satisfiability problem for $\mathcal{K}$ is to resolve for any given formula if it is satisfiable in some model from $\mathcal{K}$. Assuming that a class of models $\mathcal{K}$ is chosen we may define the logic $\mathcal{L}(\mathcal{K})$ of this class as follows.

$$\mathcal{L}(\mathcal{K}) := \{\varphi \in Form \mid \forall \mathcal{M} \in \mathcal{K},\ \forall a \in \mathcal{M}, \forall j[(\mathcal{M}, a) \Vdash_{V_j} p]\}.$$

In this definition we may use only global valuation or a dominant part of all valuations. So the definition depends on the aim of our description of information inside models. For brevity in the sequel we write $\mathcal{L}$ instead of $\mathcal{L}(\mathcal{K})$ if we assume that $\mathcal{K}$ is fixed.

Assuming that all V_j are equal and V_0 being the same as any V_j and all of them to be arbitrary, we may obtain the limit point—to obtain that $\mathcal{L}(\mathcal{K})$ is just the standard linear temporal logic LTL itself. Bigger than this—then any j-fragment of any logic $\mathcal{L}(\mathcal{K})$ for the valuation V_j to be arbitrary is again LTL itself. But if combinations of different temporal and modal operations for distinct agents are allowed, the possibility to describe properties of multi-agent reasoning is much wider.

We briefly illustrate which formulas could more plausibly describe the postponed decision of agents. The background idea here is to say that the agents need time to think of indeed necessary particular properties, their safety and other qualities, and that need time for verification, comparison, etc. So, the idea is to postpone the taking decision for a reasonable time. That from technical viewpoint may be made in various ways and via distinct technique. For example, we could consider the formulas: $m \in N$,

$$DF(\varphi) := \bigwedge_j \Diamond_j \mathcal{N}^m \varphi. \tag{1.2}$$

That means that any agent always in future may use reasonable time (m steps) to wait for verification if the statement φ will be true; that is to postpone taking decision for reasonable time.

To say that the property encoded by a formula φ is very safe—conclude that φ will be true and in remaining future, and we may repeat that verification again and again, that is

$$Safe(\varphi) := \bigwedge_j [\Diamond_j \mathcal{N}^m \varphi] \wedge [\bigwedge_j [\Box_j \Diamond_j \mathcal{N}^m \varphi]. \tag{1.3}$$

1.4 Satisfiability Problem

Here, we turn to describe our new results for satisfiability problem. To recall, a formula φ is said to be satisfiable w.r.t. a valuation V_j in a class of models $\mathcal{K}$ if there is a model $\mathcal{M} \in \mathcal{K}$ and a state $a \in \mathcal{M}$ such that $(\mathcal{M}, a) \Vdash_{V_j}$ for some j. We may differ the problem by asking only for satisfiability formulas w.r.t. the global valuation., or alternatively all of them, or just some of them. More general case is—all of them, and we consider later this case. For any class of models $\mathcal{K}$ the logic $\mathcal{L}(\mathcal{K})$ of this class is defined as follows. $\mathcal{L}(\mathcal{K}) := \{\varphi \in Form \mid \forall \mathcal{M} \in \mathcal{K}, \ \forall a \in \mathcal{M}, \forall j[(\mathcal{M}, a) \Vdash_{V_j} p]\}$. So the logic is all formulas which are true everywhere w.r.t. any valuation.

Differently from our earlier research in this area, we here consider models with distinct agents' linear time-accessibility relations.

So, as axillary instruments, we will need special models $\mathcal{M}(\Uparrow, C)$ aiming to distinguish special finite models. Recall that for $n, m, i \in \mathcal{N}$ with $n < m$ $[n, m]$ denotes the closed interval of all numbers situated between n and m and these numbers n, m themselves.

Definition 1.5 So let a model $\mathcal{M}$ for our logic defined as earlier to be given. Any $\mathcal{M}(\Uparrow, C)$ model has the following structure. For $n, c(m), m \in \mathcal{N}$, where $0 < n < c(m) \leq m$,

$$\mathcal{M}(\Uparrow, C) = \langle [0, m], \leq_j, j \in Ag, \text{Next}, V_1, \ldots, V_k, V_0 \rangle),$$

where $\text{Next}(m) := c(m)$ and

(i) C is a loop on a final part of [0,m] w.r.t. an external time order;
(ii) Any $\leq_j$, is the linear order on an interval of C coinciding with the original $\leq_j$ on the states belonging to the domain of $\leq$;
(iii) before C any $\leq_j$ acts as in the original model;
(iv) The valuations V_j are taken from the model $\mathcal{M}$ itself.

The rules for computation of the truth values of formulas in such model w.r.t. any V_j are defined similarly to as earlier in the models, simply for states bigger than $c(m)$ the order $\leq$ to be replaced by appropriate $\leq_j$ in C. More precisely, we define $(\mathcal{M}(\Uparrow, C)a) \Vdash_{V_j} (\varphi U_j \psi)$ as follows. If $a \in [0, c(m)]$ the definition is as earlier, if $a > c(m)$,

$$(\mathcal{M}(\Uparrow, C), a) \Vdash_{V_i} (\varphi U_j \psi) \Leftrightarrow \exists b\big[[(a \leq_j b \leq c(m)) \wedge (\mathcal{M}(\Uparrow, C), b) \Vdash_{V_i} \psi) \wedge$$

$$\forall c[(a \leq_j c < b) \Rightarrow (\mathcal{M}(\Uparrow, C), c) \Vdash_{V_i} \varphi]] \bigvee$$

$$\exists d\big[(b > c(m)) \wedge (\mathcal{M}(\Uparrow, C), , b) \Vdash_{V_i} \psi) \wedge$$

$$\forall c[(a \leq_j c < m) \Rightarrow (\mathcal{M}(\Uparrow, C), c) \Vdash_{V_i} \varphi]] \wedge$$

$$\forall c[(c(m), \leq_j c < b) \Rightarrow (\mathcal{M}(\Uparrow, C), c) \Vdash_{V_i} \varphi]].$$

So introduced rules act in accordance with our previous intuition of what is circled bypath by $Next$. For any formula φ, we denote by $Sub(\varphi)$ is the set of all its subformulas.

Let for any formula φ, $Tm(\varphi)$ be the temporal degree of φ; the temporal degree of formulas is defined inductively: (i) temporal degree of letters is 0, (ii) temporal degree of any formula with a temporal operation as the main one is the maximal temporal degree of the components plus 1; (iii) temporal degree of any formula with a Boolean logic operation as the main one is the maximal temporal degree of the components. Recall that k is the number of agents in our models. Denote $f(\varphi) := 2 \times 2^{2^{||Sub(\varphi)|| \times k+3}} + 5$. By the size of a model, we agree to call the number of states in this model.

Theorem 1.1 *If a formula φ is satisfiable in a model $\mathcal{M}$ at a state by a valuation V_j, then there exists a finite model of kind $\mathcal{M}(\Uparrow, C)$ with size at most $f(\varphi)$ satisfying φ at the world* 0 *by its own V_j.*

Theorem 1.2 *If a formula φ is satisfiable in a finite model $\mathcal{M}(\Uparrow, C)$ then it is satisfiable in some k-model $\mathcal{M}$.*

Recall that a logic $\mathcal{L}(\mathcal{K})$ is decidable if for any formula φ we may compute if $\varphi \in \mathcal{L}(\mathcal{K})$. Observe that $\varphi \in \mathcal{L}(\mathcal{K})$ iff $\neg\varphi$ is not satisfiable in $\mathcal{L}(\mathcal{K})$. From Theorems 1.1 and 1.2 we immediately obtain

Theorem 1.3 *The satisfiability problem for $\mathcal{L}(\mathcal{K})$ is decidable (so the logic $\mathcal{L}(\mathcal{K})$ is decidable). For a formula φ to be satisfiable it is sufficient to check its satisfiability at all models $\mathcal{M}(\Uparrow, C)$ of size at most $f(\varphi)$.*

We are also interested to consider the problem of recognizing rules admissible in our logic. Though we can do it now only for a restricted case—when the valuation in models is only single—the final global one, and when the operation $Next$ is deleted from the models (denote the resulting logic by L_{Ag}).

Theorem 1.4 *The admissibility problem for the logic* L_{Ag} *is decidable. There exists an algorithm recognizing rules admissible in* L_{Ag}.

1.5 Conclusion

There are several interesting open problems in this area. For example, to consider models with distinct rules of computation global valuation depending at which state the computation is to be done. Next one is the case when the operation NEXT STATE is different for distinct agents. That looks like a reasonable approach—agents may be distinct in perception when next time will come depending on, e.g., their accessibility restrictions, etc. The extension that results in branching time logic is very interesting and actual. The investigation of admissibility for rules for all logics from thew related area is interesting, many things are already done for non-classical logics (cf. [17–19]) and many strong results about admissibility and unification were obtained by distinct researchers. But for multi-agent logics the amount of such results is not too big as the area is very technical (cf. from Recent results [24] Rybakov 2020.). To consider technique from this paper in a combination with the fuzzy logic also looks interesting.

References

1. Babenyshev, S., Rybakov, V.: Logic of plausibility for discovery in multi-agent environment deciding algorithms. In: KES (3) 2008: Lecture Notes in Computer Science, vol. 5179/2008, pp. 210–217 (2008)
2. Babenyshev, S., Rybakov, V.: Decidability of hybrid logic with local common knowledge based on linear temporal logic LTL. In: CiE 2008: Lecture Notes in Computer Science, vol. 5028/2008, pp. 32–41 (2008)
3. Babenyshev, S., Rybakov, V.: Logic of discovery and knowledge: decision algorithm. In: KES (2), Lecture Notes in Computer Science, vol. 5178/2008, pp. 711–718 (2008)
4. Babenyshev, S., Rybakov, V.: Describing evolutions of multi-agent systems. In: KES (1) 2009: Lecture Notes in Computer Science, vol. 5711/2009, pp. 38–45 (2009)
5. Babenyshev, S., Rybakov, V.: Linear temporal logic LTL: basis for admissible rules. J. Log. Comput. **21**(2), 157–177 (2011)
6. Babenyshev, S., Rybakov, V.: Unification in linear temporal logic LTL. Ann. Pure Appl. Log. **162**(12), 991–1000 (2011)
7. Baader, F., Sattler, U.: Expressive Number Restrictions in Description Logics. J. Log. Comput. **9**(3), 319–350 (1999)
8. Baader, F., Küsters, R.: Unification in a description logic with transitive closure of roles. In: Nieuwenhuis, R., Voronkov, A. (eds.) Logic for Programming, Artificial Intelligence, and Reasoning, LPAR 2001, LNCS, vol. 2250, pp. 217–232. Springer, Berlin (2001)

9. Baader, F., Morawska, B.: Unification in the description logic EL. Log. Methods Comput. Sci. **6**(3), 1–31 (2010)
10. Belardinelli, F., Lomuscio, A.: interactions between knowledge and time in a first-order logic for multi-agent systems: completeness results. J. Artif. Intell. Res. **45**, 1–45 (2012)
11. Gabbay, D.M., Hodkinson, I.M., Reynolds, M.A.: Temporal Logic: - Mathematical Foundations and Computational Aspects, vol. 1. Clarendon Press, Oxford (1994)
12. Gabbay D.M., Hodkinson I.M.: An axiomatization of the temporal logic with Until and Since over the real numbers. J. Log. Comput. **1**, 229–260 (1990)
13. Gabbay, D., Hodkinson, I.: Temporal logic in context of databases. In: Copeland, J. (ed.) Logic and Reality. Oxford University Press, Essays on the legacy of Arthur Prior (1995)
14. Horrocks, I., Sattler, U.: A description logic with transitive and inverse roles and role hierarchies. Descr. Log. (1998)
15. Horrocks, I., Giese, M., Kharlamov, E., Waaler, A.: Using semantic technology to tame the data variety challenge. IEEE Internet Comput. **20**(6), 62–66 (2016)
16. Sattler, U.: Description Logics for the Representation of Aggregated Objects. ECAI, pp. 239–243 (2000)
17. Rybakov, V.V.: Linear temporal logic with until and before on integer numbers, deciding algorithms. In: Computer Science—Theory and Applications, Lecture Notes in Computer Science, vol. 3967, pp. 322–334. Springer, Berlin (2006)
18. Rybakov, V.V.: Linear temporal logic with until and next, logical consecutions. Ann. Pure Appl. Log.**155**(1), 32–45 (2008)
19. Rybakov, V.V.: Multi-modal and temporal logics with universal formula—reduction of admissibility to validity and unification. J. Log. Comput. **18**(4), 509–519 (2008)
20. Rybakov, V.V.: LTKK extended by multi-agent logic Kn with interacting agents. J. Log. Comput. **19**(6), 989–1017 (2009). Oxford Press
21. Rybakov, V.: Non-transitive linear temporal logic and logical knowledge operations. J. Log. Comput. **26**(3), 945–958 (2016). Oxford Press
22. Rybakov, V.: Intransitive temporal multi-agents logic, knowledge and uncertainty, plausibility. In: International Symposium on Logical Foundations of Computer Science, Volume 9537 of the series Lecture Notes in Computer Science, pp. 364–375 (2016)
23. Rybakov, V.: Temporal logic with overlap temporal relations generated by time states themselves. Siberian Math. Rep. **17**, 923–932 (2020)
24. Rybakov, V.: Multi-agent temporal nontransitive linear logics and the admissibility problem . Algebra Log. **59**, 87–100 (2020)
25. Rybakov, V.: Branching time logics with multiagent temporal accessibility relations . Siberian Math. J. **62**(3), 503–510 (2021)
26. Vardi, M.: An automata-theoretic approach to linear temporal logic. In: Banff Higher Order Workshop, pp. 238–266 (1955). Available at http://citeseer.ist.psu.edu/vardi96automatatheoretic.html
27. Vardi, M.Y.: Reasoning about the past with two-way automata. In: Larsen K.G., Skyum S., Winskel G., (eds.) ICALP, LNCS, vol. 1443, pp. 628–641. Springer, Berlin (1998)
28. Wooldridge, M., Lomuscio, A.: Multi-agent VSK logic. In: Proceedings of the Seventh European Workshop on Logics in Artificial Intelligence (JELIAI-2000). Springer, Berlin (2000)
29. Wooldridge, M.: An Automata-theoretic approach to multi-agent planning. In: Proceedings of the First European Workshop on Multi-agent Systems (EUMAS 2003). Oxford University (2003)
30. Wooldridge, M., Huget, M.-P., Fisher, M., Parsons, S.: Model checking multi-agent systems: the MABLE language and its applications. Int. J. Artif. Intell. Tools **15**(2), 195–225 (2006)

Chapter 2
Cost-Aware Dynamic Task Sharing Among Decentralized Autonomous Agents: Towards Dynamic Patient Sharing Among Hospitals

Hisashi Hayashi

Abstract In the COVID-19 pandemic era, hospitals tend to be crowded with patients. Dynamic task sharing is becoming an important research theme and can be applied to patient sharing among hospitals. Unlike in standard task scheduling, the tasks are created dynamically and asynchronously, and each agent (hospital or region) is independent. Hence, we previously designed and compared the decentralized algorithms for dynamic task sharing. However, in these algorithms, the cost of task transfers was not considered. The cost of transferring a patient to a distant hospital is high and cannot be ignored. In this paper, we present new decentralized algorithms for dynamic task sharing that consider the cost of task transfers.

2.1 Introduction

As the COVID-19 pandemic continues, hospitals tend to be crowded and might refuse admission. To accommodate more patients, hospitals need to cooperate, and patients must be transferred from busy hospitals to less busy hospitals.

Therefore, we need to find effective task-sharing algorithms. Most task-allocation algorithms previously applied are centralized algorithms wherein a single agent allocates the tasks to other agents. However, in the task (patient) sharing problem, each hospital is independent and pursues its own profit. In other words, hospitals generally do not transfer patients to other hospitals, unless their beds are full. Therefore, we need decentralized task-sharing algorithms.

Furthermore, patient sharing among hospitals needs special consideration because patients appear dynamically and asynchronously, and some patients need to be treated urgently. From this perspective, we previously evaluated and compared six decentralized task-sharing algorithms using patient sharing scenarios [10]. The algorithms were designed considering the urgency of patients. Thus, we found that the CSRN

H. Hayashi (✉)
Advanced Institute of Industrial Technology, 1-10-40 Higashi-Ooi, Shinagawa-ku, 140-0011 Tokyo, Japan
e-mail: hayashi-hisashi@aiit.ac.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_2

(continual or single random negotiation) algorithm was the best among the six algorithms proposed, for increasing the number of executed tasks before the deadline. But multiple negotiations for the transfer of the same task were not effective.

Although our conclusion in the previous study is extremely useful for patient sharing among hospitals, we would like to improve the CSRN algorithm further, considering more constraints in the real world. An important constraint is the distance between hospitals. It is expected that hospitals tend to avoid transferring their patients to distant hospitals because this process requires time and money. Therefore, we extended the CSRN algorithm and introduced two new algorithms taking the transfer cost into account. We evaluated and compared the two new and improved algorithms with the CSRN algorithm by multi-agent simulation. The results have been reported in this paper.

The rest of this paper is organized as follows. In Sect. 2.2, related work is discussed. In Sect. 2.3, the problem is described. In Sect. 2.4, two new algorithms are presented. In Sect. 2.5, simulation settings are explained in detail. In Sect. 2.6, simulation results are presented and discussed. In Sect. 2.7, concluding remarks and future works are summarized.

2.2 Related Work

Dynamic task allocation is an important research subject and is applied in areas such as coordination of robots [13, 24], allocation of taxis [6, 21] and ride-share cars [27, 28] to passengers, coordination of IoTs [22], coordination of non-playing characters in computer games [4, 11, 14, 23, 25], weapon-target assignment [2, 12, 26], and disaster relief [5, 15–17]. Owing to the COVID-19 pandemic, task sharing among hospitals has now become important.

As discussed in [3, 16], there are two types of task-allocation algorithms: centralized and decentralized. Centralized combinatorial optimization (such as maximum weight matching [20]) or auction (such as parallel auction [1]) are also related to task-allocation problems. As aforementioned, most algorithms are centralized, wherein a single agent allocates the tasks to other agents. In decentralized algorithms, however, each agent must individually negotiate with other agents to transfer tasks. As explained in the previous section, in the case of the task sharing among hospitals, decentralized algorithms are needed. Auctions can be decentralized. However, they need many communications among agents, which is not acceptable when human operators are involved in each negotiation.

Decentralized algorithms for dynamic task allocation were studied for different scenarios in [7–9]. In these studies, the task is always allocated to the agent who can handle it best, provided there is enough time. The task is handled locally only when the time is limited. These algorithms can be applied to applications such as disaster response and defense. In the case of task sharing among hospitals, the task is always handled locally when there are adequate resources, and this requires different algorithms.

Decentralized human resource sharing among companies was studied in [18, 19] where less busy companies send their employees to busy ones to level the busyness among companies. Although resource sharing is different from task sharing, the aim of human resource sharing is similar to that of task sharing among hospitals. However, in the case of task sharing among hospitals, critical tasks must be handled immediately.

2.3 Problem Description

We consider a multi-agent system in which each **agent** is given **tasks** dynamically and asynchronously, and handles the tasks using its own **resource**. The **agent** takes time (**execution time**) to finish a task, and occupies the **needed resource** when committed to the task. We assume that tasks must be commenced before the (start) **deadline**. In the case of medical tasks, tasks correspond to the treatment of ill patients, agents correspond to hospitals or regions, and resources correspond to medical staff or beds. Unexecuted tasks by the deadline correspond to the death of persons and will be removed after the deadline.

In our problem setting, to level the number of tasks among agents, we allow **transfer of tasks** among agents, if they agree. Through task transfers, busy agents can reduce the number of tasks. In the case of the COVID-19 pandemic, many people are hospitalized in some areas, whereas the other areas are relatively available.

One of the important factors to consider is the cost of task transfers. For example, when a hospital transfers a patient to another hospital, the cost increases with distance. Another important factor is the urgency of tasks. For example, we must start treatment tasks before it's too late.

In our study, we aim to minimize the **cost of task transfers** and the **number of tasks that missed the (start) deadline**. We assume that each agent cannot know the values of internal variables of the other agents, including available resources and waiting tasks.

2.4 Method

In this section, we introduce the task-sharing framework and the algorithms of simulation cycle, handling waiting tasks, and replying for a task transfer. To deal with the problem defined in the previous section, we try to improve the algorithms for handling waiting tasks that were introduced in [10], to minimize the cost of task transfers. Because our previous algorithms were incrementally defined, they are easily understandable. We recommend the interested readers to read our previous paper [10].

2.4.1 Task-Sharing Framework

In this subsection, we define a task-sharing framework that includes tasks and agents. Under this framework, we define algorithms for task sharing.

A **task sharing framework** is $\langle S_{tasks}, S_{agents} \rangle$ where S_{tasks} is a set of tasks, and S_{agents} denotes a set of agents. Each task t contains the attributes of remaining time to deadline ($t.time2deadline$) before commencing the task t, time to finish the remainder of the task t ($t.time2fishish$), and resource required ($t.res_{needed}$). The task t has to commence within $t.time2deadline$ ticks and it takes $t.time2fishish$ ticks to finish the remainder of t. While the task t is executed, it occupies the resource amount $t.res_{needed}$. When resources are occupied, they cannot be used for other tasks. However, when the occupied resources are released, they can be reused for other tasks. We assume that task execution cannot stop once started.

Each agent a contains the attributes of the available resource amount of $a.res$ and the resource threshold of $a.\theta_{res}$. When $a.res$ is below $a.\theta_{res}$, the agent a determines that the available resource is limited. Each agent a also contains the attributes of the waiting task set ($a.S_{tasks_{waiting}}$) and the committed task set ($a.S_{tasks_{committed}}$). Each agent a is assigned tasks at each tick and can commence some tasks using its own resource. However, while the agent a is executing the task t, the resource $t.res_{needed}$ is occupied. When tasks are assigned to the agent a, they are added to $a.S_{tasks_{waiting}}$. When the agent a starts the task t, t is moved from $a.S_{tasks_{waiting}}$ to $a.S_{tasks_{committed}}$.

Each agent a_1 can transfer a task t to another agent a_2 (can move t from $a_1.S_{tasks_{waiting}}$ to $a_2.S_{tasks_{waiting}}$) if the negotiation succeeds. The cost of transferring the task t from the agent a_1 to the agent a_2 is represented as $a_1.cost(t, a_2)$.

2.4.2 Simulation Cycle

In this subsection, we define our simulation cycle algorithm, which is the top-level procedure. This algorithm controls the simulation time, the agents' decision-making time, and creation/deletion of the agents' tasks.

The simulation cycle is defined in Algorithm 1. One simulation cycle corresponds to one time step ($tick$). At each time step, if an agent finishes a task (line 5), the task is removed from the agent (line 7), and the resource used for the task is released (line 8). If a task does not commence before the deadline (line 12), it is deallocated from the agent (line 14). Subsequently, the deadlines of other waiting tasks are decremented by 1 (line 16). At each time step, new tasks are assigned to agents (lines 18-19) and each agent handles the waiting tasks assigned to them (line 20). Note that the algorithm for $agent$ to handle the waiting tasks is $agent.handleWaitingTasks()$, defined as the CSCARN (Algorithm 2) and BCACN (Algorithm 3) in the following subsection.

```
   Input: S_agents /* set of all agents */
   Input: endtime /* the end time of the simulation */
1  initialize the parameter of agents;
2  for tick = 0 to endtime do
3      foreach agent ∈ S_agents do
4          foreach task ∈ agent.S_tasks_committed do
5              if task.time2finish == 0 /* task finished */
6              then
7                  remove task from agent.S_tasks_committed;
8                  increment agent.res by task.res_needed;
9              end
10         end
11         foreach task ∈ agent.S_tasks_waitng do
12             if task.time2deadline == 0 /* task could not be started
                   before the deadline */
13             then
14                 remove task from agent.S_tasks_waiting;
15             end
16             decrement task.time2deadline by 1;
17         end
18         create a new list List_tasks of tasks using a predefined method;
19         append List_tasks to agent.List_tasks_waiting;
20         call agent.handleWaitingTasks();
21         /* agent handles its waiting tasks */
22     end
23 end
```

Algorithm 1: Simulation Cycle

2.4.3 Handling Waiting Tasks

In this section, we introduce two new algorithms (CSCARN and BCACN) of agents for handling their waiting tasks at each time step. These algorithms are different instantiations of the $handleWaitingTasks()$ method that is called from line 20 of Algorithm 1. We will compare the effectiveness of these algorithms by simulation.

Continuous or Single Cost-Aware Random Negotiation (CSCARN) In this subsection, we introduce a new task-handling algorithm for agents called the "Continuous or Single Cost-Aware Random Negotiation" algorithm (defined in Algorithm 2). This algorithm accounts for the cost of task transfer.

In our previous study [10], we evaluated and compared six decentralized task-sharing algorithms using the patient sharing scenario among independent hospitals. The "Continuous or Single Random Negotiation (CSRN)" algorithm was the best in terms of the number of unexecuted tasks by the deadline.

In CSRN, when the available resource is limited and the task is not urgent, each agent continues to ask the agent who accepted the previous task transfer for another task transfer. If this is not possible, it randomly selects and asks another agent. For each task at every time step, each agent can negotiate with at most one agent.

Input: $List_{tasks_{waiting}}$ /* list of waiting tasks */
Input: res /* available resource */
Input: θ_{res} /* threshold for available resource */
Input: A_{others} /* set of other agents */
1 sort $List_{tasks_{waiting}}$ by $time2deadline$ in ascending order;
2 **foreach** *task in* $List_{tasks_{waiting}}$ **do**
3   **if** $res \leq \theta_{res}$ /* resource is limited */
4   *and* $task.time2deadline > \theta_{time}$ /* not urgent */
5   **then**
6   **if** $agent_{prev}$ *accepted a task transfer in the last negotiation* **then**
7             $agent_{next} \leftarrow agent_{prev}$;
8   **else**
9   choose $agent_{next} \in A_{others}$ with the probability proportional to $e^{-this.cost(task,agent_{next})}$;
10   /* $this.cost(task, agent_{next})$ is the transfer cost of $task$ from this agent to $agent_{next}$. */
11   **end**
12   ask $agent_{next}$ for $task$;
13   **if** $agent_{next}$ *agrees to accept* $task$. **then**
14   transfer $task$ to $agent_{next}$;
15   remove $task$ from $List_{tasks_{waiting}}$;
16   continue;
17   **end**
18   **end**
19   **if** $res \geq task.res_{needed}$ **then**
20   start $task$;
21   remove $task$ from $List_{tasks_{waiting}}$;
22   decrement res by $task.res_{needed}$;
23   **end**
24 **end**

Algorithm 2: Continuous or Single Cost-Aware Random Negotiation

If the available resource is enough, the task is urgent, or the negotiation fails, then the task is handled locally in the order of urgency. Note that CSRN does not consider the cost of task transfer.

We extend the CSRN algorithm to the CSCARN algorithm, so that it considers the cost of task transfer. CSCARN is almost the same as CSRN, except that when choosing an agent for negotiating the transfer of $task$, it randomly selects an agent ($agent_{next}$) with the probability that is proportional to $e^{-this.cost(task,agent_{next})}$ where $this.cost(task, agent_{next})$ is the transfer cost of $task$ from this agent to $agent_{next}$ (line 9). Particularly, when the cost is regarded as the distance between the two agents, CSCARN tends to choose a closer agent with a higher probability as a negotiation partner.

Better Cost-Aware or Continuous Negotiation (BCACN) In this subsection, we further try to improve the CSCARN algorithm and introduce a new task-handling algorithm called the "Better Cost-Aware or Continuous Negotiation (BCACN)" algorithm (defined in Algorithm 3).

Input: $List_{tasks_{waiting}}$ `/* list of waiting tasks */`
Input: res `/* available resource */`
Input: θ_{res} `/* threshold for available resource */`
Input: A_{others} `/* set of other agents */`
1 sort $List_{tasks_{waiting}}$ by $time2deadline$ in ascending order;
2 **foreach** *task in* $List_{tasks_{waiting}}$ **do**
3   **if** $res \leq \theta_{res}$ `/* resource is limited */`
4   *and* $task.time2deadline > \theta_{time}$ `/* not urgent */`
5   **then**
6   choose $agent_{next} \in A_{others}$ with a probability that is proportional to $e^{-this.cost(task, agent_{next})}$;
7   `/*` $this.cost(task, agent_{next})$ `is the transfer cost of` $task$ `from this agent to` $agent_{next}$ `. */`
8   **if** $agent_{prev}$ *accepted a task transfer in the last negotiation* **then**
9   **if** $this.cost(task, agent_{prev}) < this.cost(task, agent_{next})$ **then**
10                 $agent_{next} \leftarrow agent_{prev}$;
11   **end**
12   **end**
13   ask $agent_{next}$ for $task$;
14   **if** $agent_{next}$ *agrees to accept* $task$ **then**
15   transfer $task$ to $agent_{next}$;
16   remove $task$ from $List_{tasks_{waiting}}$;
17   continue;
18   **end**
19   **end**
20   **if** $res \geq task.res_{needed}$ **then**
21   start $task$;
22   remove $task$ from $List_{tasks_{waiting}}$;
23   decrement res by $task.res_{needed}$;
24   **end**
25 **end**

Algorithm 3: Better Cost-Aware or Continuous Negotiation

In the CSCARN algorithm, when finding a negotiation partner for a task transfer, each agent continues to ask the agent who accepted the previous task transfer, if such an agent exists.

Conversely, in the BCACN algorithm, when finding a negotiation partner for the transfer of $task$, the agent first selects an agent ($agent_{next}$) randomly with a probability that is proportional to $e^{-this.cost(task, agent_{next})}$ (line 6), where $this.cost(task, agent_{next})$ is the transfer cost of $task$ from this agent to $agent_{next}$ (line 7). If the cost of task transfer to the agent ($agent_{prev}$) who accepted the previous task transfer is less than the cost of task transfer to the randomly selected agent

($agent_{next}$) (line 9), then the previous agent ($agent_{prev}$) is reselected as the next negotiation partner ($agent_{next}$) (line 10).

The negotiation is conducted at most once for each task (line 13). If the available resource is enough, a task is urgent, or the negotiation fails, then the task is handled locally (line 21) in the order of urgency (line 1).

Compared with the CSCARN algorithm, the BCACN algorithm is designed to find a better negotiation partner than the previous agent, in terms of the transfer cost. Although there is a higher risk of the new negotiation failing, this risk is not necessarily a drawback from the "equal opportunities" viewpoint for task transfers among agents. Particularly, if an agent gives up a task transfer, another agent obtains a chance of task transfer. If some agents transfer too many tasks, other agents might not be able to transfer tasks.

2.4.4 When Asked a Task Transfer

When asked for a task transfer, the agent replies based on its available resource. The details of this decision-making are defined as Algorithm 4.

If the available resource amount becomes less than the threshold (line 5) after keeping the resource necessary for the asked task (line 1) and waiting tasks (lines 2-4), the agent declines the task transfer (line 7). Otherwise, the agent accepts it (line 10) and the task ($task_{asked}$) is stored in $List_{tasks_{waiting}}$ (line 9).

Input: $task_{asked}$ `/* asked task */`
Input: $List_{tasks_{waiting}}$ `/* list of waiting tasks */`
Input: res `/* available resource */`
Input: θ_{res} `/* threshold for available resource */`
1 $res2 \leftarrow res - task_{asked}.res_{needed}$;
2 **foreach** *task in* $List_{tasks_{waiting}}$ **do**
3 $res2 \leftarrow res - task.res_{needed}$;
4 **end**
5 **if** $res2 < \theta_{res}$ `/* resource is limited */`
6 **then**
7   **return** *"decline"*;
8 **else**
9   add $task_{asked}$ to $List_{tasks_{waiting}}$;
10   **return** *"accept"*;
11 **end**

Algorithm 4: Decision making on task acceptance

2.5 Simulation Settings

In this section, we discuss the details of the simulation settings. We used the same simulation scenario that was used for evaluating the CSRN algorithm [10]. This simulation scenario was made considering the COVID-19 patient sharing among hospitals in Japan. However, it is not the purpose of this research to simulate the actual situation.

The number of agents was 47.[1] For each agent, the amount of resource was set uniformly at random from 200 to 4000. To finish a task, it was necessary to occupy one resource amount during the task execution period. The task execution period was set uniformly at random from 10 to 20 ticks.[2] The deadline to start each task was set uniformly at random from 1 to 10 ticks, representing the urgency of the task.

The number of tasks assigned to each agent (a) at each time step was calculated based on its resource amount as follows: $floor(max(0, gauss(\mu, \sigma)) * a.scale)$ where $floor(x)$ rounds down x to the nearest integer, $gauss(\mu, \sigma)$ was a real number set at random based on normal distribution at each time step (μ was the average, and σ was the standard deviation). μ was $0.01 \times a.res$, $a.res$ was the resource amount of agent a, σ is $0.2 \times \mu$, and $a.scale$ was an attribute (constant real number) of agent a, that was initially set uniformly at random from 0 to 3. The higher the $a.scale$ was, the likelihood that the agent a was given tasks was higher. Furthermore, the greater resource amount an agent had, the higher was the likelihood that the agent was assigned the tasks.

The distance between two agents was initially set uniformly at random from 0 to 1. The cost of task transfer between two agents was proportional to the distance between them.

In Algorithm 1, at each time step, the order of agents that handle the waiting tasks is decided uniformly at random (line 3). The simulation continues till the simulation time reaches 150 ticks.

In Algorithms 2 and 3, the threshold of available resource (θ_{res}) is set at $0.3 \times a.res$ where $a.res$ is the resource amount of agent a. Thus, each agent recognizes that the available resource is limited when it becomes less than or equal to 30% of the total amount. Additionally, the threshold of the time remaining to the start deadline of tasks is set at 3 ticks. Thus, each agent recognizes that the start deadline of a task is approaching when the remaining time becomes less than or equal to 3 ticks.

2.6 Results

We conducted 100 simulations for each case, using different random seeds and algorithms. We show the results in Figs. 2.1 and 2.2. We also compared our new algorithms (CSCARN and BCACN) with the CSRN (continuous or single random negotiation)

[1] There are 47 prefectures in Japan.

[2] A tick corresponds to a day. It takes around 14 days to recover from COVID-19.

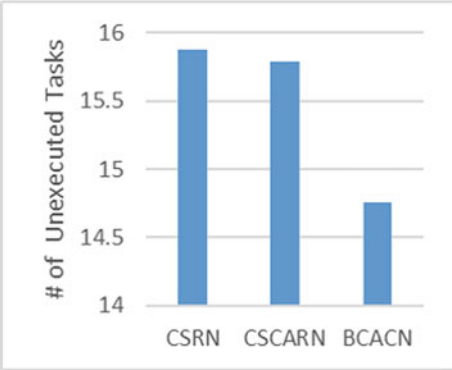


Fig. 2.1 Number of unexecuted tasks

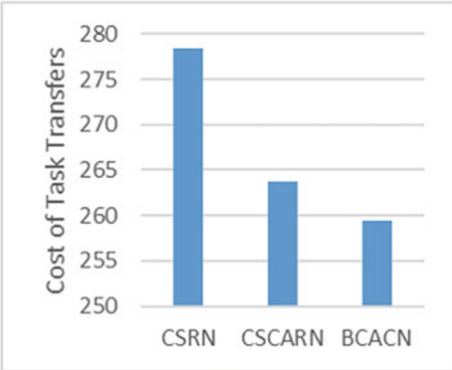


Fig. 2.2 Cost of task transfers

algorithm, which produced the best result in terms of the number of unexecuted tasks [10]. As discussed in the following subsections, CSCARN was better than CSRN, and BCACN was better than CSCARN, both in terms of the number of unexecuted tasks and the cost of task transfer.

2.6.1 The Number of Unexecuted Tasks

Figure 2.1 shows the average cumulative number of unexecuted tasks for each algorithm at time 150. Intuitively, this corresponds to the number of patients who are not treated before the deadline. As depicted in this figure, our new algorithms, especially BCACN, produced better results, which is surprising because these algorithms were designed to reduce the transfer cost, not number of the unexecuted tasks.

The number of transferred tasks was almost the same among these algorithms. However, as found in our previous research [10], equal opportunities for task sharing lead to better results. If some agents transfer too many tasks, other agents cannot transfer their tasks and miss more task deadlines. In our new algorithms, each agent restricts the negotiation partners in terms of transfer costs, leading to more number of equal opportunities. In BCACN, a greater number of negotiations tend to fail than in CSARN, which also contributes to the equal opportunities. Note that CSCARN and BCACN, like CSRN, still maintain randomness and continuity for selecting negotiation partners.

2.6.2 *The Cost of Task Transfers*

Figure 2.2 shows the average cumulative cost of task transfers at time 150 for each algorithm. Evidently, CSCARN produced better results than CSRN. Although CSCARN and CSRN maintain randomness and continuity in selecting negotiation partners, CSCARN tends to select better negotiation partners than CSRN in terms of task transfer cost. BCACN produces even better results. In BCACN, each agent tries to find a better negotiation partner, even after finding a partner agent for task transfer. This leads to better results.

2.7 Conclusion

We presented two decentralized task-sharing algorithms, CSCARN and BCACN, considering both urgency and task transfer costs. We also demonstrated that the new algorithms are better than CSRN, that was the best algorithm in [10], in terms of the number of unexecuted tasks and the cost of task transfers. Furthermore, the BCACN algorithm demonstrated the best performance.

In future, we would like to further improve the BCACN algorithm and adjust some parameters automatically, using modern techniques such as deep reinforcement learning. Furthermore, we wish to evaluate our algorithms using real data for real task sharing among hospitals.

Acknowledgements This work was supported by JSPS KAKENHI Grant No. 21K12144 and by JST, AIP Trilateral AI Research, Grant No. JPMJCR20G4.

References

1. Bertsekas, D.P.: The auction algorithm: a distributed relaxation method for the assignment problem. Ann. Oper. Res. **14**, 105–123 (1988)
2. Chen, J., Yang, J., Ye, G.: Auction algorithm approaches for dynamic weapon target assignment problem. In: Proceedings of International Conference on Computer Science and Network Technology, pp. 402–405 (2015)
3. Choi, H.L., Brunet, L., How, J.: Consensus-based decentralized auctions for robust task allocation. IEEE Trans. Robot. **25**(4), 912–926 (2009)

4. Dawe, M.: Beyond the kung-fu circle: a flexible system for managing NPC attacks. In: Game, A.I. (ed.) Pro, chap. 28, pp. 369–375 (2013)
5. Duan, R., Pettie, S.: Linear-time approximation for maximum weight matching. J. ACM **61**(1), 1–23 (2014)
6. Glaschenko, A., Ivaschenko, A., Rzevski, G., Skobelev, P.: Multi-agent real time scheduling system for taxi companies. In: Proceedings of the International Conference on Autonomous Agents and Multiagent Systems, pp. 29–36 (2009)
7. Hayashi, H.: Comparing repair-task-allocation strategies in MAS. In: Proceedings of International Conference on Agents and Artificial Intelligence. vol. 1, pp. 17–27 (2017)
8. Hayashi, H.: Integrating decentralized coordination and reactivity in MAS for repair-task allocations. In: Proceedings of International Conference on Practical Applications of Agents and Multi-Agent Systems, pp. 95–106 (2017)
9. Hayashi, H.: Evaluating task-allocation strategies for emergency repair in MAS. Trans. Comput. Collect. Intell. **28**(LNCS 10780), 253–274 (2018)
10. Hayashi, H.: Comparing decentralized algorithms for dynamic task sharing among agents with limited resources. In: Proceedings of IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (2021)
11. Jaderberg, M., Czarnecki, W.M., Dunning, I., Marris, L., Lever, G., Castañeda, A.G., Beattie, C., Rabinowitz, N.C., Morcos, A.S., Ruderman, A., Sonnerat, N., Green, T., Deason, L., Leibo, J.Z., Silver, D., Hassabis, D., Kavukcuoglu, K., Graepel, T.: Human-level performance in 3D multiplayer games with population-based reinforcement learning. Science **364**(6443), 859–865 (2019)
12. Johansson, F., Falkman, G.: Real-time allocation of firing units to hostile targets. J. Adv. Inf. Fusion **6**(2), 187–199 (2011)
13. Mi, Z., Yang, Y., H., Wang, D.: Connectivity preserving task allocation in mobile robotic sensor network. In: Proceedings of IEEE International Conference on Communications, pp. 136–141 (2014)
14. Miyake, Y., Shirakami, Y., Shimokawa, K., Namiki, K., Komatsu, T., Tatsuhiro, J., Prasertvithyakarn, P., Yokoyama, T.: A character decision-making system for FINAL FANTASY XV by combining behavior trees and state machines. In: Game AI Pro 3, Chap. 11, pp. 145–157 (2019)
15. Pujol-Gonzalez, M., Cerquides, J., Farinelli, A., Meseguer, P., Rodriguez-Aguilar, J.: Efficient inter-team task allocation in robocup rescue. In: Proceedings of International Conference on Autonomous Agents and Multiagent Systems, pp. 413–421 (2015)
16. Rahimzadeh, F., Khanli, L., Mahan, F.: High reliable and efficient task allocation in networked multi-agent systems. Auton. Agent Multi-Agent Syst. **29**(6), 1023–1040 (2015)
17. Ramchurn, S., Wu, F., Jiang, W., Fischer, J., Reece, S., Roberts, S., Rodden, T., Greenhalgh, C., Jennings, N.: Human-agent collaboration for disaster response. Auton. Agent Multi-Agent Syst. **30**(1), 82–111 (2016)
18. Saito, M., Hayashi, H.: P2P human-resource sharing and its redistribution strategy of stable coin. Int. J. Smart Comput. Artif. Intell. **4**(2), 1–18 (2020)
19. Saito, M., Komine, K., Nakato, A., Sasaki, I., Hayashi, H.: Evaluating P2P human resource allocation strategies through multi-agent simulation. In: Proceedings of International Conference on Smart Computing and Artificial Intelligence, International Congress on Advanced Applied Informatics, pp. 505–510 (2019)
20. dos Santos, F., Bazzan, A.: Towards efficient multiagent task allocation in the robocup rescue: a biologically-inspired approach. Auton. Agent Multi-Agent Syst. **22**(3), 465–486 (2011)
21. Seow, K.T., Dang, N.H., Lee, D.H.: A collaborative multiagent taxi-dispatch system. IEEE Trans. Autom. Sci. Eng. **7**(3), 607–616 (2010)
22. Skocir, P., Kusek, M., Jezic, G.: Energy-efficient task allocation for service provisioning in machine-to-machine systems. Concurr. Comput. **29**(23) (2017)
23. Straatman, R., Verweij, T., Champandard, A., Morcus, R., Kleve, H.: Hierarchical AI for multiplayer bots in Killzone 3. In: Game AI Pro, Chap. 29, pp. 377–390 (2013)

24. Vallejo, D., Remagnino, P., Monekosso, D., Jiménez, L., González, C.: A multi-agent architecture for multi-robot surveillance. In: Proceedings of IEEE International Symposium on Parallel and Distributed Processing with Applications, pp. 11–18 (2009)
25. Vinyals, O., Babuschkin, I., Czarnecki, W., Mathieu, M., Dudzik, A., Chung, J., Choi, D., Powell, R., Ewalds, T., Georgiev, P., Oh, J., Horgan, D., Kroiss, M., Danihelka, I., Huang, A., Sifre, L., Cai, T., Agapiou, J., Jaderberg, M., Vezhnevets, A., Leblond, R., Pohlen, T., Dalibard, V., Budden, D., Sulsky, Y., Molloy, J., Paine, T., Gulcehre, C., Wang, Z., Pfaff, T., Wu, Y., Ring, R., Yogatama, D., Wünsch, D., McKinney, K., Smith, O., Schaul, T., Lillicrap, T., Kavukcuoglu, K., Hassabis, D., Apps, C., Silver, D.: Grandmaster level in StarCraft II using multi-agent reinforcement learning. Nature **575**, 350–354 (2019)
26. Xin, B., Chen, J., Zhang, J., Dou, L., Peng, Z.: Efficient decision making for dynamic weapon-target assignment by virtual permutation and tabu search heuristics. IEEE Trans. Syst. Man Cybern. - Part C **40**(6), 649–662 (2010)
27. Yoshida, N., Noda, I., Sugawara, T.: Multi-agent service area adaptation for ride-sharing using deep reinforcement learning. In: Proceedings of International Conference on Practical Applications of Agents and Multi-Agent Systems, pp. 363–375 (2020)
28. Zhou, M., Jin, J., Zhang, W., Qin, Z., Jiao, Y., Wang, C., Wu, G., Yu, Y., Ye, J.: Multi-agent reinforcement learning for order-dispatching via order-vehicle distribution matching. In: Proceedings of International ACM International Conference on Information and Knowledge Management, pp. 2645–2653 (2019)

Chapter 3
Queueless: Agent-Based Manufacturing for Workshop Production

James Gopsill, Martins Obi, Lorenzo Giunta, and Mark Goudswaard

Abstract Workshops are vital to product development, supporting prototyping, research & development, bespoke and small-batch production, and education. They are composed of diverse manufacturing capability that needs to meet varied, rapid, diverse and often random changes in demand. The diversity in both composition and demand continues to challenge the optimal processing of jobs leading to considerable delays and dissatisfaction with workshop services. In this paper, we examine how a workshop can optimally utilise its manufacturing capability through an agent-based approach. We show that a relatively simple set of agent logics can provide considerable configurability and ability to optimise a workshop of twenty machines meeting a step-change in demand. Appropriate configuration can result in a 40% change in mean Time in System and 20% change in the number of jobs delayed.

3.1 Introduction

Workshops remain a vital component in product development. They support prototyping activities, research & development, and bespoke and small-batch component production. They are composed of a diverse manufacturing capability[1] enabling them to meet diverse profiles in demand that feature all manner of component and exhibit random ramps, steps and cycles in volume that is in line with the randomness of innovation.

[1] Ranging from manual through to Computer Numerical Control (CNC) processes and tools.

J. Gopsill (✉) · M. Obi · L. Giunta · M. Goudswaard
Design and Manufacturing Futures Lab, University of Bristol, Bristol, UK
e-mail: james.gopsill@bristol.ac.uk

J. Gopsill
The Centre of Modelling and Simulation (CFMS), Bristol, UK

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_3

Methods for managing jobs through the workshop have remained consistent over the years with many operating on first come first-serve (FCFS) principles [1]. Jobs are either queued up based on submission or users coming into the workshop to identify and check the availability of the machine(s) they wish to use. These have been easy to implement, reliable and effective methods for managing jobs in the past. However, the methods have also proven problematic when there are significant changes in demand resulting in low user satisfaction and productivity, and extended development lead-times. While there has been considerable research on job scheduling in production-scale facilities, its transference and application in the workshop domain have been troubled with the additional overhead it brings to an already busy technician workload and the unconstrained and diverse nature of both machines and jobs [2–4].

While job management has remained largely static, reports have revealed considerable change in workshop manufacturing capability. Of particular note and interest to this paper is the adoption of Additive Manufacturing (AM). AM machines have increased workshop capacity and diversity, and transcended workshop practice into new contexts, such as supporting Open-Source Hardware, Makerspaces and libraries [5, 6]. AM affords flexibility and agility. Flexibility in the geometry it can manufacture, and agility in being able to rapidly change materials between jobs. Combined, they provide a means to meet the diversity in demand and present an opportunity to revisit how jobs are managed through the workshop.

This paper's contribution is in the application of Agent-Based Manufacturing to workshop AM and the gains in productivity and responsiveness to changes in workshop demand it can provide. The paper continues by discussing the related work on Agent-Based AM and the management of jobs in a workshop environment (Sect. 3.2). The Agent-Based approach taken to manage workshop AM is then presented (Sect. 3.3). This is followed by a numerical experiment and results to examine its potential (Sects. 3.4, 3.5). A discussion then ensues regarding the potential of Agent-Based Manufacturing to support the workshop and future work being performed to validate the approach through a real-world demonstrator system (Sect. 3.6). The paper then concludes with the key findings from the study (Sect. 3.7).

3.2 Related Work

Research reviewing workshops reveal the diverse composition of manufacturing capability and equally diverse job requirements and submission profiles [5]. It has been highlighted that there is rarely any consistency or repeatability in these profiles. Rather, workshop demand is often treated like a signal and broken down into its constituents of background noise (steady-state job submissions) and a series of features, such as step-changes or ramps [7]. The frequency and diversity of these events is unique to workshops and often sets them apart from production-scale facilities.

The level of diversity is a stumbling block for many job-shop scheduling methodologies, which typically work by typing/categorising jobs via means of hierarchical structures [8]. However, these are inappropriate for coordinating heterogeneous manufacturing capability such as workshops [9]. Equally, the diverse nature of the manufacturing capability often results in capacity limits as the different processes are unable to accommodate the entire range of jobs. The advent of AM simplifies the categorisation of a once diverse set of jobs as the manufacturing process can handle much of the complexity. Thus, it is now timely to revisit job scheduling in the context of the workshop.

Basuki et al. [10] highlights workshops are unique manufacturing systems in that the ratio of technicians with respect to the number and variety of machines/processes that need to manage is particularly low. Thus, much of their time is in service of maintaining the capability rather than ensuring/enhancing productivity. Equally, there is little capacity for technicians to maintain and manage additional systems aimed at enhancing jobs being processed through the workshop.

AM has also led to an expansion in workshops across society. Examples include Makerspaces and Libraries that have opened up manufacturing to the wider community [11–13]. This has led to increased application of AM across society and has supported innovation by enabling transdisciplinary product development. Again, the management of jobs in these contexts utilises forms of FCFS. It is argued that maintaining a simple interface with the service increases the likelihood of uptake and adoption by the community the service wishes to support. And is one of the reasons for not implementing formalised production-based process workflows. However, it does prove problematic with the services being unable to cope with the often chaotic and diverse demands profiles with it often being hard to predict when demand will change and ultimately leaving the users frustrated with the productivity of the service.

While workshops in practice maintain FCFS as a primary means of serving their clients, research has identified the opportunity for providing optimisations to the flow of work using AM. [1, 14] have developed methods to extract individual part G-Code from multi-part G-Code files in a workshop queue. They then re-position the parts to optimise the utilisation of AM bed spaces. This minimises change-over times and technician/user interaction with the system resulting in increased productivity with machines manufacturing for longer portions of the day. Industry has also been creating solutions for managed AM, see for example the Ultimaker Digital Factory,[2] that provides facilities with top-level management for AM machines. However, many interface only with a specific set of machines which leads to challenges in the diverse AM capability often offered by workshops.

In summary, the related work highlights that the workshop provides a unique job scheduling problem due to the diversity in demand and manufacturing capability. However, the introduction of AM has provided a means to handle this diversity although optimal operation of AM machines in the workshop has yet to be developed and adopted.

[2] https://ultimaker.com/learn/introducing-ultimaker-digital-factory.

3.3 An Agent-Based Approach to Managing the Workshop

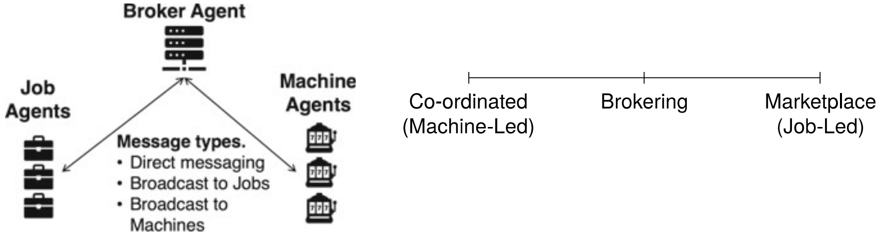
This paper argues that an Agent-Based Manufacturing is an ideal candidate for the management of a diverse set of jobs through an equally diverse system of manufacturing capability. Agent-Based approaches to manufacturing often consider jobs, machines, engineers and/or processes as agents within a system [15]. Each agent has its own internal goals and logics to manage and make decisions. These come together to process jobs through the system. They afford extensibility as additional agents can be added to the system without much disruption. It also eliminates the need to outline and implement a set of extensive process workflows. Instead, they require a set of communication rules and agent logics.

Agent-based approaches often afford greater fault-tolerance [16]. This can be considered favourable in a workshop setting as machines—with varying capabilities—are being added, removed and maintained/modified on a regular basis. However, the lack of centralised control can make it more challenging in predicting the dynamics and performance of the system. To gain an insight into these properties, modelling and simulation is required.

Having selected an Agent-Based approach, the workshop is described as follows. We consider the workshop as a system that features two populations of agents—*Machines* and *Jobs*—and a single *Broker* agent (Fig. 3.1a). *Machine* agents represent the AM machines within the workshop. Each has the necessary information to represent its own capability. *Job* agents represent the jobs that need to be manufactured and feature the necessary information for the job to be evaluated and manufactured by the machines.

The *Broker* agent brokers connections and communication between the *Machine* and *Job* agents. All *Machine* and *Job* agents exist in the system as equals with no agent taking precedence over another. Thus, we consider it '*queueless*'. The determination of which job will be manufactured is based on the logics that reside within the agents and communication strategy employed.

The *Broker* affords direct and broadcast (to all of a population) communication. Communication can be configured between *Machine-Machine*, *Job-Job*, *Machine-Job* and *Job-Machine*. Further the type of communication between agents exists on



(a) Brokering communications (b) Brokering Spectrum

Fig. 3.1 Agent-based approach

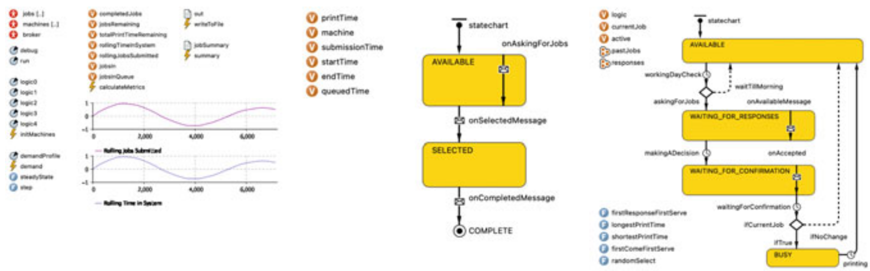
a spectrum of brokerage (Fig. 3.1b). On the one end, we have *co-ordinated manufacturing* where the *Machine* agents lead on the discussion and make the decisions as to which jobs to manufacture with the *Job* agents being submissive. On the other end, we have *marketplace manufacturing* where the *Job* agents lead the discussions and make the decisions, and the *Machine* agents are submissive. In the middle, exists *brokered manufacturing* where both *Machine* and *Job* agents negotiate and agree upon where they will be manufactured.

The *Machine* and *Job* agents feature logic that defines how they can/will interact with one another. The logic could be human-led, rule-based or Artificial Intelligence (AI)-based and affords considerable flexibility and customisability with no requirement for *Machine* and *Job* agents to have a specific logic and/or combination of logics to exist within the system. An example rule-based logic for a *Machine* agent could involve the broadcasting of a message to all *Job* agents as to their availability. The *Machine* agent would then wait for a pre-defined period for responses. From this set of responses, the *Machine* agent could employ one of the following rule-based logics:

- First-Response First-Serve—Selects the first job that replies to its request.
- First-Come First-Serve—Selects the job that was submitted earliest.
- Longest Print Time—Selects the job with the longest print time.
- Shortest Print Time—Selects the job with the shortest print time.
- Random—Randomly selects a job.

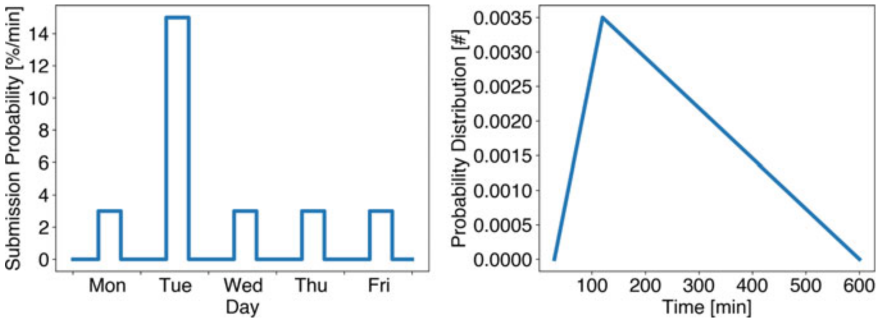
In each case, the *Machine* agent would also check and ensure that the job it selects can be manufactured on the machine.

The model has been instantiated in AnyLogic (Fig. 3.2) and configured to perform *co-ordinated manufacturing*. Figure 3.3a shows the main model view and features the parameters, agent populations and metrics that will be captured during the simulation. Figure 3.2b shows the *Job* agent, which is submissive. When the *Job* agent is created, it enters the AVAILABLE state and listens and responds to requests from *Machine* agents regarding its availability. It also listens for messages from *Machine* agents to say whether it has been accepted and if received, moves the *Job* agent into the



(a) Main (b) Job Agent (c) Machine Agent

Fig. 3.2 AnyLogic instantiation



(a) Demand profile (b) Job time distribution

Fig. 3.3 Demand on the workshop

SELECTED state. The *Job* agent will remain in this state until it receives a 'complete' message from the *Machine* agent manufacturing the job.

Figure 3.2c shows the logic of the *Machine* agent. The agent starts as AVAILABLE before proceeding to check whether the time is currently within a working day (9am–5 pm). If it is in the working day, the *Machine* agent broadcasts a message through the *Broker* agent to all *Job* agents asking if they are available. The agent then waits for a pre-defined time for responses. From the response set, the *Machine* agent selects a *Job* agent based on a pre-defined rule-based logic. The *Machine* agent then messages 'selected' to the *Job* agent and waits to receive a confirmation. Confirmation is required to account for cases where another *Machine* agent selects the *Job* whilst the *Machine* agent has been deliberating. If the *Job* agent confirms the selection, then the *Machine* agent moves to the manufacturing state and returns a 'complete' message to the *Job* agent when finished.

3.4 Experiment

The experiment emulated a workshop operating Mon–Fri 9am–5 pm with 20 AM machines. Any of the machines are able to manufacture the jobs submitted to the workshop. Five days were simulated with infinite material made available and no penalty for material changeovers. No maintenance, downtime or chance of failure were added to the model.

The week starts with a low demand (3% submission probability/min) on Monday and a step-change in demand (15% submission probability/min) occurring on Tuesday before returning to a low demand on Wednesday, Thursday and Friday (Fig. 3.3a). Jobs can only be submitted during workshop open hours. The submitted jobs had a random job time assigned according to a triangular distribution (Fig. 3.3b). The distribution featured a minimum, mode, and maximum of 60, 120 and 600 min, respectively, and reflects typical AM component production times.

Performance was measured using a rolling Time In System (TIS) metric. At each timestep, the number of jobs completed within a past time window (2 h) was gathered and their TIS (Start Time—Submission Time) was calculated. The minimum, maximum, upper and lower quartile, and median values across all runs were recorded and plotted alongside the rolling jobs submitted.

To baseline the performance, a model was created to replicate current workshop practice. This was achieved by setting the model into a *marketplace* configuration whereby the incoming jobs queried the available machines and if one was available then it would assign itself. If a machine was not available, then the job would enter the 'queue' and continue querying the state of the machines until one became available.

The combinations of machines logics considered in the *co-ordinated manufacturing* configuration were

1. All set to first come first-serve (FCFS)
2. All set to longest print time first-serve (LPT)
3. All set to shortest print time first-serve (SPT)
4. All random select (Random)
5. A hybrid combination featuring 5 machines of each logic (Hybrid).

100 ns were performed for each configuration.

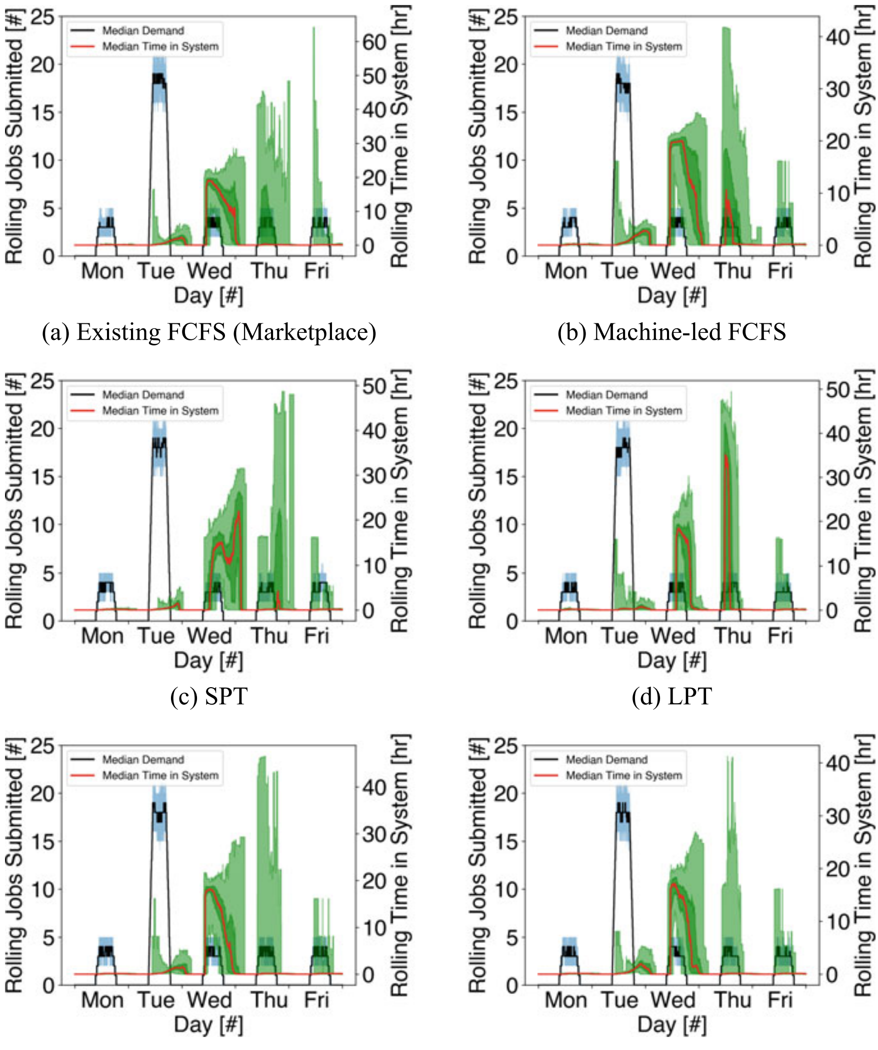
3.5 Results

Figure 3.4a shows the performance of managing jobs in a workshop through the existing FCFS approach. We can see that there is a lag in the response of the system with an increase in the TIS of jobs across Wednesday, Thursday and Friday. The peak median delay of 20 min comes early Wednesday morning.

Figure 3.4b shows the response from the *Machine* agents configured with all FCFS and exhibits a similar response to existing practice (Fig. 3.4a). This is anticipated and can be considered a form of validation as, in effect, the logic is the same, yet the instigators are the *Machine* agents rather than the *Job* agents.

Figure 3.4c shows the results from having the *Machine* agents set to SPT and reveals a twin peak response. During the step in demand, there was little effect on the TIS for the jobs but after the step there is a considerable rise in delayed jobs being returned. This suggests that the system is in a phase of 'catching up with the backlog', introduced by the step in demand, resulting in jobs being delayed. However, the system returns to a stable condition more quickly with fewer delayed jobs on Thursday and Friday.

Figure 3.4d shows that an all LPT approach also exhibits the same behaviour as SPT although the two peaks in the median TIS are split across two days with the latter reaching 35 min. This could be expected as the mode in the triangular distribution is closer to the shortest print time so one would expect SPT to perform better than LPT.



(a) Existing FCFS (Marketplace)
(b) Machine-led FCFS
(c) SPT
(d) LPT
(e) Random
(f) Hybrid

Fig. 3.4 Co-ordinated manufacture response to a step-change in demand

Figure 3.4e reveals that random selection has characteristics of both FCFS and SPT/LPT responses. The random selection responds with a ramp combined with a single peak of approx. 20 min in delayed jobs before returning to normal by Thursday. Random selection could be viewed as a good compromise over the duration of the simulation.

Figure 3.4f shows the results from the hybrid combination of logics which again, like random select, exhibits features from the previous profiles. Overall, the results

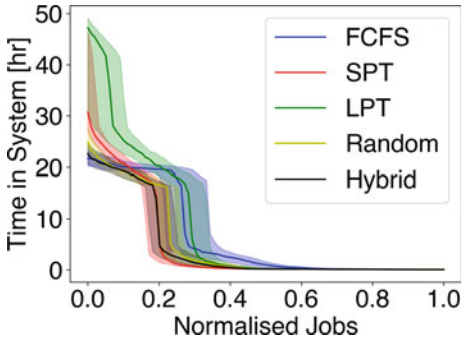


Fig. 3.5 Co-ordinated manufacture response to a step-change in demand

highlight the logic set employed can affect both the number of jobs that are delayed, the degree to which they are delayed, and when the delay will be observed.

Figure 3.5 reveals the lower, median and upper quartile ranges for the TIS across all jobs for all the simulation runs. The results were ordered by TIS and normalised against the total number of jobs created for each run. FCFS leads to a greater number of jobs being delayed although no one job is delayed significantly. In comparison, SPT affects the population of jobs the least although some jobs are considerably delayed. All other cases exhibit behaviour between the two extremes. All cases show a plateau around 20 h with a sharp decrease. This step is due to the 16 h penalty caused by submissions having to wait over a day to be printed.

Table 3.1 summarises the job TIS statistics across the configurations. It shows that a difference of 3 h can be achieved in the mean TIS based on the configuration of logics. The median scores highlight the majority of logics that outperform the current scheduling solution apart from FCFS where the median doubles. All exhibit similar max times with the upper quartiles highlighting that both FCFS and LPT have portions of the population that are significantly delayed (over 18 h). This indicates that

Table 3.1 Time in system summary statistics

	Time in system									
Logic	Mean		Median		Max		Min	Q3		Q1
	hr	%	hr	%	Hr	%	hr	hr	%	
Current	5.71	–	0.42	–	46.08	–	0.00	5.42	–	0.08
FCFS	6.47	+13	0.90	+ 114	41.94	−9	0.00	18.62	+244	0.17
SPT	4.90	−14	0.20	−52	48.99	+6	0.00	1.28	−75	0.13
LPT	8.18	+43	0.24	−43	52.47	+14	0.00	18.30	+238	0.13
Random	5.13	−10	0.20	−52	46.55	+1	0.00	3.79	−30	0.13
Hybrid	4.59	−19	0.20	−52	42.28	−8	0.00	2.77	−49	0.13

more jobs are flowing over to a second day and this incurs an unavoidable 16 h delay where the workshop is closed. The variance exhibited highlights the configurability of the system with configurations existing that both out/under-perform the current process of scheduling jobs.

3.6 Discussion and Future Work

The study shows an agent-based approach to managing workshop jobs that can emulate and improve upon current practice TIS. In addition, the study shows the configurability of the system and how the set of logics leads to a different system performance. Further work could be performed to map this space and seek to ascertain optimal combinations of logics for different input demands. Work is also required to investigate logic combinations for different input demands as well as size and scale of the workshop. Additional factors also need to be considered to increase the models' realism. Features include maintenance, change over times, part failures and machine failures.

Validation of the simulation results through real-world testing is also required. This is an area that the authors are currently pursuing with the development of a platform to broker jobs between AM machines and is being deployed in a Living Lab [13]. The system is currently in trials with students in the third- and fourth years submitting jobs through the system. All communications between the agents are being logged and will give an insight into both the demand being placed on the workshop as well as how the logics respond to the demand.

3.7 Conclusion

Workshops offer a unique job scheduling problem due to the diversity of both the demand profile and manufacturing capability. Additive Manufacturing (AM) has gained a significant foothold in workshops and features characteristics that can enable it to handle the diversity in demand. In this paper, we have shown that a set of 20 AM machines can be further optimised to tackle varying input demand via a co-ordinated manufacturing agent-based approach. The results show that the mean Time in System of jobs can be affected by up to 40% and the range of jobs affected by 20%.

Acknowledgements The work has been undertaken as part of the Engineering and Physical Sciences Research Council (EPSRC) grants—EP/R032696/1 and EP/V05113X/1.

References

1. Gopsill, J.A., Hicks, B.J.: Investigating the effect of scale and scheduling strategies on the productivity of 3D managed print services. Proc. Inst. Mech. Eng., Part B: J. Eng. Manuf. **232**(10), 1753–1766 (2018)
2. Xie, J., Gao, L., Peng, K., Li, X., Li, H.: Review on flexible job shop scheduling. IET Collabor. Intell. Manuf. **1**(3), 67–77 (2019)
3. Mohan, J., Lanka, K., Rao, A.N.: A review of dynamic job shop scheduling techniques. Proc. Manuf. **30**, 34–39 (2019)
4. Zhang, J., Ding, G., Zou, Y., Qin, S., Fu, J.: Review of job shop scheduling research and its new perspectives under Industry 4.0. J. Intell. Manuf. **30**(4), 1809–1830 (2019)
5. Wilczynski, V.: Academic maker spaces and engineering design. In: 2015 ASEE Annual Conference & Exposition, pp. 26–138 (2015, June)
6. Mersand, S.: The state of makerspace research: a review of the literature. TechTrends **65**(2), 174–186 (2021)
7. Goudswaard, M., Gopsill. J., Ma. A., Nassehi. A., Hicks. B.: Responding to rapidly changing product demand through a coordinated additive manufacturing production system: a COVID-19 case study. In: IOP Conference Series: Materials Science and Engineering, Vol. 1193, No. 1, p. 012119. IOP Publishing (2021)
8. Heragu, S.S., Graves, R.J., Kim, B.I., St Onge, A.: Intelligent agent based framework for manufacturing systems control. IEEE Trans. Syst. Man Cybern.-PART A: Syst. Humans **32**(5), 560–573 (2002)
9. Lu, Y., Xu, X., Xu, J.: Development of a hybrid manufacturing cloud. J. Manuf. Syst. **33**(4), 551–566 (2014)
10. Basuki, B., Suyetno, A., Tjiptady, B. C.: Management model of manufacturing workshop/laboratory of vocational education in the industry 4.0. In: 2020 4th International Conference on Vocational Education and Training (ICOVET), pp. 127–130. IEEE (2020)
11. Scalfani, V.F., Sahib, J.: A model for managing 3D printing services in academic libraries. Issues Sci. Technol. Librariansh. **72**(Spring), 1–13 (2013)
12. Pryor, S.: Implementing a 3D printing service in an academic library. J. Libr. Adm. **54**(1), 1–10 (2014)
13. Nagle, S. B.: Maker services in academic libraries: a review of case studies. New Rev. Acad. Librariansh. 1–17 (2020)
14. Gopsill, J. A., Hicks, B. J.: The issues & challenges of 3d managed print services: towards a support tool for 3d managed print services. In: Proceedings of the International Conference on Sustainable Design and Manufacturing (2015)
15. Ma, A., Nassehi, A., Snider, C.: Anarchic manufacturing. Int. J. Prod. Res. **57**(8), 2514–2530 (2019)
16. Khan, Z.A., Khan, M.T., Ul Haq, I., Shah, K.: Agent-based fault tolerant framework for manufacturing process automation. Int. J. Comput. Integr. Manuf. **32**(3), 268–277 (2019)

Chapter 4
Mobile Client for Crop Yield Prediction Based on Weather Data

Ivan Kralj, Pavle Skocir, and Gordan Jezic

Abstract Early crop yield prediction can address one of the most important agricultural challenges—feeding a growing population. The results of this prediction can be used to maximize crop yields. Crop growth is determined by a variety of weather, soil, and other micro-climatic variables. In addition, one of the most important parameters affecting crop growth, and over which the farmer has a large influence, is the selection of a sowing date. There are a few different models and simulators for predicting crop yields. However, they are rarely user-friendly. This paper focuses on developing a user-friendly mobile client that uses a simulator in the background to determine the sowing date which results in the highest crop yield. In the mobile application, a user selects the fixed interval of sowing dates and a crop type to obtain the sowing date that gives the highest predicted yield.

4.1 Introduction

Yield prediction can provide information for better crop management and consequently improve profitability, environmental quality, and marketing decisions. In order to forecast seasonal crop yields, several methods and models can be used: field surveys, crop growth, remote sensing, statistical models, and simulation models [1]. These methods address different aspects of crop yield prediction. Field surveys attempt to obtain information from the field through surveys conducted by farmers themselves and objective measurements. Remote sensing methods rely on

I. Kralj (✉) · P. Skocir · G. Jezic
University of Zagreb Faculty of Electrical Engineering and Computing, Internet of Things Laboratory, Unska 3, 10000 Zagreb, Croatia
e-mail: ivan.kralj@fer.hr

P. Skocir
e-mail: pavle.skocir@fer.hr

G. Jezic
e-mail: gordan.jezic@fer.hr

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_4

satellite imagery to assess current crop condition and then estimate final yield. Crop growth models simulate crop growth and development according to agronomic principles of plant, environment, and management interactions. Statistical models use weather variables and the results of field surveys, cultivated crops, and remote sensing methods as predictors to derive linear relationships between the predictors and crop yield [1].

One representative of simulation models is the Agricultural Production Systems sIMulator (APSIM Next Generation). It is a comprehensive model developed to simulate biophysical processes in agricultural systems, particularly as they relate to the economic and ecological outcomes of management practices in the face of climate risks. It uses weather parameters, such as average daily minimum and maximum temperature, vapor pressure, clear sky radiation, rainfall, and many other weather parameters, as well as field location, field size, chemicals in the soil, sowing fertilizer and many other parameters to predict crop yield for each year. In addition to predicting crop yields, APSIM Next Generation can also be used to evaluate resource use and efficiency, study the sustainability of agricultural soil processes, and provide advice to farmers.

In this paper, the focus is on creating a user-friendly mobile client for finding the best sowing date that gives the most amount of crop yield based on past weather data from previous 5 years taken from worldmodel.csiro.au website. Weather data for that year is needed in APSIM Next Generation as an input to simulate the yield prediction. Past weather data is compared using five different statistics: Average, maximum, minimum, median and custom. Using the weather data for 2016, 2017, 2018, 2019 and 2020 and the aforementioned statistics, each statistic is used to predict the weather for the year 2021. Then, these statistics are compared with the simulated yield obtained using the real weather data for the year 2021. The most accurate statistic is selected to populate weather data for the year 2022 to predict the best sowing date for a specific crop that would result in the highest yield. Mobile client is developed that provides an easy-to-use interface for end users. A user selects sowing dates interval and a crop type. The client sends the request to the back-end server, where simulation is executed for all the dates selected by the user. Finally, a response is sent back to the client with the harvest date that gives the highest yield.

The paper is organized as follows. Section 4.2 gives an overview of related work. In Sect. 4.3, system architecture is presented. In Sect. 4.4, APSIM Next Generation is described in more detail. In Sect. 4.5, five different statistics are compared and crop yield prediction for the year 2022 is shown using the best-selected statistic. In Sect. 4.6, Mobile client is presented. Section 4.7 concludes the paper and provides future work discussion.

4.2 Related Work

Sowing date estimation is one of the most important decisions a farmer has to make. Consequently, it has been a focus of many researchers.

Maresma et al. [2] conducted a research on 3 separate sowing dates: early (mid-March), normal (mid-April), and late (mid-May) over a three-year period (2003–2005) in irrigated corn under Mediterranean conditions to evaluate the effects of the date on corn yields and crop growing period. The results showed that the number of days from sowing to physiological maturity was reduced by each delay in sowing. Early sowing date increased the period from sowing to plant emergence, while late sowing date reduced the number of days to maturity producing higher humidity content in grain at harvest and taller plants. In the end, they concluded that in order to achieve maximum grain yield under irrigated Mediterranean conditions, it would be best to sow around mid-April.

Long et al. [3] conducted an analysis from the farmer annual corn contest-winner data, which was provided by the National Corn Growers Association. One of the main objectives of this study was to understand the impacts of planting date on yield. They concluded that corn yield was maximized when planting windows were 80–106 days of the year for the 30–35 °N, 107–118 days of the year for the 35–40 °N, <119 days of the year for 40–45 °N and <129 days of the year for 45–50 °N.

Baum et al. [4] analyzed corn yield from different years (2014, 2015, and 2016). Hybrid relative maturity and planting date experiments were performed at seven different sites at Iowa State University, USA (three were located in northern, one in central and three in southern Iowa) in order to determine the optimum combination of planting date and maturity of the plant to maximize corn grain yield. Their analysis indicated that the planting date had the strongest effect on grain yield and that in all cases, April and early May planting day had higher grain yields than June planting day.

Dahmardeh [5] conducted a field experiment to analyze the relationship between growing degree days, yield, and yield components of corn cultivars. Five different corn cultivars were sown on four different dates during summer. They exhibited significant differences on yield and the final results showed that corn sown on August 5th was significantly better as compared to July.

Overall, the ideal sowing date for corn has varied in several research studies. It depends on weather, location, and soil, just to mention a few. In this paper, APSIM Next Generation simulator is used to determine the best sowing date for users and their specific crop on a desired location. Additionally, a mobile application is developed to facilitate the display of the prediction results to the end users.

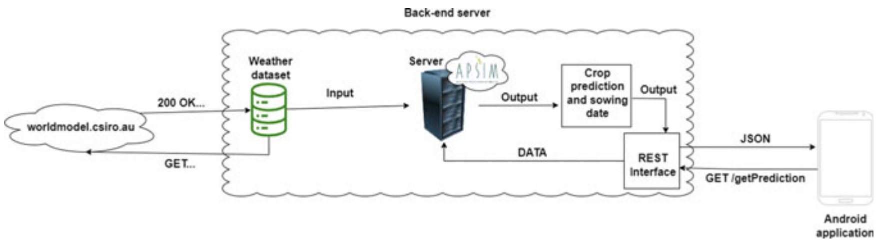


Fig. 4.1 System architecture for sowing date and crop yield prediction

4.3 System Architecture

The deployed system consists of weather dataset, APSIM Next Generation simulator, and back-end server, as shown in Fig. 4.1. Weather data is obtained from worldmodel.csiro.au website. The website requires latitude, longitude, start and end dates as input parameters. These data are stored in the database and are used as input for APSIM Next Generation simulator. Using the chosen statistic, weather data for the year 2022 is also stored in the database. Back-end server is written in Java 11 using Springboot. REST API is created to receive data on getPrediction URL. Mobile client selects start and ends fixed sowing dates and crop type. Then, mobile client sends a request, formatted as JSON. The request consists of crop name, country name, city name, start sowing date, and end sowing date. Back-end server then parses received data and runs APSIM Next Generation. When all simulations are successfully completed, it selects a date with the highest crop yield prediction. This date is then sent back to the client in JSON format as a response.

4.4 APSIM Next Generation

APSIM Next Generation is a simulator that can be used for point-based simulation that examines the effects of climate on crop growth, climate change, and historical climates within a season, month-to-month, or long-term. The APSIM simulator consists of several components. Its soil water component takes into account information such as infiltration, evaporation, transpiration, drainage, and effects of soil type on crop growth. In addition to soil water, APSIM Next Generation also has a soil nutrient component that uses soil carbon and nitrogen models, nitrogen immobilization, mineralization, C:N ratios, etc. Another component is plant and genotype traits, so you can look at the effects of the phenology, effects of plant traits in new environments, leaf size, grain weight, etc. APSIM Next Generation has models for several types of crops, such as barley, wheat, canola, chickpea, corn, potato, millet, white clover, and many more. It can also be used for monitoring crop systems rotations, such as yield and farming system effects of wheat, barley, canola, fallow, etc. In addition to

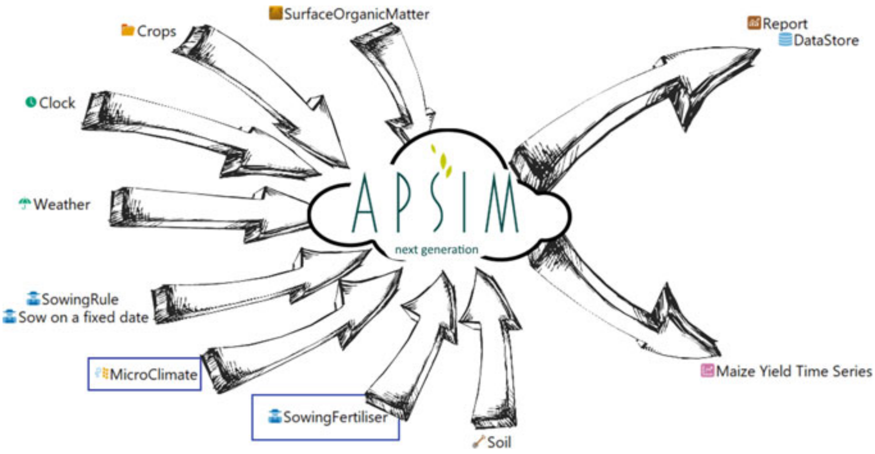


Fig. 4.2 APSIM next generation input and output component

crop types, APSIM also has a grazing system consisting of a livestock component module, dairy systems, interaction of grazing and cropping systems, tree planting, analysis of the impact of tree planting on crops, etc.

In order to simulate crop yield prediction, different components are used, some of which are necessary to run simulation, while the rest are optional. Figure 4.2 shows input components used to simulate crop yield prediction and output components for observing predicted data. Components in blue rectangle are the optional ones.

Each of the components has a different role and functionality:

- **Clock**: Determines the duration of a simulation.
- **Weather**: Gives specification of the long-term weather or meteorology characteristics for each site. It requires input file that consists of daily weather data such as solar radiation, maximum and minimum temperature, rainfall, wind speed. It also requires constant parameters: latitude, longitude, annual average ambient temperature, and annual amplitude in mean monthly temperature.
- **Soil**: Consists of different sub-components, such as physical, organic, chemical, and nutrient. Different parameters can be changed, such as clay, sand, and silt particle size in percentage at different depths, which chemical element is present in soil at different depths, etc.
- **Surface organic matter**: Consists of name, type and mass of initial residue pool, C:P and C:N ratio.
- **Microclimate**: It's a microclimate calculator that consists of different multiplies, fractions, heights of instruments etc.
- **Sowing fertilizer**: Determines how much fertilizer we want to apply to a selected crop.
- **Sowing rule and sow on a fixed date**: These two components are the same, the only difference is that sowing rules allow you to select start and end sowing

windows dates, while sow on a fixed date allows you to sow on only one date. In addition to sowing date, it also consists of sowing depth, row spacing, accumulated rainfall required for sowing, minimum extractable soil water for sowing, etc.
- **Crops**: Different types of crop can be selected; however, only one at a time can be simulated.
- **Report and datastore**: Determines which parameters to output in a .db file after simulation ends using SQLite.
- **Yield time series**: Graphs yield prediction for each year.

Since mobile client chooses start and end fixed sowing dates, sow on a fixed date component has been used instead of sowing rule. In addition to simulating crop yield prediction, APSIM Next Generation can download daily weather data from worldmodel.csiro.au website. The reason worldmodel.csiro.au website is used because it already formats the data in .met format, which is the format APSIM Next Generation is using to read weather data. In order to download weather data from this website, it needs to be in this format: https://worldmodel.csiro.au/gclimate?lat=a.b&lon=c.d&format=apsim&start=yyyyMMdd&stop=yyyyMMdd, where lat and lon indicate location. Section 4.5 will describe how this is accomplished in more detail.

4.5 Best Sowing Date Calculation

Sowing a crop at the right time is critical for maximizing grain yield and biomass yield in crops such as corn. As a result, farmers are concerned about yield response to sowing dates. However, the optimal time to sow a crop may vary from area to area due to differences in climate and the length of the growing season in which the crop is grown [2]. For beginners, it may not be easy to determine which sowing date will give the most yield at harvest. For this reason software tools such as APSIM Next Generation or other yield prediction tools such as CERES, CROPSYST, COUP, and many more have been developed. APSIM was selected since it proved to be extremely precise and reliable compared to the other simulations [6]. However, these tools are not user-friendly and were developed for researchers to predict crop yields under different conditions. Therefore, a mobile application is developed in order to help both new and old farmers make more accurate sowing date decisions.

The location and crop used for crop yield prediction simulation are Croatia, Zagreb, and corn. According to [7], for the spring season in Zagreb, the best sowing dates for corn are between March 25th and April 8th. At the center of the mentioned website is a large and complete plant database, which contains 760,129 plants and 703,268 photos.

Figure 4.3 shows predicted corn yield if sown between March 23rd and April 8th using real weather data obtained from worldmodel.cisro.eu website for the year 2021 and on which harvesting day we would get more yield. According to [8], the best

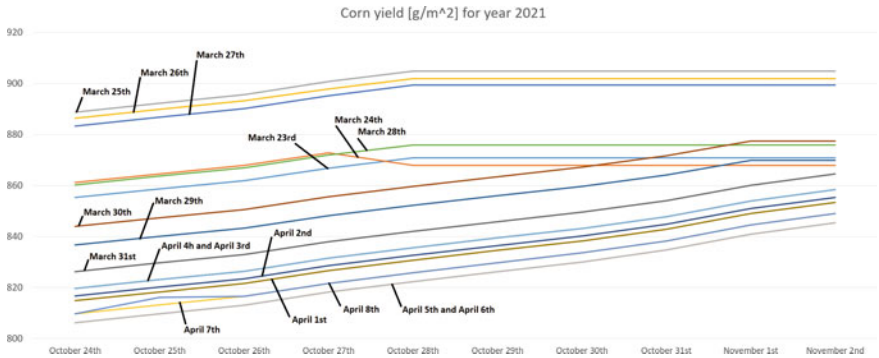


Fig. 4.3 Corn yield prediction for the year 2021 using real weather data for sowing dates between March 23rd and April 8th and harvest dates between October 20th and November 2nd

harvest dates for corn in Zagreb are between mid and late October, so only these dates are taken into account. From the graph, we can conclude that the best sowing date is March 25th and the best period to gather crops is between October 28th and November 2nd.

To predict crop yield for the year 2022, APSIM Next Generation requires weather data until the end of the year for that year. To obtain weather data for the year 2022, predictions were made based on data from the last 5 years. This period was selected since it proved to be the best option in terms of accuracy and execution time. Five different statistics were used to create a dataset with predicted values for the year 2022. The *statistics* used are average, maximum, minimum, median, and custom. The average statistic calculates average values for all weather parameters for each day, the maximum statistic takes only maximum values, the minimum statistic takes only minimum values, the median statistic takes median values and the custom statistic is a mixture of average, minimum and maximum values, where minimum is used only for minimum temperature, maximum is used only for maximum temperature and average is used for all other weather parameters. For example, to fill in the minimum temperature weather parameter for the date July 6th 2022 using the average statistic, we look at the minimum temperature values for years 2017, 2018, 2019, 2020, and 2021 for July 6th date. According to the worldmodel.csiro.au website, these values for Zagreb are 18.4, 19.0, 18.4, 18.8, and 15.0. The average value of these numbers is 17.92, which means that 17.92 is used as the minimum temperature for July 6th 2022 date for the average model.

To find out which statistic is the most accurate one, they were used to obtain weather data for the year 2021 by using years 2016, 2017, 2018, 2019, and 2020. Then, weather data obtained using these statistics were run in APSIM Next Generation to obtain the predicted crop yield. The method closest to the crop yield prediction using actual weather data for the year 2021 is selected to obtain weather data for the year 2022.

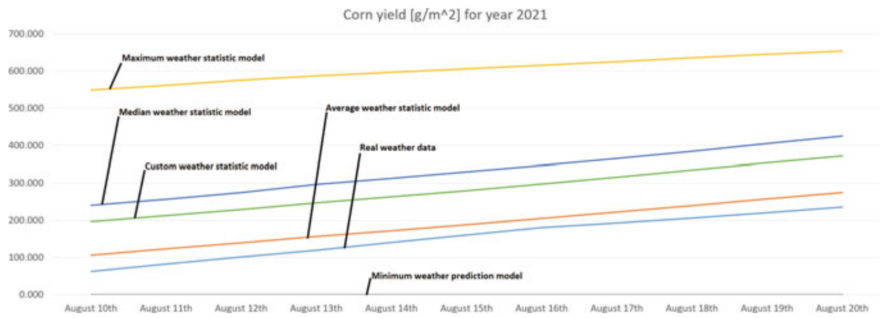


Fig. 4.4 Corn yield prediction for year 2021 using real weather data and weather data received using 5 different statistics

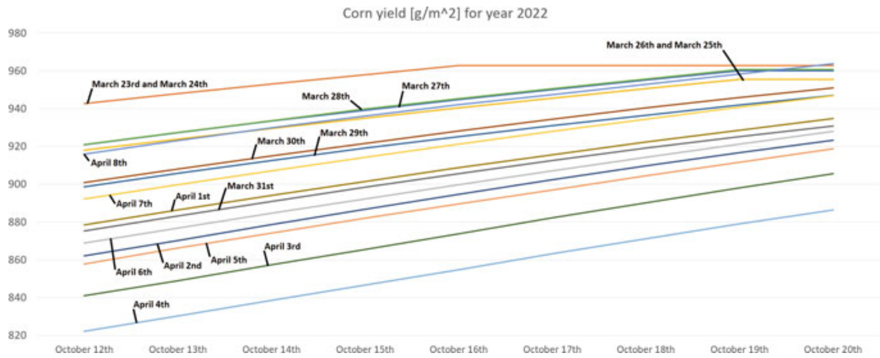


Fig. 4.5 Corn yield prediction for the year 2022 for sowing dates between March 23rd and April 8th and harvest dates between October 10th and October 20th

Simulated crop yield for the March 25th sowing date was used to determine which statistic is the most accurate. Figure 4.4 shows simulated crop yield for the year 2021 using all statistics and actual weather data for the March 25th sowing date and harvest dates between August 10th and August 20th. Most statistics did not have any data for harvest dates between October 20th and November 2nd. However, August dates had crop yield data for most of the statistics, so August harvest dates were selected for comparison to determine which statistic is the most accurate.

According to the data, the average statistic gave better results than other statistics, which means that this statistic was chosen to predict the best sowing date for the year 2022 that provides the highest yield. In other words, we look at the years 2017, 2018, 2019, 2020, and 2021 in order to see what weather data might look like for the year 2022. Figure 4.5 shows predicted corn yield using average statistic if sown between March 23rd and April 8th for the year 2022 and on which harvest day we would get more yield. From the graph, we can conclude that the best sowing date is April 8th if we harvest it on October 20th.

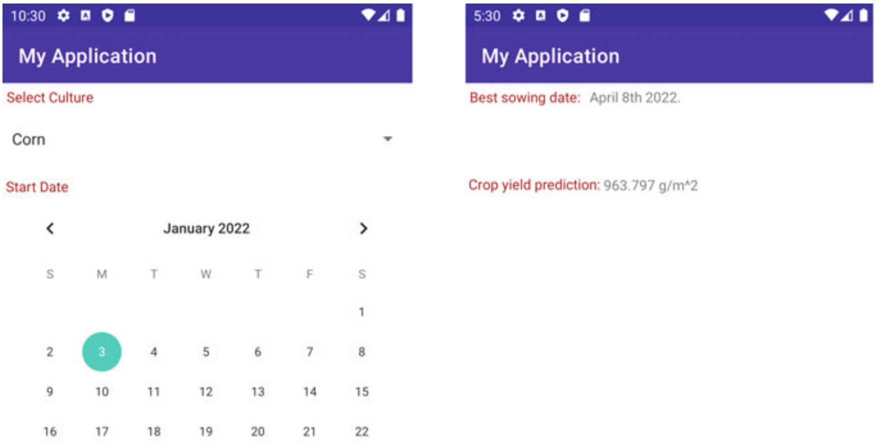


Fig. 4.6 The main screen and prediction screen of mobile client

4.6 Mobile Client for APSIM Simulator

Mobile client is developed using Android Studio and is written in Java 11. The application is designed to help farmers, especially new farmers, make better decisions when sowing a crop and to improve their agricultural skills. According to [9], most smartphone users will spend about 4 h a day on the Internet in 2020, and 88% of that time will be spent using apps rather than browsers. The main reason people use apps is because not all apps require an Internet connection and are readily available in the play store. That's why we decided to develop a smartphone application.

CSIRO[1] has already developed a mobile application for APSIM Next Generation called Graincast [10]. However, this application was only available for Australia and was discontinued as of 2020. Graincast provided paddock-level yield forecasts for over 400 farmers, agronomists, and sticky beaks during its four years of use. And it won a state-level award at the Australian Information Industry Association's iAwards competition.

In our mobile application, when users open the application, they are greeted by a main screen consisting of a crop selection and the start and end sowing date. A drop-down menu allows them to select three different crops: corn, barley, and wheat. Then, the user selects start and end sowing dates. The maximum difference between start date and end date is 15 days, in order not to overload the back-end server. If the difference is more than 15 days, a warning message appears. If the selected end date is before the start date, another warning message appears. If all checks are successfully completed, users can press the button in order to display sowing date prediction, along with crop yield prediction. Figure 4.6 shows the main screen and prediction screen of mobile application.

[1] Commonwealth Scientific and Industrial Research Organisation, https://www.csiro.au/en/.

4.7 Conclusion and Future Work

This paper presents a developed mobile application that uses APSIM Next Generation to predict yield for selected sowing dates and crop. This application could help new farmers make better decisions in the sowing process. Graincast, a smartphone application developed by CSIRO that uses APSIM Next Generation, has been discontinued as of 2020. This means that there is no alternative smartphone application that uses APSIM Next Generation.

Currently, this Android application has limited functionality. In the future, we plan to implement new features, such as location selection, usage of alternative and new crop prediction models, adding field size, fertilizer amount, soil parameters, sowing depth, and initial residue to make it a thorough application for crop yield prediction. The comparison of APSIM with alternative crop prediction models is also planned for future work.

To better predict crop yields, better long-term weather forecasting is needed. However, since weather is unpredictable, even the most reliable machine learning models and neural networks have a good chance of providing incorrect data, which means that a farmer may receive incorrect information about the yield prediction for a particular sowing date.

Acknowledgements This work has been supported by the project IoT-field: *An Ecosystem of Networked Devices and Services for IoT Solutions Applied in Agriculture* funded by European Union from the European Regional Development Fund.

References

1. Machine learning for large-scale crop yield forecasting. Agri. Syst. **187**, 103016 (2021)
2. Maresma, A., Ballesta, A., Santiveri, F., Lloveras, J.: Sowing date affects maize development and yield in irrigated mediterranean environments. Agriculture **9**(3) (2019)
3. Long, N.V., Assefa, Y., Schwalbert, R., Ciampitti, I.A.: Maize yield and planting date relationship: a synthesis-analysis for us high-yielding contest-winner and field research data. Front. Plant Sci. **8**, 2106 (2017)
4. Baum, M.E., Archontoulis, S.V., Licht, M.A.: Planting date, hybrid maturity, and weather effects on maize yield and crop stage. Agron. J. **111**(1), 303–313
5. Dahmardeh, M.: Effects of sowing date on the growth and yield of maize cultivars (zea mays l.) and the growth temperature requirements. vol. 11 (2012)
6. Salo, T.J., Palosuo, T., Kersebaum, K.C., Nendel, C., Angulo, C., Ewert, F., Bindi, M., Calanca, P., Klein, T., Moriondo, M., et al.: Comparing the performance of 11 crop simulation models in predicting yield response to nitrogen fertilization. J. Agric. Sci. **154**(7), 1218–1240 (2016)
7. Garden. https://garden.org/
8. Buhiniček, I., Kaučić, D., Kozić, Z., Jukić, M., Gunjača, J., Šarčević, H., Stepinac, D., Šimić, D.: Trends in maize grain yields across five maturity groups in a long-term experiment with changing genotypes. Agriculture **11**(9) (2021)
9. Saccomani, P.: People spent 90% of their mobile time using apps in 2021 (2021). https://www.mobiloud.com/blog/mobile-apps-vs-the-mobile-web
10. Graincast. https://research.csiro.au/graincast/

Chapter 5
Evaluating Trust and Reputation Models for IoT Environment

Mohammad Al-Shamaileh, Patricia Anthony, and Stuart Charters

Abstract The Internet of Things (IoT) provides advanced services by interconnecting a huge number of heterogeneous smart things (virtual or physical devices) through existing interoperable information and communication technologies. Due to its tenuous nature, IoT is vulnerable to different types of attacks, which usually lead to exposure of secrets from the node to the attacker, and compromises the authenticity, integrity, and real-time delivery of data. As such, it is important to have a trust and reputation model to evaluate the trustworthiness of the different players in IoT settings. Trust-based reputation models have been developed for this purpose, but to date, no attempts have been made to compare their performance in an IoT setting. The objective of this work is to implement a multi-agent framework to simulate a smart factory supply chain using IIOT and evaluate the performance of three well-known models: ReGreT, S-IoT, and R-D-C in terms of trustworthiness and cash utility. Based on our experiments, ReGreT performed the best among the three models in terms of evaluating trustworthiness and R-D-C gained the most cash utility.

5.1 Introduction

IoT can be defined as a global infrastructure for information society that provides advanced services by interconnecting virtual or physical smart objects through existing interoperable information and communication technologies. IoT gained much attention due to the overwhelming advantages that it has brought to our daily

M. Al-Shamaileh (✉) · P. Anthony · S. Charters
The Complex Systems, Big Data and Informatics Initiative, Lincoln University, Canterbury, New Zealand
e-mail: Mohammad.AI-Shamaileh@lincolnuni.ac.nz

S. Charters
e-mail: Stuart.Charters@lincoln.ac.nz

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_5

lives, and it has attracted a wide variety of applications including e-health, smart-home, smart-factory, smart-city, smart-community to run on it. All of these applications endeavor to aid humans to make better decisions, save money and time [1, 2].

Traditionally, IoT entities are interconnected with a pre-defined provider due to limited capabilities and resources, in addition to maintaining sensitive, secure, and safe data. However, as a response to the rapid development of technology and communications, IoT devices have become smarter with higher capabilities and the development of Industrial IoT (IIOT) powering Industry 4.0 including smart factories and smart manufacturing. IoT has become more open, allowing devices to interact, collaborate, and cooperate with each other without human control to solve complex problems.

There are many challenges in maintaining data privacy, reliability, integrity, and security. Studies of data sensitivity and privacy indicate the importance of evaluating the trustworthiness of IoT participants to maximize the satisfaction and the performance of IoT applications, as well as maintaining successful collaboration between the devices deployed in the network and ensure all devices operate in a trustworthy manner [3–6].

Trust is managed by Trust management systems (TMS) [7]. Current IoT trust management systems use physical behavior to monitor and detect infected entities. Security mechanisms are used by these systems to prevent misbehaving devices (malicious entities nodes or agents) that may damage the network [3, 5, 8–11]. Trust and reputation models have been developed to evaluate the trustworthiness of the other peers in the environment before starting cooperation and interaction [5, 11–13]. However, to date, no attempts have been made to compare their performance in IoT setting.

This paper introduces a general review of IoT trust management systems and evaluates three representative models in a multi-agent simulation using a smart factory case study. The rest of this paper is organized as follows: the second section presents the background. The third section discussed the implementation and environment settings, and finally in the fourth and fifth sections the results, conclusions, and future work are discussed.

5.2 Background and Related Work

Trust is a complicated concept which includes aspects of confidence, belief, and expectation. It helps overcome perceptions of uncertainty and risks and encourages user acceptance and consumption of services. It is a fundamental concern in open distributed systems to enhance user privacy, reliability, integrity, and information security. As a distributed system, IoT is vulnerable to different types of attacks (such as capture and eavesdropping), which usually lead to exposure of secrets from the node to the attacker, and the data will suffer from loss of authenticity, integrity, and timeliness [5, 7, 14, 15]. There are a few computational trust and reputation models

[5, 11–13] that deal with the multi-context nature of trust and reputation. However, most trust and reputation models such as IoT-TM, M2M-REP, IoTrust, and S-IoT [2, 3, 8–10, 16–20] perform single-context trust, focused on specific scenarios with very limited tasks without losing too much versatility.

In both approaches, IoT entities evaluate the trust and/or reputation of the other peers before starting cooperation and interaction. Models like M2M-REP [8], and IoTrust [9] use only direct information, while Caminha [2] and Maddar [10] use only direct observation. Most other models aggregate direct history and indirect information such as witness and referrals [5, 11, 13, 16, 21, 22]. Social information has also been included in models [12, 23]. In addition to the direct and indirect information, Copigneaux [13] used the end-to-end predefined agreement rules as additional source to evaluate the trustworthiness. Following the evaluation process, updating the other knowledge is very important to improve the accuracy of the system for the future transactions. Models presented by Alshehri et al. [3], Chen et al. [9], Copigneaux [13], and Saied et al. [11] update central database information with the latest interactions, while other models [10, 12, 19, 23] inform all the witness and referrals directly in the distributed decentralized systems. A time-driven update method is used by some models [5, 12, 17]. The majority of agent-based models including Ntropi [24], CRM [25], Kowshalya [12], R-D-C [26], Marsh [27], ReGreT [28], and Suryani [16] considered the interaction behaviors between the agents for the trust and reputation evaluation.

ReGreT, S-IoT, and R-D-C are well-known agent-based models that were designed to select the most trustworthy provider based on their trust and reputation's score. **ReGreT** [28] is one of the earliest models that extends the capabilities of the agent to deal with reputation and trust to improve the agent's behavior in a complex e-commerce environment. The main characteristics of ReGreT are (1) It takes into account direct experiences (individual dimension), information from third-party agents (ontological dimension), and social structures (social dimension) to calculate trust, reputation, and credibility values; (2) It has a trust model based on direct experiences and reputation; (3) It has a credibility module to evaluate the truthfulness of information received from third-party agents; (4) It uses social network analysis to improve the knowledge about the surrounding society; (5) It provides a degree of reliability for the trust, reputation, and credibility values that helps the agent to decide if it is sensible or not to use them in the agent's decision-making process; (6) and it can manage at the same time different trust and reputation values associated to different behavioral aspects; (7) It can combine reputation and trust values linked to simple aspects in order to calculate values associated with more complex attributes. ReGreT calculates the subjective reputation score using the weighted mean of the impressions' rating factors, taking into account the direct experiences, information from third-party agents, and social structures. After each interaction between two agents, each agent must update their rating and respective reputations publicly. Trust value in this model is evaluated using the equation shown in Eq. 5.1

$$Tij = direct\,experiences + Indirect\,information + Social\,dimension \tag{5.1}$$

S-IoT [10] is a trust management scheme for social internet of things. S-IoT is based on an Edge-Computing environment where every active node (person) must use a handheld device (mini-edge servers) that is used to forward the traffic and perform computations. In this network, the nodes communicate using three different types of queries: Main Query Manager (MQM), which is used to manage the traffic of the information flow across the network. Crowd Query Manager (CQM), which is operable at the Access Points, as well the Individual Query Manager (IQM) which is used by each handheld device. S-IoT evaluate the trustworthiness for any object willing to collaborate with its peers based on the direct observations (*Dij*), Indirect Recommendations (*CIij*), Centrality (*Gij*), Energy (*E*), and Service Score (*S*). All devices in SIoT are low power devices and less energy-efficient devices, so energy consumption is considered as a factor for determining if a node performs attack or not based on its energy level. For nodes performing an attack, the service score in this model, are penalized, otherwise, rewarded; the more number of times a node is penalized, the higher the chance the node is malicious. S-IoT calculates the trust of a node j with respect to node i using Eq. 5.2, where $0 < (\alpha, \beta, \lambda, \gamma, \omega, and \eta) < 1, 0 < Tij < 1$.

$$Tij = \alpha Dij + (1 - \alpha - \beta) Gij + \lambda CIij + \gamma CO + \omega E + \eta Sij \tag{5.2}$$

R-D-C [26] is a computational model that selects the most trustworthy provider agent based on computing the *Reputation* (ratings of previous satisfying interactions), *Disrepute* (ratings of previous dissatisfying interactions), and the *Conflict* (conflict in previous interactions) of each provider agent. In this model, the requester agent starts the evaluation by sending a query to advisor agents and asking them to suggest a trustworthy provider. After collecting the information from the responder advisors, including their suggested provider, the requester calculates the reputation, disrepute, and the conflict of each suggested provider to select the most trustworthy provider according to the computed components using Eq. 5.3.

$$Tij = Reputation + Disrepute + Conflict \tag{5.3}$$

5.3 Case Study

The main objective of this study is to investigate the performance and efficiency of the well-known models ReGreT, S-IoT and R-D-C implemented in a multi-agent framework to understand their relative performance and limitations. To evaluate the models, a IIoT Case study based on a smart factory supply chain has been developed. In this environment, different IoT smart agents implement the intelligent machines to work together as sellers and buyers to manufacture COVID-19 Personal Protective Equipment (PPE) products including medical masks, gloves, respirators, and oxygen

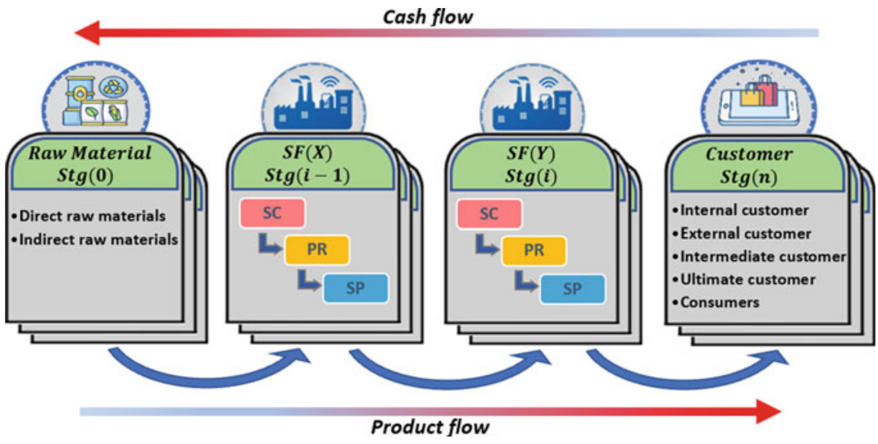


Fig. 5.1 Testing environment—Supply chain

concentrators which are needed for clinical care and health-workers. In such environment, high demand for the products means that industrial companies face a lot of challenges (like finding the best trustworthy supplier who can provide the highest quality and lowest cost replacement raw materials), due to supply chain disruption, cost escalation, and workforce dislocation. We implemented each model using agent-based approach to enable them to make decisions based on the trust and reputation score.

The case study environment is shown in Fig. 5.1. At the stage *Stg(i)*[1], the smart factory (*SF*) plays three main roles: services customers (*SC*), service producer (*PR*), and service suppliers (or provider) (*SP*). For example, the *SF(Y)* consume services that are provided from the previous stage $Stg(i{-}1)$ providers to produce the goods or/and services for others in the next stage cycle $Stg(i + 1)$ as service provider. In this case, *SF(Y)* as a *SC* needs to choose one (or more) service providers (*SP*) to provide the service from the factories *SF(X)* in the previous cycle. These service providers may be unknown to the service consumer and hence service consumer needs to determine if unknown *SP(s)* will be able to provide higher (or acceptable) service quality. At the same time, these new service providers need to sell their service to survive in the market. These services customers, service producers, and service produces are represented as agents in the simulation, and they are able to communicate with each other.

In this testing environment, the most trustworthy provider for each model is selected based on their evaluation method, and we assume that: (1) All the environment components are connected to the Open-IoT network, regardless of the connection media. (2) Service providers *aSP*.$aSPi$ must provide at least one service. (3) The service $SRVi$ should be provided by different providers with a minimum degree of similarity $mSimi$. (4) The service consumer $sSCi$ elects the best service provider

[1] i s the stage number of the stage Stg.

based on the trust and reputation evaluation that is provided by each model. (5) The agents in this environment communicate using secured XML enquiries [29]. (6) Non-honest agents (or attacker) may exist in this environment and are generated randomly. These dishonest agents use *Bad-mouthing and/or On–off attacks.* In Bad-mouthing attack, a dishonest node can ruin the trust level of well-behaved nodes by giving bad recommendations about them. Consequently, their reputation is negatively affected and the chance of these well-behaved nodes to be selected for service is reduced. With the *On–off attack,* the dishonest agents can randomly perform trustworthy service to hide its untrustworthy behavior.

5.4 Experimental Setup

We used the following parameters to evaluate the performance and efficiency of the competing models based on the described case study:

1. *Trustworthiness*: This metric is calculated using the models' trust and reputation evaluation method, as described in Eqs. 5.1, 5.2, and 5.3, to estimate all trustees' or other peers' (or the other peers) behavior in the environments. A higher trust score indicates a higher level of trustworthiness.
2. *Cash utility (CU)*: this metric is used to measure the individual performance of an agent, and the overall performance for the model based on the amount of cash (won or lost) after a fixed number of rounds. The formula that is used to calculate the cash utility is

$$\mathrm{CU} = \sum_{i=1}^{n} \begin{cases} +\ Profit\ value & ,\ for\ positive\ transactions \\ -\ Transaction\ cost * \left(\frac{Tc-Ts}{Te-Ts}\right) & ,\ for\ negative\ transactions \end{cases} \tag{5.4}$$

where the *n* is the total number of transactions, *Tc* is completion time (or interruption time), *Ts* is the service starting time, and *Te* is the expected agreed time to complete the service.

In this case study, there are 230 agents representing Service Providers and Service consumers. These were implemented in a multi-agent simulation using JADE (JAVA Agent DEvelopment Framework),[2] based on the simulation configuration detailed in Table 5.1 and tested on a virtual machine.[3] In this setup, the location of the agents and the chronology of their initiation of activity were randomly selected. A *Transaction* is defined as a cycle of detecting a service, gathering the required information, evaluating the trust and reputation value, selecting the service provider,

[2] https://jade.tilab.com.

[3] The specifications of the VM are the Operating System which is Windows Server 2019 Datacenter 64-bit, the Processor type is AMD EPYC 7452 32-Core Processor (8 CPUs), ~ 2.3 GHz, and the Available OS Memory is 32768 MB RAM (https://hpc.inde.nz/home).

Table 5.1 Simulation configuration

Parameter name	Value	Unit
Sim. Running Time	8760	Ticks
Real-life running time	52,560	Hours
Real-life tick size	6	Hours
Full-time agents	30–50%	
Services expiry range	30–700	Ticks

and signing the final agreement with the selected provider for a specific service. This transaction can be completed in one *Simulation Tick.*

5.5 Results and Discussion

To compare the performance of the three competing models, we tested them using four different sub-scenarios by injecting different percentages of dishonest agents (SSR 1.5–0%, SSR 2.5–25%, SSR 3.5–50%, and SSR 4.5–75%); where 0% means that the environment contains only trusted and honest agents, while 75% means that three-quarters of the agents are not honest and there is a high likelihood of potential of attack (Bad-mouthing and/or On–off attacks).

The trust scores of the three models are shown in Fig. 5.2. At the beginning of the simulation, no agents have enough information in their database or from the witnesses about the environment. This means that SCs have no choice but to collaborate with unknown witnesses to select unknown service providers. In this setting, ReGreT has the lowest trust scores in the first quarter, while the S-IoT and R-D-C used physical information to avoid using random selection during this period and resulted in a higher trust score than ReGreT. Once the agents have enough information, the models' performance converges. Towards the end of the experiment at time tick 5000, ReGreT performed higher than the other two models, which signals the importance of using the social information in the environment. The results also show that the performance of the S-IoT was affected more than the other models when the number of misbehaving agents increases in the environment, this is due to the use of physical information, which does not contribute to the identification of misbehaving agents, while other models use other more effective sources of information to evaluate performance. Finally, although R-D-C had a higher performance in the first third, ReGreT performed the best in terms of credibility, and integrity to the end of the experiment time.

The total cash utility of each model is shown in Fig. 5.3. This is affected negatively as the number of dishonest agents is increased in the environment. In the first sub-scenario (SSR1.5) ReGreT and S-IoT models during the period (0–1000) performed higher than R-D-C. R-D-C achieved the best performance in period of (1000–3000) but eventually converged to similar values with the other models. It can also be seen in Fig. 5.3b, c that S-IoT lost money faster than ReGreT and R-D-C. Figure 5.3d shows

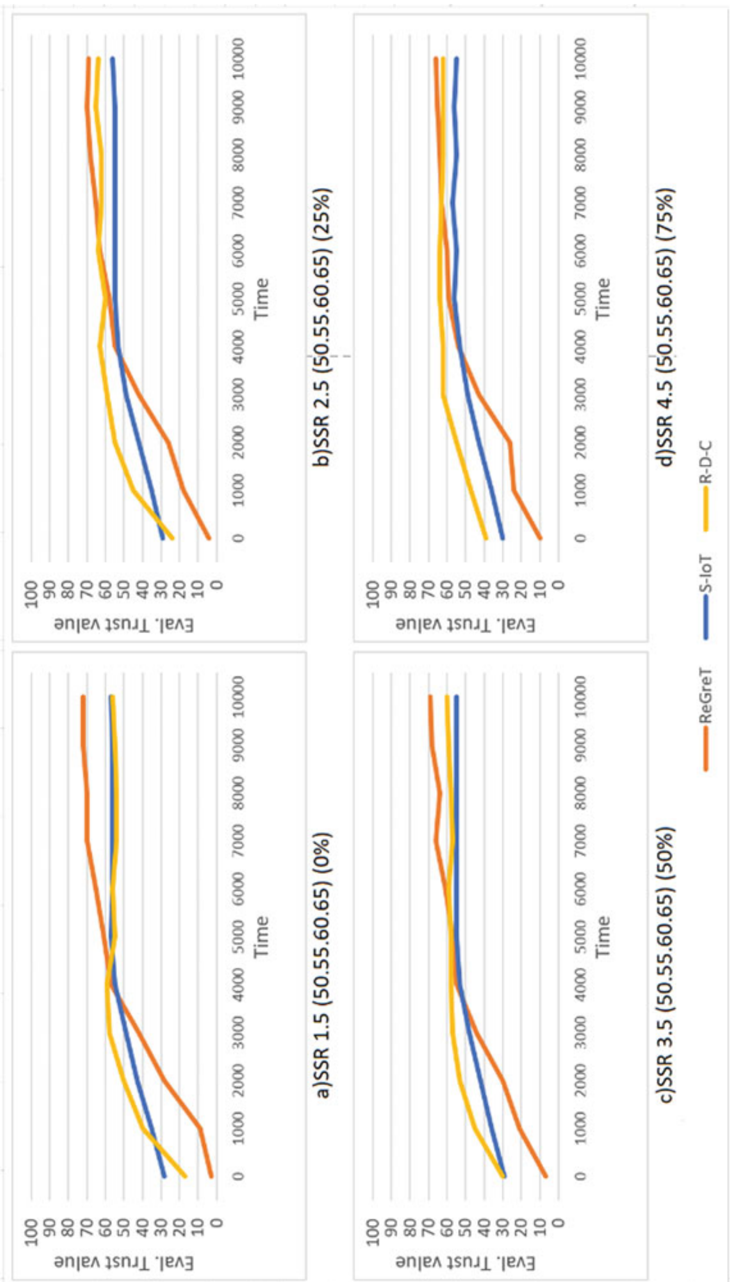


Fig. 5.2 Trust scores of nodes in different percentages of dishonest agents (0%, 25%,50%, and 75%)

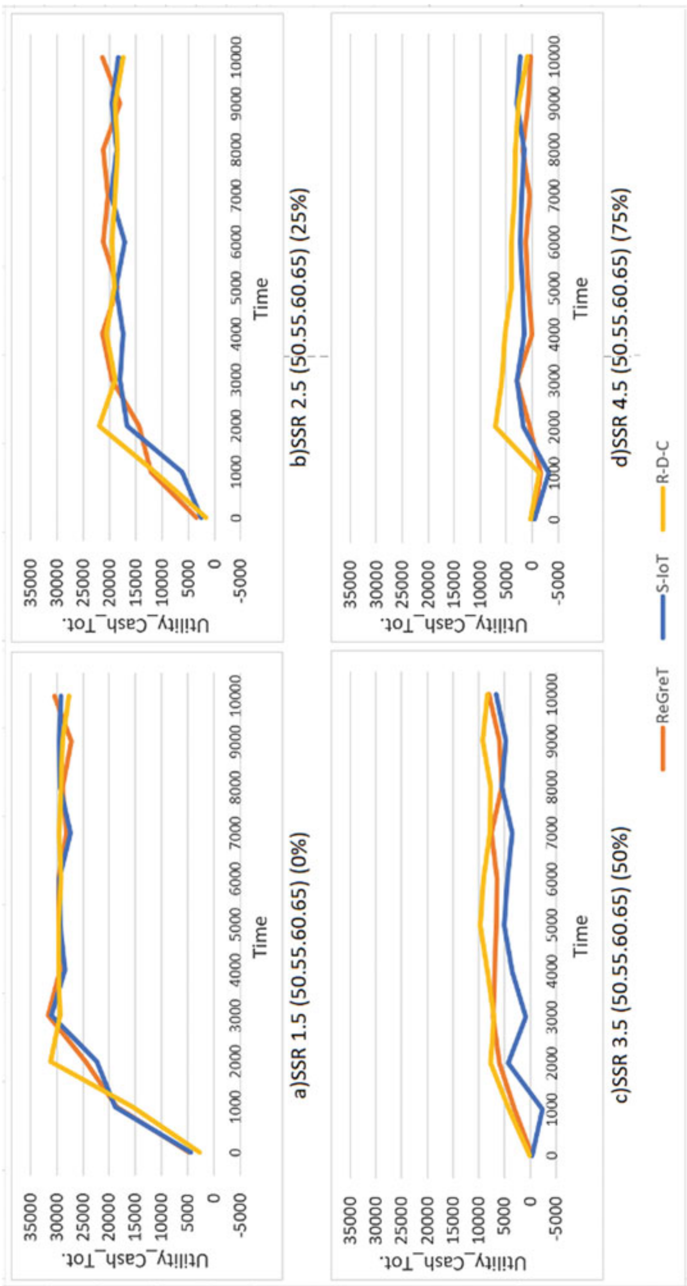
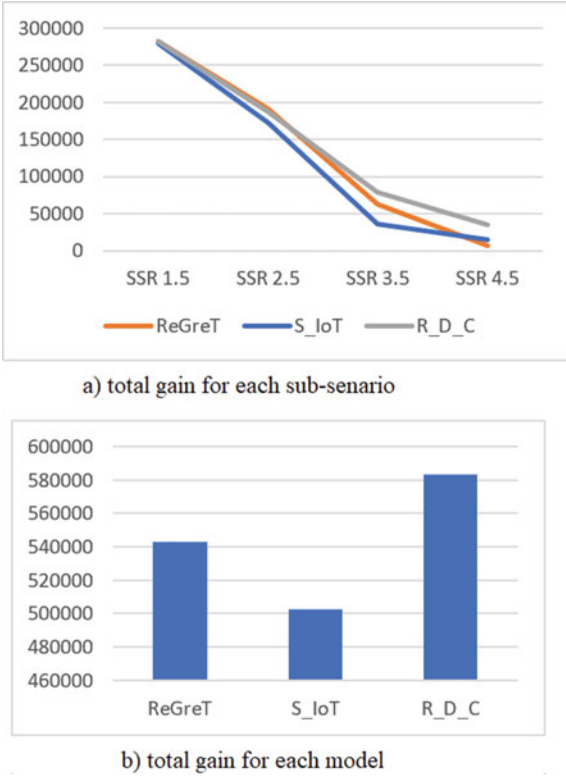


Fig. 5.3 Cash utility

Fig. 5.4 Cash utility- total gain



that R-D-C performed best in an environment where everyone is mostly dishonest. ReGreT gained the most cash in the first three scenarios but not the last one as shown in Fig. 5.3d and Fig. 5.4a. This is unsurprising and as expected because as the number of honest witness decreases, the number of credible providers will also decrease.

Finally, Fig. 5.4b shows the total cash utility gained for each model, and it's very clear that the R-D-C provides the most profit to the service consumers, followed by ReGreT and S-IoT.

5.6 Conclusions and Future Work

This paper introduced a general review of IoT trust management systems in addition to developing a common multi-agent framework implementation of three well-known trust-based reputation models in a smart factory supply chain setting. We evaluated the three models in terms of trustworthiness and cash utility. Results show that ReGreT performed the best followed by R-D-C and S-IoT based on the *trust-worthiness evaluation*, while the R-D-C had the best performance in terms of the *total cash gained*.

Current literature shows that there are limited works that deal with the issue of establishing trust mechanisms that can facilitate decision-making among agents in IoT setting. These agents should be able to decide how, when, and who to collaborate, negotiate, and operate with the other on behalf of its owner by taking into account multi-context QoS. These new models need to be more dynamic, smarter, and must be able to deal with the scalability, high heterogeneity, the fragility of traditional security approaches, in addition to the huge amount of the sensitive data exchanged. These new models also need to be accurate in selecting the most trustworthy peers (service providers) using all the available trusted resources to gather the information and reputations, taking into the consideration the context-awareness, and the quality of services. As a future work, we would like to develop a better trust and based reputation model that will address these issues.

References

1. Guo, J., Chen, R., Tsai, J.J.: A survey of trust computation models for service management in internet of things systems. Comput. Commun. **97**, 1–14 (2017)
2. Caminha, J., Perkusich, A., Perkusich, M.: A smart trust management method to detect on-off attacks in the internet of things. Secur. Commun. Netw. (2018)
3. Alshehri, M.D., Hussain, F.K., Hussain, O.K.: Clustering-driven intelligent trust management methodology for the internet of things (CITM-IoT). Mob. Netw. Appl. 1–13 (2018)
4. Sun, G., et al.: Feature selection for IoT based on maximal information coefficient. Future Gener. Comput. Syst. **89**, 606–616 (2018)
5. Yu, Y., et al.: An efficient trust evaluation scheme for node behavior detection in the internet of things. Wirel. Pers. Commun. **93**(2), 571–587 (2017)
6. Shayesteh, B., Hakami, V., Akbari, A.: A trust management scheme for IoT-enabled environmental health/accessibility monitoring services. Int. J. Inf. Secur. **19**(1), 93–110 (2020)
7. Yan, Z., Zhang, P., Vasilakos, A.V.: A survey on trust management for Internet of Things. J. Netw. Comput. Appl. **42** (2014)
8. Azad, M.A., et al.: M2M-REP: reputation system for machines in the internet of things. Comput. Secur. **79**, 1–16 (2018)
9. Chen, J. et al.: Trust architecture and reputation evaluation for internet of things. J. Ambient Intell. Human. Comput. 1–9 (2018)
10. Maddar, H., Kammoun, W., Youssef, H.: Effective distributed trust management model for Internet of Things. Procedia Comput. Sci. **126**, 321–334 (2018)
11. Saied, Y.B., et al.: Trust management system design for the Internet of Things: a context-aware and multi-service approach. Comput. Secur. **39**, 351–365 (2013)
12. Kowshalya, A., Valarmathi, M.: Trust management in the social internet of things. Int. J. **96**(2), 2681–2691 (2017)
13. Copigneaux, B.: Semi-autonomous, context-aware, agent using behaviour modelling and reputation systems to authorize data operation in the Internet of Things (2015)
14. El Hakim, A.: Internet of Things (IoT) System Architecture and Technologies, White Paper (2018)
15. Zhou, Z., et al.: Blockchain-based decentralized reputation system in E-commerce environment. Future Gener. Comput. Syst. **124**, 155–167 (2021)

16. Suryani, V., Sulistyo, S., Widyawan, W.: Trust-Based Privacy for Internet of Things. Int. J. Electr. Comput. Eng. (IJECE) **6**(5), 2396 (2016)
17. Xu, X., Bessis, N., Cao, J.: An autonomic agent trust model for IoT systems. Procedia Comput. Sci. **21**(C), 107–113 (2013)
18. White, G., Nallur, V., Clarke, S.: Quality of service approaches in IoT: a systematic mapping. J. Syst. Softw. **132**, 186–203 (2017)
19. Zeynalvand, L., Luo, T., Zhang, J.: COBRA: Context-aware Bernoulli Neural Networks for Reputation Assessment (2019)
20. Sharma, V., et al.: Cooperative trust relaying and privacy preservation via edge-crowdsourcing in social Internet of Things. Future Gener. Comput. Syst. **92**, 758–776 (2019)
21. Shehada, D., et al.: A new adaptive trust and reputation model for mobile agent systems. J. Netw. Comput. Appl. **124**, 33–43 (2018)
22. Aref, A., Tran, T.: An integrated trust establishment model for the internet of agents. Knowl. Inf. Syst. **62**(1), 79–105 (2020)
23. Sabater, J.: Evaluating the regret system. Appl. Artif. Intell. **18**(9–10), 797–813 (2004)
24. Abdul-Rahman, A., Hailes, S.: Supporting trust in virtual communities. In: Proceedings of the 33rd Annual Hawaii International Conference on System Sciences (2000)
25. Khosravifar, B. et al.: CRM: An efficient trust and reputation model for agent computing. Knowl. Based Syst. **30**(C), 1–16 (2012)
26. Majd, E., Balakrishnan, V.: A reputation-oriented trust model for multi-agent environments. Ind. Manag. Data Syst. **116**(7), 1380–1396 (2016)
27. Marsh, S.: Formalising Trust as a Computational Concept (1999)
28. Pinyol, I., Sabater-Mir, J.: Computational trust and reputation models for open multi-agent systems: a review. Artif. Intell. Rev. **40**(1), 1–25 (2013)
29. Damiani, E., et al.: A general approach to securely querying XML. Comput. Stand. Interf. **30**(6), 379–389 (2008)

Chapter 6
Anytime Evolutionary DCOP Algorithm with Distributed Solution Stores

Toshihiro Matsui

Abstract The Distributed Constraint Optimization Problem (DCOP) has been studied as a fundamental problem in multiagent cooperation. With DCOPs, a cooperation problem is represented as a combinational optimization problem whose variables and constraints are distributed among agents, and the agents solve the problem in a decentralized manner. AED is a solution method based on an evolutionary algorithm for solving relatively large-scale and densely constrained DCOPs, where each agent stochastically finds the best individual. However, all of the agents performing AED have their own sets of individuals that contain complete assignments to all variables in the system, and the decisions of unrelated agents are revealed. We propose another architecture for a solution method, where the assignment to each variable is stored by each owner agent of the variable, and agents do not publish the assignment except to related agents. We design the data flow of such a process and experimentally evaluate its influence on solution quality and computation/communication costs.

6.1 Introduction

The Distributed Constraint Optimization Problem (DCOP) has been studied as a fundamental problem in multiagent cooperation [2]. With DCOPs, cooperation problems for resource allocation and collaboration, including on smart grids, wide-area surveillance, and disaster response, are represented as combinational optimization problems whose variables and constraints are distributed on agents, and the agents solve the problem in a decentralized manner by communicating with each other. For the large-scale and densely constrained problems that are intractable for exact solution methods, quasi-optimal solution methods have been applied to DCOP solvers [3, 5, 6].

The Anytime Evolutionary DCOP algorithm (AED) [3] is a solution method based on an evolutionary algorithm, where each agent stochastically finds the best solution

T. Matsui (✉)
Nagoya Institute of Technology, Gokiso-cho Showa-ku Nagoya, Aichi 466-8555, Japan
e-mail: matsui.t@nitech.ac.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_6

by updating the sets of candidates of optimal solutions. Although this method is relatively simple, all of the agents have their own sets of candidate solutions that contain complete assignments to all variables in the system. As a result, the decision of agents is revealed to other agents that are not related by constraints. Another study on a soft-computing-based solution method applied particle swarm optimization to an extended class of DCOPs with a continuous domain of variables [1]. This solution method employed a similar representation for sets of particles, and the issue of representation seems to be a common one in fundamental studies.

In this study, we propose another architecture of a solution process, where the assignment to each variable is stored by each owner agent of the variable, and agents do not publish the assignment except to related agents. Note that such a decentralized architecture inherently requires a certain amount of additional computation and communication for the cooperation carried out among agents. Therefore, our goal is to investigate the data flow of the process and how to handle it by accepting some costs. We design the entire data flow of such a process and experimentally evaluate its influence on solution quality and computation/communication costs.

6.2 Background

6.2.1 Distributed Constraint Optimization Problem

A Distributed Constraint Optimization Problem (DCOP) is defined by $\langle A, X, D, F\rangle$, where A is a set of agents, X is a set of variables, D is a set of domains of variables, and F is a set of functions that represent cost values for constraints. In the fundamental setting commonly used, agent $a_i \in A$ has a single variable $x_i \in X$, which represents its decision, and a function $f_{i,j}(x_i, x_j) \in F$ representing the relationship among two variables x_i and x_j. Variable x_i takes a discrete value from its domain $D_i \in D$. Function $f_{i,j}(x_i, x_j)$ defines non-negative integer cost values for assignments to the two variables. A global assignment $\mathcal{A}$ is the assignment to all variables, while a partial assignment is an assignment to a subset of variables. The globally optimal solution $\mathcal{A}^*$ minimizes the global cost: $\mathcal{A}^* = \arg\min_{\mathcal{A}} \sum_{f_{i,j}\in F} f_{i,j}(\mathcal{A}_{\downarrow x_i}, \mathcal{A}_{\downarrow x_j})$. The DCOP shown above can be represented by a constraint graph consisting of agent/variable nodes and constraint/function edges, and this graph is used to show the relationships and communication paths among agents. We denote neighborhood agents connected to agent a_i by N_i. While the restriction in the number of agents' variables and the arity of functions can be generalized, we concentrate on the fundamental case similar to the previous study.

Each agent a_i searches for and determines the value of its own variable x_i in a decentralized manner by communicating with its related agents. We assume several characteristics of the agents that are commonly used in solution methods for DCOPs. Agents faithfully follow the algorithm and protocol of a solution method. Furthermore, the agents are not excessively curious and do not initiatively analyze unnecessary information regarding other agents. The information sent by an agent is received in the same order by a receiver agent. In addition, the agents can arbitrarily communicate with other agents that are not directly related by constraints if necessary. The existing solution methods for DCOPs [2] are categorized into complete methods [4, 7, 8] and incomplete methods [3, 5, 6]. Although complete methods find the optimal solution, they are not applicable to large-scale and densely constrained problems. Therefore, a number of incomplete solution methods that find the quasi-optimal solution have been developed. In recent years, several soft-computing-based methods [1, 3],

6.2.2 AED: Anytime Evolutionary DCOP Algorithm

The Anytime Evolutionary DCOP algorithm (AED) [3] is a decentralized evolutionary algorithm for DCOPs. This solution method is a synchronized algorithm that performs communication among neighboring agents on a constraint graph. It also employs a communication on a rooted best-first-search (BFS) tree on the constraint graph to synchronize anytime solutions among agents at each iteration of the solution process. In this process, agents maintain their sets of individuals that are the candidates for the quasi-optimal complete assignment. For each individual I, its fitness (cost) value $I.fitness$ is evaluated and attached. Figure 6.1a illustrates the main process of AED, and Fig. 6.3 shows the summarized pseudo code of AED. It uses several notations, including IN and ER, parameters for the number of individuals, and MI, the period between two iterations triggering migration phases (Fig. 6.3).

After building a BFS tree on a constraint graph, in preprocessing, a single set of initial individuals is constructed as follows (Fig. 6.3, l. 1–2). First, each agent a_i generates IN individuals that contain only an assignment to x_i. Then the individuals are shared between neighboring agents and partial assignments $\mathcal{A}^I$ of individuals are locally evaluated in each agent a_i with related functions as $I.fitness = \sum_{j \in N_i} f_{i,j}(\mathcal{A}^I_{\downarrow x_i}, \mathcal{A}^I_{\downarrow x_j})$. The partial individuals are aggregated in a bottom-up manner based on the BFS tree. Here, the kth individuals in the initial sets are integrated into a new kth individual by unifying the duplicated identical assignments to each variable and by computing the total fitness value. As a result, the root agents know the initial sets of individuals of complete assignments and their fitness values. Since the same initial fitness values that are evaluated by two neighboring agents are redundantly aggregated, the root agent adjusts them by dividing by two. Then the initial individuals and fitness values are duplicated to the initial individuals P_{a_i} for each agent in a top-down manner on the BFS tree.

Each agent a_i iteratively performs the following main process and locally updates its P_{a_i} and quasi-optimal assignment to x_i. First, agent a_i selects $P^{n_j}_{new}$ for each neighboring agent $n_j \in N_i$ by sampling individuals from P_{a_i} (l. 5–6). Next, a_i updates the assignment to its own variable contained in each individual in $P^{n_j}_{new}$ by sampling the assignment from D_i, after which it passes $P^{n_j}_{new}$ to neighboring agent n_j (l. 7–9). Agent n_j updates the assignment to its own variable contained in each individual

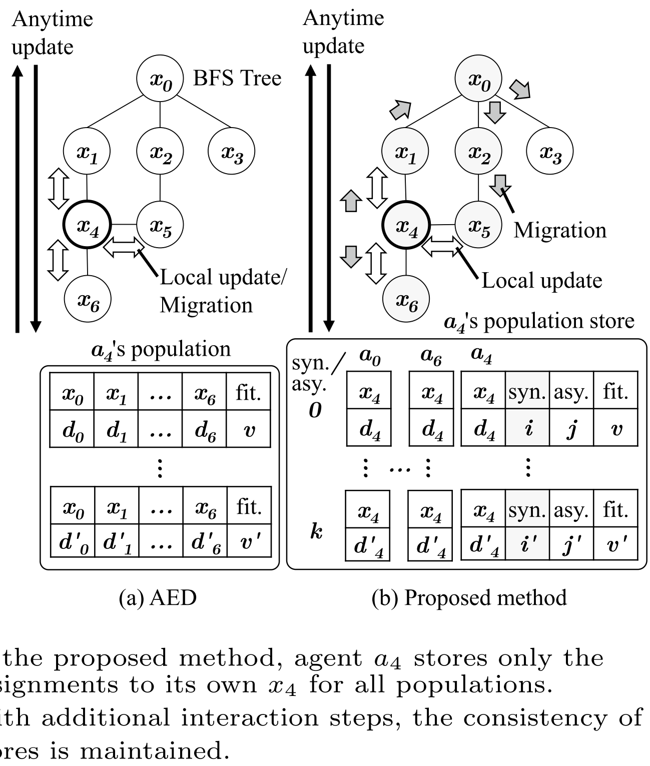
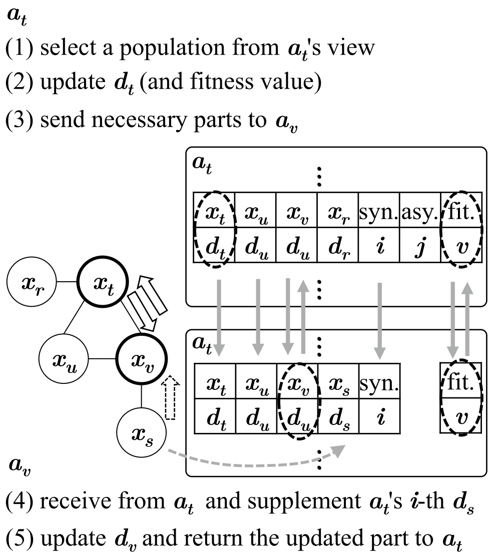


Fig. 6.1 Solution methods

in $P^{n_j}_{new}$ by locally minimizing the fitness values and then returns $P^{n_j}_{new}$ to a_i (l. 10–12). Finally, the returned $P^{n_j}_{new}$ is aggregated into P_{a_i} (l. 13). Here, the currently best individual B with the minimum fitness value is selected from P_{a_i} (l. 14). With a decentralized snapshot algorithm performed using the BFS tree, the background B is propagated to all of the agents if it is the globally best (l. 15). The algorithm also updates the currently best assignment to all variables. Then P_{a_i} is sampled again to maintain its size (l. 16). The above stochastic local search reduces the diversity of individuals. To maintain diversity, a migration process, where each agent imports a part of the individuals from its neighboring agents, is performed at every MI iteration (l. 17–20). See the literature [3] for details including the sampling equations and parameters.

While the process of AED is relatively simple, all agents have sets of complete assignments to all agents' variables. One might assume that this exposure is excessive because the complete assignments are only used for the consistency of global solutions. Therefore, by accepting the necessary computation and communication costs, we propose another architecture where the agents publish their assignments only to the limited set of agents necessary to solve the problem.



Agent x_t interacts with its neighboring agents while maintaining its view.
The update for x_t's synchronized range is stored at each iteration, and that for the async. range is applied by migration propagation.

Fig. 6.2 Local update

6.3 AED with Distributed Solution Stores

We propose a solution method based on AED with distributed solution stores. In the proposed method, the assignment to each variable in individuals is stored by the owner agent of the variable, and thus no agent collects unnecessary assignments within its view. Although each agent stores the parts for all populations, they only contain the assignments to its own variable. Due to the slightly complex formal representation of the process and the limited space, we present an intuitive explanation using figures for several parts. Figure 6.1b illustrates the main process of the proposed method, and Fig. 6.4 shows the summarized pseudo code of the method. The processing flow is arranged so that it contains additional communication steps with barrier synchronization. We also integrate the timings of message propagation for the migration of populations and the anytime-update of best solutions (Fig. 6.4, l. 4, 7, 26–28). In addition, neighboring agents share the knowledge of their neighborhood's agents in the preprocessing, and the information is employed to determine the range of agents' statuses to be synchronized at each iteration.

1 Construct a BFS tree on a constraint graph.
2 Share an initial set of IN individuals P_{a_i} by a protocol on the BFS tree.
3 $Itr \leftarrow 0$.
4 **until** Itr is within a cutoff cycle **do begin**
5 $P_{sel} \leftarrow$ a set of $|N_i| \times ER$ individuals sampled from P_{a_i} under allowing overlap.
6 Partition P_{sel} into the sets of the same size $\{P_{new}^{n_1}, \ldots, P_{new}^{n_{|N^i|}}\}$.
7 **for** n_j in N_i **do begin**
8 Update individuals in $P_{new}^{n_j}$ by sampling each assignment to a_i's variable.
9 Send $P_{new}^{n_j}$ to n_j. **end**
10 **for** $P_{new}^{n_{i,k}}$ received from n_k in N_j **do begin**
11 Update individuals in $P_{new}^{n_{i,k}}$ by selecting each best assignment to a_i's variable.
12 Return $P_{new}^{n_{i,k}}$ to n_k. **end**
13 **for** $P_{new}^{n_j}$ returned from n_j in N_j **do begin** $P_{a_i} \leftarrow P_{a_i} \cup P_{new}^{n_j}$. **end**
14 $B \leftarrow \mathrm{argmin}_{I \in P_{a_i}} I.fitness$.
15 Update and commit the globally best solution using B by a protocol on the BFS tree executing in background.
16 $P_{a_i} \leftarrow$ a set of $|N_i| \times ER$ individuals sampled from P_{a_i} under disallowing overlap.
17 **if** Itr mod $MI = 0$ **then begin** // *can be skipped for the first iteration*
18 **for** n_j in N_i **do begin**
19 Send a set of ER individuals, sampled from P_{a_i} under disallowing overlap, to n_j. **end**
20 **for** $P_{mig}^{n_k}$ received from n_k in N_j **do begin** $P_{a_i} \leftarrow P_{a_i} \cup P_{mig}^{n_k}$. **end end**
21 $Itr \leftarrow Itr + 1$. **end**

Fig. 6.3 AED (agent a_i)

6.3.1 Distributed Stores of Solution Sets

In the proposed approach, each individual is decomposed for each variable. A decomposed individual contains a single assignment to a variable and a fitness value of the original individual. Similarly, a set of individuals is decomposed to sets of decomposed individuals for single variables, and each decomposed set is separately stored to the agent that has the corresponding variable as shown in Fig. 6.1b. In each agent, the stored solutions only for the owner agent contain some additional information, including identifiers as pointers to the stores in other agents, and fitness values. Although each agent has all decomposed sets of individuals for all agents, the agent only knows the individuals' assignments for its own variable. A stored set of individuals may also be called simply stored individuals, stored solutions, or a solution store. In the solution process, each agent a_i maintains its view $\check{P}_{a_i}$ of its own current set of individuals that contain only the assignments to the variables for itself and neighborhoods agents to evaluate its related cost functions (l. 2). The view of each agent is maintained at each iteration of the solution process similar to AED (l. 8–20). At each iteration, each agent a_i also updates a part of its stored sets of individuals by the current assignments within the views of its related agents. We call the range of the related variables the synchronized range of a_i, and this range contains a_i's own variable, a_i's neighborhood variables, and the neighborhood variables of a_i's neighborhood variables. Namely, at each iteration, for each agent a_j of variable x_j in a range of two hops from agent a_i on a constraint graph, a store of individuals $P_{a_j}^{a_i}$ is updated. We also call the range of other variables the asynchronized range. The stored individuals for the asynchronized range are not updated at each iteration

1 Construct a BFS tree. Share an initial set of individuals $\{P^{a_i}_{a_k} | a_k \in A\}$. $Itr \leftarrow 0$.
2 Construct view $\check{P}_{a_i}$ by collecting the initial assignments only from the agents in N_i.
3 **until** Itr is within a cutoff cycle **do begin**
4 Process the received migration messages and prepare messages to be relayed.
5 **if** $Itr \bmod MI = 0$ **then begin**
6 Copy each current $P^{a_i}_{a_k}$ for asynchronous range to the previous $P'^{a_i}_{a_k}$. **end**
7 Process the received anytime−update messages and prepare messages to be send.
8 Prepare sets of individuals $\{\check{P}^{n_1}_{new}, ..., \check{P}^{n_{|N^i|}}_{new}\}$ from $\check{P}_{a_i}$.
9 **for** n_j in N_i **do begin** Update individuals in $\check{P}^{n_j}_{new}$ Send $\check{P}^{n_j}_{new}$ to n_j. **end**
10 **for** $\check{P}^{n_i,k}_{new}$ received from n_k in N_j **do begin** *// transfer only the part for n_i's view*
11 Supplement the missing assignment from other neighborhood agents' views.
12 Update individuals in $\check{P}^{n_i,k}_{new}$. Return $\check{P}^{n_i,k}_{new}$ to n_k. **end**
13 **for** $\check{P}^{n_j}_{new}$ returned from n_j in N_j **do begin** $\check{P}_{a_i} \leftarrow \check{P}_{a_i} \cup \check{P}^{n_j}_{new}$. **end**
14 $\check{P}_{a_i} \leftarrow$ a set of $|N_i| \times ER$ individuals sampled from $\check{P}_{a_i}$.
15 **if** $Itr \bmod MI = 0$ **then begin**
16 **for** n_j in N_i **do begin**
17 Send a set of ER individuals, sampled from $\check{P}_{a_i}$, to n_j. **end**
18 **for** $\check{P}^{n_k}_{mig}$ received from n_k in N_j **do begin**
19 Supplement the missing assignment from other neighborhood agents' views.
20 $\check{P}_{a_i} \leftarrow \check{P}_{a_i} \cup \check{P}^{n_k}_{mig}$. **end**
21 Generate remapping tables for asynchronized range IDs in new $\check{P}_{a_i}$. **end**
22 For the agents a_k in synchronized range, collect parts of views (and remapping tables) related to x_i, and update $P^{a_i}_{a_k}$ by renumbering/inheriting IDs of individuals.
23 $\check{B}_i \leftarrow \mathrm{argmin}_{I \in \check{P}_{a_i}} I.fitness$. Compute $LB^{Itr}_{a_i}$ by minimizing $\check{B}_k$ collected from the agents a_k in synchronized range.
24 **if** $Itr \bmod MI = 0$ **then begin**
25 Copy each current $P^{a_i}_{a_k}$ for synchronous range to the previous $P'^{a_i}_{a_k}$.
26 Initiate new migration propagation and prepare new messages. **end**.
27 Send prepared messages of the migration propagation.
28 Initiate new anytime−update propagation using $LB^{Itr}_{a_i}$, prepare new messages in addition to the ones in propagating, and send the prepared messages of anytime −update.
29 $Itr \leftarrow Itr + 1$. **end**

Fig. 6.4 AED with distributed solution stores (agent a_i)

but in the process related to the migration of individuals. Three types of identifiers are attached to each individual to handle this. The three identifiers are the identifier of the owner agent of the individual in the original AED, an identifier for the synchronized range, and an identifier for the asynchronized range. Agent a_i attaches all three identifiers to each individual contained in its own store $P^{a_i}_{a_i}$ as pointers to individuals in the stores placed in other agents. The individuals in other stores $P^{a_k}_{a_i}$ are used to compose assignments by finding their indices in the store that matches the identifiers of individuals. Note that the stores $P^{a_k}_{a_i}$ are categorized into those in synchronized and asynchronized ranges. Each agent also attaches the identifiers to the current individuals contained in its current view.

By using the identifiers of individuals, the preprocessing of AED to compute the initial sets of individuals can be easily modified so that only neighboring agents know the assignment to their variables. Instead of integrating the assignments of individuals, only fitness values are aggregated by relating corresponding identifiers. Then the identifiers of the synchronized and asynchronized ranges are attached to each individual, and the set of individuals is duplicated and shared by all of the agents (l. 1). Additionally, the identifiers of owner agents are attached to the individuals.

The identifiers are attached to corresponding individuals in the stores placed in the agents. In each iteration, neighboring agents locally update the partial assignment to their variables and update their stores for the synchronized range as shown in Fig. 6.2 (l. 8–14). In this process, the identifiers of the synchronized range attached to the sampled and modified individuals are updated to those of new individuals. Here, we simply renumber the new individuals by assigning integer identifiers that increase from zero. On the other hand, the new individuals inherit the identifiers of the asynchronized range from the previous ones to hold the pointers to the stores for the asynchronized range. Since the locally performed sampling process decreases the diversity of assignments for the asynchronized range, several identifiers of the asynchronized range become not longer referred to by any individual. That redundancy is eliminated in the process used for migration explained below. Then each agent updates its solution stores in the synchronized range by the sets of new individuals (l. 22).

6.3.2 *Decentralized Migration Process*

In the migration process, each agent exports some of their individuals to their neighboring agents, and the individuals imported by each agent are integrated into that agent's set of individuals. This process is performed by updating the views of related agents (l. 15–20). Here, a remapping operation of identifiers for owner agents and the asynchronized range is also performed (l. 21). The identifiers of exporter agents are replaced by those of an importer agent, and the identifiers of the asynchronous range are renumbered by skipping unused old identifiers. In addition, the same previous identifier of the asynchronized range inherited by different individuals is unified to a new single identifier to eliminate redundant duplication by sampling. The remapping information is also used to apply the update to the stored sets of individuals. The results are applied to distributed stores of individuals (l. 4, 22).

The update of stores for the asynchronous range is a challenging part of the proposed approach, since all of the stores for that range must be drastically updated in a decentralized manner. To do this, we employ a propagation of sets of remapping information on a BFS tree as shown in Fig. 6.5. Each set of remapping information contains the original and new identifiers of a new individual, which are necessary for remote agents to modify their stores. After the update of the stores in the synchronous range, the propagation of the remapping information is performed within $2H - 1$ iterations, where H is the height of the BFS tree (l. 4, 26, 27). This number of iterations is also the lower bound of the period MI between two migration phases. All agents send the remapping information of their own operation to their neighboring agents and also relay the other remapping information. When an agent receives a set of remapping information of an agent a_k, it updates a_k's stored individuals. Here, the update can be performed between two stores of exporter and importer agents. Moreover, the exporter can be the agent of both asynchronous and synchronous ranges, including itself. Agents must hold two generations of stored sets of individuals

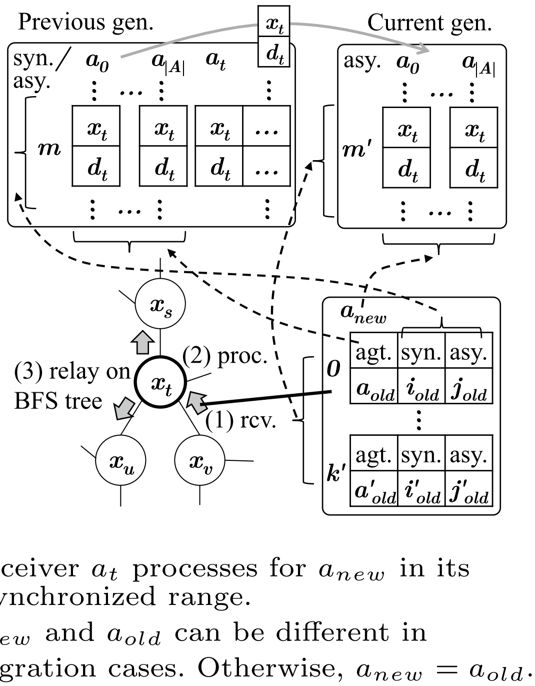


Fig. 6.5 Migration propagation

and inherit a part of the previous individuals to the new set of individuals. At every iteration that starts the migration phase, the shift (backup) of the two generations of stores is performed at different timings for the asynchronous and synchronous ranges (l. 6, 25). The update in the synchronous range at that iteration is stored as the previous generation during the propagation of remapping information. By the remapping and remote update operation, unused individuals in the stores for the asynchronized ranges are eliminated, and the population for that part is reduced.

6.3.3 Modification of Anytime-Update Process of Solutions

In the original AED, agents propagate their currently best individuals on a BFS tree in a bottom-up manner, and the root agent propagates the globally best individual and a time stamp in a top-down manner. With the received globally best individuals, all of the agents update the currently and globally best value of their variables at the same iteration by considering the delay in propagation. In the proposed approach, the propagated information does not contain any assignments to variables but consists of the three identifiers shown above, a fitness value and one (or two) time stamp(s) as

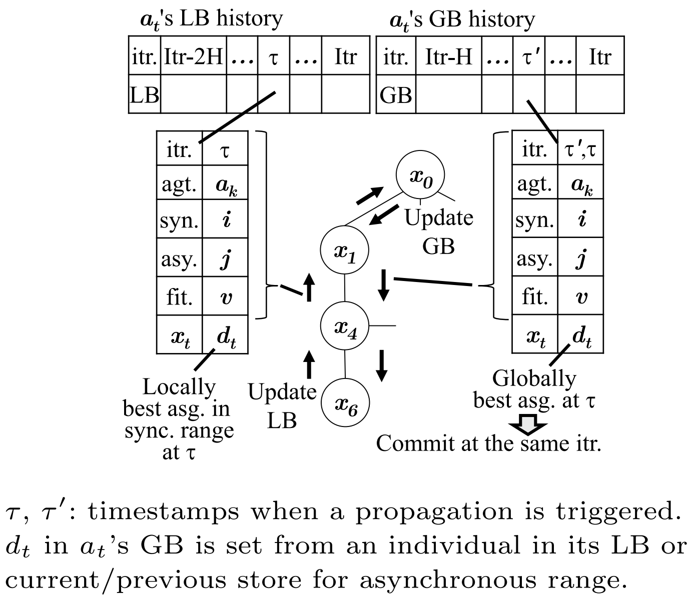


Fig. 6.6 Anytime-update

shown in Fig. 6.6. The fitness value and agent identifier are employed to determine the best individual, while the agent identifier and the two identifiers of the synchronous and asynchronous ranges are employed to select the best assignment to each agent's variables from stored sets of individuals. The steps of this processing are as follows. In each iteration, each agent collects the best individuals from the agents in its synchronized range, selects the best one, and saves it with the current time stamp (l. 23). If it is the best individual, the agent sends the individual to its parent with a Found-LB message which is propagated to the root agent. Then the root agent propagates the globally best individual with an Update-GB message to establish the new best assignment in a top-down manner as mentioned above (l. 7, 28).

This propagation is also performed within $2H - 1$ iterations. Note that the propagation for anytime-update is performed at an appropriate timing with the propagation for migration (l. 4, 7, 26–28). Although the anytime-update propagation is basically processed after the migration propagation at each iteration, its bottom-up and top-down processing is different from the flooding on a BFS tree done for migration. When the anytime-update triggered in the previous period of migration is received, the previously stored sets of individuals are employed.

6.3.4 Mitigating Exposure of Relationship Among Agents

The above solution process can correctly handle the solution stores distributed among agents without revealing any unnecessary parts of each solution to the agents in the asynchronized range. On the other hand, it exposes the relationship among agents to other agents because it is used for cooperative management of the distributed solution stores. To mitigate this, we modify the stores of individuals for the agents/variables in the asynchronized ranges. In the modified version, each agent has only a single set of individuals for all agents in its asynchronized range by removing agent identifiers from the stored individuals. Instead of that, each identifier for the asynchronized range is replaced by a unique and unpredictable number. By this modification, in the propagation of the migration process, agents cannot be directly aware of the owner of new individuals for their asynchronous range. In the propagation of migration, each agent can integrate several sets of remapping information received from neighboring agents into a single set and shuffle them. Although there are several possibilities of using distributed protocols to generate the new unique identifiers for the asynchronized range without any conflict, here we experimentally employ pseudo random integer values whose seed values are set differently by agents for simplicity. This was inspired by the use of practical unique IDs partially based on the sufficient length of random values. Indeed, in our experimental results with 32-bit integer random values whose seed values were different in all agents, there was no conflict. Even though this implementation is naive, the conflict can be easily checked when individuals are to be stored, and the solution process can be retried by some relatively simple extensions.

However, this modification is still insufficient, since the propagated information in anytime-update contains identifiers of agents to select an assignment from a corresponding solution store. Therefore, in the anytime-update propagation, we also replace the agent identifiers with unpredictable unique numbers. At the time when each agent collects the best solution among its synchronized range (l. 22), the agent also generates and exchanges its unique identifier value with its related agents, and it records them as a table of identifiers for the related agents. In the propagation of anytime-update, this table is employed so that each agent can check whether the replaced identifiers of agents are those of the agents in their synchronized range. The unpredictable unique identifiers are only used within two generations for the migration process, and they are also only used within a single period for anytime-update.

6.3.5 Details of Referred Data in Managing Solution Stores

In the following, we summarize the details of referred data in the management of the solution stores.

Stores of synchronized range updated in each iteration Each agent a_i collects its assignment from the views of agents in its synchronized range and updates corresponding agents' stores. a_i also inherits several assignments from the current stores in a_i. The copy operation of the assignment is slightly complicated in the case of migration because the exporter agents can be various agents including the collecting agent a_i itself.

1. Own store: Each agent copies assignments, identifiers, and fitness values from its own view and renumbers the identifiers of synchronous range. In the case of migrated assignments from neighboring agents, their identifiers of owner agents are replaced by that of importer agents. In addition, the identifiers of the asynchronous range is remapped for the migration. The assignments are copied from the views of the corresponding agents to obtain fresh data.
2. Neighboring agent's store: Each agent a_i basically copies assignments, identifiers, and fitness values from the views of its neighboring agents and updates the identifiers. That basically resembles the above case. If the owner agent of an assignment is a neighboring agent or a_i itself, the assignments are copied from the view of the corresponding agent. Otherwise, the assignments are copied from not the views but the current stores, considering whether their owners are within its synchronized range.
3. Other agent's store: Each agent basically copies assignments, identifiers, and fitness values from the views of other agents in its synchronized range and updates the identifiers. If the owner agent of an assignment is a neighboring agent, the assignment is copied from the view of the corresponding agent. Otherwise, the assignments are copied from the current stores, considering whether their owners are within their synchronized range.

Note that the renumbering/remapping of identifiers must be done in the same manner among all the related agents.

Migration propagation When each agent a_i receives the information of migration propagation, it copies the related assignment between the previous and the current stores in a_i. Here, only the copy operations to the agents in a_i's asynchronized range are processed. The pairs of source and destination stores in a copy operation are based on the received remapping information. If it is not a migration, assignment information in a_i's asynchronized range is copied from the corresponding store and its identifiers are renumbered. Otherwise, the copy is performed considering whether the source assignment information is in the synchronized range of a_i. The renumbering/remapping of identifiers is done in the same manner as the update of synchronized range stores.

Anytime-update propagation When each agent a_i receives the information of anytime-update propagation of the globally best solution, it copies the related assignment from a corresponding store in a_i to the store of the globally best assignment to be committed. On the other hand, the assignments in the stores of locally best assignments are held as views of locally aggregated information. When an agent a_i receives the information of the globally best assignment, its related agent a_j^{GB} that found the best solution is considered. If a_j^{GB} is within a_i's synchronized range, a_i copies the related assignment from not the stores of $\{P_{a_k}^{a_i} | a_k \in A\}$ but the store of locally best assignment $LB_{a_i}^{Itr'}$, where Itr' is the corresponding iteration. Otherwise, a_i copies the related assignment from the stores of $\{P_{a_k}^{a_i} | a_k \in A\}$ considering whether a_j^{GB} is within its synchronized range. Whether the store corresponding to the iteration of the best solution is the previous or the current one is also considered.

6.4 Evaluation

We experimentally evaluated the proposed method with benchmark DCOPs having n variables and c constraints (cost functions), and the domain size of each variable is denoted by d. The following two types of cost functions were employed. 'uniform': Random integer values in [1] based on uniform distribution; 'gamma': Rounded random integer values in [1] based on gamma distribution with $\alpha = 9$ and $\beta = 2$. We compared the following three methods. 'aedv'/'aedm': our implementation based on the original AED; 'ds': the proposed method without mitigating exposure of agents' relationship; 'dssn': the complete proposed method. To evaluate the computational overhead of solution methods, we performed two versions of AED. 'aedv' employs arrays (vectors) to represent the assignments to variables by assuming the variables' identifiers are ordered integer values from 0. On the other hand, 'aedm' employs associative arrays (maps) to represent them for general cases with arbitrary identifier values. For all solution methods, we employed the same set of AED's parameters [3] based on the literature and our preliminary experiment, except for the period MI between two migration phases: $IN = 5$, $ER = 5$, $\alpha = 1$, $R_{max} = 5$ $\beta = 5$, $O_{max} = 5$, where α, R_{max}, β, and O_{max} were sampling parameters. MI was set to 5 for AED. In the case of the proposed methods, this was set to the lower bound value, which was limited by the height of each BFS tree. Although we set a small number of populations, such a setting was still effective in the original study of AED [3].

The cutoff iteration was set to 1000. The results were averaged over 10 instances for each problem setting and 10 trials with different seed values. The experiment of 'uniform' was performed on a computer with g++ (GCC) 8.5.0–O3, Linux version 4.18, Intel(R) Core (TM) i7-9700K CPU @ 3.60 GHz, and 64 GB memory. Another computer with almost the same specification except for Intel (R) Core (TM) i9-9900 CPU @ 3.10 GHz was used for the case of 'gamma' to perform the experiment in parallel. In the first study, the total computation time was evaluated, excluding communication delay. Note that there exist possibilities to improve our experimental implementation.

Tables 6.1 and 6.2 show the final fitness value, the number of barrier synchronization steps per iteration, the maximum total size of assignment information in stored solution sets, the total size of exchanged information per iteration, the period MI between two migration phases, and the total execution time. To quantify the amount of stored and exchanged information in the different types of solution methods, we excluded the inherent primal key of stores (e.g., agent/variable identifiers in the case

Table 6.1 Solution quality and execution cost (uniform)

Prb.	Alg.	Fitness	Barrier			Max. sz.	Trans. info.		MI	Exec. time [s]	
			Min.	Ave.	Max.	store	Max.	Ave.		(aedv)	(aedm)
$n = 50$	aedv/aedm	8974.6	3	3.2	4	8211	387547	280928	5	4.4	39.9
$d = 3$	ds	8975.1	5	5.2	7	10927	1430367	519985	6		17.3
$c = 250$	dssn	"	"	"	"	10894	1427627	494954	"		40.2
$n = 50$	aedv/aedm	4007	3	3.2	4	5763	234547	168835	5	2.5	26.3
$d = 5$	ds	4014	5	5.1	7	6395	591844	214231	6.9		8.8
$c = 150$	dssn	"	"	"	"	6164	592220	201960	"		19.4
$n = 100$	aedm	7960	3	3.2	4	12726	929097	671426	5	6.9	104.1
$d = 5$	ds	7947	5	5.1	7	11384	1452090	535595	8.1		32.1
$c = 300$	dssn	"	"	"	"	10254	1454530	493983	"		77.1

Table 6.2 Solution quality and execution cost (gamma)

Prb.	Alg.	Fitness	Barrier			Max. sz.	Trans. info.		MI	Exec. time [s]	
			Min.	Ave.	Max.	store	Max.	Ave.		(aedv)	(aedm)
$n = 50$	aedv/aedm	3644	3	3.2	4	8211	387547	280928	5	4.1	38.2
$d = 3$	ds	3643	5	5.2	7	10926	1430367	519944	6		16.5
$c = 250$	dssn	"	"	"	"	10893	1427627	494927	"		38.4
$n = 50$	aedv/aedm	1929	3	3.2	4	5763	234547	168833	5	2.4	24.6
$d = 5$	ds	1926	5	5.1	7	6395	591844	214226	6.9		8.4
$c = 150$	dssn	"	"	"	"	6164	592220	201956	"		18.5
$n = 100$	aedv/aedm	3859.3	3	3.2	4	12726	929097	671373	5	6.4	102.5
$d = 5$	ds	3859.6	5	5.1	7	11381	1452090	535891	8.1		31.0
$c = 300$	dssn	"	"	"	"	10252	1454530	494182	"		74.0

of the original AED) and included assignment values to variables, additional identifiers, and time stamps. While the final fitness values were nearly identical, there is the influence of MI whose lower bound was limited by the height of the BFS trees in the proposed methods. We also found that the proposed methods converged faster due to the different paces between the local search by sampling and the migration period. This revealed the opportunity of adjusting other sampling parameters of AED considering the limited MI although that is an issue of tuning in the AED.

Regarding the execution costs of the solution methods, the overhead of the proposed method was relatively large in the case of $n = 50$ and $c = 250$ whose constraint density $c/n = 5$ was relatively high, while it was relatively small in other cases of constraint density 3. Although the agents in the proposed methods store two generations of solution sets to handle the distributed migration phases, the maximum size of their stores was sufficiently smaller than the doubled size of that in the original AED due to the compression of solution stores in the asynchronized ranges. It is also inevitable that the amount of exchanged information in the proposed methods is larger than that in the original AED. On average, the overhead of the exchanged

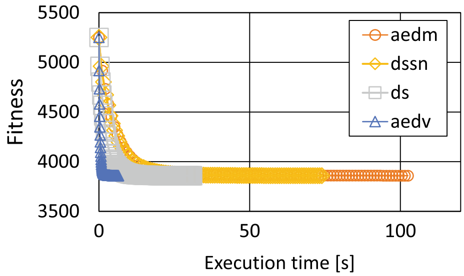


Fig. 6.7 Anytime curve of fitness ($n = 100$, $d = 5$, $c = 300$, gamma)

information was within twice that of the original values. There is no explanation for the smaller execution time of 'aedv', which is the AED simply implemented with arrays for assignments. However, we note that the computation overhead of the proposed methods was competitive with another version of AED 'aedm', which is implemented with associative arrays assuming the unordered arbitrary identifiers. While the results in the two tables resemble each other, the influence of these types of cost functions on the search process was slightly different.

Figure 6.7 shows the anytime curves of fitness values in the case of $n = 100, d = 5$, $c = 300$, and gamma. The solution processes converged within relatively earlier iterations although the total execution times varied. Since there are still opportunities for improving the experimental implementation, and the major part of solution quality was obtained in the early iterations, we expect the proposed approach to be applicable in certain situations.

6.5 Conclusion

We proposed a solution method based on AED with distributed solution stores and experimentally investigated its fundamental applicability. Although we focused on the decentralized implementation of solution information, another direction of related study will be an implementation with cryptographic techniques that require a relatively large overhead in computation. Our future work will also involve further improvement of the proposed method, including optimized message passing, and detailed evaluations in practical settings.

References

1. Choudhury, M., Mahmud, S., Khan, M.M.: A particle swarm based algorithm for functional distributed constraint optimization problems. In: Proceedings of the 34th AAAI Conference on Artificial Intelligence, vol. 34, pp. 7111–7118 (2020)
2. Fioretto, F., Pontelli, E., Yeoh, W.: Distributed constraint optimization problems and applications: a survey. J. Artif. Intell. Res. **61**, 623–698 (2018)

3. Mahmud, S., Choudhury, M., Khan, M.M., Tran-Thanh, L., Jennings, N.R.: AED: an anytime evolutionary DCOP algorithm. In: Proceedings of the 19th International Conference on Autonomous Agents and MultiAgent Systems, pp. 825–833 (2020)
4. Modi, P.J., Shen, W., Tambe, M., Yokoo, M.: Adopt: asynchronous distributed constraint optimization with quality guarantees. Artif. Intell. **161**(1–2), 149–180 (2005)
5. Nguyen, D.T., Yeoh, W., Lau, H.C., Zivan, R.: Distributed gibbs: a linear-space sampling-based DCOP algorithm. J. Artif. Intell. Res. **64**(1), 705–748 (2019)
6. Ottens, B., Dimitrakakis, C., Faltings, B.: DUCT: An upper confidence bound approach to distributed constraint optimization problems. In: Proceedings of the 26th AAAI Conference on Artificial Intelligence, pp. 528–534 (2012)
7. Petcu, A., Faltings, B.: A scalable method for multiagent constraint optimization. In: Proceedings of the 19th International Joint Conference on Artificial Intelligence, pp. 266–271 (2005)
8. Yeoh, W., Felner, A., Koenig, S.: BnB-ADOPT: an asynchronous branch-and-bound DCOP algorithm. In: 7th International Joint Conference on Autonomous Agents and Multiagent Systems, pp. 591–598 (2008)

Chapter 7
Impact of COVID-19 on Digital Business Models—Focus on Sustainability

Ralf Härting, Ana Gobechia, and Ikkei Tatsumi

Abstract The COVID-19 pandemic has accelerated the digital transformation worldwide and is challenging many companies across a wide range of industries. As a result, companies are subject to digital transformation and must improve their sustainability in the long term to remain competitive in the future. In this context, countries are at different stages of development. Therefore, the impact of COVID-19 on digital business models in different countries (Germany, Japan and Georgia) with a focus on sustainability has been investigated. A qualitative model was developed based on a structured literature review. Further hypotheses have been established based on empirical data from international experts using Grounded Theory. Important influencing factors related to digitalization include transparency, efficiency, data protection, digital mindset and sustainability aspects. Regarding sustainability, a distinction can be made between the two determinants "Sustainable office" and "The idea of sustainability".

7.1 Introduction

The world has been in constant upheaval since the beginning of the industrial revolution [1]. The terms "digital business models" and "sustainability" have been shaping events for some years now. While everyone involved has recognized that digitalization offers extensive opportunities and that the climate catastrophe ahead will bring about huge upheavals, people have still taken a sluggish approach to these issues [2].

Today, the COVID-19 pandemic has generated a societal upheaval of enormous magnitude and economic disruptions that in fact led to a simultaneous standstill for the whole society and economy. Today, there is a similar development, the new and highly dangerous COVID-19 virus, which has taken us by surprise and demands

R. Härting (✉) · A. Gobechia · I. Tatsumi
Aalen University of Applied Sciences, Aalen, Germany
e-mail: ralf.haerting@hs-aalen.de

A. Gobechia
e-mail: kmu@kmu-aalen.de

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_7

complete attention. Since the Corona pandemic, the pressure to change has grown massively on all fronts. Business models without physical contacts are booming and all companies must invest billions in the development of digital solutions in the shortest possible time in order to remain competitive in the market. [3]. But this is the only way to avoid being squeezed out of the market. At the same time, COVID-19 was a huge, global wake-up call to actively tackle the future and still avert the looming climate catastrophe [4]. Based on these disruptive times, the focus of society and business has transformed toward a sustainable future. A new era has dawned and the world has turned its focus to the future. The dynamic and importance of sustainability and digitization are inevitable, and customer focus must be specifically placed on this topic in order to remain competitive. The global battle for sustainability has gained momentum and the fight for tomorrow's customers will be fought on the digital front [5]. A qualitative research approach will be used to investigate the impact of COVID-19 on digital business models with a focus on sustainability [6].

7.2 Methodology

The following section explains the research design and applied methodology for collecting and analyzing the interview data to identify the influences of COVID-19 on digital business models. The term "digital business model" refers to business models which operate purely digitally on the one hand, and on the other hand, it includes business processes which are optimized and accelerated by digitalization. There have been used two scientific approaches, a Systematic Literature Review (SLR) and Qualitative Interviews based on Grounded Theory (GT).

The literature review, focusing on Georgia and Japan, was carried out in order to gain a better understanding of the mentioned topics.

During the SLR, certain important factors were discovered. Nine major criteria linked to the COVID-19 impact on digitalization (focus sustainability) conceptualization were identified and published [7]. In the SLR, it was discovered that post-pandemic economic recovery will be encouraged by digital technologies. For developing countries, it is crucial to have the financial, technological and infrastructural resources required to realize the benefits of digital technology. To maximize customer response capacity, digitization requires process reorganization, investment in organic structures, standardization and automation in business. Therefore, a qualitative study was conducted subsequently to determine the influence of COVID 19 on digital business models focused on sustainability.

7.2.1 Research Method

Qualitative research has been used to determine the possible impacts of COVID-19 on digital business models. The study design is based on the methodology of Grounded

Theory according to Glaser. This research aims to gain new insights into the research question being addressed [8]. The primary objective of this process is to create a new theory. This method can easily be separated from a quantitative verifying approach, When employing Grounded Theory, objectivity toward the subject is critical. A qualitative research approach in the form of semi-structured interviews is helpful when it comes to unveiling answers to "how" and "why" questions [9], which allows addressing the impact of COVID-19 on digital business models. The semi-structured interviews ensure scientific rigor, while still being able to integrate new ideas from the field. In combination with a narrative interviewing style support analyzing the interviewees' world of emotions and reasoning [10] in order to ultimately understand how the pandemic influences the digital business models. Additionally, a review of the literature was conducted to identify relevant questions. This increases the likelihood of discovering previously unknown correlations [11].

7.2.2 Data Collection

This qualitative research study is based on data from semi-structured interviews. The interview method is particularly known for obtaining valuable insights and knowledge from the surveyed experts, because the developing atmosphere is characterized by mutual trust [12]. This research is internationally focused, so companies from three different countries were analyzed. In this paper, both experts' assessments and opinions from several industries and countries are reflected. The three-country focus provides the qualitative study with an international and unique character. After suitable companies were located, qualified interviewees were identified based on established criteria, like years of professional experience for instance.

The interviews were conducted between December 2020 and January 2021. The duration of the interviews was 40 min on average. After eleven interviews from eight different sectors in Georgia, Germany and Japan were conducted and recorded, they were subsequently transcribed. This sample is sufficient for the development of such a concept.

Taking a look at the origin of the interviewed experts, the authors paid attention to a homogeneous survey. The diagram in Fig. 7.1 shows that the experts have been from Germany, Georgia and Japan. The participants of the survey can not only be distinguished according to their origin. Furthermore, Fig. 7.2 shows the sector distribution of the companies.

7.2.3 Data Analysis

After the semi-structured interviews were completely transcribed, the data analysis process started. The data was analyzed by using the Strauss and Corbin [13] coding method. The coding method described by Strauss and Corbin follows a systematic

Fig. 7.1 Origin of experts

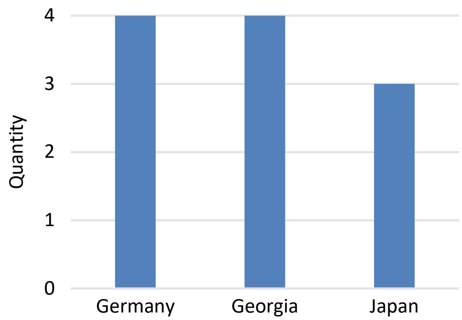
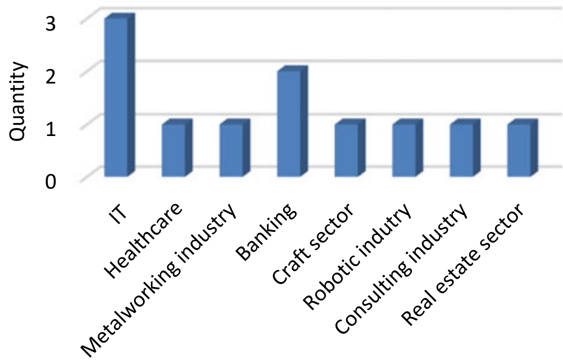


Fig. 7.2 Sector distribution



format with open, axial and selective coding. In the first step, the researchers were able to form initial categories from the raw data of the interviews (open coding). By comparing these categories, sub-categories of related categories could be formed in the next step. These sub-categories gave rise to new categories (axial coding). In the last step, all categories without reference to the core category were eliminated (selective coding). In this study, the core category represents the influences of COVID-19 on digital business models.

7.3 Empirical Findings

Based on Grounded Theory, six different main determinants, two sub-determinants and two influencing moderators have been identified. These determinants are potential influencing factors on digital business models influenced by COVID-19. The developed empirical model can be seen in Fig. 7.3.

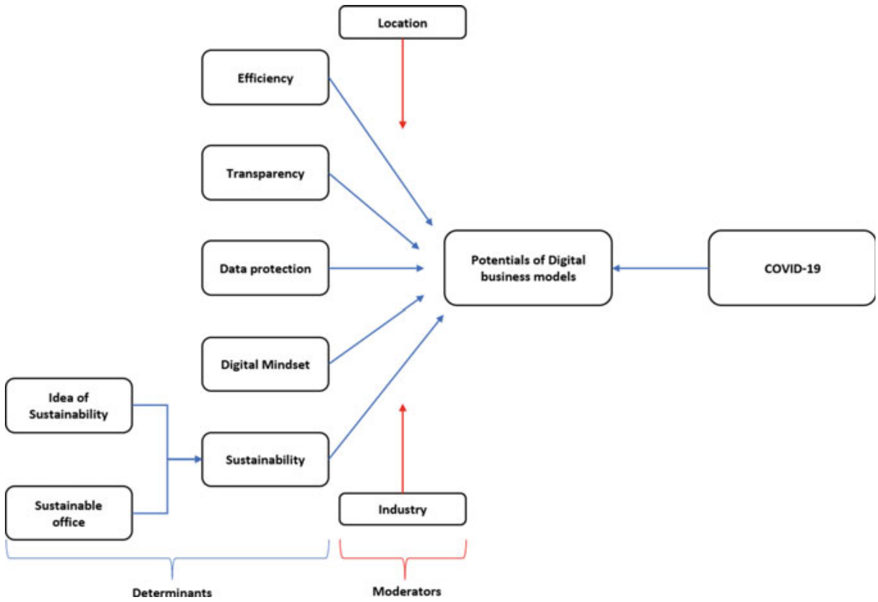


Fig. 7.3 Empirical findings based on grounded theory

7.3.1 Efficiency

One of the most important characteristics of efficiency in customer contact is time efficiency. The challenge here is to convey the right thing in a reasonably short time. The digitalization of all internal and external processes is extremely important as a support measure. The time saved is particularly appreciated by experts in video conferences.

There has been a significant increase in the use of chat functions—especially since COVID-19. In this online contact, there is a high level of conception down to the essentials. The elimination of organizational effort in face-to-face appointments saves a lot of time for the company and the customer. Customers also appreciate the fact that the company responds to inquiries with a high response speed. Increasing the speed of reaction using digital media is therefore of enhancing importance.

H1: *Efficiency positively influences the potential of digital business models*

7.3.2 Transparency

In these disruptive times, data breaches, enhanced privacy concerns and fake news have become commonplace resulting in a growing customer demand for transparency and accountability. Thereby, collecting data and getting information using the world wide web, online platforms and tutorials in a short time is crucial, nowadays. One aspect of transparency that regularly calls data protection officers on the scene is the increased transparency that results from the fine-grained storage of customer data.

The digital patient file, for example, is extremely helpful for the processes in the doctor's office, but it must be protected to the greatest possible extent against data loss and external attacks. Digital early warning systems create transparency about critical processes and ensure that risks are recognized at an early stage and countermeasures can be taken to minimize damage. The digital possibilities of data transmission have increased the trend toward intensive use of real-time data.

H2: *Transparency positively influences the potential of digital business models*

7.3.3 Data Protection

Increasing digital networking makes companies more and more vulnerable. To counter these threats, companies are planning to invest a lot in this area in the future. One of the experts we interviewed perceives risks above all in the interfaces to customers and suppliers.

> [...] A big challenge at the beginning of the pandemic was to reconcile working from home with the current General Data Protection Regulation. [...]

Most of the experts rated data protection as one of the greatest challenges for companies in the future.

H3: *Data protection positively influences the potential of digital business models*

7.3.4 Digital Mindset

The digital mindset is one of the biggest barriers to implementing digital projects in companies. However, since the outbreak of COVID-19 and the downright compulsion to implement digital solutions, a rethink seems to have taken place in society. To speed up the process of digital reorientation, many companies have implemented training programs for digital applications. The acceptance of digital solutions has not only grown significantly in the industrial or service sectors, but also in health care, digital applications facilitate daily work. The acceptance of digital solutions has grown both in the industry and service sector and in other segments like the healthcare sector.

H4: *Digital mindset positively influences the potential of digital business models*

7.3.5 Sustainability

The determinant sustainability is derived from the two sub-determinants "Sustainable office" and "The idea of sustainability". The sustainable office combines working from home with the aspect of sustainability and all its positive effects. At first, high investments in the corresponding infrastructure were necessary until advantages for companies arise. For example, employees can work from anywhere in the world. The physical separation made a complete digitalization of all data necessary. However, paper savings are not the only benefit for companies. In addition to the economic and ecological areas of sustainability, social benefits through working from home are also emerging.

H5: *Sustainable office positively influences the potential of digital business models*

The second sub-determinate "idea of sustainability" refers to society's increasing awareness of how to use the earth's resources. The conducted interviews support this hypothesis, although the level of expression depends on the country. Moreover, this conscious use of resources will become increasingly important for a company's competitiveness in the future. These described sub-determinates represent the main determinates of sustainability in the empirical model.

H6: *The idea of sustainability positively influences the potential of digital business models*

7.3.6 Moderators

In the meantime, the world has recognized that the resource-conserving use of nature is an essential key to the world's continued existence. However, this realization is very location-dependent. The level of development of the respective country is a key indicator of this. Based on the interviews conducted in the countries Germany, Japan and Georgia, different levels of awareness and digitalization stages could be identified.

H7: *Location influences the potential of digital business models*

In addition to this country-dependent moderator, there are also differences in digitalization and sustainability in the individual industries.

H8: *Industry influences the potential of digital business models*

7.4 Conceptional Model

After the topic has been examined by a literature analysis and a qualitatively executed Grounded Theory, the following section summarizes the results in Fig. 7.4. The "Potential of Digital Business Models" that can be recognized today is based in Germany on a long-term process that has taken place over several generations. The increased efficiency through heavily modified and digitized processes results in a strong improvement in sustainability. The development is not the same in all countries. In Georgia, people have a very little digital mindset and few modern resources.

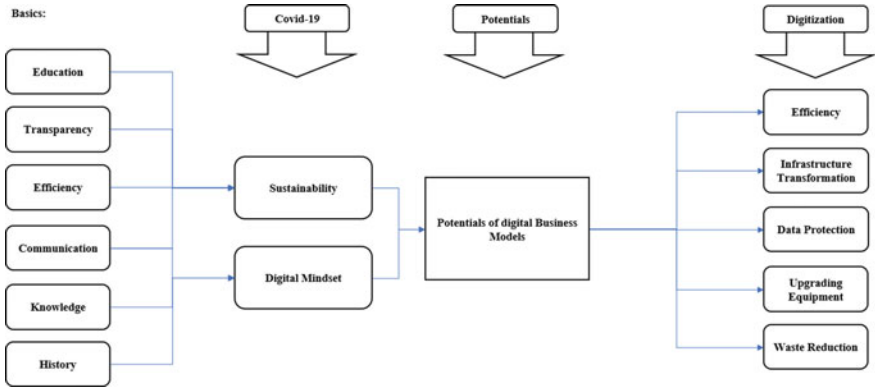


Fig. 7.4 Resulting empirical model

Development there will therefore lag Germany for a long time [14]. In Japan, there are traditionally good economic resources, but unfortunately there is hardly any recognition that sustainability and environmental protection are important [15, 16].

Overall, both manufacturing and service organizations will choose for the digital transformation of industries and production systems. Growing inequalities within and across countries are expected due to differences in digital skills, capacities and infrastructure. In fact, trade conflicts may cause market volatility and uncertainty [17]. To maximize customer response capacity, digitalization requires process reorganization, investment in organic structures, standardization and automation. The countries of the world will swiftly embark on the right route for the future due to the vast differences in views and resources around the world.

7.5 Conclusion

The aforementioned consequences had various effects on different parts of the organization, and they were also distinct across different countries, because each country has its own development cycle. According to the findings of the research, businesses were able to increase their efficiency, which in turn saved both the time of their consumers and the time of the business itself. During this period, the flow of information inside the organization becomes more fluid. Because of the nature of remote employment, data protection has become an issue. Of course, it will take more time for some countries to gain a better understanding of data protection, and the amount of awareness varies from country to country and from company to company, but the overall results demonstrate that knowledge of the necessity of data security was positively influenced. Companies attempt to generate cultural change for digital transformation through training programs for their staff. Cultural change for digital transformation is not a simple process. It is a long-term process that necessitates fundamental adjustments in one's mentality. And it is the most important aspect of accelerating digital transformation, which can lead to sustainable development for businesses in the future. Our study also goes along with limitations, among which a key limitation is our limited sample size. While our sample helped to tease out certain patterns and tendencies which evolved in hypothesis generation and conceptual model development, we call for follow-up studies to confirm (or disapprove) our results.

References

1. Obermaier, R.: Handbuch Industrie 4.0 und Digitale Transformation-Betriebswirtschaftliche, Technische und Rechtliche Herausforderungen, Springer Gabler, pp. S.10 (2019)
2. Jacob, M.: Digitalisierung und Nachhaltigkeit-Eine unternehmerische Perspektive, Springer Vieweg, pp. S. 1f (2019)
3. Gorynia-Pfeffer, N.: Corona-Krise: große Chance für digitale Ge-schäftsmodelle? https://www.rkw-kompetenzzentrum.de/gruendung/blog/corona-krise-grosse-chance-fuer-digitale-geschaeftsmodelle/ (2020). Accessed 15 February 2021
4. WHO: Saving a Generation within a Generation, https://www.who.int/life-course/news/saving-a-generation/en/ 2021. Accessed 15 February 2021
5. O'gorman, V.: Digitisation of the Courts: Could Covid-19 be the Catalyst Needed For Change? https://www.lexisnexis.co.uk/blog/future-of-law/digitisation-of-the-courts-could-covid-19-be-the-catalyst-needed-for-change (2020). Accessed 15 February 2021
6. Deutsche Telekom A. G.: Impact of Covid-19: Corona as a catalyst for digitalization? https://www.telekom.com/en/careers/our-focus-topics/center-for-strategic-projects/trafo-talk/impact-of-covid-19-corona-as-a-catalyst-for-digitalization-part-3--601542 (2020). Accessed 15 February 2021
7. Gobechia A., Tatsumi, I., Härting, R.: COVID-19, Digitalization and Sustainability—Insights from a Literature Review. http://www.kmu-aalen.de/kmu-aalen/forschung/publikationen/ (2021). Accessed 10 February 2021
8. Glaser, B., Strauss, A.: The Discovery of Grounded Theory: Strategies for Qualitative Research. Routledge, London and New York (2017)
9. Pratt, M.G.: From the editors: for the lack of a boilerplate: tips on writing up (and reviewing) qualitative research. Acad. Manag. J. **52**(5), 856–862 (2009)
10. Myers, M.D.: Qualitative Research in Business & Management. Sage Publications, Thousand Oaks (2008)
11. Strauss, A., Corbin, J.: Grounded theory methodology—An overview. In: von Denzin, N., Lincoln, Y. (eds.) Published in Handbook of Qualitative Research, Thousend Oaks (1994)
12. Myers, M.D., Newman, M.: The qualitative interview in IS research: Examining the craft. Inf. Organ. **17**(1), 2–26 (2007)
13. Strauss, A., & Corbin J.: Grounded theory methodology: an overview. In: Denzin, N.K., Lincoln, Y.S. (eds.) Handbook of Qualitative Research, pp. 273–285. Sage, Thousand Oaks, CA (1994)
14. Kvernadze, A.: Voluntary National Review Georgia, https://sustainabledevelopment.un.org/content/documents/10680SDGVoluntaryNationalReviewGeorgia-.pdf (2021). Accessed 15 February 2021
15. Zenbird: Sustainability in Japan. https://zenbird.media/sustainability-in-japan/ (2021). Accessed 15 February 2021

16. Nesheiwat, J., Cross, J.S.: Japan's post-Fukushima reconstruction: a case study for implementation of sustainable energy technologies. Energy Policy **60**, 509–519 (2013). https://doi.org/10.1016/j.enpol.2013.04.065
17. The Rise of Digital Challengers: How Digitization can Become the Next Growth Engine for Central and Eastern Europe. https://digitalchallengers.mckinsey.com (2021). Accessed 10 February 2021

Chapter 8
An Investigation into Influences of Tweet Sentiments on Stock Market Movements

Zhicheng Hao and Yun-Heh Jessica Chen-Burger

Abstract The increasingly common practice by the public of using social media as an information source and basis for decision making for investment has given social media, such as Twitter, a growing influential role in people's behaviour. We investigate the impact of Tweets on the US stock market using sentiment analysis. We examine how the sentiments in Tweets influence the price movements in S&P 500, an excellent indicator for the US stock market and economy in general. We compared the top five influential Twitter outlets and found WSJ, Bloomberg, Forbes, and Reuters consistently showed similar sentiments. We also discovered a significant two trading days' delay in impacting S&P 500 trends where obvious agreements are found between the above outlets. An enhanced version of SentiStrength has been used where we injected finance-related lexicons underpinned by our investor's ontology to obtain a significantly improved and consistent performance.

8.1 Introduction

Social media such as Twitter provides valuable information that reflects public and analysts' opinion and moods and are increasingly used by investors as a tool for making investment decisions [1]. Tweets provide useful insights for smarter decisions on whether one should sell, buy, or hold their shares. However, the stock market is highly volatile and complicated, and stock prices can be largely driven by real-time information that makes them extremely difficult to predict [2]. Twitter is one of the most popular platforms that provide real-time market information and can be automatically extracted to provide features for analysing and exploring hidden financial emotions. Such emotions may indicate market moods leading to stock price changes and volatilities, change volumes of trades, and even cause risks in businesses [3]. However, it is very challenging to accurately understand sentiments from Tweets that

Z. Hao (✉) · Y.-H. J. Chen-Burger
School of Mathematical & Computer Sciences, Heriot-Watt University, Edinburgh, UK
e-mail: zh3@hw.ac.uk

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_8

may include implicit and finance-specific information, e.g., company or macroeconomic information, irregular large volume of transactions, or changes in investors' minds.

In this paper, we describe our efforts to investigate the relationship between the S&P 500 stock price movements and the sentiments as shown in Tweets. S&P 500 is commonly regarded as the best single indicator for the health of the US stock market, as it covers approximately 80% of US market capitalisation. The S&P 500's indexes (SPX) were extracted from Yahoo's Finance portal (yfinance) and the top five financially influential Twitter accounts (WSJ, Bloomberg, Reuters, Forbes, and Donald Trump) were selected for sentiment analysis [4]. The sentiment analysis is implemented by using the lexicon-based sentiment analysis tool SentiStrength [5].

We have chosen to work on data from April 2021 when many significant financial events were discussed on Twitter, e.g., SPX dropped 7% and triggered a trading curb, UK's FTSE 100 fell 10.87%, Frances's CAC 12.28%, and Canadian S&P/TSX 12%. Our research explores the effects of financial related Tweets at the time, then we studied the correlations between these Tweets and SPX.

To boost the capabilities of the general SA analyser SentiStrength, we have developed an Investor's Ontology to capture financially related information, including macroeconomy. We then developed a set of finance-specialism lexicon based on the ontology. This approach enables SentiStrength to show great improvements and consistent performance in analysing finance-related Tweets from an investor's point of view when comparing with the ground truth.

We then deployed the enhanced SentiStrength to analyse Tweets and compare them with movements of SPX. We found very interesting results. We found major financial Twitter outlets reach agreements on their positive or negative sentiments. We also found Tweets of Donald Trump sometimes showed opposite sentiments, but this may be explained by his personal political motivation. Moreover, we detected a consistent two trading days' delay of stock market trend impact, following consensus in Tweets sentiments. It shows media's mood can reverse an upward trend to go down or vice versa. If so, this can be very useful when deciding how to trade in the stock market.

8.2 Background Information

8.2.1 Financial Market

Efficient Market Hypothesis (EMH) [6] declares that prices reflect all information. Investors cannot trade overvalued or undervalued stocks and select a specific timing to sell or buy stocks. However, many researchers and economists found that stock prices can be predicted to some degree [6]. Xu and Berkely [7] evaluated news by using textual information from social media (e.g., Twitter) and found significant correlations between news articles and stock price movements. There are two types of analysis that help investors to outperform the market. First is a technical analysis which explores trading opportunities and predicts future movements by using historical data, such as past stock trends, trading values, and price patterns. The second method is the fundamental analysis based on economic and financial factors, e.g., macroeconomic indexes (e.g., GDP) and microeconomic information (e.g., company performance).

8.2.2 Sentiment Analysis in Tweets and Stock Market

The stock market is highly dynamic and volatile, but it plays a key role in shaping the global economy. Due to its timely publication, social media such as Twitter has become one of the most important sources of information for decision making whether for investment or speculation on the stock market [3, 8]. Chen [1] discovered that articles and commentaries on social media improve the price discovery process and investors' decision-making. Ruiz [9] found important correlation between stock market movements and social media activities. Bollen [3] explored how public mood can affect investors' decision-making and behaviours.

Popular Twitter accounts can greatly influence the stock market, e.g., newsagents (Reuters), well-known companies (Amazon), and individuals (former US President Donald Trump). Tweets allow users [10] multi-directional interaction with companies and have changed the dynamics and nature of corporate disclosure [11]. Companies and public figures can quickly fill information in a vacuum by using their Tweets before rumours, misinformation, and speculation intensify the crisis. Official information can help investors make smarter decisions. Public sentiments and opinions play an important role in human decision-making [3]. Ranco [12] investigated the relationships between 30 stock companies' Twitter accounts and Dow Jones Industrial Average index and discovered the correlation between Twitter sentiments and abnormal returns.

Sentiment analysis (SA) identifies and categorises the emotion and preference of text. However, sentiment analysing Tweets is more challenging compared with conventional text because of their short length, and because they frequently use informal words and symbols that have rapidly evolved. The lexicon-based SA method uses lexicons that are labelled with sentiment polarities [10] that are created manually and are carefully vetted [10]. Generic lexicons can be taken from SentiWordNet [13], WordNet Affect [14], General Inquirer lexicon [15], or LIWC dictionary but they are not labelled with sentiment values [16]. However, SA with a financial background may improve the accuracy of its sentiment classifications. It is therefore interesting to examine the performance of such a SA tool.

8.3 Methodology

We followed a similar methodology as in our previous work [4]. The first step is to identify highly influential Twitter accounts and interesting time periods where important finance-related events have happened for investigation. Secondly, relevant Tweets and stock price data were collected for this duration. The third step includes pre-processing of collected Tweets and stock price data. This is followed by data cleansing and standardisation. Then the automatically generated sentiments and ground truth values are assigned to each Tweet. Sentiment scores are then normalised for exploring their correlations with stock price movements.

8.3.1 Twitter Data Collection

Tweets were extracted via Twitter's API. For each Tweet, we extracted its main text, author_id, creation_date, Tweet_id, and language_used, for the duration of April 2021. We have selected the top five financially influential Twitter accounts: Reuters (23.8 million followers), Wall Street Journal (19 million), Forbes (17 million), Bloomberg (7.5 million), and Donald Trump (88.7 million—before the account suspension). S&P 500's Index was chosen as the target measure that is a weighted index of the market capitalisation of the 500 largest companies in the USA. It represents the overall trend of the US economy and stock market. Yahoo's finance API (yfinance) provides access to SPX. For each trading day, the opening price, hourly closing price, and closing price of the day have been retrieved as indicators to reflect the stock market movements of the day.

8.3.2 Sentiment Analysis and the Ground Truth

SentiStrength is a lexicon-based sentiment analysis method specialising in extracting sentiments from short text [5]. For each text, it detects the pair of negative and positive sentiment polarities: -1 (not negative) to -5 (extremely negative), and 1 (not positive) to 5 (extremely positive). At the heart of this method is the sentiment lexicon that enables SentiStrength to judge the sentiment values of the processed text. Sentiment lexicon is a list of words or phrases that are assigned with emotive semantic orientations, such as the values above.

We used the original and domain-independent lexicon of SentiStrength as a seed and gave it a financial context by adding financially related words, jargon, idioms, and phrases. We then assigned a sentiment value for each vocabulary and phrase for their potential impact on stock market price movements. These financially important and meaningful terms have been taken from an Investor's Ontology that we built based on vocabularies and concepts as presented in financial articles, dictionaries from industry investor's websites, financial research ontologies, and textbooks.

To judge the performance of the newly enhanced SentiStrength, we have defined a set of principles to generate the ground truth from an investor's point of view:

- The decision should be based solely on the possible influence of the Tweets on the US stock market, and not how an individual investor may decide to trade in the stock market.
- The judgement should be made based on the impact on the overall US stock market, and not for a few specific companies.
- The decision should primarily be focused on shorter term (e.g., within 1–7 days), although impacts of some Tweets may be longlasting.
- Use S&P 500 as an indicator for US stock market trends.
- Dramatic news of very large companies will have a bigger impact (esp. in the short-term) on price movements, e.g., Apple Inc. (AAPL) is weighted 6.2% in SPX, so its breaking news will likely show a visible impact on the stock market—such news often affects its business partners, thereby generating rippling effects that amplify its effects in the stock market in the US or elsewhere.

8.4 Experiments

Based on the stock price data collected via Yahoo Finance, we randomly selected 1000 Tweets from each Bloomberg, WSJ, Reuters, Forbes, and Donald Trump as published in April 2021, resulting in 5000 Tweets in total. We have chosen 1000 Tweets per account, so can get a more balanced view across different accounts—news outlets can have far more Tweets per day. These Tweets are also evenly distributed during the trading hours each day. Each Tweet is assigned with a pair of sentiment scores of negative and positive values (Neg, Pos), using SentiStrength and by ground truth. This pair of values is then converted into a single compound sentiment score, SA: SA = Neg, if |Neg| > |Pos|; SA = Pos, if |Neg| < |Pos|; otherwise, SA = 0 if |Neg| = |Pos| = 1. Our newly devised formula, based on our experiments, is superior to the traditional summation of the pair of SA values, as the values of -1 and $+1$ weaken extreme emotions and the range of resulting compound SA is shrunk to [−4, 4] that removes extreme sentiments of −5 and 5. However, -1 and $+1$ can represent no opinion at all.

We determine the sentiment of the entire day based on all Tweets published that day to generate SA_c using our newly devised formulas 8.1 and 8.2. We first determine the general mood of the day, SA_w, that is a weighted SA score based on all Tweets that have expressed an emotion.

$$\mathrm{SA}_w = \frac{\overline{N}_{pos} * N_1 + \overline{N}_{neg} * N_3}{N - N_2} \tag{8.1}$$

where N_1, N_2, and N_3 are the number of positive, neutral, and negative Tweets published that day. $\overline{N}_{pos}$ and $\overline{N}_{neg}$ are the means of the positive and negative sentimental scores. As a result, SA_c shows the compound sentiment score of the day that is determined by the strength of the weighted SA_w of the day, as described below.

$$SA_c = \begin{cases} if\, SA_w > 0,\ SA_c = \overline{N}_{pos} \\ if\, SA_w < 0,\ SA_c = \overline{N}_{neg} \\ if\, SA_w = 0,\ SA_c = 0 \end{cases} \tag{8.2}$$

The Pearson correlation coefficient (P) was calculated to determine the correlation between the sentiments of Tweets and the stock market price movements. The range is between −1 and 1, where 0 indicates no correlation, 1 indicates a perfect positive linear correlation, and −1 indicates a perfect negative linear correlation.

$$P = \frac{\sum (x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum (x_i - \overline{x})^2 \sum (y_i - \overline{y})^2}} \tag{8.3}$$

where P is Pearson's correlation coefficient, x_i is SA_c scores in the dataset, $\overline{x}$ is the mean of all x_i, y_i is stock prices, and $\overline{y}$ is the mean of all y_i.

8.5 Results

8.5.1 Tweets Sentiment Statistics Analysis

Since the sentiment scores include a pair of negative [−1, −5] and positive [1, 5] values, Fig. 8.1 shows the distributions of the sentiment scores as produced by the SentiStrength and ground truth. Overall, these two methods produced similar results and distributions. Many Tweets are fact-based and therefore evaluated neutral

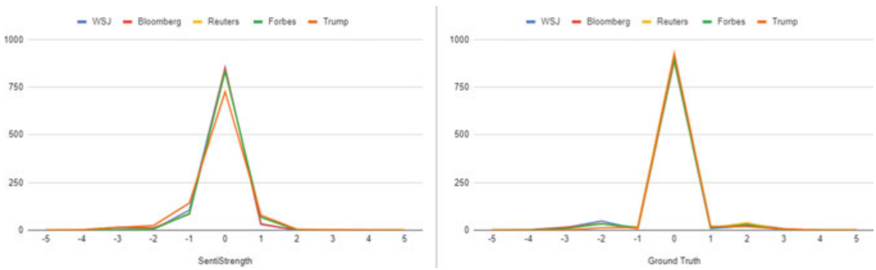


Fig. 8.1 Distributions of compound SA_c scores as generated by SentiStrength (left) and ground truth (right)

sentiments that indicate the attitudes of many (financial) outlets as conservative and do not express positions in their Tweets. However, all Twitter accounts show slightly more negative sentiments. Interestingly, although the account of Donald Trump deploys many positive emotive words, the tool and ground truth, however, have generated more negative sentiments. In addition, many of the "negative" Tweets are judged to be less negative by the tool and the ground truth: the ground truth is also slightly less negative than the tool results. This observation may be explained by the fact that positive emotive words may not necessarily have a positive influence on the stock market if the Tweets include key words/phrases that are perceived to be negative financially. Similarly, negative emotive words may not necessarily generate a negative SA value, if they are not relevant to the financial context, or not having a similar negative impact on the stock market. Overall, Reuters and Forbes exhibit similar sentiments and are more positive than others.

SPX is made available between 9:30 am and 3:30 pm. However, Tweets' publishing time is not limited by this timeframe. To map the effects of Tweets on stock market prices, we have divided a trading day into the following time windows for sampling purposes: 9:30–10:30, 10:31–11:30, 11:31–12:30, 12:31–13:30, 13:31–14:30, 14:31–15:30 (time of closing price), and 15:31–9:29 (9:29 of the next trading day). As a result, we captured the stock market prices at the beginning of a trading day (opening price), the last price at the end of each time window, including the closing price (last price of the day). We also generated the weighted SA_w for all Tweets falling into each of the observed time windows above.

Since the SA_w values and stock prices have different ranges and are therefore not directly comparable, it is necessary for normalisation to place them on the same scale. The min−max normalisation method has therefore been applied to produce the value of N_{diff} for each stock price and SA_w, where N is the variable of concern, and $N_{\min}$ and $N_{\max}$ are the maximum and minimum values in the same time window. The range of N_{diff} is between 1 and 0. Z-score converts a raw value into a normalised value Z by using mean and standard deviations.

$$N_{\text{Diff}} = \frac{N - N_{\min}}{N_{\max} - N_{\min}} (\text{Min} - \text{Maxnormalisation}) \tag{8.4}$$

$$Z = \frac{\text{Value} - \text{Mean}}{\text{Standarddeviation}} (\text{Mean} - \text{SDnormalisation}) \tag{8.5}$$

Table 8.1 shows Pearson correlation coefficients using the normalised N_{diff} of SA_w scores and SPX indices in two trading days' time, as N_{diff} gives a better differentiation. The range of Pearson correlation coefficient can be interpreted as weak

Table 8.1 Pearson correlation coefficient (P) between SA scores and stock market price (in two trading days' time)

	WSJ	Bloomberg	Reuters	Forbes	Trump
S&P 500	0.26	0.33	0.65	0.56	−0.11

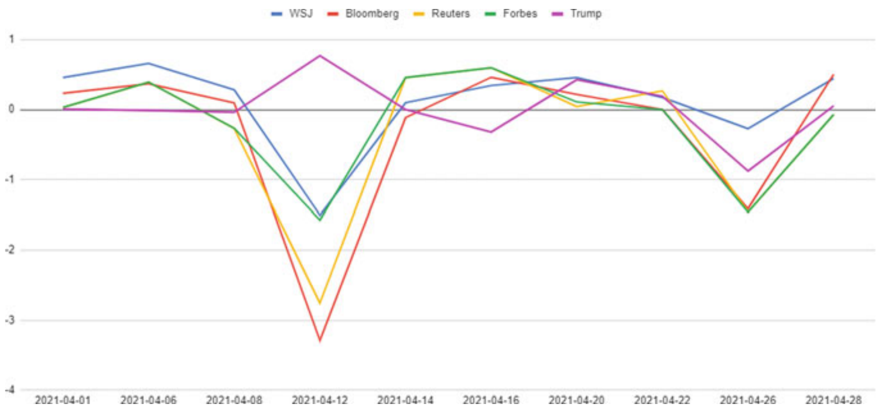


Fig. 8.2 Sentiment distributions of WSJ, Bloomberg, Reuters, Forbes, and Donald Trump

correlation (0.1 < |*P*| < 0.3), moderate correlation (0.3 < |*P*| < 0.5), and strong correlation (|*P*| > 0.5). We can see that all Twitter accounts, except Donald Trump's, have a positive correlation with stock market movements. Reuters and Forbes show relatively strong correlations; Bloomberg shows a moderate one, and WSJ shows a weaker one. Donald Trump's account has a weak and negative correlation with SPX's movements.

In Fig. 8.2, we further compare the normalised sentiments of the top five financially influential accounts. Although Tweets of different accounts contain the opinion of many different investors and analysts, they showed similar opinion trends in the four media outlets (WSJ, Bloomberg, Reuters, and Forbes), except for Donald Trump's account that it sometimes exhibited opposite movements. The strong positive sentiment shown in Donald Trump's Tweets can sometimes link to negative changes in SPX. In fact, when many negative events/news occurred in the stock market, Donald Trump sometimes published opposite positive opinions to encourage investors and stock market. This may explain why the sentiments of Donald Trump's Tweets do not always correspond with that of other news outlets, but may then follow mainstream opinion with one day's delay. In addition, many of Donald Trump's Tweets captured during this time are not directly related to the stock market or finance—as a result, we have decided to exclude Donald's Tweets in our predictive analysis below.

8.5.2 Lagging Effects of Tweets

Increasingly, sentiments of financial related Tweets signal early bullish or bearish trends for stock price movements. It is therefore important to examine these early indicative signals. We analysed the lagging effects of sentiments of Tweets on SPX. According to our analysis, SPX showed a lag of approximately two trading days of impact by the publications of relevant Tweets. In Fig. 8.3, we compared the

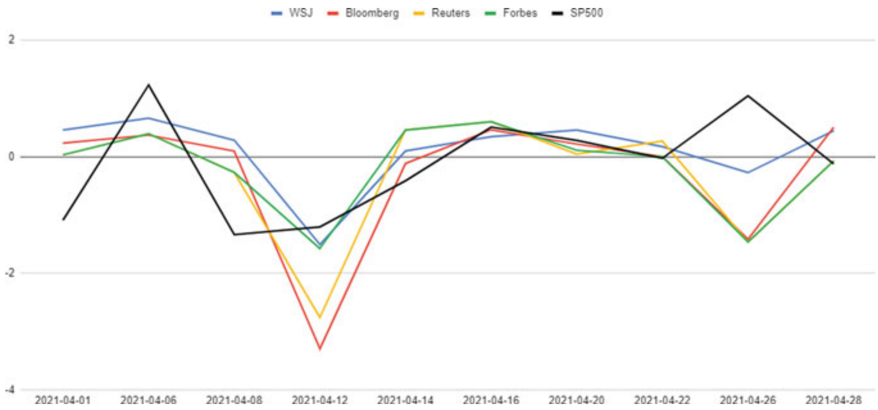


Fig. 8.3 Comparison between sentiments of Twitter accounts and SPX

normalised sentiment values (*Z*-score) of the four financial news outlets (excluding Donald Trump's Tweets) and SPX. *Z*-score is used, as it exhibits a bigger differentiation here. Figure 8.3 shows that a strong dip in commonly shared opinion from news outlets (local minimum) can impact SPX with a (reversed) downward trend in two trading days' time (e.g., 12 and 16 April). Similarly, a commonly shared upbeat opinion (local maximum) can be followed by an upward trend in SPX on two trading days time (e.g., 12 and 16 April). This lagging effect may be explained by the fact that investors need time to digest and process information before making an investment decision. It can also be that information takes time to spread between investors before actions are taken. There are also the "sheep" effects where some investors blindly follow stock market movements.

8.6 Conclusion and Discussion

In this paper, we assessed the impact of financial related Tweets on stock market price movements by using sentiment analysis. We explored the correlation between the opinion of the top five financially influential Twitter accounts and the stock price movements of the S&P 500. All Tweets were collected from Wall Street Journal, Bloomberg, Reuters, Forbes, and the former US President Donald Trump's accounts. The chosen data collection period (1–30 April 2021) is very interesting because many significant events happened during that time: the US–China trade war, crash in stock market (trading curb), and the emergency of Coronavirus. We divided this period into smaller observation time windows (hourly when suitable) to obtain suitable samples for comparison. Within these time windows, we then compared the sentiments as expressed in these Tweets and how they corresponded with SPX's movements.

We use the SA scores as generated by SentiStrength for comparison. The original generic domain-independent sentiment analysis tool, SentiStrength, was enhanced by our set of newly developed financially related lexicon that is underpinned by our Investor's Ontology. This set of lexicons greatly enhances the accuracy of SentiStrength in analysing financially related Tweets. As a result, we found a high level of agreement between the sentiment values as generated by the tool and the ground truth.

In our research, we found the four major news outlets (WSJ, Bloomberg, Reuters, and Forbes) forming similar positive or negative opinions. However, Donald Trump's Tweets sometimes showed opposite opinions. This may be because his Tweets can exhibit political motives that are not consistent with the financial market mood.

We, therefore, compared the sentiments of the above four major news outlets with the movements of SPX. We found a relatively strong and positive correlation between them, especially Bloomberg and Forbes have shown strong correlations. In addition, we found Tweets possessing significant sentiments (i.e., local maximum and minimum) when in agreement with the news outlets, it showed a consistent trend in SPX in two trading days time. However, such impact can sometimes reverse price trends, when the sentiments are extreme, e.g., when many $SA_w > |2|$.

Given the data in the above interesting time period, we found significant correlations between the sentiments in Tweets as published by major news outlets and SPX movements. However, we plan to expand our data set to a smaller granularity or a longer duration to further investigate and determine whether such influences are consistent and whether there is any anomaly. Also, if there is any anomaly, what will they be? Having such further investigation will enhance our understanding of the reliability and predictability of sentiments in Tweets towards stock market movements. We also learned that different news outlets have their own "personalities", i.e., more "conservative" or "positive" than others. However, when we aggregated their opinions to find "significant" opinion spikes, their summated opinions showed consistent predictability towards stock market trends. As not all Donald Trump's Tweets are finance-related, it may therefore be interesting to include other major financial outlets in our research for comparison purposes.

References

1. Chen, H., De, P., Hu, Y.J., Hwang, B.-H.: Wisdom of crowds: the value of stock opinions transmitted through social media. Rev. Financ. Stud. **27**(5), 1367–1403 (2014)
2. Yang, S.Y., Mo, S.Y.K., Zhu, X.: An empirical study of the financial community network on twitter. In: 2014 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr), pp. 55–62. IEEE (2014)
3. Bollen, J., Mao, H., Zeng, X.: Twitter mood predicts the stock market. J. Comput. Sci. **2**(1), 1–8 (2011)
4. Hao, Z., Chen-Burger, Y.-H.J.: Analysing tweets sentiments for investment decisions in the stock market. In: Agents and Multi-Agent Systems: Technologies and Applications 2021, pp. 129–141. Springer (2021)
5. Thelwall, M., Buckley, K., Paltoglou, G.: Sentiment strength detection for the social web. J. Am. Soc. Inform. Sci. Technol. **63**(1), 163–173 (2012)

6. Malkiel, B.G.: The efficient market hypothesis and its critics. J. Econ. Perspect. **17**(1), 59–82 (2003)
7. Xu, S.Y., Berkely, C.: Stock price forecasting using information from Yahoo finance and Google trend. UC Brekley (2014)
8. Yang, S.Y., Mo, S.Y.K., Liu, A.: Twitter financial community sentiment and its predictive relationship to stock market movement. Quant. Financ. **15**(10), 1637–1656 (2015)
9. Ruiz, E.J., Hristidis, V., Castillo, C., Gionis, A., Jaimes, A.: Correlating financial time series with micro-blogging activity. In: Proceedings of the fifth ACM international conference on Web search and data mining, pp. 513–522. 2012
10. Dhaoui, C., Webster, C.M., Tan, L.P.: Social media sentiment analysis: lexicon versus machine learning. J. Consum. Mark. (2017)
11. Lee, L.F., Hutton, A.P., Shu, S.: The role of social media in the capital market: evidence from consumer product recalls. J. Account. Res. **53**(2), 367–404 (2015)
12. Ranco, G., Aleksovski, D., Caldarelli, G., Grčar, M., Mozetič, I.: The effects of Twitter sentiment on stock price returns. PLoS ONE **10**(9), e0138441 (2015)
13. Baccianella, S., Esuli, A., Sebastiani, F.: Sentiwordnet 3.0: an enhanced lexical resource for sentiment analysis and opinion mining. Lrec **2010**(10), 2200–2204 (2010)
14. Strapparava, C., Valitutti, A.: Wordnet affect: an affective extension of wordnet. In: Lrec, vol. 4, 1083–1086 edn, p. 40. Citeseer (2004)
15. Stone, P.J., Dunphy, D.C., Smith, M.S.: The General Inquirer: A Computer Approach to Content Analysis (1966)
16. Pennebaker, J.W., Mehl, M.R., Niederhoffer, K.G.: Psychological aspects of natural language use: our words, our selves. Annu. Rev. Psychol. **54**(1), 547–577 (2003)

Chapter 9
Negotiation-Based Multi-agent System for Ambient Conditions Control in Accordance with Multiple User Preferences

Katarina Mandaric, Pavle Skocir, Gordan Jezic, and Ignac Lovrek

Abstract The Internet of Things has set the foundation for countless innovative solutions, some of which are designed specifically for homes, offices, etc., with the aim to increase user comfort. In order to automatically increase user comfort by saving the user time and energy, the system has to obtain and process information about the conditions in the smart space, and the user's needs and wishes. Context awareness, without which ambient intelligence could not be developed, relies on data collected from connected devices. Ambient intelligence is about meeting users' needs and desires while taking context into account and making instantaneous adjustments to their actions and other context changes. In this paper, we propose a context-aware, user-centric multi-agent system that is able to independently determine ambient settings in a smart space according to the preferences of users present without any user intervention. The main advantage is that it serves more users, i.e., it is not focused on only one user and his preferences, but takes care of all present users and satisfies their wishes and needs regarding ambient conditions while harmonizing their different preferences. To achieve this, a negotiation process between intelligent user agents is proposed and described. The presented model is described on the use case of smart lighting.

K. Mandaric (✉) · P. Skocir · G. Jezic · I. Lovrek
University of Zagreb Faculty of Electrical Engineering and Computing, Internet of Things Laboratory, Unska 3, 10000 Zagreb, Croatia
e-mail: katarina.mandaric@fer.hr

P. Skocir
e-mail: pavle.skocir@fer.hr

G. Jezic
e-mail: gordan.jezic@fer.hr

I. Lovrek
e-mail: ignac.lovrek@fer.hr

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_9

9.1 Introduction

We are witnessing a continuous growth in the number of connected devices. Initially, users were enthusiastic and openly embraced the innovations and opportunities offered by these devices, but due to the heterogeneity of devices, associated applications, etc., it has become tedious for users to have to constantly adjust device settings. As a result, users are now looking for automated solutions where devices adapt to them depending on the conditions at hand.

Many researchers have pointed out that Multi-Agent Systems are a powerful and efficient tool for modeling complex systems, with an emphasis on distributed systems. Savaglio et al. [1] see agent-based computing as an efficient paradigm for modeling, programming, and simulating distributed and dynamic systems. Multi-agent systems offer the ability to handle the complex task of adapting device settings to users' needs and preferences. In this work, we propose a user-centric multi-agent system for service provisioning in an Internet of Things (IoT) Smart Space, focusing on ambient conditions based on user preferences. It has context-aware intelligent agents that can autonomously determine ambient settings that are suitable for the user based on user preferences for relevant conditions without user intervention. Another important focus is on scenarios with multiple users. When more than one user is present in the room, the different user preferences for ambient conditions must be reconciled. Therefore, agents have the ability to negotiate on behalf of their users' interests to find a solution through dialog, i.e., settings that are suitable for all users present.

The rest of this paper is organized as follows: Sect. 9.2 presents an overview of related work. Section 9.3 describes the proposed model of the multi-agent system. Section 9.4 provides a detailed description of the use case and the negotiation process in different scenarios involving changes in context. Section 9.5 concludes the paper and describes the planned future work.

9.2 Related Work

A software agent is a computer program that acts on behalf of its owner, performing complex information and communication tasks in the network, and enables the automated execution and coordination of processes. Intelligent software agents are characterized by autonomy, reactivity, proactivity, and sociability, which include the ability to cooperate, coordinate, and negotiate. In his overview of software agents [2], Nwana highlights three primary attributes of agents, though he does not claim that these attributes are necessary or sufficient: autonomy, learning, and cooperation. The application of intelligent software agents in the IoT domain opens new doors in the development of the IoT.

The implementation of software agents in IoT systems is not a novelty, as the ability to describe complex systems and processes using agents has been known for a long time. Decentralized multi-agent systems are a valuable foundation for the development of decentralized intelligence in distributed systems [3]. Intelligent agents can take on a number of actions that, for example, in a Smart Home, achieve higher customer satisfaction through greater convenience and less customer intervention. Some of these actions may consist of monitoring the user's behavior and preferences in relation to external factors, recognizing the user's preferences, and adjusting the ambient conditions in the home according to the context. This is confirmed by Pico-Valencia and Holgado-Terriza [4] with their assertion that software agents are able to perform autonomous tasks according to specific goals. Behind these actions can be a set of complex technologies such as machine learning, pattern recognition, and artificial intelligence.

For example, agents are used as a tool in modeling ambient-assisted living spaces to provide support in the specific scenarios of this research area, which aims to increase the independence and quality of life of elderly people [5, 6]. Engineering ambient intelligence systems by using agent technology and service-oriented software development was applied by Spanoudakis and Moraitis [7] to develop an ambient-assisted living application for elderly people suffering from cognitive impairment and other diseases such as diabetes, with the aim of improving their lives at home. The integration of intelligent agents has made a significant contribution to the development of ambient intelligence systems. The goal behind developing these systems and providing services is to meet the needs of users in a seamless, unobtrusive, and invisible way, as pointed out by Santofimia et al. [8]. Context awareness is fundamental to the development of ambient intelligence and consequently to the provision of ambient services to the user, so the development of ambient intelligence is impossible without it. For example, context awareness is used in the development of automatic control for energy savings based on recognizing daily activities as well as agentized IoT devices to provide flexible services [9].

Context awareness became a subject of research thirty years ago and Lovrek [10] points out that it is promising and challenging because it affects the functionality, efficiency, and complexity of the system. It has been recognized as a needed and valuable area of research for the IoT [11]. There are many definitions of context, such as that of Dey [12] "*Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.*", while Schilit et al. [13] point out that three important aspects of context are "*where you are, who you are with, and what resources are nearby*."

9.3 Service Provisioning Based on User Preferences

By introducing intelligent context-sensitive software agents, it is possible to achieve intelligent service delivery in IoT systems. The proposed multi-agent system for the IoT addresses the challenge of autonomously determining ambient settings based

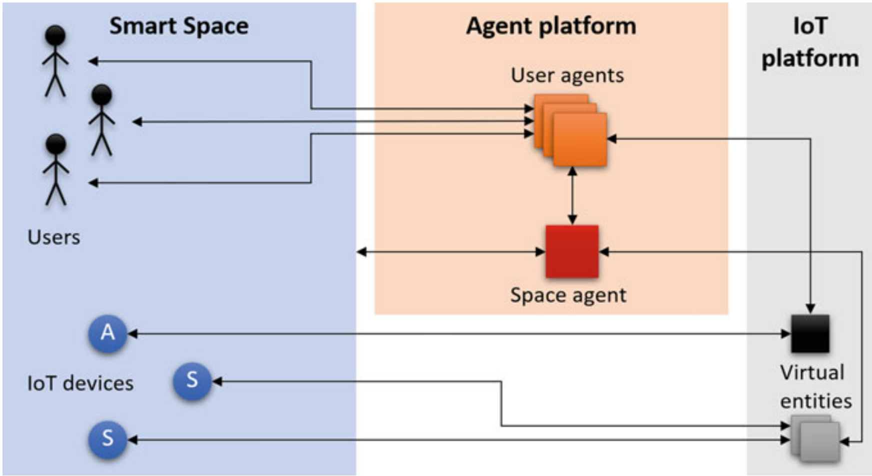


Fig. 9.1 System overview

on user preferences for relevant conditions, i.e., context, without user intervention. The relevant context for this system is divided into two parts—one related closely to the user (his preferences, flexibility factor...) and the other is related to the physical environment (conditions, devices...). The set of relevant conditions, i.e., context is marked as $C = (c_1, c_2, \ldots, c_i, \ldots,$ and $c_n)$, where c_i denotes a specific component of the context.

As shown in Fig. 9.1, the smart space is equipped with sensors (S) and actuators (A) accessible through an IoT platform. Each space has its own space agent that monitors the number of users in the space and other factors that are part of the context. The space agent is responsible for monitoring the context and reporting its state and changes to the user agents of the users present, and in some scenarios, it negotiates with certain user agents. Each user is represented by its own user agent u_agent_j. The multi-agent system has two agent types, the space agent s_agent and user agents u_agent_n: $A = (s\_agent, u\_agent_1, u\_agent_2, \ldots, u\_agent_j, \ldots, u\_agent_n$, where the number of user agents is determined by the number of present users in the smart space. Each user agent is equipped with an Artificial Neural Network (ANN) that predicts the user's ambient preferences for unseen conditions based on previous preferences defined by the user for certain conditions. The inputs of the ANN are relevant conditions in the physical space sensed by sensors and time, while the outputs are settings for devices that change the ambient conditions, i.e., while training, the user's preferred settings. For example, for a smart lighting system, the inputs would be the luminosity sensor reading and time of day and the outputs are lighting intensity and lighting color. For the application example presented in the following chapter, users were asked to define in advance up to ten preferences on which their ANN was trained to predict their preferences. Users can define new preferences, modify existing ones, or delete them.

When only one user is present, the settings will be set according to his preferences only. However, when more than one user is present in the space, the agents negotiate vicariously for the interests of their users to find a solution through dialogue, i.e., settings that satisfy all users present. It is necessary to limit the number of negotiation rounds because in some specific cases an agreement is unattainable between user agents. The details of the negotiation process and the definition of the necessary limitations are described in Chap. 4.

The negotiation process is based on the Zeuthen strategy [14], which is based on the willingness to risk conflict. The smaller the difference in utility between the agent's own proposal and the proposal of another agent causing the conflict, the more willing the agent is to risk the conflict. The risk is influenced by the user's flexibility factor, i.e., the extent to which they are willing to compromise and deviate from their own preferences. For example, a user is willing to deviate from his ideal temperature setting by 1 or 2 degrees Celsius. If the user has a high flexibility factor, the user agent will be more likely than not to have a low risk of conflict. On the other hand, if the flexibility factor is low, the user agent will have a high risk of conflict. Accordingly, the agent that loses the least in the event of a conflict will concede in the negotiation.

9.4 Use Case

The proposed system can be used for many purposes, some of which are: Smart Home, Smart Office, Smart Zoo, and Smart Greenhouse. In the Smart Zoo use case, the users are animals, and in the Smart Greenhouse, the users are plants. Additional steps and devices are required to implement these two use cases.

The system and the negotiation process are described in more detail using a Smart Office example that focuses on lighting. The relevant information, i.e., contexts for this system are the time of day, brightness sensor data, and present users' preferences. The 24 h of a day are divided into time periods for ease of use. The time periods are defined to best cover and describe the periods of the day when natural light changes the most. The division also took into account the differences in natural lighting, i.e., the timing of sunrise and sunset, in the different seasons. The brightness sensor data is also divided into groups, so the change of only 1 lux would not trigger a recalculation of preferences and the negotiation process because it is not profitable for such a small change imperceptible to the user.

The input of the ANN, which each user agent has for its user to determine their preferences, is the time of day and the brightness group, and the output is the light intensity and color, i.e. in training the user's preference for device settings. The user agent represents its user's preferences in negotiations with the user agents of the other users present. In addition to user preferences, in the negotiation process, the agents also have information about the flexibility of the users which will be explained below in more detail on specific scenarios.

In the experimental setup for this use case, three Philips Hue LED white and colored light bulbs were used for artificial lighting in the Smart Office. The luminosity sensor was connected to a Waspmote device that transmitted data to a Raspberry Pi device. The users enter the office by unlocking a Smart Lock via their ID card. The data was available through the openHAB platform. The agents were developed as Spring microservices [15].

9.4.1 Sensor Data Changed

Users' personal preferences are defined with respect to the sensor data read in the Smart Space. Therefore, each user agent must repeat the calculation of preferences after a change in sensor data or time of day. As explained above, this doesn't happen for the change of 1 min or 1 lux, as for the user there is no tangible difference. It occurs after a major change, i.e., a change in time and brightness between the defined time of day or brightness groups. In that case, the space agent sends the information about the changed conditions to the user agents as soon as it learns about the change. From this, it is obvious that the space agent must constantly keep track of the context, i.e., the sensor readings relevant to the context.

Once the preference computation is complete, the coordinating user agent, in the example shown in Fig. 9.2 that is User 1 Agent, initiates negotiations with the goal of achieving common ambient settings that are suitable for all users by calling each user agent in the space and requesting their preference computations based on all user preferences. The coordinating user agent is the one with the longest stay in the room, but any user agent is capable of taking on this duty. After the coordinating user agent requests its proposal, the it asks all other user agents for their preferences and flexibility factor. The request contains the coordinating user agent's preferences (his initial proposal) and flexibility factor, so the user agent whose proposal was requested does not need to request them from it. According to the Zeuthen strategy, in the first round of negotiation, each user agent will propose values that maximize its own utility function, i.e., its proposal returned to the coordinating user agent will be its preference, regardless of the other users' preferences. After receiving all the proposals from the other user agents, the coordinating user agent compares the collected proposals, including its own proposal. Based on the comparison, the coordinating user agent decides whether a new round of negotiation is required. Figure 9.2 shows a scenario where three users are present and their agents agree on the proposal in the first round.

If only one of the user Agents in this round disagrees with the proposed value, a new round begins. As in the first round, the coordinating user agent requests proposals from the other user agents, but now the other user agents will not request the preferences that maximize their utility function from their peers, i.e., their first "selfish" proposal. They will request their computed proposal taking into account the other users' proposals from the previous negotiation round. After receiving the proposals from all the other user agents, the agent will compute its own proposal and its own risk that a conflict will arise, as well as the other agents' risk that a conflict will arise.

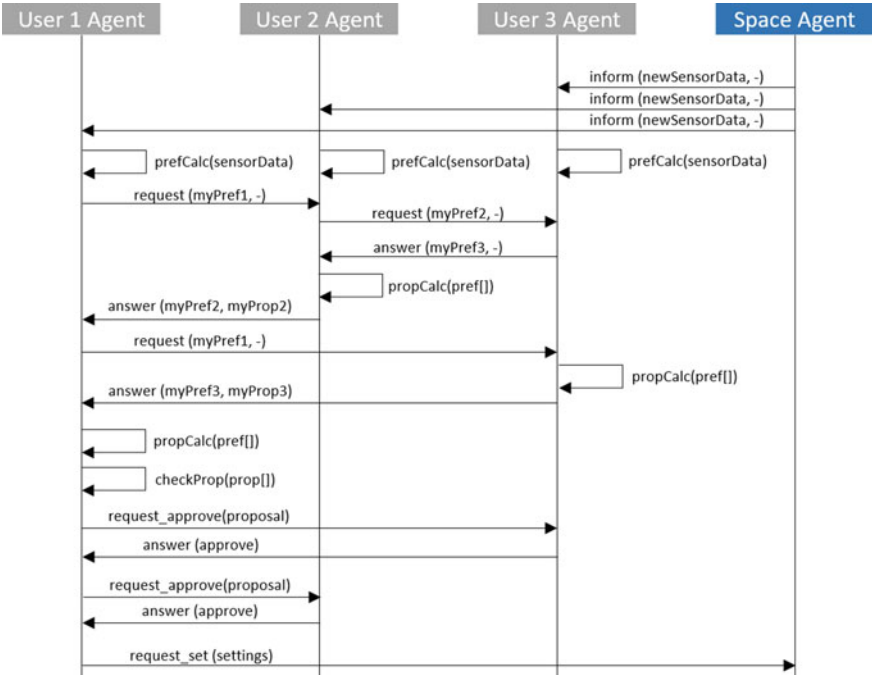


Fig. 9.2 Scenario: sensor data changed

Negotiations continue for as many rounds as needed until all agents agree on the proposed settings. However, since this can be endless, the maximum number of rounds is determined by the number of users present and the nature of the objective of the negotiation. The number of rounds isn't only complicated by the number of users but also by the difference in user preferences. Two agents usually need two or three rounds to reach an agreement, while three agents need three to five rounds and four agents even ten rounds. It is important to note that the more users, especially if they have very different preferences, the group decision will tend to be more and more neutral, i.e., in terms of light, this would mean that the light color is white and the intensity is inversely proportional to the intensity of the outdoor light. If the user agents do not reach a conclusion in the specified number of rounds, the space agent takes over the calculation of settings for the users present based on their preferences. The multiple-user calculation model of the space agent has already been used and described in our previous works [16].

Fig. 9.3 Scenario: new user entering space

9.4.2 New User Entering Space

When a new user enters the smart space, the ambient settings must be adjusted to accommodate the preferences of this new user. After the user enters the room by registering with the space agent, the new user agent receives a message from the space agent containing the context information of the space and the current settings, as shown in Fig. 9.3. In order to minimize the negotiation faze between user agents, the space agent negotiates with the newcomer User agent. This negotiation is shortly delayed as there is a possibility that the user entered the room for just a very short period of time. First, he checks if the current settings suit him, that is why the space agent sends the current settings. After receiving the sensor data and current settings, the newcomer User agent will predict his preferred settings for the current sensor data which will be then compared to the current settings. If the current settings please the newcomer User agent, he will answer with approval as shown in Fig. 9.3. This is possible, for example, when the new user has a high flexibility factor. If the current settings are declined, the space agent will negotiate with the newcomer User agent, but if there is no agreement, the space agent will send the information of a new present user in the Smart Office to the other user agents, and the coordinating user agent will start the process of the negotiation as described above for the sensor change. The only difference is that, unlike the newcomer's agent who has to predict his user's preference, the already previously present user agents do not have to do so because nothing has changed that affects the users' personal preference.

If the space is empty and a user enters, his user agent takes on the duty of coordinating user agent until he leaves. He will perform the duty of the coordinator until he leaves the room.

9.4.3 User Leaving Space

When a user leaves smart space, the user agent notifies the space agent. Upon receiving the information the space agent delays the notification of other user agents as more often than less, users leave the room for just a very short period of time. After

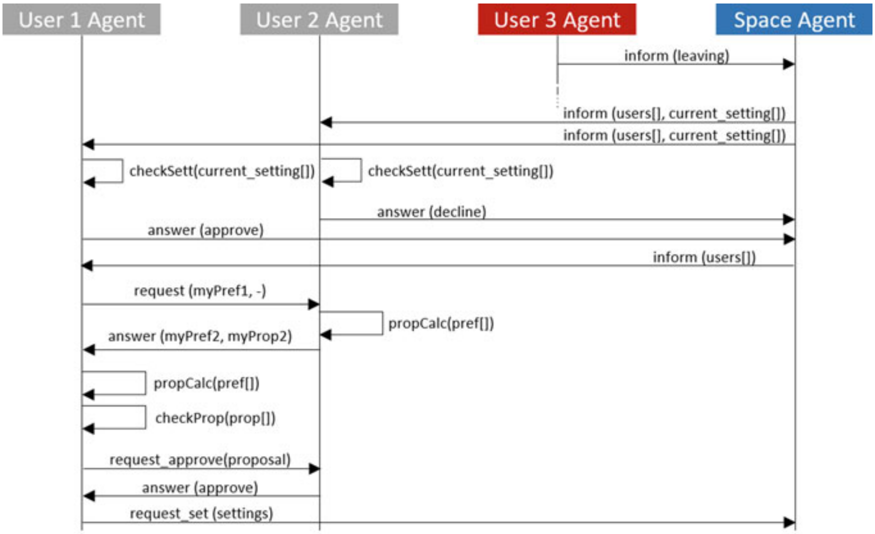


Fig. 9.4 Scenario: user leaving space

waiting, the space agent notifies the remaining user agents of the change and questions their willingness to keep the current settings unchanged. If all user agents don't agree, as in the case shown in Fig. 9.4, the space agent notifies the coordinating user agent. After the notification is received, the coordinating user agent then starts the negotiation process again with the new context information. The negotiation process is the same as described previously. If the agent leaving is the coordinating user agent, the coordination duties will fall on the user agent that has had the second longest stay in the room. The information of this coordination change is shared with all user agents by the space agent. If only one user agent is present, he is the coordinating user agent.

9.5 Conclusion and Future Work

This paper proposes a context-aware multi-agent system that provides services to users based on their previously recorded preferences. The system is characterized by the negotiation of user agents to meet the preferences of users, even when not only one but also several of them are present in the smart space. Each user agent is committed to ensuring that the ambient settings match their user's preferences, with some variation possible depending on the flexibility factor set by the user. The system described is sensitive to and adapts to changes in context, which in this example are time of day, sensory readings, and users present.

As for future work, the goal is to optimize the system with respect to the number of users and the differences in their preferences by grouping users with similar preferences to make an independent decision that is used in further negotiations with another group of user agents with different preferences. In such negotiations, the number of users plays an important role in the final decision about the ambient settings. Such a solution would potentially lead to a shorter negotiation process with results that more accurately suit the users.

Acknowledgements This work has been supported by Croatian Science Foundation under the project 1986 (IoT4us: Human-centric smart services in interoperable and decentralized IoT environments).

References

1. Savaglio, C., Fortino, G., Ganzha, M., Paprzycki, M., Bădică, C., Ivanović, M.: Agent-Based computing in the internet of things: a survey. In: Intelligent Distributed Computing XI, pp. 307–320. Springer International Publishing (2018)
2. Nwana, H.S.: Software agents: an overview. Knowl. Eng. Rev. **11**(3), 205–244 (1996)
3. Singh, M.P., Chopra, A.K.: The internet of things and multiagent systems: decentralized intelligence in distributed computing. In: 2017 IEEE 37th International Conference on Distributed Computing Systems (ICDCS), pp. 1738–1747 (2017)
4. Pico-Valencia, P., Holgado-Terriza, J.A.: Agentification of the internet of things: a systematic literature review. Int. J. Distrib. Sens. Netw. 14(10) (2018)
5. McNaull, J., Augusto, J.C., Mulvenna, M., McCullagh, P.: Multi-agent interactions for ambient assisted living. In: 2011 Seventh International Conference on Intelligent Environments, pp. 310–313 (2011)
6. Mowafey, S., Gardner, S.: Towards Ambient intelligence in assisted living: the creation of an intelligent home care. In: 2013 Science and Information Conference, pp. 51–60 (2013)
7. Spanoudakis, N., Moraitis, P.: Engineering ambient intelligence systems using agent technology. IEEE Intell. Syst. **30**(3), 60–67 (2015)
8. Santofimia, M.J., Moya, F., Villanueva, F.J., Villa, D., Lopez, J.C.: Integration of intelligent agents supporting automatic service composition in ambient intelligence. In: 2008 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology, vol. 2, pp. 504–507 (2008)
9. Lu, C.H.: IoT-enabled adaptive context-aware and playful cyber-physical system for everyday energy savings. IEEE Trans. Hum.-Mach. Syst. **48**(4), 380–391 (2018)
10. Lovrek, I.: Context awareness in mobile software agent network. RAD Croat. Acad. Sci. Arts **513**, 7–28 (2012)
11. Perera, C., Zaslavsky, A., Christen, P., Georgakopoulos, D.: Context aware computing for the internet of things: a survey. IEEE Commun. Surv. Tutor. **16**(1), 414–454 (2014)
12. Dey, A.: Understanding and using context. Pers. Ubiquitous Comput. **5**, 4–7 (2001)
13. Schilit, B., Adams, N., Want, R.: Context-aware computing applications. In: 1994 First Workshop on Mobile Computing Systems and Applications, pp. 85–90 (1994)
14. Wooldridge, M.: An Introduction to Multiagent Systems, 2 edn. Wiley, New York (2009)

15. Krivic, P., Skocir, P., Kusek, M., Jezic, G.: Microservices as agents in IoT systems. In: Jezic, G., Kusek, M., Chen-Burger, Y.H.J., Howlett, R.J., Jain, L.C. (eds.) Agent and Multi-Agent Systems: Technology and Applications, pp. 22–31. Springer International Publishing, Cham (2017)
16. Mandaric, K., Skocir, P., Jezic, G.: Agent-based approach for user-centric smart environments. In: Jezic, G., Chen-Burger, J., Kusek, M., Sperka, R., Howlett, R.J., Jain, L.C. (eds.) Agents and Multi-Agent Systems: Technologies and Applications 2020, pp. 37–46. Springer, Singapore (2020)

Part II
Business Economics and Agent-based Modelling

Chapter 10
Altruistic Behavior Structural Holes and Team Performance

Kazumasa Ninomiya and Setsuya Kurahashi

Abstract In companies, individual optimization of organizations, silos, isolation of individuals, and division of organizations often become issues. In this study, we quantitatively grasp connections between people from data of a company's transmission and reception logs through evaluation points with the theme of "thanks". We also verified the relationship with the team's performance to examine how altruistic behavior fills the division between organizations. The analysis results showed that brokers who fill structural gaps have an important influence on team performance. And the more broker younger than the average age of the team have connections with key players of other teams, which have the higher the team performance. This study proposed an innovative way to diagnose the state of the organization by analyzing the log data of the company's evaluation points to the management of the divided organization.

10.1 Introduction

Japanese companies have promoted measures such as standardization and modularization of work accompanying the use of ICT, a review of the lifetime employment system, measures to establish employment adjustment valves such as switching routine work from regular employees to non-regular employees, and a performance-based personnel system, which has created various organizations. On the other hand, these organizations have been individually optimized and siled, and the isolation of individuals and the division of organizations have often been brought up as issues. The division of them likely reduces the inheritance of know-how, long-term human resource development, organizational unity, fostering trust and norms, and overall organizational strength by respecting harmony, which was the strength of traditional Japanese organizations [1].

K. Ninomiya (✉) · S. Kurahashi
University of Tsukuba, Tokyo, Japan
e-mail: ninomiya.kazumasa.lw@alumni.tsukuba.ac.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_10

In this study, we focus on social capital formed by altruistic behavior and connections between people and quantify what kind of work style should be practiced in order to improve team performance using social network analysis. It also provides suggestions for solutions to organizational divisions and individual optimization, which are often problems in the promotion of innovation and digital transformation, as well as human resource evaluation and human resource development for transformation.

10.2 Social Network Analysis and Altruistic Behavior

10.2.1 Social Network Analysis

Social network analysis quantitatively measures the relationship between social actors and actors, and from the characteristics captured as numerical values, inter-company relationships, inter-organizational relationships such as corporate groups, in-house human networks, knowledge networks, etc. It is an approach to analyze the management phenomenon in the above and is deeply rooted in business administration [2]. For example, Reagans et al. Investigated the productivity of design work teams and registered them as individual contacts rather than individual demographic attributes (gender, skin color, academic background, lifelong employment status). It was clarified that the list that was given, who was assigned to which project, and the human network were more strongly related to the productivity of the team [3]. In addition, in social network analysis, the assertion of openness that social relationships and their networks should be dense [4] and the linkage with groups with heterogeneous sources in order to search for useful information. There is an openness claim [5] that should make it possible, and many empirical analyzes of economic merits have been accumulated.

10.2.2 Altruistic Behavior

Takahashi and Yamagishi [6] clarified by analysis using simulation that it is ultimately more profitable to behave altruistically to others. He also argues that it is important to create a social environment in which it is more profitable to act in consideration of the overall interests than to pursue only one's own interests. In other cases, using questionnaires, from the perspective of the knowledge creation process, companies with abundant social capital supported by social norms of trust and reciprocity have higher performance [7, 8]. Although there are many cases, cases that have been quantitatively demonstrated from the records of specific altruistic behavior are rare.

10.2.3 Summary of Previous Research

Based on this, in this study, we will examine the effect of person-to-person connections on the performance of the entire team, targeting networks within the organization. In addition, we use evaluation points transmission/reception data with the theme of "gratitude" as data for analyzing the internal network. In this way, we examine the effect of the network formed by trust and reciprocity on the performance from the record of concrete altruistic behavior.

10.3 Research Methods and Data Collection

10.3.1 Analytical Data

This research is an organization consisting of 1 group of "(1) Business Headquarters" in the first level, 7 groups of "(2) Business Department" in the second level, and 50 groups of "(3) Team" in the third level, for A total of 626 people data is used.

For altruistic behavior, we use evaluation points data with the theme of gratitude. The outline is shown in Fig. 10.1. This is data that can be obtained from a mechanism where, for example, when Mr. A sends a message "Thank you for preparing the presentation materials" from the application, points are given to Mr. B, and when a certain number of points are accumulated, they can be exchanged for prizes. The implementation period is 56 days, the maximum number of sheets that can be sent per person is 20, and the target of gratitude is limited to the content related to the work.

Fig. 10.1 Overview of sending and receiving gratitude in evaluation points

10.3.2 Analytical Method

In this study, we proceed with the analysis using the following network indicators.

Eigenvector centrality. The eigenvector centrality EC_i of node i is the sum of all the centralities x_i of node j that has an edge with respect to i. A_{ij} is an element of the adjacency matrix and returns 1 only when there is an edge from i to j. In this research, the more we receive gratitude from people who often send and receive gratitude to people other than ourselves, the higher EC_i is.

$$EC_i = \sum_j A_{ij} x_j \tag{10.1}$$

Degree centrality. The degree centrality DC_i of node i. is normalized by dividing the degree k_i of node i by the number of edges $n-1$ that can be applied to all nodes other than itself, which is the maximum value of k_i.

$$DC_i = \frac{k_i}{n-1} \tag{10.2}$$

Network constraint. It is an index showing the lack of structural voids and the degree of constraint C_{ij} for node j of node i is expressed by the following equation.

$$C_{ij} = (P_{ij} + \sum_q P_{iq} P_{qj})^2, i \neq q \neq j \tag{10.3}$$

P_{ij} represents how much time and energy i has is invested in the relationship with j. Also, $\sum_q P_{iq} P_{qj}$ shows how many structural voids do not exist in a tripartite relationship with one other member q between i and j, and there are few voids around j. Then, it becomes difficult to rely on other players to avoid the request from i, and as a result, he is bound by j [9].

In this study, the lower this value is, the more access to structural voids is, and it plays a role in bridging the separated networks with high heterogeneity that do not overlap with each other.

10.4 Results

10.4.1 Network Visualization

The entire network has 626 nodes and 127 components. Figure 10.2 shows a directed graph that visualizes the networks of the A1, B1, and F1 teams. It can be seen that the yellow F1 team is an organization with a long distance between nodes and a strong tendency to be open compared to the other two teams. In addition, the size of

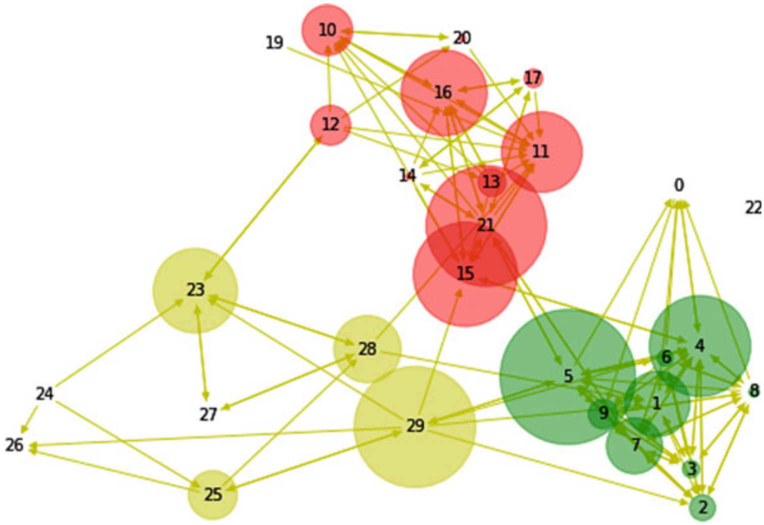


Fig. 10.2 Directed graph of A1 team, B1 team, F1 team

the node indicates the degree of restraint and the number of access to the structural voids. Node 29 located at the end of the yellow F1 team is the green A1 team, and node 23 is the red. It can be seen that it connects with the B1 team and plays the role of a bridge.

10.4.2 Analytical Model

In order to clarify the network indicators that affect team performance, select one person with the least degree of restraint in each team, that is, a bridging person who connects highly heterogeneous components, and determine the centrality of that person. We tried to analyze it with a model that uses explanatory variables as representative values of the team. By doing this, we think that it will be possible to clarify what kind of network structure the bridging human resources such as node 29 of the F1 team should form to improve the team performance.

Since the analysis has many explanatory variables for network indicators. The model and variables were automatically selected using Lasso regression. Lasso regression is one of the frameworks called the regularization method to avoid overfitting, and it is possible to select a sparse model in which the regression coefficient of the explanatory variable that does not contribute to the objective variable is increased by 0.

Table 10.1 Partial regression coefficient when team performance is used as the objective variable and the network index of bridging human resources is used as the explanatory variable

Explanatory variable	Coefficient
In Degree (③ Team)	0.058
Degree centrality (③ Team)	0.017
Eigenvector centrality (① Headquarters)	−0.046
Betweenness centrality (① Headquarters)	−0.024
Degree centrality (② Division)	−0.044
Eigenvector centrality (② Division)	0.065
Sales amount (2019 + 2020)	−0.031
Age of bridger	−0.034
Regularization parameters	0.013
Coefficient of determination	0.33

10.4.3 Impact on Team Performance

Table 10.1 shows the results. Among the variables that affect team performance, the variables that have a positive effect are (2) the eigenvector centrality (0.065) of the business unit network, followed by (3) the degree of the team network (0.058). Those with a negative impact are (1) the eigenvector centrality (−0.046) of the business headquarters network is the highest. It can also be seen that the younger the age of the bridging personnel than the average age in the team, the higher the performance (−0.034).

10.5 Discussion

10.5.1 Impact of Network Indicators

Table 10.2 summarizes the results of the Lasso regression when the network index of bridging human resources is used as an explanatory variable.

First, pay attention to the fact that the age of the bridging personnel, the degree of centrality within the team, and the degree of entry affect the improvement of team performance. Successful networks, regardless of the reason for success, are stronger and more stable [10], but strong ties formed by trust and norms are “insensitive to new ideas” and “narrow the horizons”. Negative aspects are also pointed out [11]. Therefore, rather than relying on networks formed by past successful experiences, it is positive for young personnel to gain new connections through access to structural voids in terms of interaction and knowledge organization and utilization. In an organization with high team performance, young bridging personnel are considered to be grateful for providing new and useful information to the team in order to give a “shock” [12].

Table 10.2 Indicators that affect team performance

Network hierarchy	Indicators that affect performance
① Headquarters Network	• Eigenvector centrality (negative effect) • Between centrality (negative impact)
② Division network	• Eigenvector centrality (positive effect) • Degree centrality (negative impact)
③ Team network	• In Degree (positive effect) • Degree centrality (positive influence) • Age of bridger (negative impact)

Next, we will focus on (2) the eigenvector centrality and degree centrality of the business division, focusing on the person to whom the bridging human resources are grateful and the object that has performed altruistic behavior. High eigenvector centrality represents a connection with a node with a high order, and in this research, it can be expressed as a connection with key people of other teams within the same division, whose work contents are relatively close. Considering from the viewpoint of selection criteria, who is altruistic and grateful to whom with limited resources, the bridging personnel are directly connected to the key man who is sending and receiving gratitude to many people. It can be said that it has the characteristic that it does not directly connect with a person who has not received gratitude from anyone.

This book is because it is said that a person who uses whether the other person is as altruistic as himself or herself as a selection criterion when performing altruistic behavior will benefit more than a person who does not [6]. The study supports the results of the simulations of previous studies and suggests the importance of direct connection with altruistic individuals in access to structural voids.

Also, from the perspective of organizational norms, the fact that a person who acts selfishly is not subject to altruistic behavior can be regarded as a euphemistic punishment. This supports the content of previous studies that meta-normative behavior promotes voluntary mutual cooperation [13], and what relatively young people in the team are doing is only for themselves within the team. It is also considered that the norms that emphasize contribution to the entire organization, rather than considering profits, are deeply infiltrated.

10.5.2 Validity of Evaluation Points Data

Next, we consider the effectiveness of social network analysis using evaluation points. So far, many studies have been conducted using questionnaires [14] and mail logs [15] to acquire data by social network analysis. Since the questionnaire is data for consciousness, not the behavior itself, in order to look back on the behavior and answer, in addition, as it is called “behavioral irrationality” in behavioral economics, human beings do it themselves. Since it is not possible to rationally explain the behavior that was performed later [16], the behavior that was not actually performed may be answered in the questionnaire. In addition, the mail log is used for analysis aimed at removing noise, whether it is because they are on good terms because they are in a fight, or because there are only a lot of information sharing mails when the number of transmissions and receptions is large. There are some aspects that need to be devised, and in addition, multiple names can be entered in the destination and CC, so when expressed on a network, one case is 1 without considering the weight of the actually existing destinations. It may be measured as the edge of a book. On the other hand, in the evaluation points that send gratitude on a one-to-one basis, the content and weight are uniform, and since the daily gratitude is sent obediently, the recipient is aware of the value provided that he was not aware of. It is considered to be useful data in that it is possible to obtain added value of a certain size or more, including unconscious behavior.

The evaluation point of this research is the Web system. Conventional ICT has played a major role in supporting cohesive connections [1], but the evaluation points system used in this research has elements as a “place” for activating communication and fostering altruistic norms. It is considered that it has shown the possibility of being used as a tissue condition diagnosis tool.

10.5.3 Utilization for Organizational Management

As mentioned above, the suggestion for improving team performance is shown by the network index of altruistic behavior calculated from the transmission/reception log of the evaluation points. The purpose of this study was to obtain suggestions for management to obtain great performance as an organization as a whole by connecting experts, diversifying organizations, and individual divisions.

An important suggestion in this study is that by using log data of evaluation points with the theme of altruistic behavior, who is the bridging personnel of the own team, who is the key man of the next business division, and in real time the organization’s It is possible to diagnose the condition. The importance of structural voids in innovation has been studied extensively, but heterogeneity does not always lead to the recombination of new knowledge, reorganization of network configurations is the source of innovation, and companies are networks. As it is said that management functions should be developed regularly [17], it is important for organizational management to first visualize the state of one’s own organization and set specific KPIs and actions. In addition, the experience of constructing a network with abundant access to structural voids is said to behave beyond the role of individual optimization by constructing a similar network even when it becomes another role [18]. Therefore, entrusting the role of bridging to young human resources is considered to be an important arrangement from the viewpoint of human resource development in addition to improving team performance.

10.6 Conclusion

10.6.1 Conclusion of This Study

The results of the analysis revealed the factors that improve the performance of the team. It is that relatively inexperienced people in the team act as a bridge, connect with many key people on other teams that are relatively close to work, and receive appreciation from many on their team. It was also found that using the log data of the evaluation points with the theme of "gratitude" can provide a lot of information that gives suggestions for improving the performance of the organization.

10.6.2 Academic Value/Practical Value

Until now, research that analyzed quantitative financial indicators such as sales from the network structure within the organization has been limited. It has also been argued that altruistic behavior affects organizational performance by increasing work satisfaction and commitment to the organization. A study that analyzes the effect of specific altruistic behavior data on performance. Was limited. This study is new for altruistic behavior and social network analysis by obtaining results that improve team performance from the network structure calculated using log data of altruistic behavior through a mechanism that supports previous research. I was able to make an academic contribution. In addition, it is practical that we obtained useful suggestions for organizational management such as human resource development, evaluation, and allocation by network analysis using evaluation points data with the theme of gratitude, which has been introduced once in many companies. I think it is a contribution.

10.6.3 Challenges and Future Prospects

The issue of this research is that the preliminary examination of the data acquired from the evaluation points is insufficient. Specifically, the maximum number of transmissions and receptions should be abolished, something should be added in addition to "gratitude" in the transmission category, the points that can be sent at one time should be given a range, and the strength of the ties should be considered. A wide variety of studies can be considered, such as opening up to stakeholders instead. In particular, since the subject of this research is narrowed down to the content related to business, the verification focuses on the information on the official network. By extending the operational rules to informal behavior, it may be possible to clarify the relationship with performance in a more multifaceted manner by formal and informal multi-network analysis.

Another issue is the lack of consideration of the development and qualifications of bridging human resources. In this study, we showed the importance of not only forming new connections but also converting them into useful information for team members and practicing gratitude-worthy actions. However, this is not something that anyone can do, and it is necessary to clarify what qualities and training are needed.

In order to capture the innovation created by structural voids, it is necessary to continue to collect medium- to long-term performance data, but this is not easy. Therefore, it is considered necessary to have a social simulation that models the data obtained from the above-mentioned various studies and the changes in the external environment and internal environment.

References

1. Itoda, H., Shozugawa, Y., Miyoshi, H.: Introduction to corporate social capital research for sustainable innovation. Doshisha University Technology, Corporate and International Competitiveness Center (ITEC). Work. Pap. Ser. **11**(3), 138–142 (2011)
2. Kanamitsu, J.: Social network theory. Kyoto Manage. Rev. **32**, 1–21 (2018)
3. Reagans, R., Zuckerman, E., McEvily, B.: How to make the team: social networks vs. demography as criteria for designing effective teams. Adm. Sci. Q. **4**(1), 101–133 (2004)
4. Coleman, J.S.: Social capital in the creation of human capital. Am. J. Sociol. **94**, 95–120 (1988)
5. Burt, R.S.: The network structure of social capital. Res. Organ. Behav. **22**, 345–423 (2000)
6. Takahashi, N., Yamagishi, T.: Social relational basis of altruistic behavior. Exp. Soc. Psychol. Res. **36**, 1–11 (1996)
7. Leana, C.R., van Buren, I.I.I., H.J.: Organizational social capital and employment practices. Acad. Manag. Rev. **24**(3), 538–555 (1999)
8. Yasuda, Y., Wakabayashi, T.: Analysis of network data using Pajek. Proc. Soc. Organ. **1**(2), 155–167 (2012)
9. Opper, S., Burt, R.S., Holm, H.J.: Social network and cooperation with strangers. Acad. Manag. **2018**(1), 10101 (2018)
10. Cohen, D., Prusak, L.: In good company: how social capital makes organizations work, p. 214. Harvard Business School Press (2001)
11. Soda, G.B., Mannucci, P.V., Burt, R.S.: Networks, creativity, and time: staying creative through brokerage and network rejuvenation. Acad. Manag. **64**(4), 62 (2021)
12. Axelrod, R.: An evolutionary approach to norms. Am. Polit. Sci. Rev. **80**(4), 1095–1111 (1986)
13. Yasuda, Y.: Young people's intention to change jobs and human relationships in the workplace-preventing bosses and workplaces from leaving/changing jobs. Res. Bull. Work. Rev. **3**(3), 1–14 (2008)
14. Haraoka, K.: A method of organizational innovation-by email log analysis. Dev. Eng. **38**(1), 13–16 (2018)
15. Kawanishi, S.: Illustrated behavioral economics: how to interact with "irrational behavior", p. 263. Shuwa System (2010)

16. Mariotti, F., Haider, S.: Managing institutional diversity and structural holes: Network configurations for recombinant innovation. Technol. Forecast. Soc. Chang. 160-C (2020)
17. Burt, R.S.: Network-related personality and the agency question: multirole evidence from a virtual world. Am. J. Sociol. **118**(3), 543–591 (2012)

Chapter 11
Construction of a News Classification System Related to Information Security Incidents

Jiansen Zhao and Hiroshi Takahashi

Abstract In this study, based on previous studies on the impact of news related to information security incidents on stock prices, we attempted to extract news related to information security incidents by using sentence similarity calculation in BERT. The stock price fluctuations of the sample news and the extracted news were also measured by event study and compared to verify the effectiveness of the classification model. As a result, the news data with a similarity of about 85% approximates the results of event studies in previous studies. The potential of the classification system was demonstrated.

11.1 Introduction

In recent years, with the advancement of IT technologies such as IoT and AI, companies around the world have been undergoing rapid DX (Digital Transformation). With these developments, information security issues such as the handling of personal information and the safety of databases have become more important, and when an information security incident occurs, the information is made public, which may have an impact on the stock price of the related stock, which in turn may have an impact on the corporate value. Information security incidents have become one of the main concerns in corporate management. For this reason, the analysis of the impact of information security incidents on corporate stock prices has been gradually increasing.

Many previous studies have shown a deep interest in the impact of information security incidents on stock prices. First of all, Cavusoglu et al. [8] analyzed the impact on corporate value in the stock market by using the event study research method with a sample of 66 cases of Internet security damage in the United States from 1996 to 2001. The results showed that the average corporate value of the companies that

J. Zhao (✉) · H. Takahashi
Graduate School of Business Administration, Keio University, Hiyoshi 4-1-1, Kohoku-ku, Yokohama-shi, Kanagawa-ken, Japan
e-mail: jiansen_zhao@keio.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_11

suffered security damage fell by 2.1% in the 2 days after the damage was announced, excluding market factors.

In Japan, a previous study found that among 18 leakage incidents that occurred in 2003, the average daily change in stock price was concentrated in the range of ±0% to −2% in 12 cases (Japan Network Security Key Association, 2004). In addition, Kawaji [10] analyzed 118 incidents of information leakage of listed companies that occurred from 1997 to 2004, before the implementation of the 2005 "Personal Information Protection Law," using the research method of an event study. As a result, an average −0.667% negative abnormal rate of return was observed. It also shows that large-scale incidents have a larger negative abnormal rate of return (−1.726%) than small-scale incidents.

In a previous study, Zhao [16] examined the impact of information security incident news on stocks and its news text polarity through event study and FinBERT's analysis method on a sample of 156 information security incident news that occurred in five countries or regions. (1) Information security incidents tend to have a negative impact on stock prices over a certain period of time. (2) Depending on the market, the impact of information security incidents on stock prices is large in some countries, while it is limited in others. (3) There is a possibility that the impact of information security incidents on stock prices will be long-term. (4) According to FinBERT's polarity analysis, news with "negative" polarity has a larger negative trend on stock prices. (5) In the case of a series of information security incidents in the Japanese stock market, the impact on stock prices may be sustained over a certain period of time.

In each of the previous studies, the number of samples was small, and the samples were extracted mainly by keywords or tags. In the previous study,[1] there were only 156 news data[2] extracted by keywords and manual methods from about 6 million news data. In addition, there is a possibility of error depending on the extraction method. In order to improve the accuracy of the analysis results for a large amount of text data and to increase the number of highly relevant sample data, this research attempted to construct a system to classify information security incidents based on the BERT model.

---

[1] A study of the impact of information security incidents on enterprise value in various markets. Zhao [16].

[2] 156 news items were selected based on the following keywords: "Security breaches", "Phishing", "IT security investments", "Software vulnerabikities" and "IT security legislation", "Personal data", "Personal info", "Data leak", "Data breach", "Information leak", "Information breach", and "Information security". "Personal data", "Personal info", "Data leak", "Data breach", "Information leak", "Information breach" and "Information security" in the body or title of the news. News data containing "personal info", "data leak", "data breach", "information leak", "information breach", and "information security" in the news body or title. In addition, news data that contains the words "data leak", "data breach", "information leak", "information breach", and "information security" in the body or title of the news.; 2. News of a possible information leakage incident related to a company or business partner related to the stock RIC code (the correlator pointed out the information security risk, it was announced that there was no information leakage after the attack); 3. Three types of news data were extracted. In this study, we focused on the more obvious news data, such as news of information security incidents.

In order to improve the accuracy and increase the number of relevant sample data, this research attempts to build a system to classify information security incidents based on the BERT model. This research uses the data of 156 incidents from the previous research as a sample and uses the BERT model to classify the news data that is similar to the sample among the news that occurred in Japan. We also measure the impact of the classified news on stock prices and compare the impact of news related to information security incidents that occurred in the Japanese market on stock prices for the prior studies.

11.2 Data and Analysis Methods

In this study, we use both news data and stock market data. The news data is analyzed using English news articles distributed by Thomson, which mainly contain key information such as the posting time, title, and body of the news. In this study, we further narrowed down the information content and picked up 66 more typical news articles from 156 news articles on information security by country from 1996 to 2018, which were manually extracted with keywords in the previous study. As for the market data, the Japanese market data was obtained from Nikkei NEEDS. The sample period was from 1995 to 2018, and the data used was the daily ex-rights closing price data of each listed stock and TOPIX.

We also use a trained Sentence-Bert [1] based on Google's published BERT [9] model as the analysis method. In this study, we use the Sentence-Bert model to calculate the vector of sample data and overall news data and then use cosine similarity (Eq. 11.1) to calculate the similarity between each sample and each news item. Then, by using the cosine similarity (Eq. 11.1), we can classify the news according to the similarity.

$$\cos(a, b) = \frac{a \cdot b}{\|a\| \|b\|} = \frac{\sum_{i=1}^{n} a_i b_i}{\sqrt{\sum_{i=1}^{n} a_i^2} \sqrt{\sum_{i=1}^{n} b_i^2}} \tag{11.1}$$

Finally, we validate the classification system by measuring the impact of the classified news on stock prices using event studies. Event study (Campbell et al., 2012) is one of the methods to analyze the impact of a specific event or incident on a company's stock price. The event study measures abnormal returns as opposed to normal returns. By analyzing the movement of the cumulative abnormal returns of a stock before and after an event related to the company, the impact of the event on the stock price is analyzed.

The normal return is the return when the event has not occurred. The normal return is measured according to the market model (Eq. 11.2), and the normal return is estimated by performing regression analysis on individual stocks and market indexes within the estimation window period.

$$R_{i,t} = a_i + \beta_i \cdot R_{M,t} \tag{11.2}$$

Normal return is the outlier of a stock after an event occurs, relative to normal return. It was calculated using Eq. 11.3 below. The cumulative abnormal return CAR(T1,T2) is the accumulation from period T1 to period T2. The calculation method is shown in Eq. 11.4

$$AR_{i,t} = R_{i,t} - \alpha_i - \beta_{i,t} R_{M,t} \tag{11.3}$$

$$CAR(T_1, T_2) = \sum_{T_2}^{T_1} AR \tag{11.4}$$

In this study, the announcement date of the news data is defined as the event day. If the same event is reported more than once, the earlier point in time is defined as the event day. If the announcement day is a Saturday, Sunday, or a national holiday, the event day is defined as the next business day. If the announcement time is between 3:00 p.m. and 24:00 p.m., the event day is defined as the next business day because the impact on stock prices is not reflected on that day.

In this analysis, the estimation window is from 140 business days before the announcement date to 20 business days before the announcement date. The event window was analyzed for multiple periods, including in the short term.

11.3 Results

The results of the extraction of 66 samples, divided into several stages of similarity, are shown in Table 11.1 and Fig. 11.1 below. In terms of the number of samples extracted by similarity, a large amount of data was extracted at the 50% similarity

Table 11.1 Quantity of data extracted by similarity

Similarity	50%	55%	60%	65%	70%	75%
Quantity	2,513,807	1,310,592	480,849	114,419	27,104	6708
quantity of dropped duplicates	525,124	377,344	195,409	54,913	12,178	4292
Similarity	80%	85%	90%	95%	99%	–
Quantity	650	45	30	26	25	–
quantity of dropped duplicates	602	45	30	26	25	–

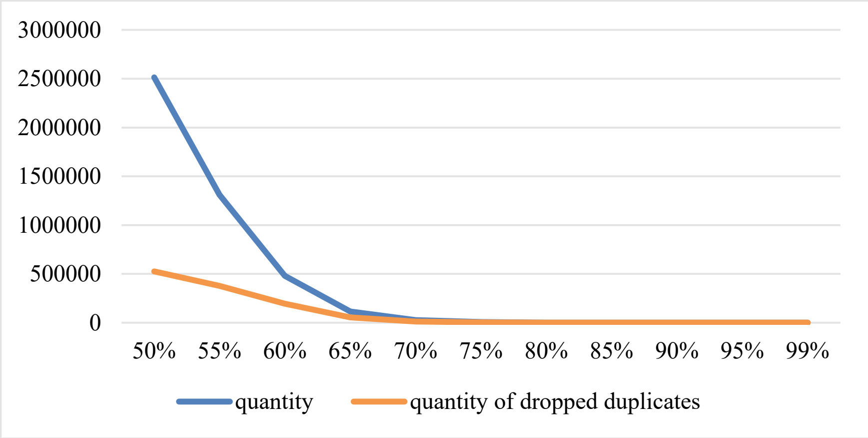


Fig. 11.1 Quantity of data extracted by similarity

level. As the similarity condition increased, the number rapidly decreased up to 65%. In addition, since the news extracted by each sample text has duplicate news, the number after eliminating the duplicate news has a slower slope in the figure. In other words, the lower the similarity, the more often the different texts extracted the same news.

For the data with 80% similarity or higher, we divided the data into five intervals and measured the number of data that overlapped with the sample data, since the sample data itself may be extracted among the news extracted at each similarity. If the similarity is 85%, 20 out of 45 news data are not from the sample. For the 90th, 95th, and 99th percentiles, there are 5, 1, and 0, respectively. In other words, the higher the similarity, the more often the same text as the sample is extracted.

According to the above extraction results, we analyzed the impact of the extracted news on stock prices using the event study method for the data with 80% and 85% similarity to the sample and compared the results with the results of the event study of the news for the Japanese stock market in the previous study. The results of the event study are shown in Fig. 11.2, Table 11.2 and Fig. 11.3, Table 11.3 for the data with 80% and 85% similarity. The horizontal axis shows the time before and after the event (t). The event date (the day the news was posted) is 0, −20 is 20 business days before the day the news was posted, and 20 is 20 business days after the day the news was posted. The vertical axis is AR or change in CAR.

The analysis shows that by one day before the event date, there is only a slight fluctuation in the stock price. One day before the event date, a downward trend is observed for CAR (0, +20) with a return of −9.14%. For the entire period, a cumulative abnormal return of −10.73% is observed.

And for the data extracted at 85% similarity, the downward trend was expressed at an earlier time point. The CAR for the entire period was −3.86%, and the CAR(0,

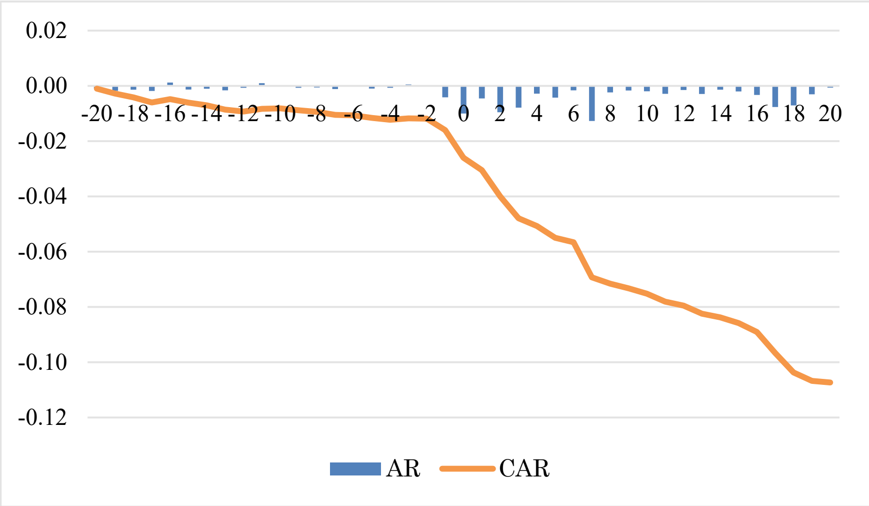


Fig. 11.2 Event study results for data with 80% similarity

Table 11.2 Event study results for data with 80% similarity

(T1,T2)	Average CAR(T1,T2)
(−20, +20)	-0.1073^{***}
(−20, −1)	-0.0160^{***}
(0, +1)	-0.0145
(0, +3)	-0.0319^{**}
(0, +5)	-0.0390^{***}
(0, +10)	-0.0592^{***}
(0, +20)	-0.0914^{***}

*** T-value ≤ 0.01, ** T-value ≤ 0.05, * T-value ≤ 0.10

+20) was 0.54% until 20 days after the event date. On the sixth day after the event date, a recovery trend was observed.

In the previous study, the results of the analysis of 73 news data of the Japanese market show that there is a negative trend in the Japanese market from one day before the news is published. In the period 10 days after the event date, the CAR(0, +10) reached −0.0218. In the period 20 days after the event date, CAR(0, +20) reached −0.0164. In other words, the decline in the 10-day period was larger because of the information security incidents in the Japanese market, and the recovery trend was shown in the period from 10 to 20 days. The reaction of the stock market is shown in Fig. 11.4. The results of the analysis in the previous study approximate to some extent the width and trend of the 85% similarity data.

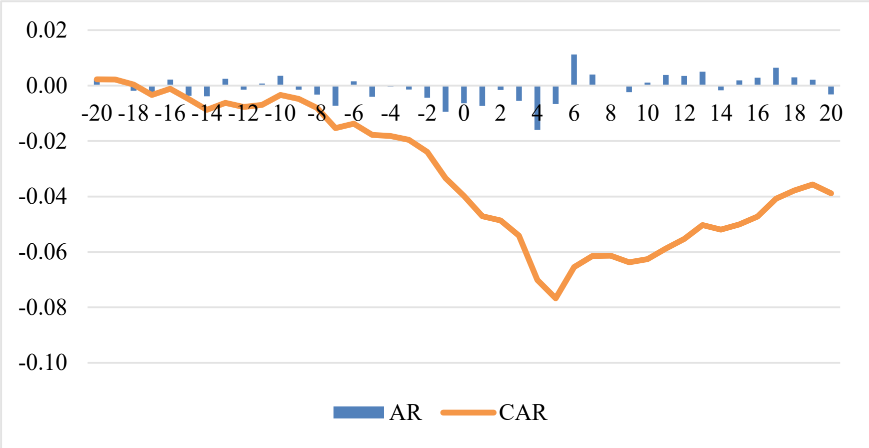


Fig. 11.3 Event study results for data with 85% similarity

Table 11.3 Event study results for data with 85% similarity

(T1,T2)	Average CAR(T1,T2)
(−20, +20)	-0.03885^{***}
(−20, −1)	-0.03342^{***}
(0, +1)	-0.01369
(0, +3)	-0.02072^{**}
(0, +5)	-0.04333^{**}
(0, +10)	-0.02922^{***}
(0, +20)	-0.00544^{***}

*** T-value ≤ 0.01, ** T-value ≤ 0.05, * T-value ≤ 0.10

11.4 Conclusion

In this study, we attempted to extract similar news from a sample of the news content of information security incidents. As a result, the event study results of news with a similarity of more than 85% are similar to the event study results of information security incidents in previous studies. As for future work, the first thing to be done is to conduct a study of the upcoming event study.

The results of the event study on information security incidents are similar to the results of previous studies. If the increments are made finer, there is a possibility that more accurate results will be obtained. Also, the sample size is small and the news content includes news that is not otherwise relevant. There is a possibility that a database could be used to train the BERT model to produce more accurate results.

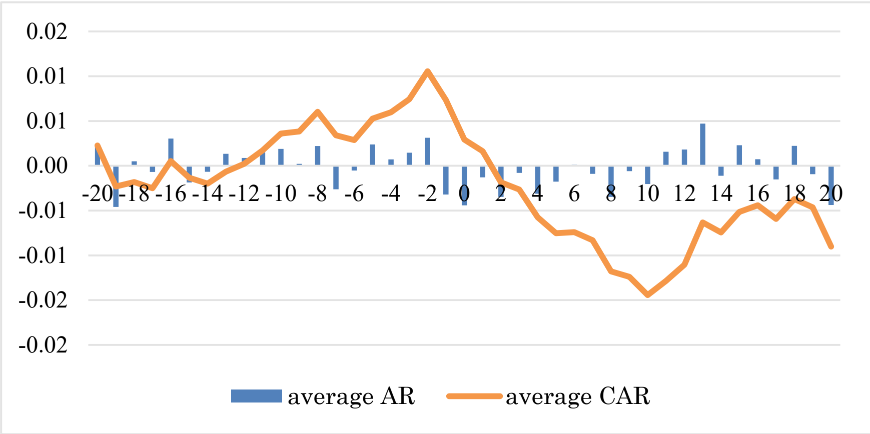


Fig. 11.4 Information security incident reacts in the Japanese stock market (average abnormal return and cumulative abnormal return). *Source* A study of the impact of information security incidents on enterprise value in various markets. Zhao [16].

References

1. Reimers, N., Gurevych. I.: Sentence-bert: sentence embeddings using siamese bert-networks. ArXiv preprint ArXiv:1908.10084 (2019)
2. Campbell, J.Y. et al.: The econometrics of financial markets. Macroecon. Dyn. **2**(4), 559–562 (1998)
3. Yamashita, Y., Johtaki, H., Takahashi, H.: Analyzing the influence of head-line news on the stock market in Japan. Int. J. Intell. Syst. Technol. Appl. **12**, 328–342 (2013)
4. Nishi, Y., Suge, A., Takahashi, H.: Construction of a news article evaluation model utilizing high-frequency data and a large-scale language generation model. SN Bus. Econ. **1**, 104 (2021)
5. Nishi, Y., Suge, A., & Takahashi, H.: Text analysis on the stock market in the automotive industry through fake news generated by GPT-2. In: Proceedings of the International Workshop Artificial Intelligence of and for Business (AI-Biz2019) (2019)
6. Spanos, G., Angelis, L.: The impact of information security events to the stock market: a systematic literature review. Comput. Secur. **58**, 216–229 (2016)
7. Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A.N., Polosukhin, I.: Attention is all you need. ArXiv preprint ArXiv:1706.03762 (2017)
8. Cavusoglu, H., Mishra, B., Raghunathan, S.: The effect of internet security breach announcements on market value: Capital market reactions for breached firms and internet security developers. Int. J. Electron. Commer. **9**(1), 70–104 (2004)
9. Devlin, J., Chang, M.W., Lee, K., Toutanova, K.: Bert: pre-training of deep bidirectional transformers for language understanding. ArXiv preprint ArXiv:1810.04805 (2018)
10. Kawaji, T.: The impact of customer privacy breaches on market value. Jpn. Assoc. Manag. Account. **15**(1), 35–56 (2006)
11. Fama, E.F., French, K.R.: Common risk factors in the returns on stocks and bonds. J. Financ. Econ. **33**(1), 3–56 (1993)
12. Nishi, Y., Suge, A., Takahashi, H.: Construction of a news article evaluation model utilizing high-frequency data and a large-scale language generation model. SN Bus. & Econ. **1**(104), 1–18 (2021)
13. Tanaka, K.: Empirical study on the impact of stock price by corporate information security incidents (prize paper at 2011 students prize paper Contestin Graduate School of International Management). Int. Manag. Res. **2**, 40–55 (2013)

14. Hiromatsu, T.: Analysis of the Impact of Information Security Incidents on Corporate Value An Attempt at Risk Assessment Using the Event Study Method (In Japanese) (2011)
15. Miyauchi, S., Takahashi, H.: The information security accident about the impact and relevance to the corporate value. JSAI Special Interest Group on Business Informatics (SIG-BI #15) (2020)
16. Zhao, T.: A study of the impact of information security incidents on enterprise value in various markets (2022)

Chapter 12
System for Analyzing Innovation Activities in Mergers and Acquisitions by Measuring Technological Distance

Nozomi Tamagawa and Hiroshi Takahashi

Abstract In this study, we construct an analysis system for the impact of mergers and acquisitions (M&A) on innovation activities using large-scale patent data in Japan, the U.S., and German. In the analysis, we focus on the technological similarity between the acquirer and the target companies in M&A. Specifically, we use natural language processing to analyze the patent document data and measure the technological distance among companies. In addition, we measure the innovation output in M&A using the patent data and classify the analysis targets according to the size of the technological distance. We also analyze the trend of the innovation output after the announcement. By conducting the analysis, we confirm that the innovation output after M&A announcement tends to increase in the M&A group with medium technological distance. In this result, one of the novelties is the applicability of unstructured data and machine learning methods to the research field of M&A and innovation.

12.1 Introduction

In this study, we construct an analysis system for the impact of mergers and acquisitions (M&A) on the subsequent innovation activities of a company. In previous studies, technological results are the main objectives to examine M&A in a corporate strategy [1]. In addition, the conditions and characteristics of M&A and the technological outcomes have been discussed from various perspectives, such as technological overlap between the acquirer and the target company, complementarity, and the ratio of the size of the knowledge base [2–4]. However, the indices used in these previous studies, such as the number of patent applications, the International Patent Classification (IPC), and industry classifications, do not consider the details of the technologies owned by the companies. From another aspect, with the development

N. Tamagawa (✉) · H. Takahashi
Graduate School of Business Administration, Keio University, 4-1-1 Hiyoshi, Kohoku-ku, Yokohama City, Kanagawa 223-8526, Japan
e-mail: tmrevo1996@keio.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_12

of information technology in recent years, various methods and unstructured data, which have been difficult to analyze in the past, are being applied in many research fields. Based on such a background, in this study, we present an analysis system on the relationship between M&A and innovation output while paying attention to innovation activities among technological achievements, focusing on M&A in Japan, the U.S., and Germany. Specifically, in this analysis, we quantitatively measure the technological similarity among companies by analyzing the patent document data using the method of natural language processing. We also analyze the index that represents the innovation output. By doing so, we attempt to add the details of the technologies owned by companies to this analysis and apply the methods of information technology to the field of finance. In this way, this study presents an analysis system and its analysis results on the relationship between M&A and innovation, focusing on technological similarity.

Previous studies made various discussions on M&A and innovation and showed their importance. For example, Kaplan [1] claimed that many M&A deals have been conducted for technological purposes. However, from another aspect, M&A is argued to have a negative impact on the innovation output of companies. The reasons are mentioned as the large cost incurred by M&A and the delay in technical decision-making that must be done daily because the management's time and effort are directed to the work generated by M&A [5, 6]. However, utilizing a large dataset of patents, Bena and Li [2] showed that a technological overlap has a positive impact on the probability of M&A deal occurrence. Moreover, M&A with a technological overlap generates more innovation output after the deal.

These previous studies mainly used certain criteria-based indicators in their analysis, such as financial indicators, industry classifications, and the IPC. In many cases, patent data are used to analyze the technological characteristics and innovation output of firms. However, the conventional methods used in previous studies, such as focusing on the number of patent applications, the IPC, industry classifications, and financial indicators, may not allow us to consider the details of the technology. From another aspect, recent advances in information technology lead to the use of unstructured data. Moreover, large-scale document data, which have been difficult to analyze in the past, are now being analyzed and used in various research fields. For example, Hoberg and Phillips [7] analyzed the unstructured data of product descriptions and utilized them for research on corporate finance. In addition, Matsumoto et al. [8] attempted to use patent document vectors to quantitatively measure the degree of technological diversification of firms. In other cases, patent document data are analyzed through natural language processing and are applied to the analysis of the relationship between M&A and innovation activities [9, 10].

Based on these previous studies, this study attempts to apply the methods of unstructured data and information technology to the research field of M&A and innovation activities. Specifically, in this analysis, we calculate the patent document vector by analyzing patent documents through natural language processing. We also quantitatively measure the technological distance that indicates the degree of technological similarity between the acquirer and the target company. By applying this method to the analysis of the relationship between M&A and innovation, we try to conduct an analysis that considers the detailed content of the technology possessed by a company using textual information, such as patent abstracts, which have been difficult to utilize in the past. In addition, relatedness between acquirer and target knowledge base has a nonlinear impact (inverted U-shape) on innovation outcomes [4]. Based on this content, we analyze the trends in the impact of M&A on innovation output by classifying the M&A by technological distance. Through the above, we construct an analysis system for the impact of M&A on the subsequent innovation activities in companies by applying the method of information technology.

12.2 Data

In this chapter, we explain the data used in this study. We use patent data and M&A deal data in this study. First, we use the Derwent World Patent Index (DWPI) for patent data[1] of Japan, the U.S., and Germany, which is a secondary patent database provided by Clarivate. Therefore, by using DWPI's abstracts, we can have the advantage of considering patent documents from an objective point of view, without depending on the patent applicant [11]. The sample period for the patent data is 1970–2015 for Japan, 2001–2015 for the U.S., and 2003–2015 for Germany. In this study, only patent data with DWPI abstracts are used for the analysis of natural language processing to measure patent document vectors, as described below. In addition, the applicant code of DWPI and company names in English are used to search each patent data in this analysis. In the DWPI database, all applicants are assigned a four-letter code, and this code is assigned to the patent [12]. However, since in some cases, the same applicant code is assigned to both the parent and subsidiary company or a single code is assigned to multiple companies, searches using only this code extract companies that are not directly related to the M&A. Therefore, to extract company patents more accurately, we also use the English name of the companies analyzed.

Second, data on M&A deals are obtained from Refinitiv Eikon. In the following, the extraction of M&A deals to be analyzed in this analysis is divided into three steps. In Step 1, we extract M&A deals that were announced between 1975 and 2012 and conducted among public companies in Japan, the U.S., and Germany. In Step 2, among those M&A deals, we exclude the deals that are classified as "Exchange Offer", "Buyback", or "Recapitalization". We also extract only the deals that are classified as the "Completed" status in the Refinitiv Eikon database. In addition, from the M&A data extracted up to this point, we extract only those deals where the ratio of acquired stocks exceeds 50%. In Step 3, we extract deals in which the mid-industry of the acquirer company is classified as "Materials". In addition, among the extracted M&A deals, we extract only those in which the acquirer and the target company have published for at least one patent in the period from the year of deal announcement to 3 years prior to the announcement. As a result, 102 M&A deals are the final analysis targets of this analysis. Figure 12.1 shows the extraction of M&A

[1] Some of the data used in this study include patents that have not been licensed by the applicant.

Step1

- **M&A deals announced by public companies in Japan, the U.S., and Germany between 1975 and 2012.**

Step2

- **we exclude the deals that are classified as "Exchange Offer", "Buyback" or "Recapitalization" and extract only the deals that are classified as "Completed" status in the Refinitiv Eikon database.**
- **Deals in which the ratio of the number of shares acquired exceeds 50%.**

Step3

- **The mid-industry of the acquire company is classified as "Materials".**
- **Deals in which the acquirer and the target company have publicized at least one patent during the year of the deal announcement up to three years ago.**

Result

102 M&A deals.

Fig. 12.1 Extraction of mergers and acquisitions deals for analysis

to be analyzed up to this point.

12.3 Method

In this chapter, we show the analysis methods in this study. First, we present the measuring of innovation output in Sect. 12.3.1, the calculating of patent document vector in Sect. 12.3.2, and the measuring of technological distance in Sect. 12.3.3.

12.3.1 Measuring Innovation Output

Following Bena and Li [2], we calculate the *Patent Index* for each M&A deal using the patent data and use it as an index of innovation output. We measure the *Patent Index* of each year for 7 years from *ayr*-3, which is 3 years before, to *ayr*+3, which is 3 years after, based on the year when each M&A deal was announced (*ayr*), to compare the change of innovation output around the announcement of M&A. The calculation of the *Patent Index* is shown below in three steps.

The first step is to extract the group of firms that have at least one patent published for each technology class k in each year t. Then, the second step is to calculate the median number of patents published for the entire group of firms for each technology class k in each year t. In this study, "technology class k" refers to the classification code assigned to patents in the IPC. In the IPC, patents are classified into four levels:

section, class, subclass, and group; moreover, each level is assigned a classification code [13]. In this analysis, the classification symbols up to the class in the IPC are treated as technology class *k*. In the case of patents with multiple applicants, it is assumed that all firms that applied filed one application each. In the second step, for each technology class *k* in each year *t*, the total number of patents filed and published by the acquirer and target firms in each M&A is measured and divided by the median value calculated in the first step. One of the duplicate patents is eliminated to avoid duplicate counting of patents filed jointly by the acquirer and the target firms. The third step is to calculate the *Patent Index* for each M&A deal in each year *t* by summing up the values calculated for each technology class *k* in each year *t* in the second step from *ayr-3*, which is three years before, to *ayr*+3, which is three years after, based on *ayr*, the year when the deal was announced. In accordance with the above calculation method, we measure the *Patent Index* for each year (from *ayr*-3 to *ayr*+3) for each M&A deal to be analyzed.

12.3.2 Calculating the Patent Document Vector

In this study, we calculate the patent document vector by using natural language processing techniques on patent document data. We use Sparse Composite Document Vector (SCDV) to vectorize patent documents and calculate the patent document vector, referring to Mekala et al. [14]. The analysis target of SCDV and the settings of various parameters are determined by following the analysis of Matsumoto [8]. In the current study, only patent data with DWPI abstracts are included in the analysis. Moreover, we analyze the four textual information items in the DWPI abstract: novelty, detailed description, use, and superiority of the patent as the objects of SCDV. First, the word vectors are obtained using the Skip-gram model with the dimensionality *d* set to 200 after the stemming process. Then, the entire word vector is classified with the number of group *k* being 60 using the Gaussian mixture model, and each group is weighted by assigning a probability. Then, we combine the word vector wcv_{ik} with the number of groups *k* ($\oplus_{(1\sim k)}$) to obtain the $d \times k$-dimensional word vector. Finally, this word vector is re-weighted by the inverse document frequency IDF to obtain wtv_i. The following Eqs. (12.1–12.3), we illustrate the above analysis method, where *N* is all documents and df_t is the number of documents in which a word *t* appears.

$$wcv_{ik} = wv_i \times P(C_k|w_i) \tag{12.1}$$

$$IDF_t = log\frac{N}{df_t} + 1 \tag{12.2}$$

$$wtv_i = IDF_t \times \oplus_{(1\sim k)} wcv_{ik} \tag{12.3}$$

Finally, we sum, standardize, and sparse this $w\overrightarrow{t}v_i$ at the threshold to compute the document vector.

12.3.3 Measuring Technological Distance

In this section, we present a method to measure the technological distance between the acquirer and the target company for each M&A deal. In this study, we calculate the distance between the centers of gravity from the patent document vector filed and published by the acquirer and the target company before the deal. We use this value as an indicator of the technological distance in each M&A deal. First, for each acquirer and target company in each M&A deal, we extract the patents and their document vectors between *ayr*-1 and *ayr*-3 for year *ayr* when the deal was announced. Then, for each acquirer and target firm, we average the extracted 12,000-dimensional patent document vectors and calculate the center of gravity (*cv*). Next, we calculate the Euclidean distance between the centers of gravity (*cv*) of the acquirer and the target company for each case, which is defined as the technological distance. Equations (12.4) and (12.5) below illustrate the above analysis method.

$$cv_i = \begin{bmatrix} \left(\frac{p_1+p_2+\cdots+p_n}{n}\right)_{1,} \left(\frac{p_1+p_2+\cdots+p_n}{n}\right)_{2,} \\ \cdots, \left(\frac{p_1+p_2+\cdots+p_n}{n}\right)_{12000} \end{bmatrix} \tag{12.4}$$

$$Distance\ etween\ Firm_i,\ Firm_{i+1} = \sqrt{\begin{matrix} (p_{i1} - p_{i1+1})^2 + (p_{i2} - p_{i2+1})^2 \\ \cdots + (p_{i12000} - p_{i12000+1})^2 \end{matrix}} \tag{12.5}$$

Finally, we classify the M&A to be analyzed using the technological distance and compare the innovation output after M&A for each group. Specifically, we first calculate the percentage of the *Patent Index* for each year in each M&A. To begin with, we calculate the total of the seven *Patent Index* values from *ayr*-3 to *ayr*+3 calculated above for each M&A deal. Then, for each M&A deal, the value of the *Patent Index* is divided by the 7-year sum of it for each deal. Through this process, we can calculate the value that represents the ratio of the *Patent Index* for each year (from *ayr-3* to *ayr*+3) to the total value of the *Patent Index* of 7 years in each year *t* of each M&A deal. When this value is summed up from *ayr-3* to *ayr*+3 for each M&A, it takes a value of 1. This value indicates what percentage of innovation output was calculated for each year against the total *Patent Index* from *ayr*-3 to *ayr*+3. Then, for each M&A, we divide the value of the percentage of the *Patent Index* for each year from the year of announcement to each of the 4 years after the M&A by the value of *ayr*, the year in which the M&A was announced. In this case, the four M&A cases in which the value of the *Patent Index* is zero in the year when the deal was announced are excluded from the analysis because the above process could not be performed. Finally, the 98 M&A are classified into five groups from Group 1 to Group 5 in the order of decreasing technological distance for analysis. We compare these values among the groups to discuss the change in innovation output after M&A in each group.

12.4 Result

In this chapter, we show the analysis results of the trend in the *Patent Index* after M&A in each group. Figure 12.2 shows the average value of the percentage of the *Patent Index* in each year based on *ayr* for M&A classified into each group. The horizontal axis in Fig. 12.2 is time and shows 4 years from *ayr*, the year when each M&A deal was announced, to *ayr*+3, 3 years later. The vertical axis in Fig. 12.2 shows the average value of the percentage value of the *Patent Index* after M&A in each year divided by the value of *ayr*, classified into each group. The figure shows the average of all M&A classified into each group and that of all M&A deals to be analyzed.

From Fig. 12.2, we can confirm the trend of the scale of the *Patent Index* after M&A in each group. We confirm that the value of the *Patent Index* of group 3 has increased compared with the average of other groups and analysis targets, particularly in the period from *ayr* to *ayr*+3, which is the period after the announcement of M&A. Group

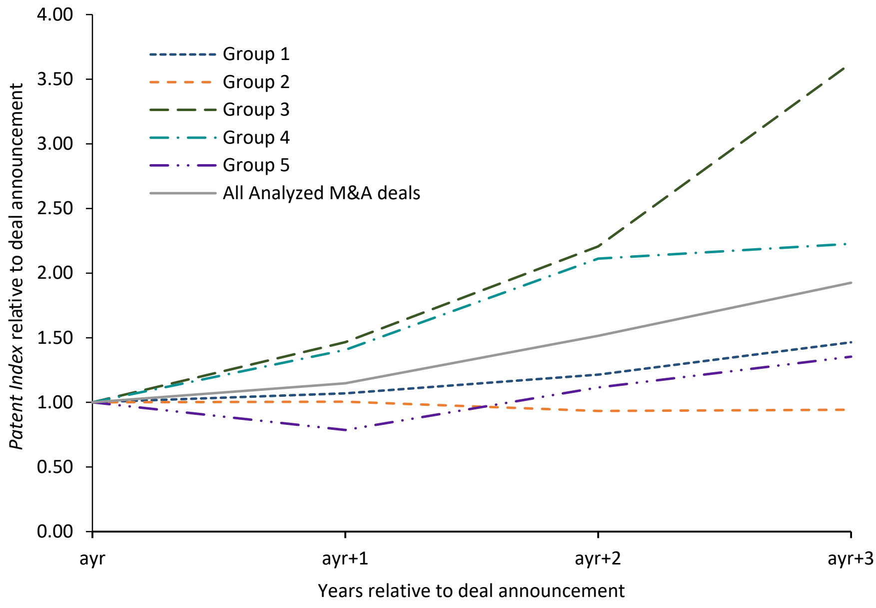


Fig. 12.2 Innovation output after mergers and acquisitions in each group

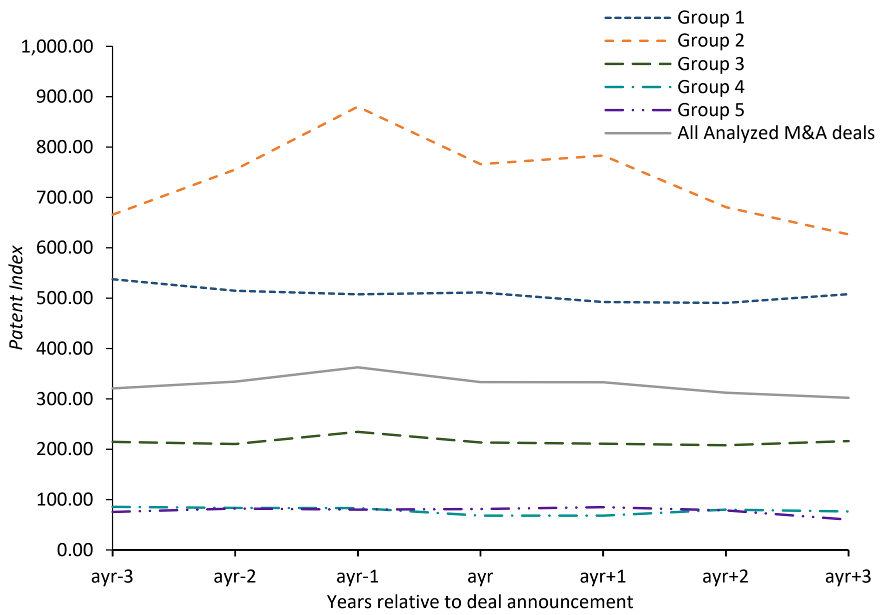


Fig. 12.3 Innovation output of each group around M&A

3[2]is moderate among the groups analyzed in terms of the value of technological distance, which is larger than groups 1 and 2 and smaller than groups 4 and 5. The results of this analysis are consistent with the content of the previous studies that the relatedness between acquirer and target knowledge base has a non-linear impact (inverted U-shape) on innovation outcomes [4].

Next, we present the analysis results of the scale of the value of the *Patent Index* classified into each group. Figure 12.3 shows the average value of the *Patent Index* for each group of M&A. The horizontal axis in Fig. 12.3 is the time and shows the 7-year period from *ayr-3* (three years ago) to *ayr*+3 (three years later) based on the year when each M&A deal was announced. The vertical axis in Fig. 12.3 shows the average value of the *Patent Index* after M&A was classified into each group. The figure shows the average value of the *Patent Index* of all M&A classified into each group and all M&A deals to be analyzed. From Fig. 12.3, we can confirm the trend of the scale of the *Patent Index* after M&A in each group. We confirm that the scale of *Patent Index* around M&A in Group 3, where the innovation output after M&A increased, is the third largest among the five groups. The relationship between technological scale and innovation activities is a subject for future studies.

Finally, we test for the difference in means for the results in Figs. 12.2 and 12.3. Table 12.1 shows the results of the tests for the difference of means in each group

[2] The technological distance of group 3 is tested for differences from the other groups using a *t*-test (assuming that variances are not equal), and the difference is statistically superior (*p*-value (two-tailed) < 0 .01).

Table 12.1 Results of the test of difference

	Innovation output after M&A				The scale of innovation output			
	Group1	Group2	Group3	Group4	Group1	Group2	Group3	Group4
Group2	0.049**				0.086*			
Group3	0.011**	0.001***			4.93E-08***	8.34E-05***		
Group4	0.051*	0.004***	0.335		1.95E-18***	5.73E-07***	8.49E-05***	
Group5	0.498	0.568	0.006***	0.028**	1.01E-18***	5.40E-07***	4.98E-05***	0.986

*$p < 0.1$
**$p < 0.05$
***$p < 0.01$

for innovation output and the size of innovation output. As for innovation output, the test is performed on the *Patent Index* values based on *ayr* from *ayr*+1 to *ayr*+3 for each group in the analysis of Fig. 12.2. In addition, for the scale of innovation output, we test the *Patent Index* values from *ayr*-3 to *ayr*+3 for each group in the analysis of Fig. 12.3. In the test, we assume that the variances are not equal. Table 12.1 shows the *p*-values (two-tailed). From the results in Table 12.1, we can confirm that group 3 is statistically superior to all groups except group 4 in the analysis of innovation output in Fig. 12.2. In addition, the results show that group 3 is statistically superior to all groups except group 4 in the analysis on the scale of innovation outputs in Fig. 12.3.

12.5 Discussion

In this chapter, we discuss the results of the analysis. First, we confirm that the innovation output after M&A tends to increase for M&A groups with medium technological distance and what the previous studies showed. At this point, when the contents of acquired technologies are neither too similar nor too dissimilar, new combinations of technologies might be created, which may contribute to the innovation activities after M&A. Next, the scale of innovation output around M&A in that group is the third largest of the five groups. Regarding this point, it is conceivable that acquiring a firm that is too technologically large may reduce innovation output by making it difficult to integrate research and development (R&D) organizations. On the other hand, acquisitions that are too technologically small may have a smaller impact on innovation. In this context, the acquisition of a company with enough technological scale that the acquirer can take the initiative and obtain new technological knowledge may lead to the smooth integration of R&D organizations and increase the innovation output after M&A.

12.6 Conclusion

In this study, we measured the technological distance between companies by analyzing the patent document data. We also constructed an analysis system of the impact of M&A on the subsequent innovation activities of companies using the value. In addition, we showed the analysis results of M&A in the materials industry in Japan, the U.S., and Germany using the system.

From the analysis, we confirmed that the innovation output after M&A tends to increase in the M&A group with medium technological distance, which is shown by previous studies. In addition, the scale of the innovation output around M&A in that group is the third largest of the five groups. This finding is a novelty in this study because we applied the method of information technology to the research field of M&A and innovation and obtained interesting results.

Next, we present the usefulness and limitations of this study. First, as usefulness, it is possible to contribute to the objective and quantitative evaluation of intangible assets in the due diligence practice of M&A. In addition, by using large-scale patent data, it is also possible to analyze the trend of companies' innovation activities while considering the details of the technology. Secondly, it is difficult to consider qualitative information such as communication within a company's R&D organization because of empirical analysis. In addition, there are limitations on the accuracy of SCDV in vectorizing patent documents.

Finally, a direction for future research is to conduct a detailed analysis of the relationship between technological-scale and innovation activity in M&A. In addition, it is assumed that the effect of M&A is realized after organizational restructuring and integration of R&D organizations. Therefore, it is important to analyze the changes in innovation output around the integration of M&A. The utility of patent document vectors and a detailed analysis of the factors that reduce or increase innovation output are also future tasks.

References

1. Kaplan, S.N.: Mergers and Productivity. University of Chicago Press (2000)
2. Bena, J., Li, K.: Corporate innovations and mergers and acquisitions. J. Financ. **69**(5), 1923–1960 (2014)
3. Cassiman, B., Veugelers, R.: In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition. Manage. Sci. **52**, 68–52 (2006)
4. Ahuja, G., Katila, R.: Technological acquisitions and the innovations performance of acquiring firms: a longitudinal study. Strateg. Manage. J. **22**(3), 197–220 (2001)
5. Hitt, M.A., Hoskisson, R.E., Ireland, R.D., Harrison, J.S.: Effects of acquisitions on R&D inputs and outputs. Acad. Manage. J. **34**(3), 693–706 (1991)
6. Hitt, M.A., Hoskisson, R.E., Johnson, R.A.: The market for corporate control and firm innovation. Acad. Manage. J. **39**, 1084–1119 (1996)
7. Hoberg, G., Phillips, G.: Product market synergies and competition in mergers and acquisitions: a text-based analysis. Rev. Fin. Stud. **23**, 3773–3811 (2010)
8. Matsumoto, Y., Suge, A., Takahashi, H.: Analysis of the relationship between technological diversification and enterprise value using patent data. In: Nippon Finance Associate 27th Annual Conference Program (2019)
9. Tamagawa, N., Takahashi, H.: Classifying mergers and acquisitions through clustering method with innovation output. In: International Workshop: Artificial Intelligence of and for Business (2021)
10. Tamagawa, N., Takahashi, H.: Empirical analysis of the impact of M&A on Innovation activities through clustering. In: International Workshop: Artificial Intelligence of and for Business, (working paper)
11. Matsutani, T., Oka, N., Kobayashi, N., Kato, K.: Evaluation of the derwent world patents index (DWPI) abstracts quality using Japanese patent documents. J. Inf. Process. Manage. **56**(4), 208–216 (2013). (in Japanese)
12. Clarivate Homepage. https://www.clarivate.com/derwent/dwpi-reference-center/dwpi-patent-assignee-codes/. Accessed 10 Feb 2022
13. JAPAN PATENT OFFICE Homepage. https://www.jpo.go.jp/system/patent/gaiyo/bunrui/ipc/ipc8wk.html. Accessed 17 Oct 2021

14. Mekala, D., Gupta, V., Paranjape, B., Karnick, H.: SCDV: Sparse composite document vector using soft clustering over distributional representations, Association for Computational Linguistics. In: Proceedings of the 2017 Conference on Empirical Methods in Natural Language Processing, pp. 659–669 (2017)

Chapter 13
How Can We Make the Best Use of Intellectual Capital? Building an Analysis System Through Agent-Based Models

Kazuya Morimatsu and Hiroshi Takahashi

Abstract It is important to utilize intellectual capital to overcome the severe business environment. However, it is difficult to grasp the causal relationship between how to utilize them and how to improve business performance. In this study, we have developed a system that can elucidate the strategies of excellent companies through the analysis of their behavior in a complex business environment using an agent-based model. The system consists of three layers of business environment: external layer, decision-making layer, and choice of action layer. In addition, there are three types of investment targets: human capital, structural capital, and relational capital. Through this system, we can optimize investment strategies according to market conditions and recommend strategies that consider the behavior of competitors, which is the strength of agent-based models. In this paper, the construction of the system and a case study of analysis are presented. One of the novelties of this research is that we have developed a structure that allows us to consider the utilization of intangible assets from a quantitative perspective.

13.1 Introduction

Since the use of intangible assets is important to overcome the severe business environment, there is interest in the contribution of intangible assets to business performance. Research on intangible assets includes the field of "Intellectual capital," which is the study of intangible assets related to economic activities that do not appear on the balance sheet, such as organizational institutions and human resources. It is generally argued that intellectual capital can be divided into three major categories: "Human Capital," "Structural Capital," and "Relational Capital" [1, 2].

K. Morimatsu (✉) · H. Takahashi
Keio University Graduate School of Business Administration, 4-1-1 Hiyoshi, Kohoku-ku, Yokohama City, Kanagawa 223-8526, Japan
e-mail: kazuya.morimatsu@keio.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_13

Many useful suggestions are using the perspective of intellectual capital [3, 4]. However, even if a company possesses useful resources, there are many cases where it cannot adapt to changes caused by innovation and declines. Therefore, although it is important to understand how to utilize them, it is difficult to grasp the causal relationships, and it is also difficult to extract observed events inductively as research.

Nevertheless, there are still some excellent companies that have succeeded in sustainable management, and I believe that there are still some generalizations that can be made. We are launching this research to clarify this.

13.2 Setting up the Situation

As a model of the situation, we use a motif of a fabless company, for example, which has no tangible or intangible assets. Here, the suggestion is that fabless firms face an intensely competitive environment because of their low yield to scale in a competitive environment [5]. To analyze the behavior of the target company in this study, it is necessary to construct a simulation environment that can represent the competitive environment with competitors. An agent-based model is a method that allows the simulation target to move autonomously and to analyze complex situations that take competitors into account. An agent-based model is a method that simulates complex phenomena by preparing autonomous agents and the environment surrounding the agents and then allowing the agents to interfere with each other and analyze the results [6].

To comprehensively analyze the business environment, it is important to be able to examine both the "External environment" surrounding the company and the "Internal environment" such as actual behavior. For the external environment, in addition to the degree of market oligopoly, the degree of adaptation to the market environment can be implemented based on the hypothesis that the excessive adaptation of companies to the market is the cause of their decline. As for the internal environment, the focus will be on analyzing how to make companies dare to invest in new businesses that tend to be inefficient in the short term. In summary, this study is intended to provide a comprehensive analysis of the impact of a company's investment in new businesses.

In summary, this research aims to derive concrete suggestions on how to utilize intellectual capital to overcome the severe business environment through the analysis of the behavior of excellent companies using agent-based models by expressing their strategies from both external and internal aspects, with intellectual capital as a proxy variable as the concrete behavior that supports the strategy.

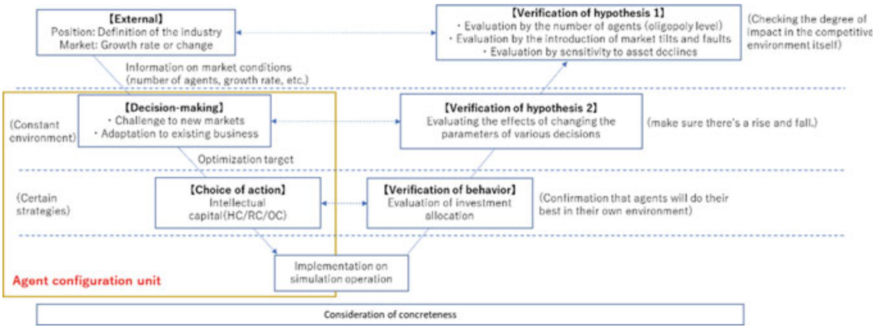


Fig. 13.1 The overall structure of the hypothesis and model

13.3 Modeling

13.3.1 Overview

Figure 13.1 shows the overall structure, which is consistent with the setting of the situation.[1] The left-hand side shows the steps a company takes to act, and the right-hand side contrasts the contents that can be verified by the hierarchy. The top and bottom are categorized according to the degree of freedom of choice of the target company. With this diagram, we analyze the need to implement the following four hierarchies to build a model: “External” (such as the market), “Decision-making” (which promotes decision-making), “Choice of action” (which decides the actual action), and “Specification” (which is necessary for the simulation operation).

To implement these, we try to construct an axis through the entire model from previous studies. The approach to the overall model can be divided into two major categories: the NK model and the economic model [7]. The NK model focuses on the network structure, and there are many studies on the granularity of decision-making within organizations and their complex dependencies; as for economic models, there are many studies that utilize economic theories to construct models aimed at maximizing utility, so we adopt the economic model type in this study.

In previous studies of economic models, Chang et al. (2006) consider agents as customers, define supply and demand based on the findings of economics, and adjust prices [8]; Song et al. (2006) model the behavior of both customers and firms, with the firm side using price and development strategies and the customers using utility management [9]. Both can be seen as a clarification of strategy. Chang et al. (2000) analyzed the behavior of the retail chain at different levels of decision-making granularity by modeling stores and customers, with companies striving to maximize their utility [10]. This can be seen as an elucidation of organizational structure. However, none of these studies can be directly referenced as this study, as they all target products as the center of corporate activities. Few papers use agent-based models for the

[1] This summary uses a method called the V-shaped model.

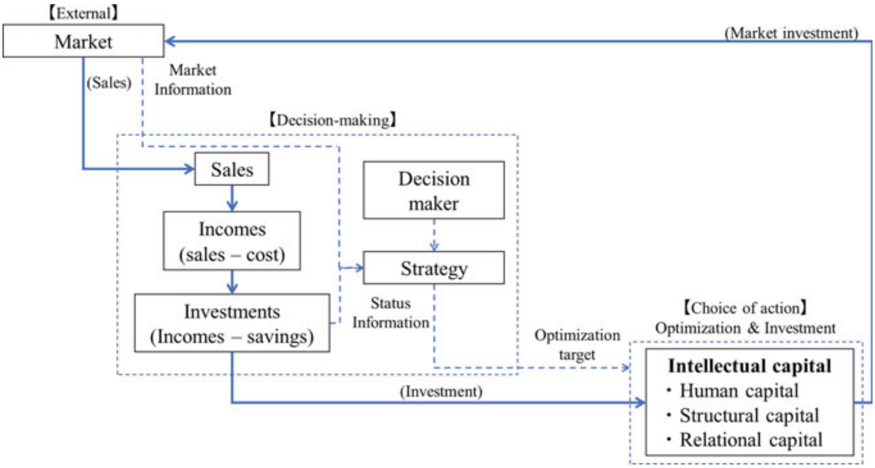


Fig. 13.2 Detailing the overall structure of the model to be built

intellectual capital component which is the focus of this study. While defining the relationship between intangible assets, utility is seen as difficult, especially in Morimatsu et al. (2021), pursuing the elucidation of the behavior of investment strategy through an agent-based model of the element of intellectual capital [11, 12]. Since this is close to the goal of this research, this paper is positioned as a developmental form while following the implementation. In particular, the fact that we have not been able to define all the elements of intellectual capital and the specification of the decision maker's strategy issues in this paper will be improved in this paper.

To summarize the contents so far, we can define the structure of this research as shown in Fig. 13.2. In the following, we will describe the details along with the order of [External], [Decision-making], and [Choice of action] in Fig. 13.2.

13.3.2 External Details

As it is the top level of the model, in addition to creating the market environment, it manages the entire simulation and the operation of the agents. This specification follows the content of "environment" in Morimatsu et al. [11].

The market environment is defined in such a way that parameters such as the number of agents, market specification, and decay rate can be changed so that hypotheses can be tested. In addition, a lifecycle is set for the market to represent a severe business environment, and new markets can be generated to represent alternatives.

For existing markets, we manage the growth of that market based on the output values of the diffusion model for new products by Mahajan et al. [13]. A new market receives investments from agents, makes decisions on whether the generation is successful or not, and feeds back the results to each agent. If successful, the corresponding agent is assumed to be available as an existing market from the next period. In this setting, the generation probabilities are adjusted by looking at the simulation results so that corporate activities can be simulated.

13.3.3 Decision-Making Details

The calculation of the amount available for investment in the current period shall be based on accounting concepts.

$$P = \sum_{i=1}^{n} s_i - \sum_{j=1}^{m} c_j \tag{13.1}$$

$$I = (1 - a)P \tag{13.2}$$

$$D_t = (a)P + D_{t-1} \tag{13.3}$$

where P is the profit for the current period, s_i is the actual sales in the relevant market, n is the number of businesses owned, c_j is the cost of the relevant employee, m is the total number of employees, I is the amount available for investment in the current period, a is the savings rate, D is the amount of savings, and t is the time.

In addition to the amount available for investment in the current period, information on market conditions, and the agent's current asset situation, the goal is calculated according to the agent's code of conduct at the time of generation. A code of conduct is a set of strategic directions for the agent at the time of generation. Figure 13.3 summarizes the calculation of behavioral norms and optimization targets.

At the time of initial generation, the investment ratios of human resources, organizational, and relationship capabilities are randomly generated, and the amount of each possible investment is communicated to the [Choice of action] using these ratios. It is assumed that the sum of the ratios is 1 and does not change after the time of generation. These factors are communicated to the later stage of processing "Choice of action" (13.3 – 1). In addition, various decisions are made to determine the Optimization target (Ot) and the Flag to challenge new markets (Fc). In detail, the company decides whether or not to challenge a new market (13.3 – 2), assesses the situation in the existing market (13.3 – 3), and determines competition with competitors (13.3 – 4). Finally, if growth is expected in the existing market, decisions are made to act to maximize the efficiency of the existing market during the growth period (13.3 – 5).

Note, however, that decisions are not made based on the actions and results of each competitor, as in game theory. Rather, they are making decisions based on the market and their internal situation, and therefore are aiming for a partial best.

```
Algorithm 1: Decision to optimization target
  Input:
    Sn: Strategies for challenging new markets (Initial value)
    Se: Strategies for stagnant existing markets (Initial value)
    Jc: Judgment conditions for new business challenges
  Output:
    Ot: Optimization target
    Fc: Flag to challenge new markets
1   HC: Investment allocation ratio to Human capital (Initial value)
1   RC: Investment allocation ratio to Relational capital (Initial value)
1   OC: Investment allocation ratio to Organizational capital (Initial value)

2 CASE Sn OF
    | 1: Jc = Company's capabilities exceed the threshold
    | 2: Jc = Market growth rate falls below threshold
    | 3: Jc =A market for substitutes has been generated
  IF Jc is applicable THEN
    | Fc = on
  ENDIF
3 IF Mature market timing THEN
4   | CASE Se OF
    |   | 1: Ot = Pursuit of market share
    |   | 2: Ot = Pursuit of profit ratio
    |   | 3: Ot = Pursuit of internal asset growth
    |   | 4: Ot = Pursuit of new business
  ELSE
5   | Ot = Aim for maximum corporate value
  ENDIF
```

Fig. 13.3 Algorithm for the decision to optimization target

As shown above, the system generates the main parameters randomly, except when verifying by statistics, to eliminate the arbitrariness of the simulator as much as possible.

13.3.4 Choice of Action Details

First, we define intellectual capital. In the field of "Intellectual capital," there are many theories that "Human capital" and "Relational capital" have a direct impact on sales, but there are many discussions on whether "Organizational capital" is direct or indirect, and whether it is difficult to uniquely define it at this time. Therefore, if we replace the perspective of "Organizational capital" with that of "Operational efficiency" we would like to define the stance of this paper by determining whether

“Operational efficiency” is directly attributable to sales, based on suggestions from other research fields. Prior studies on “Operational efficiency” have shown that it contributes to sales growth but has an indirect effect [14–17]. From this, organizational power is defined as "organizational efficiency," which is a supplementary element to human capital and relational capital, and sales are defined in this study as consisting of human capital and relational capital. From this, the following equation can be defined:

$$M_{i,t} = H_{i,t} \times R_{i,t} \tag{13.4}$$

where $M_{i,t}$ is the amount of investment in the relevant market, H_i is the human resource input to the relevant market, R_i is the relationship power to the relevant market, and t is the time.

The definition of human capital is then based on the method of Morimatsu et al. [11, 12] and is controlled by the capability of human resources and the working hours they are engaged in. In addition, human resources take the form of capabilities that are improved by investment. This uses the concept of time (man-hours) as the management of engineering of real conditions. In addition, the logarithm as a model of increasing competence is based on the learning curve proposed in the field of psychology.

$$H_{i,t} = eff \times \sum_{j=1}^{l} \left(b_1 \times \log(E_{j,t}) \times h_{j,t}\right) \tag{13.5}$$

$$E_{j,t} = E_{j,t-1} + I \tag{13.6}$$

where $H_{i,t}$ is the input of human capital to the relevant market, eff is the efficiency influenced by the organizational power, l is the number of employees engaged, b_1 is the bias index used to adjust the ratio of human capital to relational capital, $E_{j,t}$ is the cumulative investment in the target employees, $h_{j,t}$ is the time spent in the relevant business, t is the time, and I is the amount of investment in the relevant employees.

Furthermore, the definition of relational capital will be represented by a form of advertising, such as marketing. Therefore, we will define it as a specification that has a good investment-to-sales efficiency but tends to saturate and is also highly decaying. In addition to this sense of reality, prior research suggests that the effects of marketing are not permanent [18].

$$\begin{gathered} R_{i,t} = log(F_{i,t}) \\ s.t. 1 \leq R_{i,t} \end{gathered} \tag{13.7}$$

$$F_{i,t} = \gamma F_{i,t-1} + eff \times I \tag{13.8}$$

where $R_{i,t}$ is the relevant market power, $F_{i,t}$ is the cumulative investment in the relevant market, t is the time, γ is the decay rate, I is the amount of investment in the relevant market, and eff is the efficiency affected by the organizational capital.

The definition of organizational strength is represented by efficiency. Since previous studies have suggested that organizational size has an advantage over complexity as a factor that reduces efficiency, but not efficiency (not only this factor) [19], considering the actual situation, we will define efficiency as the additional factor of decision-making minuteness.

$$\begin{aligned} eff &= e^{-(A_t+B_t-O_t)} \\ s.t.0 &< eff \le 1 \end{aligned} \tag{13.9}$$

$$A_t = \frac{m}{b_2},\ B_t = \frac{1}{d},\ \begin{aligned} O_t &= log(o_t) \\ o_t &= o_{t-1} + I \\ s.t.0 \le\ & O_t \le 3 \end{aligned} \tag{13.10}$$

where eff is the efficiency influenced by the organizational capital, A_t is the influence of the number of people in the organization, B_t is the influence of the organizational structure, O_t is the organizational strength, m is the total number of employees, b_2 is the bias index used to adjust the ratio of the number of human resources to the efficiency, d is the resolution, I is the amount of investment in the organization, and t is the time.

Finally, for the optimization method, there is a suggestion from Klabunde (2016) that the rules of decision-making can be either random decision-making by dynamic programming or theory-based action [20]. This study adopts a dynamic discrete choice model that optimizes accordingly based on various information [21]. After obtaining the available investment amount and target from the "Decision-making" within that range, while calculating the above three factors, the agent will consider maximizing investment efficiency through the hiring of human resources and determine the actions to be taken for this term. Investments in new and existing markets are coordinated through labor allocation. Therefore, this model does not result in any loss from investment in new markets. It is only expressed in terms of a reduction in the short-term profits that would be earned due to less investment in existing businesses.

$$\begin{aligned} V(x_t) = max_{a\in A}\Big\{ & u(x_t, \alpha, H_{i,t}, R_{i,t}, o_t) \\ & + \beta \sum_{m=1}^{M} V(x_t) f(x_t | (x_t, \alpha, H_{i,t}, R_{i,t}, o_t, I, g, s, OT, F_c, HC, RC, OC) \Big\} \end{aligned} \tag{13.11}$$

where V is the value function, x_t is the state in period t, α is the number of people hired, $u(x_t, \alpha, H_{i,t}, R_{i,t}, o_t)$ is the state in the current period, $H_{i,t}$ is the human capital, $R_{i,t}$ is the relational capital, O_t is the organizational capital, β is the discount rate, M is the expected number of years, I is the amount of investment, g is the market growth rate,

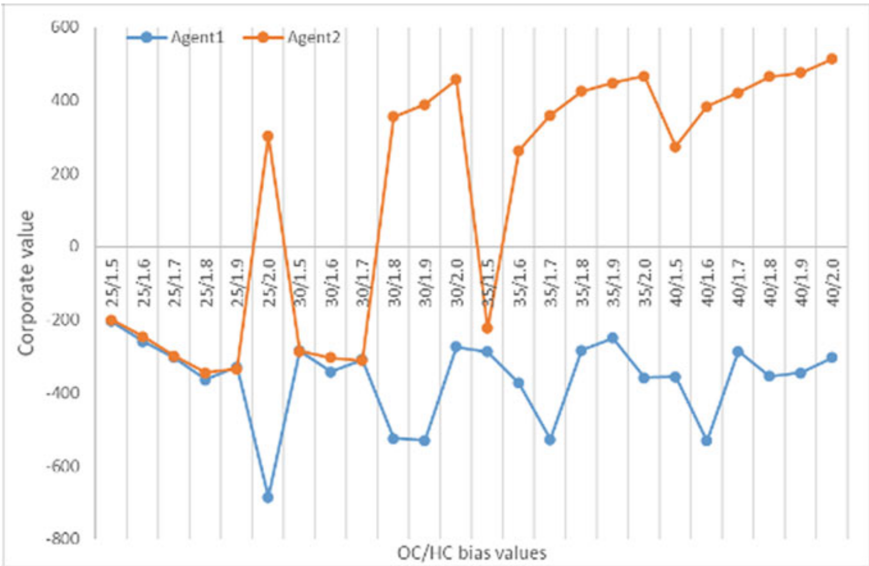


Fig. 13.4 Valuation of corporate value in bias change

s is market share, OT is the optimization target, F_c is the new business challenge, and HC/RC/OC is the ratio of investment to intellectual capital, respectively. However, the parameters to be fixed at the time of forecasting are β, M, g, s, OT, F_c, HC, RC, and OC. If there are multiple states where similar profits can be expected due to market saturation, the state with the lowest number of recruits is selected. The cost per hire can be added by setting.

13.4 Example of Verification Results

Figure 13.4 shows the competition results when using this model and varying the bias (b_1, b_2, Eqs. 13.5 and 13.10) in the three factors, the investment allocation ratio of HC/OC/RC is 0.8/0.1/0.1 for Agent1 and 0.33/0.33/0.33 for Agent2. Figure 13.4: Competition results the vertical axis show the average enterprise value in the final period, and the horizontal axis shows the values of the bias of HC (b_1) and the bias of OC (b_2) as they are varied.[2]

Since this model setup does not own products, the difference in competition is which elements of Intellectual Capital are accumulated with the assets. A detailed

[2] The detailed parameters are Market relationship (P = 0.03, q = 0.38, bias = 2,000), Agent relationship (employee initial deployment headcount and capacity are similar; hiring and firing cost: 1; β: 0.9; α: 0.2; M: 2; d: 4; sample size N = 200 (respectively). Note that the lower limit of this bias (25/1.5) is the limit at which the agent is active).

look at the results shows that the analysis shows that the tendency to actively recruit employees at the dawn of the company due to the fierce competition for market share does not improve organizational efficiency when the investment is biased as in Agent1, resulting in inefficient investment in education. It can be taken that excellent companies in this environment tended to keep the investment allocation ratio constant. In addition, the trends in our results are analogous to previous studies of intellectual capital [4], and there are no cases in which the relationship between each factor and performance is biased. However, we consider that there is still room to examine the verification of this causal relationship.

13.5 Conclusions and Further Work

This system consists of three layers of the business environment: the external layer, the decision-making layer, and the choice of action layer. In addition, there are Human Capital, Structural Capital, and Relational Capital as investment targets. Through this system, we can optimize investment strategies according to market conditions and recommend strategies that consider the behavior of competitors, which is the strength of the agent-based model. One of the novelties of this research is that we have developed a structure that allows us to consider the use of intangible assets from a quantitative perspective.

The most important issue for the future is to determine the contribution of each element of intellectual capital to sales. In addition, it is necessary to define the simulation conditions (such as the determination of environmental specifications and the type and number of competing agents) and conduct research into specific suggestions. Furthermore, since the strategy can be extended, it is desirable to implement it over the strategies of real companies. Since the initial value of the strategy has randomness, it is desirable to implement it because of its affinity to genetic algorithms. On the other hand, due to its versatility, the amount of computation is becoming huge, and we believe that it will be necessary to improve the optimization algorithm later.

References

1. Edvinsson, L.: Developing a model for managing intellectual capital. Eur. Manage. J. **14**(4), 356–364 (1996)
2. Petty, R., Guthrie, J.: Intellectual capital literature review measurement, reporting, and management. J. Intellect. Cap. **1**(2), 155–176 (2000)
3. Bontis, N.: Intellectual capital an exploratory study that develops measures and models. Manage. Decis. **36**(2), 63–76 (1998)
4. Zeglat, D., Zigan, K.: Intellectual capital and its impact on business performance: evidence from the Jordanian hotel industry. Tour. Hosp. Res. **13**(2), 83–100 (2013)
5. Lu, W.-M., Wang, W.-K., Tung, W.-T., Lin, F.: Capability and efficiency of intellectual capital: the case of fabless companies in Taiwan. Expert Syst. Appl. **37**, 546–555 (2010)

6. Tesfatsion, L.: Modeling Economic Systems As Locally Constructive Sequential Games. Iowa State University Working, Paper Number 17022 (2017).
7. Chang, M-H., Harrington, J.E. Jr.: Agent-Based Models of Organizations. Handbook of Computational Economics, vol. 2, pp. 1273–1337 (2006)
8. Kaddoura, I., Kickhöfer, B., Neumann, A., Tirachini, A.: Optimal public transport pricing: towards an agent-based marginal social cost approach. JTEP **49**(2), 200–218 (2015)
9. Song, Z., Zhang, Z., Xu, X., Liu, C.: An agent-based model to study the market dynamics of perpetual and subscription licensing. J. Oper. Res. Soc. **66**(5), 845–857 (2015)
10. Chang, M-H., Harrington, J.E. Jr.: Centralization vs. decentralization in a multi-unit organization: a computational model of a retail chain as a multi-agent adaptive system. Manage. Sci. **46**(11), 1427–1440 (2000)
11. Morimatsu, K., Takahashi, H.: What is the investment strategy to overcome the severe business environment?- Perspectives on decision makers competencies and institutional designs -, International Workshop: Artificial Intelligence of and for Business (2021)
12. Morimatsu, K., Takahashi, H.: What is the investment strategy to overcome the severe business environment?- Perspectives on the relationship between business and human resources management - (Working paper).
13. Mahajan, V., Muller, E., Bass, F.M.: New product diffusion models in marketing: a review and directions for research. J. Market. **54**(1), 1–26 (1990)
14. Oh, W., Pinsonneault, A.: On the assessment of the strategic value of information technologies conceptual and analytical approaches. MIS Q. **31**(2), 239–265 (2007)
15. Mithas, S., Tafti, A., Bardhan, I., Goh, M.J.: Information technology and firm profitability mechanisms and empirical evidence. MIS Q. **36**(1), 205–224 (2012)
16. Sabherwal, R., Jeyaraj, A.: Information technology impacts on firm performance an extension of Kohli and Devaraj. MIS Q. **39**(4), 809–836 (2015)
17. Mithas, S., Rust, T.R.: How information technology strategy and investments influence firm performance conjecture and empirical evidence. MIS Q. **40**(1), 223–245 (2016)
18. Dekimpe, G.M., Hanssens, M.D.: Sustained spending and persistent response: a new look at long-term marketing profitability. J. Market. Res. **36**(4), 397–412 (1999)
19. Klabunde, A., Willekens, F.: Decision-making in agent-based models of migration: state of the art and challenges. Eur. J. Popul. **32**(1), 73–97 (2016)
20. Armandi, R.B., Mills, W.E. Jr.: Organizational size, structure, and efficiency: a test of a Blau-Hage model. Am. J. Econ. Sociol. **41**(1), 43–60 (1982)
21. Rust, J.: Structural estimation of markov decision processes. Handb. Econ. **4**, 3081–3143 (1994)

Chapter 14
A Customer Experience Mapping for Knowledge Extraction from Social Simulation Results

Takamasa Kikuchi, Masaaki Kunigami, Hiroshi Takahashi, and Takao Terano

Abstract Various methodologies have been proposed for extracting knowledge from the output results and logs of social simulations. Such analysis methods are important not only for model developers and analysts, but also for sharing knowledge and communication among other stakeholders. In this paper, we attempt to apply the System Experience Boundary Map, which is one of the experience mapping methods used in the field of design thinking, for the analysis and formal description of the results of social simulation.

14.1 Introduction

In order to solve problems in economy and society, methods that utilize both real data and social simulation have been proposed. For example, Yamada et al. and Ohori typified several categories of human behavior at airports based on real-world data and succeeded in reproducing the congestion situation at Fukuoka Airport when new aircraft were introduced by agent simulation [1, 2]. In addition, a social simulation based on individual questionnaire data has been used to approach the issue of the sustainability of assets of the pre- and post-retirement generations [3–5]. These practical decision-making analyses are expected to contribute to efficient decision-making in social and economic activities and to the design of services and products. On the other hand, the understanding and interpretation of the model structure and simulation results are not limited to the model developers and analysts, but may

T. Kikuchi (✉) · H. Takahashi
Keio University, 4-1-1 Hiyoshi Kohoku-ku, Yokohama, Kanagawa, Japan
e-mail: takamasa_kikuchi@keio.jp

M. Kunigami
Tokyo Institute of Technology, 4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa, Japan
e-mail: mkunigami@gakushikai.jp

T. Terano
Chiba University of Commerce, 1-3-1 Konodai, Ichikawa-shi, Chiba, Japan
e-mail: terano@cuc.ac.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_14

be widely used by decision makers and field personnel in management and administration. Therefore, it is important to have a methodology to extract knowledge and insights from simulation log data and a framework to propagate the extracted knowledge and insights among stakeholders.

On the other hand, in the design of products and services, “design thinking” has been attracting attention [6–8]. The elements of design thinking are (1) a human-centered perspective and (2) trial-and-error problem solving using prototypes. For the human-centered perspective, experience mapping methods such as persona-scenario method [9], customer journey map, experience map [10], and System Experience Boundary Map (SEBM) [11] are used as observational methods to uncover the latent needs of users. However, the application of the above experience mapping methods in simulation log analysis is limited, although Kikuchi and Takahashi [12] have applied the persona method. This method has the potential to become an effective measure to facilitate communication among stakeholders, which is an issue in log analysis.

In this paper, we examine a framework for log analysis and formal description of social simulations that directly relates to the design of services and products. We apply the concept of human-centered design, which is used in the field of design thinking, to the formal description of simulation results using SEBM, which is one of the experience mapping methods. As a case study demonstration of the proposed method, we apply it to the simulation of asset sustainability of pre- and post-retirement generations. The requirements for the formal description of the simulation logs are as follows [13]: (1) it should be able to express the perspective of customers and users to contribute to the design of services and products, (2) the content derived from the log analysis results should be concisely contained in a single map, and it should not require any special explanation or justification, and (3) the map should contain information that suggests the next design action.

14.2 Related Work

14.2.1 System Experience Boundary Map (SEBM)

System Experience Boundary Map (hereinafter referred to as SEBM) is an experience mapping model that formally describes the changes in customer experience caused by new products and services in business innovation cases [11].

SEBM describes the new changes in the customer experience for existing goods and services due to the emergence of goods and services in the following three-step procedure (Fig. 14.1). It consists of the following three steps: (1) Stage-aspect decomposition of the characteristics of the experience into two axes: stage and aspect; (2) Extraction of the potential limits/constraints of the experience in each decomposed stage and aspect: boundary, and (3) description of the new behavior by the solution to the limits/constraints.

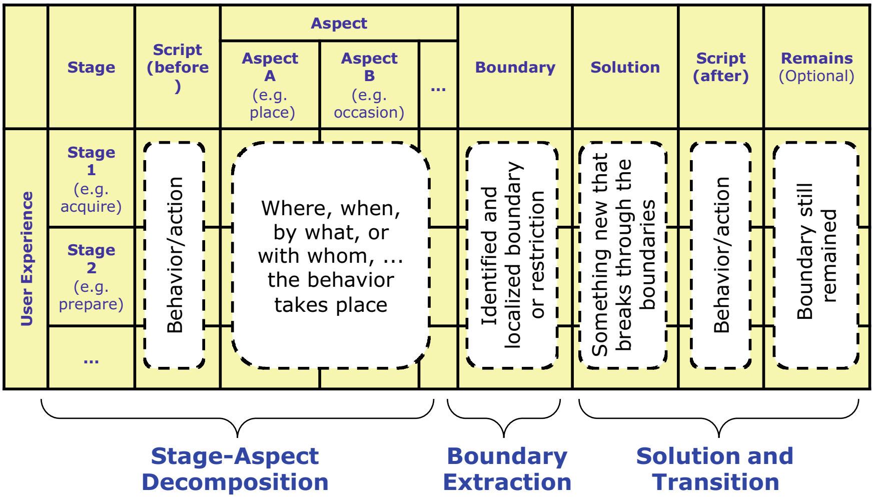


Fig. 14.1 System experience boundary map (SEBM)

Through these procedures, SEBM describes the changes in the customer experience as a table (experience map) decomposed from certain perspectives. With this experience map, it is possible to describe what constraints exist for the customer at what time, where, and with whom, and what kind of experience is created by the resolution of these constraints.

Compared to user experience mapping methods such as User Experience Map, Customer Journey Map and Mental Model Diagram [10, 14], SEBM is closer to focusing on changes in the user interface. However, it differs from conventional methods, in that, it extracts the limits and constraints of customer behavior from the existing user experience and focuses on the changes in customer behavior caused by the introduction of new goods and services. Therefore, it is suitable for visualizing business innovation cases as changes before and after innovation and their factors.

In this paper, we use SEBM to provide a formal description of the results (logs) of a social simulation.

14.2.2 Simulation Analysis

Social simulation is an approach in the social sciences that uses computer simulation to analyze social phenomena [15, 16]. In recent years, many studies have been grounded in real data in the field of social simulation [1, 2]. The combination of data from the past and computational modeling of future scenarios is expected to improve our understanding of the ongoing social complexity [17].

There is a widespread body of research that attempts to share awareness and understanding among stakeholders about the results of social simulation runs and the structure of models. In terms of knowledge extraction from simulation results, there is micro-level analysis [18], macro-level analysis [19], and meso-level analysis [20, 21], depending on the granularity of the analysis. In addition, a language model has been proposed to describe results formally in simulations mainly targeting business organizations [22], and there are actual examples of its application to the results of agent simulation runs [23, 24].

However, as mentioned earlier, not much work has been done on frameworks for log analysis and formal description of social simulations that directly relate to the design and design of services and products.

14.3 Demonstration

The authors have analyzed the sustainability of assets by simulating the asset formation and withdrawal of the pre- and post-retirement generations based on the types (person attributes) generated from individual questionnaire data [3–5]. In the following, we reiterate some of the results of our analysis and examine the feasibility of formal descriptions using the experience mapping method.

14.3.1 Outline: Asset Formation and Withdrawal Simulation

The authors have proposed a social simulation model that represents the asset formation and withdrawal of the pre- and post-retirement generation (Fig. 14.2) [3–5]. The actors in the model hold specific asset balances at a certain age. In addition, actors have regular income and expenses (cash inflows and outflows) and sudden income and expenses (due to life events), depending on their own condition (pre-retirement or post-retirement). The assets held by actors include cash and deposits and risky assets. The risky assets are fully invested in a portfolio of traditional assets and earn a return commensurate with the risk of the portfolio. The regular balance of payments fluctuates according to the inflation rate. The external environment is given by the risk-return of the portfolio, the inflation rate, and their variances.

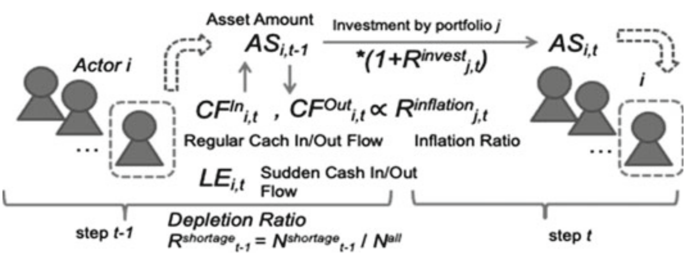


Fig. 14.2 Outline of the simulation model

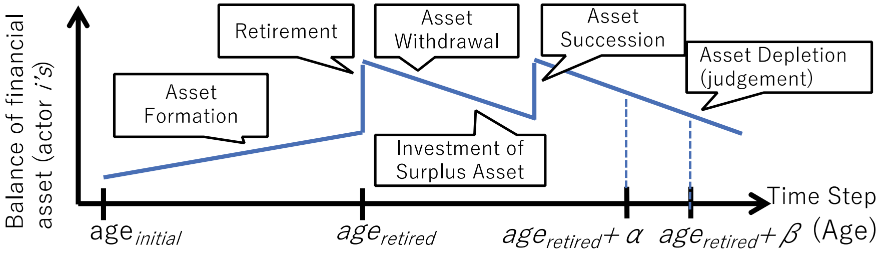


Fig. 14.3 Schematic diagram of changes in asset balance and life events

Figure 14.3 shows a schematic representation of the time series of asset balance of an actor as a sample. The balloons indicate the life events and decisions of the actors, which correspond to the "Stage" in the SEBM.

Then, we have confirmed that the proposed model could reproduce the results of previous studies [25]. Specifically, we have checked that the output of the model, i.e., the asset depletion ratio, is consistent under the same assumptions [3].

14.3.2 Feature Analysis of Individual Questionnaire and Asset Formation Simulation

By clustering the individual questionnaire data, we classified the respondents into five clusters (Table 14.1). In our previous study, we used individual questionnaire data from the "Awareness Survey on Life in Old Age for Before and After Retirement Generation" conducted by the MUFG Financial Education Institute [26]. This questionnaire is characterized by the fact that it comprehensively surveyed not only the asset status of each individual (current asset balance and expected income and expenditure in retirement), but also the asset balance to be inherited from relatives and investment preferences. In a previous study [4], the following attributes were used to classify the respondents: age, current balance of financial assets (FA^{now}),

Table 14.1 Results of feature analysis: attributes for each cluster [4]

# 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 14.2 Simulation results: asset depletion rate at a future point in time [4]

# 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

Table 14.3 Implications of the simulation: measures to reduce the depletion rate [4]

# 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

balance of financial assets to be inherited (FA^{future}), and percentage of risk assets held (R^{risk}).

Based on the classification, we set the attributes of the actors and simulated the likelihood of asset depletion (depletion rate) at a specific age in the future for each inflation scenario (Table 14.2).

In addition, we examined measures to reduce the depletion rate for each personality type (Table 14.3).

14.3.3 Formal Description by SEBM

The results of the log analysis of the social simulation shown in Sect. 14.3.1 (Tables 14.1, 14.2, and14.3) are formally described in the figure below using the SEBM mentioned in Sect. 14.2.1. Then, clusters #1 and #4 are used as samples (Figs. 14.4 and 14.5).

First of all, the "Aspect" part of Figs. 14.4 and 14.5 could represent various values and major indicators related to the simulation such as the initial settings of the simulation, the attributes of the actors, and the macro variables observed in the simulation results. By mapping the results of Tables 14.1 and 14.2, the attributes of the actors at the beginning of the simulation and the attributes expected in the future can be represented. This makes it possible to describe not only the results of the

	Stage	Script (before)	Aspect: Value/ Key Indicator	Boundary	Solution	Script (after)
Customer Experience	At Work Asset Formation (age: 55-59)	Increase asset balances with employment income	Stock : 30~50 [mYen]	-	-	Same as before
	Retirement (age: 60)	Shift to asset withdrawal stage	-	-	-	Same as before
	Post-Retire Asset Withdrawal (age: 60-)	Withdraw assets according to asset class	Flow: ▲0.684 [mYen/year]	-	-	Same as before
	Post-Retire Investment (age: 60-	Asset management according to the risk assets held	Holding Ratio : 25%	-	-	Same as before
	Post-Retire Asset Succession (age: 70)	Receiving succession of assets from relatives	Flow: +25 [mYen]	Failure of assumed asset succession	Appropriate and steady asset succession	Receiving succession of assets from relatives steadily
	Post-Retire Asset Depletion (age: 90/100)	Possibility that asset balance will become negative	Depletion Ratio : 0% / 0%	-	-	Prevents the probability of negative asset balances from increasing

Fig. 14.4 Formal description of simulation results by SEBM (Cluster #1)

	Stage	Script (before)	Aspect: Value/ Key Indicator	Boundary	Solution	Script (after)
Customer Experience	At Work Asset Formation (age: 55-59)	Increase asset balances with employment income	Stock : 15~20 [mYen]	-	-	Same as before
	Retirement (age: 60)	Shift to asset withdrawal stage	-	Early transition to asset withdrawal stage	Postponement of retirement	Extend retirement age and postpone transition to asset withdrawal stage
	Post-Retire Asset Withdrawal (age: 60-)	Withdraw assets according to asset class	Flow: ▲0.615 [mYen/year]	Deterioration of Net income	Curbing spending	Reduce amount of withdrawal ▲0.495[mYen/year]
	Post-Retire Investment (age: 60-	Asset management according to the risk assets held	Holding Ratio : 5%	Loss of reproductive opportunities, Inflation tolerance: Low	Increase in the percentage of risk assets held	Asset management by increasing amount of risk assets held
	Post-Retire Asset Succession (age: 70)	Receiving succession of assets from relatives	Flow: +0 [mYen]	-	-	Same as before
	Post-Retire Asset Depletion (age: 90/100)	Possibility that asset balance will become negative	Depletion Ratio : 60% / 86%	-	-	Reduces possibility of negative asset balances

Fig. 14.5 Formal description of simulation results by SEBM (Cluster #4)

feature analysis of the individual questionnaire data, but also the data extended by the social simulation log (see "Depletion rate at age 90" and "Depletion rate at age 100" in Figs. 14.4 and 14.5) On the other hand, the information obtained from this part alone is static (snapshot-like) and does not provide enough information to lead to the next design action.

Next, the "Stage" part of Figs. 14.4 and 14.5 represents the operating variables of the simulation. In addition, the "Solution" part could express how the results of the simulation are able to change by adopting the measures that correspond to the results of Table 14.3. In this way, the dynamic changes in the user experience are able to be depicted on a single map. By incorporating information that leads to the next design action, such as improvement measures for each cluster, it is possible to compare "As Is" and "To Be" with each other. On the other hand, there is room for improvement in terms of the perspective of service and product design, as the thoughts and feelings of customers and users may not be expressed.

Thus, the formal description of simulation results using SEBM could be considered to have the following usefulness: simulation results could be (1) aggregated; the information in Tables 14.1, 14.2, and14.3 could be represented in a single table for each cluster (shown as Figs. 14.4 and 14.5), (2) compared among clusters; differences in the various attributes of each cluster and the measures that should be taken to enhance the sustainability of the assets could be compared, and (3) visualized in a unified format.

14.4 Summary and Remarks

In this paper, we examined a framework for log analysis and formal description of social simulations that directly relates to the design of services and products. We applied the concept of human-centered design, which is used in the field of design thinking. As a case study demonstration of the proposed method, we conducted a formal description of the simulation results using SEBM, one of the experience mapping methods, for the simulation results of asset sustainability of pre- and post-retirement generations (Sect. 14.3.3). The formal description of simulation results using SEBM could be considered to have the following usefulness: simulation results could be (1) aggregated, (2) compared among clusters, and (3) visualized in a unified format. However, referring to the requirements for the formal description of the simulation log (the latter half of Chap. 1), there is still room for improvement.

Future tasks are as follows: (1) Detailed mapping of simulation results to SEBM components, (2) Expansion of the target cases for case study demonstration, and (3) Comparative verification of other experience mapping methods.

References

1. Yamada, H., Ohori, K., Iwao, T., Kira, A., Kamiyama, N., Yoshida, H., Anai, H.: Modeling and managing airport passenger flow under uncertainty: a case of Fukuoka Airport in Japan. In: 9th International Conference on Social Informatics (SocInfo), LNCS 10540, 419/430 (2017)
2. Ohori, K.: Systems science approaches toward social implementation of AI. J. Jpn. Soc. Artif. Intell. **35**(4), 542–548 (2020) (in Japanese)
3. Kikuchi, T., Takahashi, H.: Policy simulation on retirement planning considering individual attributes. J. Japan Soc. Manage. Inf. Res. Note **30**(2), 105–119 (2021) (in Japanese)
4. Kikuchi, T., Takahashi, H.: Policy simulation for retirement planning based on clusters generated from questionnaire data, agents and multi-agent systems: technologies and applications 2021. Smart Innovation, Systems and Technologies, Springer, Singapore, vol. 241, pp. 285–298 (2021)
5. Kikuchi, T., Takahashi, H.: Life planning support system for older generations using social simulation log analysis. Trans. Soc. Instr. Control Eng. 57(12), 552–562 (2021) (in Japanese)
6. Kelley, T., Litterman, J.: The art of innovation: Lessons in creativity from IDEO. Doubleday, America's leading design firm (2001)
7. Moggridge, B.: Designing Interactions 1/e. The MIT Press (2006)
8. Brown, T.: Design Thinking. Harvard Bus. Rev. **86**(6), 84/92 (2008)
9. Pruitt, J., Adlin, T.: The Persona Lifecycles: Keeping People in Mind Throughout Product Design. Morgan Kaufmann (2006)
10. Kalbach, J.: Mapping Experiences: A Complete Guide to Creating Value through Journeys, Blueprints, and Diagrams, 1st edn. O'Reilly Media (2016)
11. Kunigami, M., Kikuchi, T., Takahashi, H., Terano, T.: A customer experience mapping model for business case description of innovation and value co-creation. In: Jezic, G., Chen-Burger, J., Kusek, M., Sperka, R., Howlett, R.J., Jain, L.C. (Eds) Agents and Multi-Agent Systems: Technologies and Applications 2021. Smart Innovation, Systems and Technologies, vol. 241, pp. 255–264. Springer (2021)
12. Kikuchi, T., Takahashi, H.: A persona design method based on data augmentation by social simulation. In: The IEEE/ACIS 21st International Fall Conference on Computer and Information Science (ICIS 2021-Fall), In proc., pp. 136–143 (2021)
13. Risdon, C.: The anatomy of an experience map, Adaptive Path's web site (2011)
14. Gibbons, S: UX Mapping Methods Compared: A Cheat Sheet, Nielsen Norman Group (2017). https://www.nngroup.com/articles/ux-mapping-cheat-sheet/
15. Gilbert, N., Doran, J. (Eds.): Simulating Societies: The Computer Simulation of Social Phenomena. University College of London Press (1994)
16. Carley, K.M., Prietula, J. (Eds.): Computational Organization Theory. Lawrence-Erlbaum (1994)
17. Farmer, J.D., Foley, D.: The economy needs agent-based modelling. Nature **460**(7256), 685–686 (2009). https://doi.org/10.1038/460685a
18. Ju-S. L., Tatiana, F., Arika, L., Behrooz, H., Forrest, S., Iris, L., Alexey, V., Gary, P., Zhanli, S., Dawn, C.P.: The complexities of agent-based modeling output analysis. J. Artif. Soc. Soc. Simul. **18**(4) (2015)
19. Matsushima, H., Uchitane, T., Tsuji, J., Yamashita, T., Ito, N., Noda, I.: Applying design of experiment based significant parameter search and reducing number of experiment to analysis of evacuation simulation. Trans. Jpn. Soc. Artif. Intell. **31**(6), AG-E_1/9 (2016) (in Japanese)
20. Tanaka, Y., Kunigami, M., Terano, T.: What can be learned from the systematic analysis of the log cluster of agent simulation. Stud. Simul. Gaming **27**(1), 31–41 (2018) (in Japanese)
21. Goto, Y.: Hierarchical classification and visualization method of social simulation logs reflecting multiple analytical interests. Trans. Soc. Instr. Control Eng. **56**(10), 463–474 (2020) (in Japanese)
22. Kunigami, M., Kikuchi, T., Takahashi, H., Terano, T.: A formal, descriptive model for the business case of managerial decision-making, agents and multi-agent systems: technologies and applications 2020. Smart Innovation, Systems and Technologies, Springer, vol. 186 (2020)

23. Kikuchi, T., Kunigami, M., Takahashi, H., Toriyama, M., Terano, T.: Explaining log data of agent-simulation results with managerial decision-making description model. Stud. Simul. Gaming **29**(1), 36–48 (2019) (in Japanese)
24. Kikuchi, T., Kunigami, M., Takahashi, H., Toriyama, M., Terano, T.: Description of decision-making process in actual business cases and virtual cases from organizational agent model using managerial decision-making description model. Trans. Inf. Process. Soc. Japan **60**(10), 1704–1718 (2019) (in Japanese)
25. Kato, Y.: Post-retirement asset management framework. Secur. Anal. J. **56**(8), 19–28 (2018) (in Japanese)
26. Awareness Survey on Life in Old Age for Before and After Retirement Generation, MUFG Financial Education Institute, 2019. (in Japanese). https://www.tr.mufg.jp/shisan-ken/pdf/kinnyuu_literacy_04.pdf Accessed 1 Feb 2022

Chapter 15
Corporate Governance Considerations for Driving ESG Performance

Akihiko Matsubara and Setsuya Kurahashi

Abstract This study focuses on the relationship between ESG investment and corporate governance. In addition, this study will examine the effect of outside directors, in particular, targeting approximately 340 domestic listed companies. The results of the analysis suggest that it is not the outside directors but the companies themselves that are promoting ESG, that the social significance of ESG has changed, and that ESG is no longer a cost to be paid by companies but a management issue that companies themselves should actively address. The results also suggest that the quality of the outside director's effect is important. Specifically, it was shown that there is an effect on whether or not outside directors hold stock. In addition to the incentive effect, it is possible that stock ownership is an indicator of the level of interest of outside directors in the company.

15.1 Introduction

Society as a whole has been making progress in its efforts to realize a sustainable society. This trend has led to the rapid expansion of ESG investment in the asset management field, taking into account the three elements of E (Environment), S (Society), and G (Governance). In particular, governance, which is one of the ESG elements, is becoming increasingly important with the recent revision of the Corporate Governance Code. Among the elements of governance, independent outside directors have been attracting attention. The introduction of a certain number of independent outside directors is required as a condition for listing on the prime market, which will be introduced in fiscal 2022, and the development of such a system is progressing rapidly. In addition, the "Practical Guidelines for Outside Directors (Guidelines for Outside Directors)" published by the Ministry of Economy, Trade, and Industry (METI) in July 2020 requires outside directors to be aware of the impor-

A. Matsubara (✉) · S. Kurahashi
University of Tsukuba, Tokyo, Japan
e-mail: s2040073@s.tsukuba.ac.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_15

tance of sustainability-oriented management, including ESG and SDGs, in addition to medium- and long-term perspectives.

Therefore, this study focuses on the relationship between ESG and governance, particularly the effects of introducing independent outside directors, and examines their effects. Specifically, this study asks two research questions: "Are outside directors effective in promoting ESG performance?" and "If so, under what conditions are they effective?"

15.2 Previous Studies

There are many theories about the effects of introducing outside directors. Previous studies on Japanese companies have shown that the effect varies depending on the characteristics of the company and the employment history of the outside director.

Miyajima and Ogawa (2012) conducted an analysis by focusing on the cost that outside directors pay when they acquire corporate information [1]. As a result of their analysis, they found that the introduction of outside directors has a negative effect on companies with high information acquisition costs. Takeda and Nishitani (2014) conducted an analysis focusing on the professional experience of outside directors and found that those from other companies with knowledge of corporate management had a stronger positive correlation with stock value than those from other professional backgrounds [2]. Furthermore, Kubo (2001) analyzed the shareholdings of directors in Japanese firms and found a positive correlation between shareholdings and firm value, referring to the alignment effect of shareholdings [3]. The alignment effect refers to the positive effect on the corporate value that directors have when they become active in increasing corporate value through their shareholdings.

15.3 Hypothesis Setting

Based on these previous studies, this study formulates and analyzes the following hypotheses:

- **Hypothesis1**
  The effect of the introduction of independent outside directors on ESG performance varies depending on company characteristics. In particular, the effect is positive for companies with low information acquisition costs and negative for companies with high information acquisition costs.
- **Hypothesis2**
  The effect on ESG performance varies depending on the employment history of the independent outside director. In particular, people from other companies have a positive effect on ESG performance.

No	Category	code	Details	Source
1	ESG	ESG_Score	Total Socre	Sustainalytics
2	ESG	ESG_Governance_Score	Govnenance Score	Sustainalytics
3	ESG	ESG_Performance	Percentage change in total score minus governance score	Sustainalytics
4	Financial Indicators	DASS	debt ratio	Nikkei NEEDS-Cges
5	Financial Indicators	EROA	Industry Adjusted ROA	Nikkei NEEDS-Cges
6	Financial Indicators	SIZE	Log of total assets	Nikkei NEEDS-Cges
7	Information acquisition cost	R&DRATE	R&D	Nikkei NEEDS-Cges
8	Information acquisition cost	MUKEIRATE	the ratio of intangible assets	Nikkei NEEDS Nikkei Financial
9	Information acquisition cost	PBR	the ratio of book value to market value	Nikkei NEEDS-Cges
10	Information acquisition cost	VOL	the standard deviation	Nikkei NEEDS-Cges
11	Corporate Information	LSTDATE	corporate age	Nikkei NEEDS Nikkei Financial
12	Corporate Information	TCLS	Industry Dummy	Nikkei NEEDS-Cges
13	capital ties	CROSS	cross shareholdings	Nikkei NEEDS-Cges
14	capital ties	INST	Ratio of Institutional Investors	Nikkei NEEDS-Cges
15	reward	DIR	Percentage of shares held by directors and corporate auditors	Nikkei NEEDS-Cges
16	reward	IDIR	Percentage of shares held by outside directors and officers	Nikkei NEEDS-Cges
17	reward	IDIR_Treat	Outside directors' shareholding dummy	Nikkei NEEDS-Cges
18	Board of Directors	EBRDNUM	Number of Board of Directors	Nikkei NEEDS-Cges
19	Board of Directors	IDOUTRTO	Composition of Independent Outside Directors	Nikkei NEEDS-Cges
20	Board of Directors	IDOUTNUM	Number of independent outside directors	Nikkei NEEDS-Cges
21	Board of Directors	IDB NUM	Percentage of outside directors with banking experience	Nikkei NEEDS-Cges
22	Board of Directors	IFO NUM	Ratio of other outside directors	Nikkei NEEDS-Cges
23	Board of Directors	IDA NUM	Percentage of outside directors with positions at affiliated companies	Nikkei NEEDS-Cges
24	Board of Directors	IDMB NUM	Percentage of outside directors with positions at major banks	Nikkei NEEDS-Cges
25	Board of Directors	IDMT NUM	Percentage of outside directors with positions at reciprocal companies	Nikkei NEEDS-Cges
26	Board of Directors	IDOCEO NUM	Outside directors who concurrently hold president-level positions at other companies Ratio	Nikkei NEEDS-Cges

Fig. 15.1 Dataset

- **Hypothesis3**
  Stock ownership by independent outside directors has a positive effect on ESG performance.

15.4 Data

In this study, I will use the Sustainability ESG Risk Ratings as my objective variable. These Ratings score the risks to which a company is exposed that are not managed by the company's initiatives (=Unmanaged Risk). Therefore, the lower the score, the lower the risk and the better the score. In this study, I define ESG performance as the rate of change in the score after excluding the governance score from the Total Ratings. The basic statistics of the scores are shown in Table 15.1, and it can be seen that ESG is being promoted with average scores improving year by year. The analysis period is the two-year period from 2018 to 2020. And since there is a limit to the number of companies that disclose a breakdown of their Total rating, the

Table 15.1 ESG Score Basic Statistics

yyyy	n	Min	1st Qu	Median	Mean	3st Qu	Max	sd
2018	1170	9.24	22.42	29.52	30.70	37.83	67.17	10.83
2019	1244	9.26	22.55	29.50	30.58	37.55	70.53	10.62
2020	1310	7.91	22.17	28.63	29.37	35.37	67.37	9.62

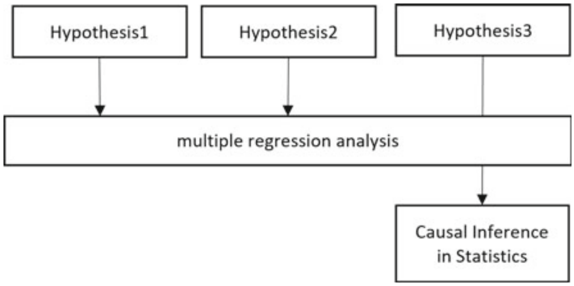


Fig. 15.2 Methods

analysis covers approximately 340 of the domestic listed companies that disclosed a breakdown of their total rating during the analysis period, excluding financial institutions. And, I will use governance and financial indicators obtained from Nikkei NEEDS-Cges and Nikkei NEEDS Nikkei Financial Data as explanatory variables. The dataset is organized as shown in Fig. 15.1. The descriptive statistics are also shown in Table 15.2.

15.5 Methods

The analysis methodology is organized as shown in Fig. 15.2. I will use multiple regression analysis to test Hypotheses 1 and 2 of this study. For Hypothesis 3, in addition to multiple regression analysis, I will use statistical causal inference to estimate the effect of granting shares. The following table summarizes the analytical methods.

15.6 Result1-Analysis by Information Acquisition Costs

I used Miyajima and Ogawa (2012) as a reference and conducted a multiple regression analysis using the ratio of independent outside directors (=IDOUTRTO) as an indicator of the introduction effect to test Hypothesis 1. As proxy variables for information acquisition costs, I used four indicators: the R&D ratio, the ratio of intangible assets, the ratio of book value to market value, and the standard deviation of the 36-month price-earnings ratio and divided each indicator into quartiles for analysis. The results are shown in Table 15.3. Only the R&D ratio showed statistically significant results with respect to high and low information acquisition costs.

Table 15.2 Descriptive statistics

	vars	n	mean	sd	min	max	range	se
ESG_Score	1	343.00	25.84	8.76	0.00	67.37	67.37	0.47
Governance_Score	2	343	5.51	0.88	0.00	6.90	6.90	0.05
ESG_Performance	3	343	−0.04	9.66	−29.76	31.29	61.05	0.52
DASS	4	343	46.40	19.35	0.00	99.30	99.30	1.04
EROA	5	343	2.48	6.17	−9.81	51.30	61.12	0.33
SIZE	6	343	13.62	2.08	0.00	19.47	19.47	0.11
R&D	7	343	2.01	2.60	0.00	13.52	13.52	0.14
MUKEIRATE	8	343	6.53	9.62	0.00	65.19	65.19	0.52
PBR	9	343	2.53	3.55	0.00	38.69	38.69	0.19
VOL	10	343	1.92	0.44	0.00	3.55	3.55	0.02
LSTDATE	11	343	47.31	23.42	0.00	70.93	70.93	1.26
CROSS	12	343	6.97	7.31	0.00	45.20	45.20	0.39
INST	13	343	15.92	7.45	0.00	40.90	40.90	0.40
DIR	14	343	1.40	4.41	0.00	36.60	36.60	0.24
IDIR	15	343	0.00	0.01	0.00	0.17	0.17	0.00
EBRDNUM	17	343	0.77	0.23	0.00	1.49	1.49	0.01
IDOUTRTO	18	343	29.94	12.85	0.00	85.70	85.70	0.69
IDOUTNUM	19	343	3.06	1.37	0.00	11.00	11.00	0.07
IDB NUM	20	343	0.02	0.04	0.00	0.25	0.25	0.00
IFO NUM	21	343	0.26	0.12	0.00	0.75	0.75	0.01
IDA NUM	22	343	0.00	0.03	0.00	0.38	0.38	0.00
IDMB NUM	23	343	0.01	0.03	0.00	0.25	0.25	0.00
IDMT NUM	24	343	0.01	0.04	0.00	0.33	0.33	0.00
IDOCEO NUM	25	343	0.03	0.06	0.00	0.30	0.30	0.00

15.7 Result2-Analysis by Work History

I tested Hypothesis 2 by conducting a multiple regression analysis referring to the model of Takeda and Nishitani (2014). I used the following indicators to measure the effect: the ratio of outside directors who have held positions at major banks, the ratio of outside directors who have held positions at mutual employment agencies, the ratio of outside directors who have held president-level positions at other companies, the ratio of outside directors who have held positions at banks, and the ratio of outside directors who have not held any of these positions. However, as shown in Table 15.4, no statistically significant results were obtained for any of the ratios.

Table 15.3 Information acquisition cost

Category	Quartile	IDOUTRTO	Significance level
R&D ratio	1st	−0.090	–
R&D ratio	2st	−0.237	10%
R&D ratio	3st	0.151	–
R&D ratio	4st	0.173	5%–
The ratio of intangible assets	1st	0.076	–
The ratio of intangible assets	2st	0.074	–
The ratio of intangible assets	3st	0.010	–
The ratio of intangible assets	4st	0.096	–
The ratio of book value to market value	1st	0.063	–
The ratio of book value to market value	2st	0.091	–
The ratio of book value to market value	3st	−0.045	–
The ratio of book value to market value	4st	0.050	–
The standard deviation	1st	0.047	–
The standard deviation	2st	0.036	–
The standard deviation	3st	−0.041	–
The standard deviation	4st	0.122	–

Table 15.4 Analysis of outside directors by background

Type	Composition of outside directors	Significance level
Controlling Company	−12.56	–
Affiliated companies	−13.27	–
From a major bank	10.99	–
Mutual dispatch	7.73	–
Concurrently serving as president	−9.38	–
Personnel from banks	11.39	–
Other	2.27	–

15.8 Result3-Stockholding Effect

In this section, I test Hypothesis 3 using multiple regression analysis and statistical causal inference techniques.

15.8.1 Multiple Regression Analysis

I conducted a multiple regression analysis based on the model of Miyajima and Ogawa (2012) described above. The results are as shown in Table 15.5. The ratio of shares held by independent outside directors was not statistically significant. However, its coefficient was negative, indicating the possibility of improved ESG performance. In addition, a dummy variable indicating whether or not outside directors hold stock was statistically significant.

I also tested for a difference in means for shareholding. As shown in Table 15.6, the results were statistically significant for the difference, suggesting that ESG performance may be improved by stock ownership.

However, the multiple regression analysis only confirmed the correlation, so it is difficult to say that the effect is fully estimated. Therefore, in the next section, I will estimate the causal effect using statistical causal inference.

15.8.2 Causal Inference of Statistics

I conducted the analysis by creating dummy variables based on whether the outside directors held stock in the company. I used three methods of analysis: propensity score matching, Inverse Probability Weighting, and doubly robust estimator to measure the average treatment effect of stock ownership by matching with similar firms. The results are shown in Table 15.7. All methods suggest that stock ownership by independent outside directors has a positive effect on ESG performance.

Table 15.5 Results from multiple regression analysis

Indicator	Coefficient	Significance level
Shareholding ratio	−39.016	
Shareholding ratio (dummy)	−2.791	5%

Table 15.6 Test results for difference of means

t-value	p-value	No possession	Possession
2.24	0.03	1.38	−0.99

Table 15.7 Estimation results

Analytical methods	ATE	p-value
Propensity score	−2.65	0.0381
IPW	−3.04	0.0043
Doubly robust	−3.51	

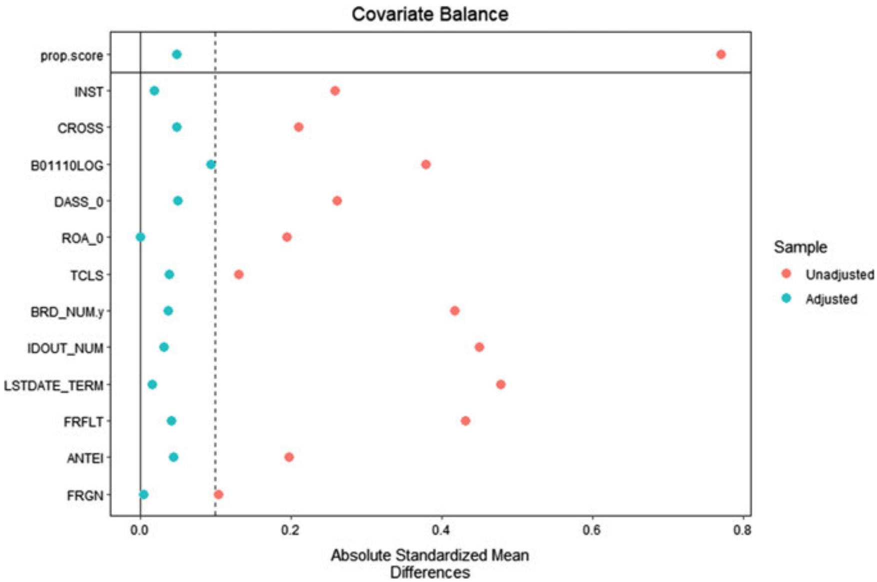


Fig. 15.3 ASAM (Inverse Probability Weighting)

As for the validity of the model used, the C statistic, which indicates the explanatory power of the propensity score, was 0.7018, and Average Standardized Absolute Mean distance (=ASAM), which indicates the balance of covariates, was within 0.1, as shown in Fig. 15.3, satisfying the standard values shown in related studies [4, 5].

15.8.3 Discussion

In this analysis, Hypothesis 1 was partially supported, while Hypothesis 2 was not. The reason for this may be the progress made in introducing independent outside directors. Figure 15.4 is an aggregate of data from the White Paper on Corporate Governance 2020. As Fig. 15.4 shows, the introduction of independent outside directors has been progressing rapidly since the Corporate Governance Code called for their introduction. As a result, most of the listed companies in Japan have completed the introduction of independent outside directors, and there are no differences among

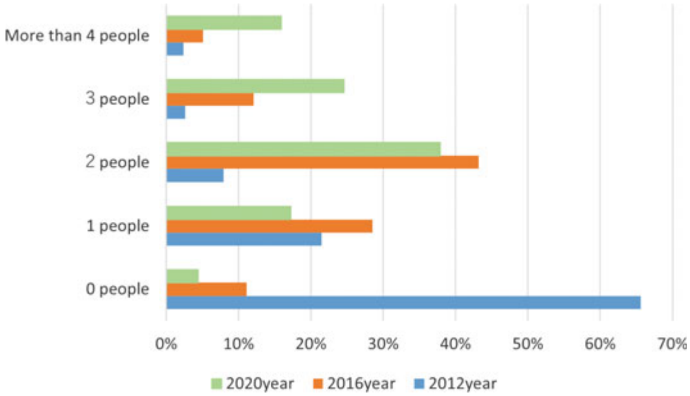
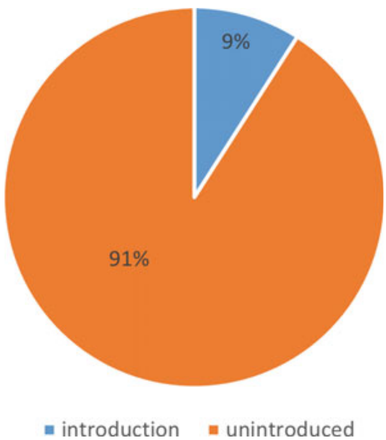


Fig. 15.4 Status of introduction of independent outside directors in Japan

companies. As a result, the ratio of independent outside directors used as an indicator in this study may be insufficient as an indicator.

On the other hand, the results of the analysis supported Hypothesis 3. There are two main reasons for this result. The first is the alignment effect of owning shares as mentioned above. In other words, the compensation is granted to outside directors so that they will be more active in increasing the value of the company. The second is that stock ownership may be a proxy indicator of the level of interest in the company. Due to the nature of independent outside directors, ensuring their independence is a prerequisite. Therefore, most companies have adopted a fixed compensation system. Figure 15.5 shows the adoption of stock option plans by outside directors in Japan. This figure shows that more than 90% of companies have not introduced stock options, indicating that each company has adopted a compensation system that emphasizes independence. Therefore, it is highly likely that stock ownership is an

Fig. 15.5 Status of stock option adoption by independent outside directors



action taken voluntarily by independent outside directors. Based on this assumption, outside directors who own stock are likely to be more active in improving corporate value. This is because holding shares of a company makes them more active in gathering information about the target company and also increases their interest in the target company.

15.9 Conclusion

With regard to the first research question, "Do outside directors have an effect on promoting ESG performance?", I would like to conclude that there is no direct effect. I have analyzed the results from various perspectives, but none of the results clearly indicate a facilitating effect. One of the reasons for this may be that the social significance of corporate ESG initiatives has changed. In other words, it is highly likely that the main driver of ESG promotion is not external advice, but the initiative of the companies themselves. Therefore, the role of outside directors is to support ESG, and it is the companies themselves that should take the lead. This was also suggested by the interviews I conducted with firms separately to analyze qualitative information

The second research question, "If there is an effect, under what conditions does it take place?", I would like to suggest two possible conditions. One is to establish an appropriate system according to the characteristics of the company, such as the cost of acquiring information. The other is to introduce incentives for independent outside directors through stock ownership or to raise the level of interest in independent outside directors.

Based on the above, I believe that given the current state of independent outside directors in Japan, improving the system is no longer a major issue, but rather improving the quality of independent outside directors is an important issue. In this study, I have argued that in order to improve the quality of independent outside directors, it is important for companies to take the initiative, especially in creating a mechanism to incorporate the opinions of outside directors and to increase the level of interest of independent outside directors in the company. Once again, I hope that Japanese companies will take a proactive approach to corporate governance so that they can enjoy the benefits of independent outside directors.

15.10 Issues and Prospects

First, the use of the special objective variable of ESG performance limited the sample size and analysis period. In this respect, it is necessary to conduct additional analysis by changing the sample size and period. Next, the effect of shareholding needs to be further examined since there are few related studies. Finally, this study suggested the importance of management. Therefore, in the future, I would like to conduct an analysis that takes into account the relationship between management and independent outside directors, which will lead to further research.

References

1. Miyazima, H.,Ogawa, R.: How to understand the changes in the composition of the board of directors of Japanese companies? Determinants of Board Composition and the Effects Of Introducing Outside Directors. RIETI Policy Discussion Paper series 12-P-013 (2012)
2. Takeda, K., Nishitani, M.: Independent outside directors and their attributes and shareholder value. Security analysts journal 84–94 the Securities Analysts Association of Japan (2014)
3. Kubo, K.: Does executive stock ownership affect corporate performance? Hitotsubashi University Institutional Repository HERMES-IR 1–23 (2001)
4. Kubo, T.: Indicators of test usefulness and RoC analysis. Clin. Exam. **49**(12), 1335–1340 (2005)
5. Elizabeth, S.: Matching methods for casual inference. A Rev. J. Inst. Math. Stat. **25**(1) (2010)
6. Tokyo Stock Exchange: Corporate Governance White Paper 2021

Chapter 16
Using the Knowledge of Competent Salespeople: Modeling Business Negotiation Topics to Obtain Customers' Real Needs

Eiji Takaki and Yoko Ishino

Abstract This study focuses on the business negotiations conducted by competent salespeople to elicit the true needs of their customers. Herein, we devise a system wherein the knowledge embedded in the negotiation process is stored as a network of negotiation topics, and an agent will be able to recommend appropriate topics during the new negotiation based on the network structure. We assume that the comprehensive topic network is a result of superimposing typical negotiation cases. Under this assumption, if the importance information of individual partial networks, meaning typical negotiation cases, is known, it can be combined to calculate the importance of each node (topic). The agent can recommend topics with reference to the importance of each node. The analytic hierarchy process is proposed as a method for measuring the importance of each business negotiation case. Then, we take up a B2B transaction example, that is, a sale with consulting regarding a security camera system to another company, to show the results when the proposed method is applied.

16.1 Introduction

Over the decades, research that applies concepts from cognitive psychology has emerged in the business administration field. In particular, research on the knowledge of salespeople has been conducted since the 1980s, adopting a cognitive approach. Knowledge is generally divided into declarative (e.g., facts and concepts) and procedural (e.g., methods and skills) knowledge [1]. How these kinds of knowledge quantitatively and qualitatively differ between competent and less competent salespeople has also been studied [2, 3]. The Tacit Knowledge Inventory for Managers (TKIM) was developed in relation to the procedural knowledge acquired through practical experience. Studies using the TKIM have revealed changing trends regarding the tacit knowledge valued by managers and salespeople [4].

E. Takaki · Y. Ishino (✉)
Yamaguchi University, 2-16-1 Tokiwadai, Ube, Yamaguchi 755-8611, Japan
e-mail: ishino.y@yamaguchi-u.ac.jp

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_16

Elucidating explicit and tacit knowledge can be useful in training to facilitate its acquisition and designing environments that enable its sharing. However, in everyday life, where adaptive prediction is necessary for complex dynamic situations, possessed knowledge alone does not necessarily guarantee high performance. Designing, managing, and coordinating the expression of knowledge in a predictive manner while learning about the situation and working on the target are important [5].

Therefore, the act of discerning and controlling that specialized knowledge to express and how to express it according to the purpose and situation is required. This study focuses on the topics of business negotiations that competent salespeople conduct to elicit the true needs of their customers. The research aims to propose a method for storing and using this kind of knowledge. We specifically propose a system that stores knowledge of business meeting topics in the form of a network, from which agents can recommend appropriate topics according to business meeting contents.

The proposed system is built by performing the following three steps:

(1) We will interview competent salespeople to list several typical and important cases and clarify the skeleton of the topic network of business negotiations in each case (this becomes a partial network).
(2) A simple superposition of the partial networks in (1) will form the framework of a comprehensive network and check for missing topics.
(3) We will calculate the importance of typical cases listed in (1) using the analytic hierarchy process (AHP) and obtain the degree of importance of each node, which means each topic, by superimposing the weighted partial network.

The AHP is a decision-making method used for complex problems with two or more evaluation criteria. It was developed by Thomas L. Saaty in 1971 [6]. The entire problem is represented in a hierarchical diagram of the end goal, evaluation criteria, and alternatives. A synthesis of the big-picture judgment of the entire problem is then created based on the intuitive judgment of a one-to-one comparison of the two factors.

The network structure and the important information of each node created in this procedure basically become a comprehensive topic network that can be used by agents to recommend topics for business negotiations. For example, when a salesperson clicks on a topic being discussed with a customer, the topics connected to that discussed topic by edges are displayed in order of importance. For a newly occurring case, the similarity values between this case and the typical cases listed in (1) may possibly be obtained. These values are then used to update the importance of each node to a more appropriate one.

Having presented an overview of the proposed method, we will take up the B2B sales of security camera systems as an experimental example to verify the modeling of business negotiation topics.

16.2 Related Work

To date, recommendation systems with agents that have been mainly studied are often collaborative or content-based filtering [7]. These filtering systems are a method of automatically predicting user interests by collecting information on the tastes and preferences of many users. On the one hand, collaborative filtering in a product purchase recommendation system uses the purchase history data of a certain target person and those of many other people. From the purchase patterns, the similarity between people and the co-occurrence between products are clarified by correlation analysis. The products to be recommended are then presented [8]. On the other hand, content-based filtering uses keywords and attributes assigned to objects in a database (e.g., products in an online marketplace) and matches them with user profiles to make recommendations [9]. Take music as an example. Music is modeled based on its content. The user preferences and interests are also modeled. The recommendation is then determined by comparing both models. Both filtering types require much data about the object and the user.

In this study, the data on competent salespeople were obtained through in-depth interviews and are qualitative rather than quantitative. Therefore, we used not the correlation analysis between records for recommendation, but the importance obtained through a subjective AHP analysis. It is difficult to judge the quality of a recommendation system built on qualitative data because it is not supported by quantitative data. Therefore, an interactive recommendation system that can be improved by user feedback is desirable [10]. However, we will not go as far as the feedback part. Instead, we will focus on building a recommendation system based on qualitative data.

Research on a topic model in the field of text mining is similar to this study in that network structures are key to understanding the phenomenon [11]. A topic model is a kind of statistical model for natural language processing that discovers the abstract "topics" appearing in a set of documents. It is often used as a tool for text mining to discover semantic structures hidden in a text body. Studies on a topic model, which deal with the network structure, differ from this study in their objectives and methods.

16.3 Proposed Model

Compared to B2C sales, where off-the-shelf products are sold to a large number of consumers, B2B sales, which require product customization for client companies, cannot smoothly proceed without building a relationship of trust with the customer. A competent salesperson uses his or her extensive product knowledge and accumulated experience to gain the trust of the other party and draws out their true needs by offering appropriate topics. Business negotiation topics cover a wide range. We created a topic network by obtaining information through interviews on what topics competent salespeople offer in business negotiations and what connections between business topics are important.

We adopted a network representation for the model of business meeting topics. No direction was considered in the connection of topics; hence, it was an undirected graph. The way it was created will be briefly explained below.

Suppose that a business meeting topic is represented by a lower-case alphabet. For example, suppose that there are three typical business cases (talks), and the topics to be discussed in the three talks are $\{a, b, c, e\}$, $\{c, d, e, h, i\}$, and $\{b, c, f, g\}$. Note that the parentheses represent the constituent elements, but not their order.

$$\mathrm{Talk}_1 = \{\mathrm{a, b, c, e}\}\ Talk_1 = \{a, b, c, e\} \tag{16.1}$$

$$Talk_2 = \{c, d, e, h, i\} \tag{16.2}$$

$$Talk_3 = \{b, c, f, g\} \tag{16.3}$$

Suppose that there are the following connections (edges) between topics, where a connection between two topics is represented by a colon:

- *$Talk_1$ has a:b, a:c, a:e, b:c, b:e.*
- *$Talk_2$ has c:d, c:e, c:h, c:i, d:e, e:h, h:i.*
- *$Talk_3$ has b:c, b:f, b:g, c:f, f:g.*

Not all combinations in a talk can have a direct link. Only those that the expert judges to be subjectively connected can have a direct link. For example, in the first business talk, $Talk_1$, there is no direct connection between *c* and *e*.

A comprehensive network was created by simply superimposing these three cases (talks) (Fig. 16.1). This case presents nine topics from *a* to *i*. At this stage, the approximate importance of each topic can be predicted by calculating the centrality of degree, closeness, and betweenness [12], as indicated in Table 16.1.

However, it is impossible to know which topics are important just from the structure of the topics appearing in a comprehensive network. In the first place, a business

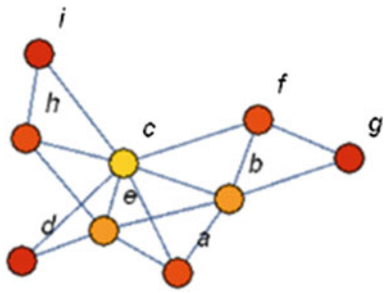


Fig. 16.1 Example of a comprehensive network

Table 16.1 Various centrality values for each node

Centrality	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Degree	3	5	7	2	5	3	2	3	2
Betweenness	0.0	5.3	12.3	0.0	3.2	1.7	0.0	0.5	0.0
Closeness	0.6	0.7	0.9	0.5	0.7	0.6	0.5	0.6	0.5

Table 16.2 Pairwise comparison table of the evaluation criteria

	Scalability	Versatility	Productivity	Robustness	Importance
Scalability	1	5	1/3	3	0.275
Versatility	1/5	1	1/5	1/3	0.062
Productivity	3	5	1	5	0.540
Robustness	1/3	3	1/5	1	0.123

trade must have objectives, and achieving these objectives would require important perspectives (evaluation criteria).

Therefore, herein, we will introduce the idea of extracting important perspectives (evaluation criteria) for the transaction purpose of a product or a service in advance and applying the AHP to clarify the importance of each case and that of the perspective. Once the importance of each case is derived, the value can be used to calculate the importance of each node.

For example, suppose that the purpose of a product transaction is to produce semiconductors, and four evaluation criteria must be considered, namely, scalability, versatility, productivity, and robustness. Using the AHP framework, the respondent, a competent salesperson, first performs a pairwise comparison of all combinations of evaluation criteria. Then, the geometric mean or eigenvalue method is used to calculate the importance of each of the evaluation criteria. Table 16.2 shows values of the importance when using the geometric mean method in this example.

Next, consider that there are several patterns in the choice of business negotiation topics when selling the semiconductor manufacturing system in this example. These patterns are called negotiation cases. Herein, this example assumes that the negotiation cases are those shown in Eqs. (16.1)–(16.3), relating to Fig. 16.1. These three negotiation cases are set as alternatives, or choices, in the AHP, and then compared on a one-to-one basis in all combinations under each of the four evaluation criteria: scalability, versatility, productivity, and robustness. Consequently, it leads to four different tables, in which the table head and the table side are negotiated cases. Each table gives the importance of the three cases under one evaluation criterion. For a single negotiation case, the importance of each evaluation criterion, shown in Table 16.2, is multiplied by the importance of that case under that criterion, and the values are added together to obtain the overall importance [6].

In the example illustrated in Fig. 16.1, suppose that the overall importance of negotiation cases 1 to 3 calculated by the AHP are set to x_1, x_2, and x_3, respectively. In addition, the value for bottoming out that all nodes have equally in advance is set as ω, which has the constraint of $x_1 + x_2 + x_3 + \omega = 1$. The importance of nodes a to d can then be obtained as $x_1 + \omega$, $x_1 + x_3 + \omega$, $x_1 + x_2 + x_3 + \omega$, and $x_2 + \omega$, respectively. An agent is able to refer to the magnitude of this importance and the presence of links in addition to the centrality information described above when recommending topics.

16.4 Case Study in the B2B Transactions of Security Camera Systems

16.4.1 Creating a Flowchart of Business Negotiations

We first interviewed a veteran sales representative and listed the things he mentions in his daily business negotiations. The results included many things that should be observed at the actual site and checked with the customer. The final list comprised 288 topics in 16 categories, including knowledge of crime prevention, motivation for crime prevention, electrical and building conditions, laws, night illumination, and the client's organizational structure, among others. We asked the salesperson to list typical important negotiation cases, elicit strong connections between topics, and structure the topics into a comprehensive network (Fig. 16.2).

The general flow of business negotiations begins with the sales activities starting with the consideration of the need for security equipment other than security cameras, followed by the design of a security environment based on security theory and confirmation of the installation purpose. The targets that can be filmed are divided into "external criminals," "internal criminals," and "both." The necessary information for equipment installation is obtained, including the camera location and the security style. Depending on how security cameras are used, they can cause legal problems, such as voyeurism, violation of privacy and portrait rights, etc. Hence, they must be carefully and strictly operated. Confidentiality must also be explained because many customers do not understand this matter.

In actual business negotiations, details like the number of cameras, location of recording devices, and operation methods are examined, with rework often occurring due to budget and physical constraints. Moreover, the priorities of budget, operation, and specifications of the system to be implemented often change. Priorities also greatly vary depending on the person in charge. Security cameras and recorders are not stand-alone products, but system products used in combination. Customer needs are not a single thing, but an aggregate of various needs with their own strength and weakness. The best combination of equipment must be considered while checking the equipment specifications to meet the aggregate needs of the customer.

The ease of installation and maintenance must also be considered at the end of the business discussion. Although ease of installation is often emphasized for security cameras and recording devices, ease of maintenance should also be considered, as their internal components are actually consumables. In many cases, recording

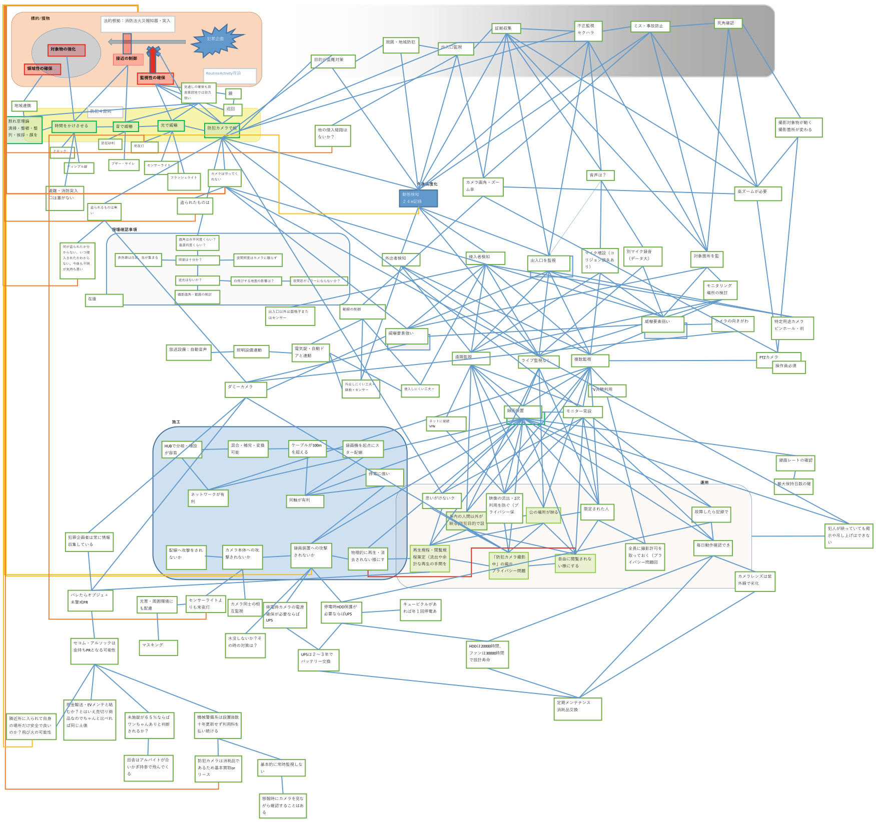


Fig. 16.2 Comprehensive network of business topics related to security camera systems

devices are destroyed or the entire recording device is stolen; thus, installation and storage methods that prevent attacks on recording devices and cameras are necessary. After-sales service must also be considered.

16.4.2 Applying AHP to the B2B Transactions of Security Camera Systems

In applying the AHP, six perspectives were adopted as the evaluation criteria for the business objective of the B2B transactions of security camera systems:

- Severity of the reason for introducing the security camera system
- Degree of difficulty of the assumed target of the shooting
- Degree to which the system must be linked with other equipment (automatic doors, lighting, broadcasting, etc.)

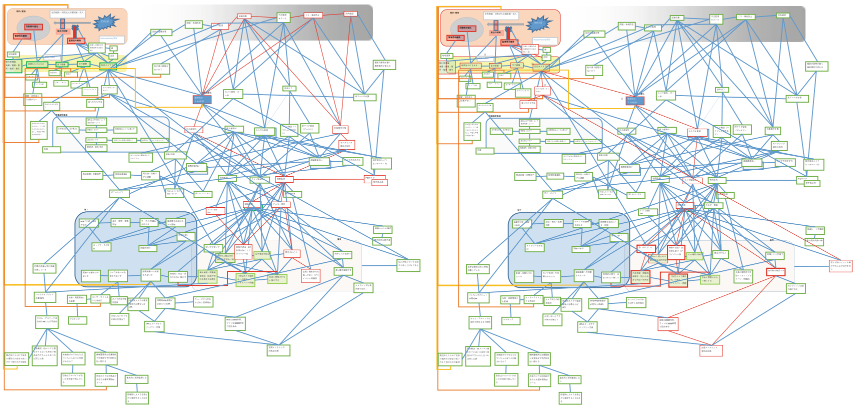


Fig. 16.3 Two types of partial networks. The red partial networks on the left and right drawings represent cases of installations in a hospital room for COVID-19 patients and in a detached house, respectively

- Location where the images and videos are to be monitored
- Installation requirements for recording devices
- Required playback skills and frequency.

The following four cases were then set as typical cases:

- Installation in a detached house
- Installation in a school
- Installation in a drugstore
- Installation in a hospital room for patients with COVID-19.

The left side of Fig. 16.3 shows the main flow of business negotiations for a request from a hospital treating COVID-19 infected patients to install cameras around the patient's bed for care (red line). The right side presents the main flow of business negotiations for a request from a general household (detached house) to deter crimes from the outside with red lines. Although the base negotiation topics and the arrangement in both the left and right figures are the same, the main flow (red line) differs.

We asked competent sales representatives to conduct the AHP. Figure 16.4 shows the importance of each evaluation criterion. The Consistency Index (CI) of the AHP was 0.079, satisfying the criterion of 0.1 or less. The CI is called Saaty's Consistency Index and is a typical criterion for confirming the reliability of a pairwise comparison matrix. In general, the entire pairwise comparison is empirically judged as consistent if the CI value is less than 0.1.

Figure 16.5 presents the magnitude of importance of typical cases. The importance of installation in a detached house is the lowest. The installation in detached houses falls into the B2C category. The company to which the sales representative belongs focuses on B2B, and installation in detached houses is actually the case with the fewest requests. From this point of view, the results are reasonable.

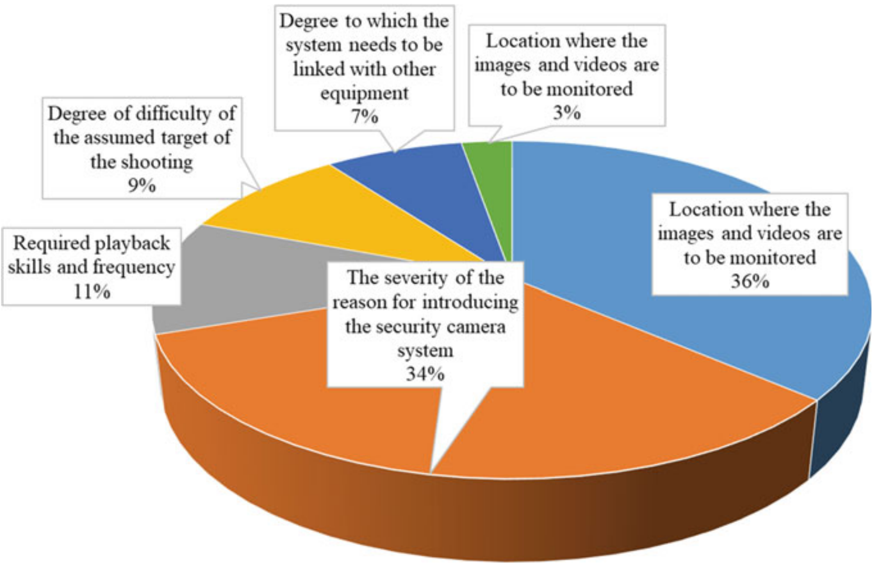


Fig. 16.4 The importance of the six evaluation criteria

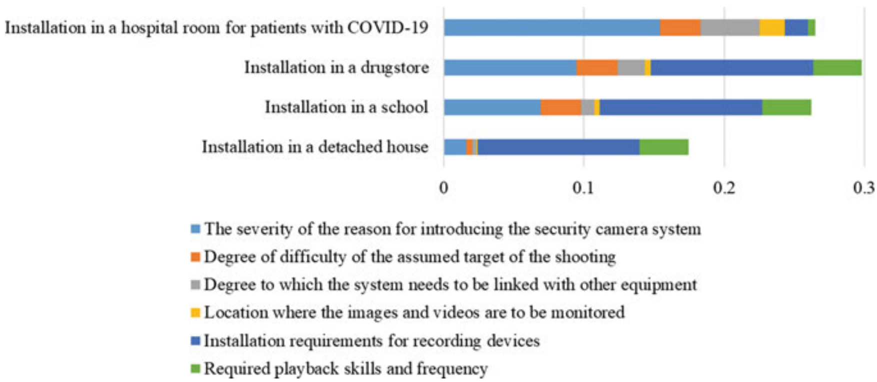


Fig. 16.5 The importance of the four typical cases

We then assumed two new cases that would arise, that is, installation in a nursery school and installation in an apartment building (housing complex). Table 16.3 resents the similarity values of these two cases against the four representative cases calculated based on the subjective judgments of a salesperson. The similarity values of the two new cases were very different; hence, the importance of the nodes in the network calculated based on the similarity must also be very different. When building the agent's topic recommendation system for such a new case, the importance of each node should be flexibly updated to a more appropriate one by using the similarity to the typical cases.

Table 16.3 Similarity values of the two new cases against the four typical cases

	Similarity	
	Installation in a nursery school	Installation in an apartment building
Installation in a detached house	0.00	0.24
Installation in a school	0.41	0.76
Installation in a drugstore	0.00	0.00
Installation in a hospital room for patients with COVID-19	0.59	0.00

16.5 Conclusions

In this study, we attempted to construct a topic network of the business negotiations of salespeople necessary to create a negotiation agent to elicit the true needs of customers. We proposed a model in which the importance of each node (topic) is varied by combining representative important cases with different weights. The AHP was used for the part of the model that reveals the weights of the cases. Finally, as an example of a B2B transaction, we applied the proposed method to a sale by consulting on security camera systems to another company to demonstrate the usefulness of our proposed model.

In the future, we would like to build a system in which agents actually propose topics to actual salespersons using the proposed model and demonstrate its effectiveness.

References

1. Winograd, T.: Frame representation and the declarative/procedural controversy. In: Bobrow, D.G., Collins, A. (Eds.), Representation and Understanding: Studies in Cognitive Science. Academic Press, pp. 185–210 (1975)
2. Leigh, T.W., McGraw, P.F.: Mapping the procedural knowledge of industrial sales personnel: a script-theoretic investigation. J. Mark. **53**, 16–34 (1989)
3. Machintosh, G., Anglin, K.A., Szymanski, D.M., Gentry, J.W.: Relationship development in selling: a cognitive analysis. J. Personal Selling Sales Manage. **12**, 23–34 (1992)
4. Wagner, R.K.: Managerial problem solving. In: Sternberg, R.J., Frensch, P.A. (Eds.), Complex Problem Solving, pp. 159–183, Lawrence Erlbaum Associates, Inc. (1991)
5. Osterland, C.S.: Learning across context: a field study of salespeople's learning at work. Aarhus University, Psykologisk Institut (1996)
6. Saaty, T.L., Vargas, L.G.: Models, Methods, Concepts & Applications of the Analytic Hierarchy Process, ISBN 0-7923-7267-0. Kluwer Academic (2001)
7. Riecken, D.: Introduction: personalized views of personalization. Commun. ACM **43**(8), 27–28 (2000)
8. Ricci, F., Rokach, L., Shapira, B.: Introduction to Recommender Systems Handbook, Recommender Systems Handbook, Springer, pp. 1–35 (2011)
9. Aggarwal, C.C.: Recommender Systems: The Textbook. Springer. ISBN 9783319296579 (2016)

10. He, C., Parra, D., Verbert, K.: Interactive recommender systems: a survey of the state of the art and future research challenges and opportunities. Expert Syst. Appl. **56**, 9–27 (2016)
11. Gerlach, M., Pexioto, T.P., Altmann, E.G.: A network approach to topic models. Sci. Adv. **4**(7) (2018). https://doi.org/10.1126/sciadv.aaq1360
12. Borgatti, S.P., Everett, M.G.: A graph-theoretic perspective on centrality. Soc. Netw. **28**(4), 466–484 (2006). https://doi.org/10.1016/j.socnet.2005.11.005

Part III
Intelligent Agents in Health, Wellness and Human Development Environments Applied to Health and Medicine

Chapter 17
Explainable AI for Autism Classification in Children

Ma. Sheila A. Magboo and Vincent Peter C. Magboo

Abstract Autism spectrum disorder (ASD) is a neurodevelopmental disorder affecting all age groups. At present, there are no diagnostic tests that can quickly diagnose ASD. In this study, several machine learning models (logistic regression, k-nearest neighbors, Naïve Bayes, support vector machine, decision trees, random forest, AdaBoost, XGBoost, and deep neural network) with model explainability were applied to a publicly available child ASD dataset. The best performing models were obtained by support vector machine, logistic regression and AdaBoost with 99–100% accuracy. Feature importance identified the most important features necessary to make an ASD prediction. These features were shared by the best-performing models and were also in consonance with clinical assessment of ASD. LIME helped visualize the reasoning employed by the models to come up with its predictions for better understanding of physicians. This is needed for the potential incorporation of XAI tools in routine clinical practice. Our findings are promising and have generated useful insights in the development of automated models that are faster and with high reliability which can be of use to physicians in predicting autism in children. The early and prompt assessment using XAI tools can potentially reduce the number of patients required to undergo a lengthy and multistep process for diagnosis. Early intervention efforts and treatment ensure the best quality of care for our patients.

Keywords Autism · XAI · LIME · Feature importance · Machine learning · Support vector machine · Logistic regression · AdaBoost

Ma. S. A. Magboo (✉) · V. P. C. Magboo
Department of Physical Sciences and Mathematics, University of the Philippines, Manila, Philippines
e-mail: mamagboo@up.edu.ph

V. P. C. Magboo
e-mail: vcmagboo@up.edu.ph

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_17

17.1 Introduction

According to American Psychiatric Association, Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by challenges in social communication and interaction, restricted interests, and repetitive behavior [1]. The Center for Disease Control's Autism and Developmental Disabilities Monitoring (ADDM) network reported about 1 in 44 children are diagnosed with ASD, four times more common among boys than girls, and affects all racial, ethnic, and socioeconomic groups [2]. Usually, parents observe the onset of symptoms of ASD among children during the infancy stage; becoming more prominent in early childhood and persisting until adolescence and adulthood. This observation allows the health professional to make diagnosis of ASD within any of these age periods [3]. The severity of the disease process would largely determine whether patients could be functionally independent or would be needing constant care. An extensive and lengthy evaluation by psychologists is done using numerous tools such as Autism Diagnostic Interview-Revised (ADI-R) and Autism Diagnostic Observation Schedule Revised (ADOS-R) to come up with an ASD diagnosis [4]. An assessment of ASD in children is very important in the early stages so that prompt intervention can be implemented, thereby improving the quality of life of the patient. It is in this area of early diagnosis where machine learning can be utilized, thus enhancing the whole diagnostic process and leading to the prompt institution of the much-needed therapy.

17.2 Literature Review

In the study, by Andrade et al. involving 0–5 year old children in Brazil, a hybrid approach of combining decision trees with random forest and verbal decision analysis were used to diagnose ASD. The authors concluded that out of more than 80 variables evaluated, only 9 would be sufficient to make an autism diagnosis [5]. Eslami et al. [6], evaluated machine learning (ML) and deep learning (DL) models to make a diagnosis of ASD and attention deficit/hyperactivity disorders (ADHD) using neuroimaging data. The pros and cons of these techniques were also discussed. In Garg et al. [7], the authors applied a hybrid approach of combining DL and eXplainable artificial intelligence (XAI) to determine the most important features of early and late ASD among toddlers. A 4-layer deep learning model has been applied with a 98% accuracy rate while XAI using SHAP model generated the important features that contribute to accurate prediction. In a study by Garbulowski et al., authors studied gene expression measurements of ASD individuals from Gene Expression Omnibus Repository using a centrality distance to generate dissimilarities between ASD subtypes [8]. They applied interpretable machine learning via a rule-based approach to merge databases and estimate dissimilarities between clinical subgroups.

Liang et al. [9], applied a layer-wise relevance propagation method as part of the interpretability of the ML models to classify ASD. Authors combined an unsupervised temporal coherency deep network for feature extraction from unlabeled videos and supervised classification methods (support vector machine (SVM), k-Nearest Neighbors (kNN), and discriminant analysis (DA)) for which accuracy rates of 98% at frame level and 98.3% at video level were obtained. Balaji and Raja applied a DL technique to obtain the most significant features of child ASD dataset and combined it with the k-means clustering technique to generate patterns [10]. Patterns were then fed to stochastic gradient descent (SGD) to determine the classification with enhanced accuracy and which became the basis for the recommendation learning system for autism-affected individuals. Batsakis et al. [11], studied various ML algorithms on ASD classification with high-performance metrics. Interpretability, as well as the relative cost of various types of errors, were also assessed. In their study, SVM with polynomial kernel was the best predictive model with a 0.833 area under the curve (AUC), while the best interpretable model with feature selection was Ridge Logistic Regression (LR) with a 0.794 AUC.

In the study by Andre-Perez et al., the authors applied an XAI inference mechanism called eXplainable multivariate pattern analysis (xMVPA) on infant functional near-infrared spectroscopy (fNIRS) data [12]. The explanation provided is in the form of patterns of interactions between activated brain regions for processing of perceptual stimuli. The xMVPA has comparable performance metrics with SVM, random forest (RF), and multilayer perception (MLP). In the study by Barua et al. [13], the authors reviewed several studies summarizing the range and effectiveness of AI-assisted tools and ML models on students with neurodevelopmental disorders like ASD in children. They concluded that AI tools can be successfully used to improve social interaction and supportive education of these individuals. In the study of Supekar et al. [14], authors applied an XAI via a multivariate time series deep neural network extracting brain dynamic features to classify children with ASD. XAI analyses concluded that brain features associated with default mode network, human voice/face processing, and communication systems, appeared to be the most clearly distinguishing features of ASD as compared to typically developing children. Furthermore, the posterior cingulate cortex emerged as a robust predictor of the severity of social and communication deficits in ASD. Biswas et al., studied an AI model for the early detection of autism in children [15]. The authors concluded that explainability approaches should be incorporated whenever AI systems are applied in healthcare. Finally, Hilal et al. [16], highlighted XAI in the prediction of ASD. Authors used bacterial foraging optimization-based feature selection technique to select important features and whale optimization algorithm with deep belief network and parameter tuning to improve diagnostic performance. Their models had excellent performance metrics (92–98% accuracy, sensitivity, and specificity) and outperformed traditional ML models such as DT, LR, and neural network.

Our objective is to predict ASD in children using a variety of ML classification algorithms namely: Logistic Regression (LR), Naive Bayes (NB), k-Nearest Neighbor (kNN), Support Vector Machine (SVM), Decision Tree (DT), Random Forest (RF), AdaBoost, XGBoost, and Deep Neural Network (DNN) evaluated on a publicly available child autism dataset. It is also our aim to determine the logic employed by the classifiers in their ASD prediction. Performance metrics include accuracy, precision, recall, specificity, and F1 score. Confusion matrices were also obtained.

17.3 Methodology

In our research, the first step is the loading of the dataset. This is to be followed by the preprocessing steps which include data cleaning for inconsistent data, application of imputation technique for missing data, and dataset normalization. We then applied various ML algorithms followed by an assessment of their performance. Feature importance and AI explainability assessment were also performed. The ML pipeline for this study is seen in Fig. 17.1.

17.3.1 Dataset Description

We used a publicly available dataset from the University of California Irvine Machine Learning Repository entitled Autism Spectrum Disorder Screening Data for Children Data Set [17]. The dataset contains 292 instances, with 208:84 male: female sex ratio and an average age of 6.00 ± 0.45 years. The description of the attributes is shown in Table 17.1. The dataset is also a balanced dataset with 141 (48%) with ASD and 151 (52%) without ASD and is based on the AQ-10 screening tool which is used to ascertain whether an individual requires a comprehensive autism assessment. Each of the AQ-10 categories has 10 screening test questions and the results would guide if a patient would need extensive autism assessment. The questions are extracted uniformly from five different sections: attention to detail, attention switching, communication, imagination, and social interaction [3].

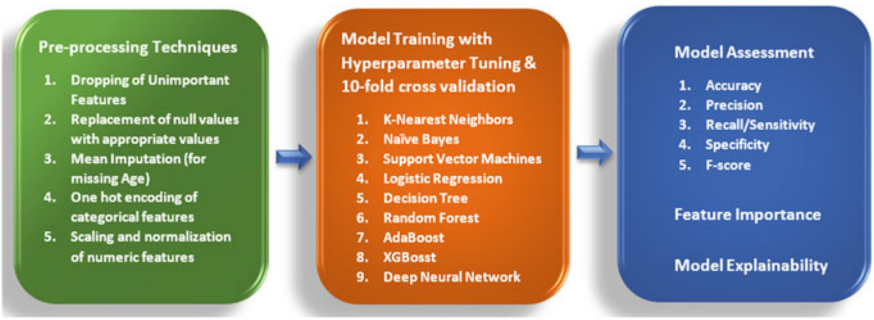


Fig. 17.1 Machine learning pipeline for explainable AI for autism classification in children

Table 17.1 Description of features of the child autism dataset

Attribute	Type	Description
Age	Number	years
Sex	String	Male or female
Ethnicity	String	List of common ethnicities in text format
Born with jaundice	Boolean (yes or no)	Whether the case was born with jaundice
Family member with PDD (pervasive development disorder)	Boolean (yes or no)	Whether any immediate family member has a PDD
Who is completing the test	String	Parent, self, caregiver, etc
Country of residence	String	List of Countries in text format
Used the screening app before	Boolean (yes or no)	Whether the user has used a screening app
Screening method (A1-A10)	Binary (0, 1)	Answer to the question based on screening method used (AQ-10)
Screening score	Integer	Final score based on the screening method
Age description	String	Age description of patients
Class/ASD	Boolean (yes or no)	Class description

17.3.2 Preprocessing Steps

Data cleaning and applied pre-processing methods were applied to the dataset in preparation for ML model training. We dropped the feature ‘result’ since its value can be directly computed from the Ai_scores. We also dropped the ‘age description’ feature since it is irrelevant for an ASD classification. A few missing age values were imputed using the mean imputation. Missing ‘ethnicity’ values were replaced by ‘others’ while the missing values for the ‘relation’ feature were reencoded as ‘not mentioned’. One-hot encoding was applied to encode categorical variables. Feature scaling with normalization using the StandardScaler() function of scikit-learn library was also applied to numeric features in order to resize the distribution so that the mean will be 0 and variance = 1.

17.3.3 Machine Learning Models

The dataset was divided into 70% training and 30% testing with tenfold cross validation applied to each model. We utilized python 3.8 and its various machine learning libraries (scikit-learn, keras, tensorflow, pandas, Matplotlib, seaborn, NumPy, and LIME) in our experiment. The models tested were LR, NB, kNN, SVM, DT, RF, AdaBoost, XGBoost, and DNN.

17.3.4 Feature Importance and Model Explainability

For each model, we obtained the feature importance scores to generate the most important attributes contributing to the ASD classification. A higher score means that the specific feature will have a larger effect on the model that is being used to predict the target. Feature importance helps us understand better which variables are important to the target and which ones are irrelevant. It can also help us interpret and communicate the model to stakeholders. To understand the local behavior of the model for a single instance of an ASD patient, we applied LIME (Local Interpretable Model-agnostic Explanations). LIME is used to explain individual prediction of a black-box machine learning model [18, 19].

17.4 Results and Discussion

The performance metrics of the 9 ML models for our dataset are shown in Table 17.2. The best performing models for the child dataset were SVM, LR, and AdaBoost, with equally superior accuracy rates (99%–100%), precision (97–100%), sensitivity (100%), specificity (98–100%), and F-scores (99–100%). XGBoost, RF, and DNN also have acceptable performances followed by kNN and NB. It is also evident that DT performed rather poorly for this dataset. All models underwent hyperparameter tuning to improve performance. Table 17.3 highlights the confusion matrix of the best-performing models. Comparative performance of best machine learning models is shown in Fig. 17.2.

Table 17.2 Performance metrics for the child ASD dataset

ML model	Accuracy	Precision	Recall (sensitivity)	Specificity	F-score
LR	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
kNN	0.84	0.74	0.95	0.76	0.83
NB	0.83	0.72	0.97	0.73	0.83
SVM	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
DT	0.76	0.66	0.89	0.67	0.76
RF	0.91	0.85	0.95	0.90	0.90
AdaBoost	**0.99**	**0.97**	**1.00**	**0.98**	**0.99**
XGBoost	0.93	0.88	0.97	0.90	0.92
DNN	0.91	0.87	0.92	0.90	0.89

Table 17.3 Confusion matrix of the best performing ML models

SVM	LR	AdaBoost
[[51 0] [0 37]]	[[51 0] [0 37]]	[[50 1] [0 37]]

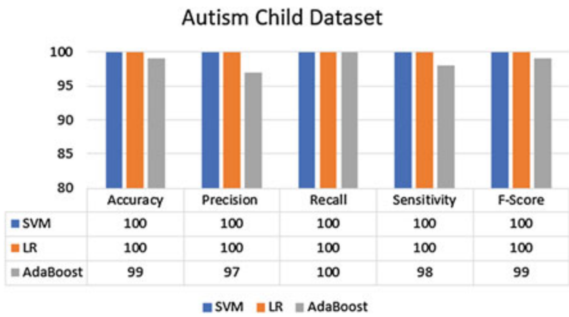


Fig. 17.2 Performance metrics of best models for autism classification in children

The feature importance of the attributes of the best-performing models is seen in Fig. 17.3. For SVM, the most important features relevant to ASD classification are 10th, 5th, 8th, 4th, and 1st questions (A10_score, A5_score, A8_score, A4_score, A1_score) from the AQ-10 questionnaire. For LR, the most important features are the 5th, 10th, 4th, 1st, and 8th questions (A5_score, A10_score, A4_score, A1_score, A8_score), while for AdaBoost, the 1st, 4th, 5th, 7th, 8th questions (A1_score, A4_score, A5_score, A7_score, and A8_score) that are the most important features. Note that the 1st, 4th, 5th, and 8th responses are shared by these three best -performing models. An illustration of explainability for the use of feature importance is shown in

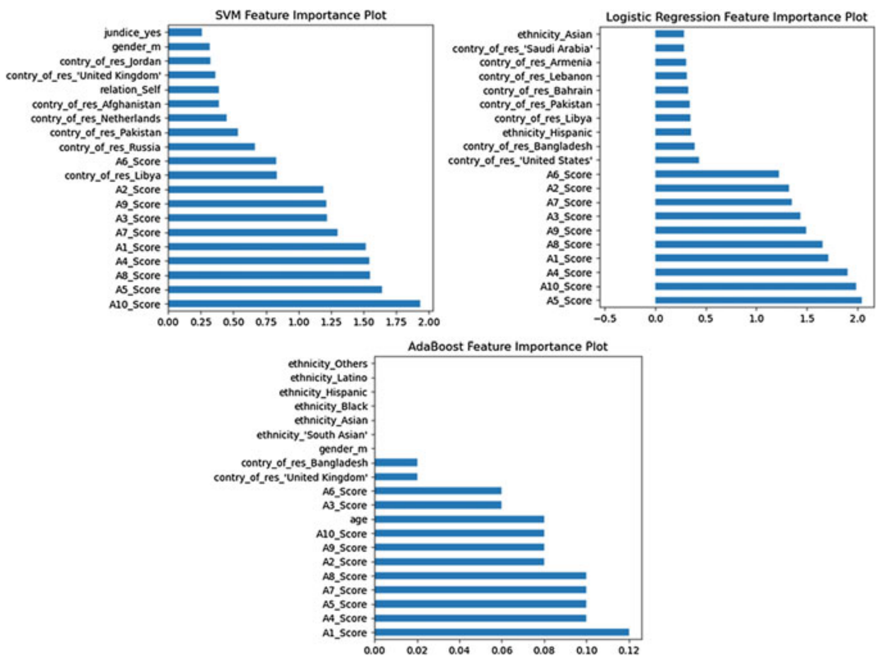


Fig. 17.3 Feature importance of the best models for autism classification in children

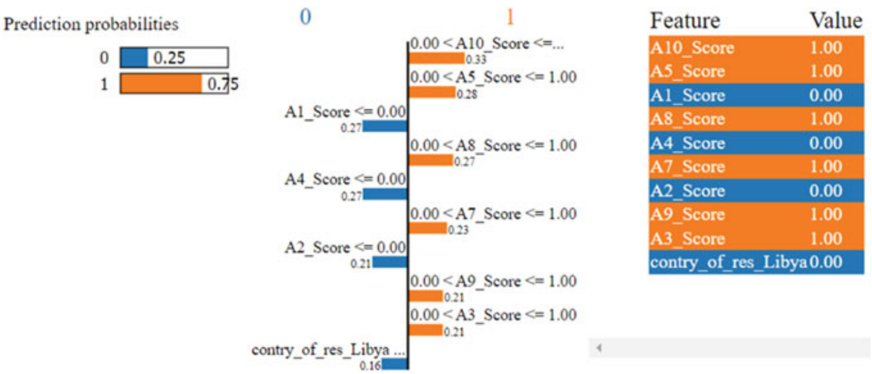


Fig. 17.4 A sample LIME output to explain the features led to the classification (class 1)

Fig. 17.4. Take the case of a child patient correctly classified by SVM as having ASD. The important features used by SVM to make the classification are the following: A10_score, A5_score, A8_score, A7_score, A9_score, and A3_score in that order. Note that these features were in the top 10 most important features of SVM as shown in Fig. 17.3. According to a physician, these top features were also the top determinants for autism.

In Fig. 17.4, the left shows the predicted probabilities of Class 0 (without autism) and Class 1 (with autism). Here, SVM got a prediction probability of 75% for Class 1. The center of Fig. 17.4 shows the average influence of a particular feature in the final prediction. In this example, the top 6 features that influenced the final prediction of Class 1 are A10_score, A5_score, A8_score, A7_score, A9_score, and A3_score which all had a value of 1.0 as shown in the rightmost part of Fig. 17.4. The center of Fig. 17.4 shows how each feature increase on average the predicted probability of that child belonging to class 1. In this example, an A10_score > 0 would increase *on average* 33% the prediction probability of that child belonging to class 1 (with autism), while 28% for A5_score, 27% for A8_score, 23% for A7, 21% each for A9_score and A3_score. This result is acceptable as it was verified by a physician.

With respect to performance metrics, our results are comparable with other studies [3, 4, 16, 20–22]. Additionally, we highlighted the importance of utilizing XAI in ASD classification. In [16], authors have validated the use of their XAI-ASD in improving diagnostic performance and concluded that XAI has brought the machines closer to humans because of its capability to explain the logic behind the diagnosis. Yang et al., likewise, emphasized the insufficient explainability and transparency in most existing AI systems as the major reason for unsuccessful implementation and integration of AI tools in routine clinical practice [19]. While the use of deep learning models could improve performance as compared to traditional ML models, Lombardi et al., have described them as typical black boxes which offer no explanations for reaching a prediction [18]. Our findings suggest the utility of XAI models to make a diagnosis of ASD with acceptable results. The clinical relevance of our experiment is even more highlighted with XAI models that can provide faster predictions with high reliability to help physicians in the screening of children for autism. An early diagnosis leading to prompt intervention efforts is very crucial in children as they are more likely to demonstrate improved cognitive, developmental and adaptive functioning, enhanced language and social skills compared to children who were diagnosed later.

17.5 Conclusion

Autism Spectrum Disorder is a neurodevelopmental disorder afflicting all age groups. We applied several machine learning models with model explainability to a publicly available child ASD dataset. The best performing models were obtained by SVM, LR, and AdaBoost with a 99–100% accuracy. For each model, feature importance scores were obtained to identify the most important features necessary to make an ASD prediction and many of these top features were common to the best-performing models. These identified attributes were also in consonance with the clinical assessment of ASD. LIME exposed the logic employed by the models to come up with its predictions for a better understanding of physicians which is relevant to gain acceptability and potential incorporation of XAI tools in clinical practice. Our findings are promising and have generated useful insights into the development of automated models that are faster and with high reliability in predicting autism in children. The early and prompt assessment using XAI tools can potentially reduce the number of patients required to undergo the lengthy, multistep process to get an official diagnosis. Early intervention efforts and treatment ensure the best quality of care for our patients. Future enhancements of this study should focus on the inclusion of other feature selection techniques such as wrapper, embedded, and hybrid techniques, as well as techniques in XAI such as SHAP, DeepLift, or AIX360 for better understanding of the models by healthcare providers. Moreover, datasets combining symptoms with neuroimaging features seen in functional magnetic resonance imaging or with genetic data can also be explored.

References

1. American Psychiatric Association Homepage. https://www.psychiatry.org/patients-families/autism/what-is-autism-spectrum-disorder. Accessed 21 Dec 2021
2. Center for Disease Control and Prevention Homepage. https://www.cdc.gov/ncbddd/autism/data.html. Accessed 21 Dec 2021
3. Omar, K.S., Islam, M.N., Khan, N.S.: Exploring tree-based machine learning methods to predict autism spectrum disorder. In: Neural Engineering Techniques for Autism Spectrum Disorder, vol (1), pp 165–183. Academic Press (2021). https://doi.org/10.1016/B978-0-12-822822-7.00009-0

4. Vakadkar, K., Purkayastha, D., Krishnan, D.: Detection of autism spectrum disorder in children using machine learning techniques. SN Comput Sci **2**, 386 (2021). https://doi.org/10.1007/s42979-021-00776-5
5. Andrade, E., Portela, S., Pinheiro, P.R., Nunes, L.C., Filho, M.S., Costa,W.S., Pinheiro, M.C.: A protocol for the diagnosis of autism spectrum disorder structured in machine learning and verbal decision analysis. Comput. Math. Meth. Med. article ID 1628959 (2021). https://doi.org/10.1155/2021/1628959
6. Eslami, T., Almuqhim, F., Raiker, J.S., Saeed, F.: Machine learning methods for diagnosing autism spectrum disorder and attention- deficit/hyperactivity disorder using functional and structural MRI: a survey. Front. Neuroinform. **14**, 575999 (2021). https://doi.org/10.3389/fninf.2020.575999
7. Garg, A., Parashar, A., Barman, D., Jain, S., Singhal, D., Masud, M., Abouhawwash, M.: Autism spectrum disorder prediction by an explainable deep learning approach. Comput. Mater. Cont. **71**, 1459–1471 (2021). https://doi.org/10.32604/cmc.2022.022170
8. Garbulowski, M., Smolinska, K., Diamanti, K., Pan, G., Maqbool, K., Feuk, L., Komorowski, J.: Interpretable machine learning reveals dissimilarities between subtypes of autism spectrum disorder. Front. Genet. **12** (2021). https://doi.org/10.3389/fgene.2021.618277
9. Liang, S., Sabri, A.Q.M., Alnajjar, F., Loo, C.K.: Autism spectrum self-stimulatory behaviors classification using explainable temporal coherency deep features and SVM classifier. IEEE Access **9**, 34264–34275 (2021). https://doi.org/10.1109/ACCESS.2021.3061455
10. Balaji, V., Raja, S.K.S.: Recommendation learning system model for children with autism. Intell. Autom. Soft Comput. **31**(2) (2022). https://www.techscience.com/iasc/v31n2/44543
11. Batsakis, S., Adamou, M., Tachmazidis, I., Antoniou, G., Kehagias, T.: Data-driven decision support for autism diagnosis using machine learning. In: Proceedings of the 13th International Conference on Management of Digital EcoSystems (MEDES 2021). Association for Computing Machinery, New York, NY, USA, pp. 30–34 (2021). https://doi.org/10.1145/3444757.3485101
12. Andreu-Perez, J., Emberson, L.L., Kiani, M., Filippetti, M.L., Hagras, H., Rigato, S. Explainable artificial intelligence based analysis for interpreting infant fNIRS data in developmental cognitive neuroscience. Commun. Biol. **4**, article number 1077 (2021). https://doi.org/10.1038/s42003-021-02534-y
13. Barua, P.D., Vicnesh, J., Gururajan, R., Oh, S.L., Palmer, E., Azizan, M.M., Kadri, N.A., Acharya, U.R.: Artificial intelligence enabled personalised assistive tools to enhance education of children with neurodevelopmental disorders—a review. Int. J. Environ. Res. Public Health **19**, 1192 (2022). https://doi.org/10.3390/ijerph19031192
14. Supekar, K., Ryali, S., Yuan, R., Kumar, D., De Los Angeles, C., Menon, V.: Identification of robust and interpretable brain signatures of autism and clinical symptom severity using a dynamic time-series deep neural network. Eur. Psychiatry **64**(S1), S145–S145 (2021). https://doi.org/10.1192/j.eurpsy.2021.397
15. Biswas M., Kaiser M.S., Mahmud M., Al Mamun S., Hossain M.S., Rahman M.A.: An XAI based autism detection: the context behind the detection. In: Mahmud M., Kaiser M.S., Vassanelli S., Dai Q., Zhong N. (Eds.) Brain Informatics. BI 2021. Lecture Notes in Computer Science, vol. 12960. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-86993-9_40
16. Hilal, A.M., Issaoui, I., Obayya, M., Al-Wesabi, F., Nemri, N., Hamza, M.A., Duhayyim, M.A., Zamani, A.S.: Modeling of explainable artificial intelligence for biomedical mental disorder diagnosis. Comput. Mater. Cont. **71**(2), 3853–3867 (2022). https://doi.org/10.32604/cmc.2022.022663
17. Fadi Fayez Thabtah: Autistic Spectrum Disorder Screening Data for children. https://archive.ics.uci.edu/ml/machine-learning-databases/00419/ last accessed 2021/11/4.
18. Lombardi, A., Diacono, D., Amoroso, N., Monaco, A., Tavares, J.M.R.S., Bellotti, R., Tangaro, S.: Explainable deep learning for personalized age prediction with brain morphology. Front. Neurosci. **15**, 674055 (2021). https://doi.org/10.3389/fnins.2021.674055
19. Yang, G., Ye, Q., Xia, J.: Unbox the black-box for the medical explainable AI via multi-modal and multi-centre data fusion: a mini-review, two showcases and beyond. Inf. Fus. **77**, 29–52 (2022). https://doi.org/10.1016/j.inffus.2021.07.016

20. Raj, S., Masood, S.: Analysis and detection of autism spectrum disorder using machine learning techniques. Proc. Comput. Sci. **167**, 994–1004 (2020). https://doi.org/10.1016/j.procs.2020.03.399
21. Radha, S., Arathy, S.L., Chatterjee, J.M., Alaboudi, A., Jhanjhi, N.: A machine learning way to classify autism spectrum disorder. Int. J. Emerg. Technol. Learn. (iJET) **16**(06), 182–200 (2021). https://doi.org/10.3991/ijet.v16i06.19559
22. Mohanty, A.S., Parida, P., Patra, K.C.: ASD classification for children using deep neural network. Glob. Trans. Proc. **2**(2), 461–466 (2021). https://doi.org/10.1016/j.gltp.2021.08.042

Chapter 18
Voice Control System Through NLP (Natural Language Processing) as an Interactive Model for Scalable ERP Platforms in Industry 4.0

Tanya Rojas González, Martha-Alicia Rocha, Rosario Baltazar, Miguel-Ángel Casillas, and Josue del Valle

Abstract The present paper analyzes one of the latest NLP Google Bert algorithms in a particular use case that allows business administrators to not only gather useful business statistics for managing the Data Manipulation Languages, but it is also capable of managing the Data Definition Languages in a flexible ERP system by voice command entry, with more than only English languages for voices entries to be analyzed with Google Bert NLP. supporting automatic vertical and horizontal data growth considering the infrastructure complexity in manufacturing organization in the industry 4.0 and their considerations and inconveniences to be implement.

18.1 Introduction

In this work, we introduce a methodology to apply the NLP Bert algorithm with Latin America Spanish as a sample voice entry to be applied in the Manufacture Industry 4.0.

T. R. González (✉) · M.-A. Rocha · R. Baltazar · M.-Á. Casillas · J. del Valle
Instituto Tecnológico de León, Av.Tecnológico s/n 37290, León, GTO, Mexico
e-mail: tanya-rojas@leon.tecnm.mx
URL: http://www.itleon.edu.mx

M.-A. Rocha
e-mail: marthaalicia.rocha@leon.tecnm.mx

R. Baltazar
e-mail: rosario.baltazar@leon.tecnm.mx

M.-Á. Casillas
e-mail: miguel.casillas@leon.tecnm.mx

J. del Valle
e-mail: josue.delvalle@leon.tecnm.mx
URL: http://orcid.org/0000-0003-1758-4092

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_18

Nowadays, the production paradigms are characterized by an increase in the variety of products developed in the assembly lines, which forces to manage a greater number of models in production systems. The just-in-time principle generates the need to modify production lines to make them more easily configurable in the following generations of products. For this reason, it is important to consider that the production paradigms have evolved in response to the trend of change in the commercial environment, generating frequent changes in the production lines, both in volume and in the reduction of lifetimes in the market and, consequently, generate a management system which is highly scalable and flexible for multinational organizations.

This project aims to develop a model for a Multi-Agent system that allows unifying different phases in the process of developing tools for productive environments, directing these to the administrators of manufacturing companies, who are usually non-technical personnel, and therefore, create useful tools to streamline the analysis of requests for new tools or requests for productive information allowing an improvement of statistical data that could help to facilitate management and support the integration of new technologies in this type of environments. To be more specific, the project pretends to implement an NLP (Natural Language Processing) system that takes DQL (Data Query Language) and DML (Data Manipulation Language) requests to take production information decreasing the complexity and time of forcing the user to learn a big user-guide with extending commands.

18.2 Related Work

To propose the present project, we took into consideration that the configuration of assembly systems exists in four principles of industry 4.0: connectivity, information, knowledge, and intelligence.

There are four production paradigms proposed in the research that according to their acronym in English will be: DAS—Dedicated Assembly Systems, RAS—Reconfigurable Assembly Systems, FAS—Flexible Assembly Systems, and MFAS—Manual Flexible Assembly Systems (Fig. 18.1).

Currently, there are a wide variety of tools that support manufacturing companies at different stages.

Actually, there are tons of tools such as MES or MDC directly provided by the distributors of the productive equipment for the management of the processes in which the machines are particularly involved, these tools are usually supported by direct communication with scada or TCP/IP protocols to store statistical information which we can access through our administrative layer, which are usually ORPS applications that provide the possibility to deploy the information through graphical results throughout the entire supply chain.

The current state-of-the-art research shows us that there are various platforms developed in order to obtain data through hardware interfaces, developed and distributed to name a few by Amazon, Google, Apple, and Microsoft, such as Alexa,

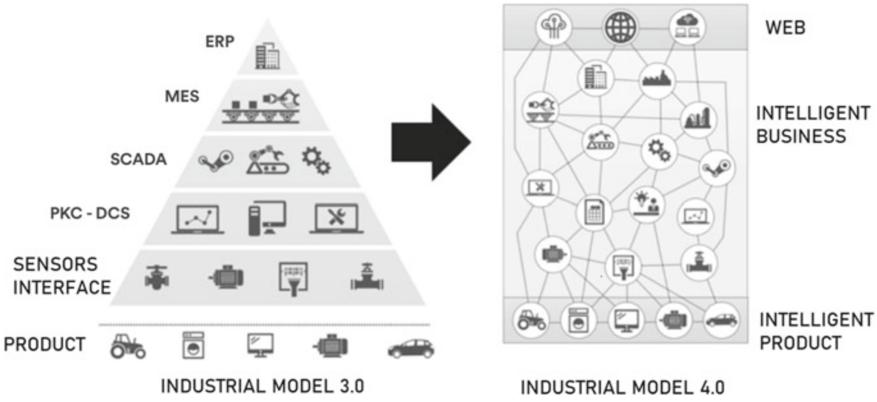


Fig. 18.1 Industrial Model

Google, Siri, and Cortana [1] in their last user or general public products but we also find that big manufacture companies gather information from Siemens, RockWell, ABB... PLC's connect to the device peripherals by OPC most commonly by tcp/ip communication.

This business complexity in the infrastructure force that the deployment of a solution for NLP have more variables in the implementation of the solution either if an open source library as spacy [7] is implement or a paid system that already has the voice entry peripheral as echo for Amazon.

On one hand, the open-source libraries or API's such as spacy, that is widely know and have a big community contributing to it, by itself already contains the token algorithms proposed by Bert and pre-trained corpus that make the natural language processing also reachable and handle by its matcher module, so as the Bert Algorithm but this is a library whose implementation should also be set as service in a microservices structure save and process by a local or cloud server.

On the other hand, some technologies such as Amazon need to be processed on cloud servers to adapt them into private developments, such as native clouds, for example, Azure, Amazon or Google cloud, generating a cost per service that varies according to the deployment configured in the correspondent cloud.

However, they have the advantage of containing themselves, with the ability to obtain information by voice ordering, convert it to text, analyze the said text, compare it with a pseudo-trained matrix, and therefore, generate an output; meaning that the first part in the propose flow for this particular utility model could be handle.

We must consider that each interface will have different commands and capabilities depending on the training Corpus, therefore, reliability varies between each provider. In particular, for the skills that Amazon provides in its Alexa tool, it limits the configuration to the definition of intentions, better known as "intents", emulating a pseudo-intelligent system that despite that it can increase the set of intents defined for a command, it is not a NLP even that it allows adding a set of phrases to invoke actions, however if the user enters a non-predefined command in the set, these tools

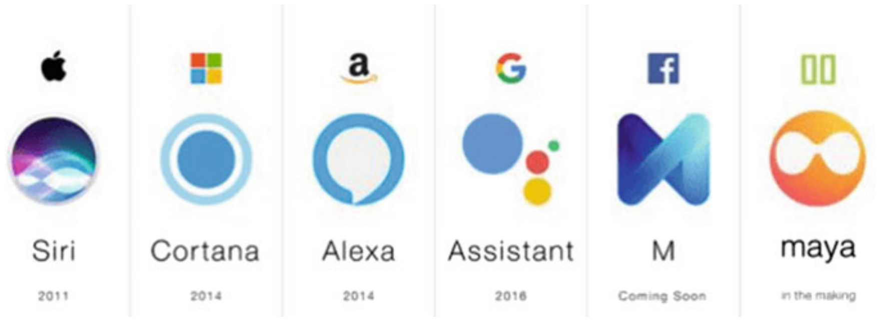


Fig. 18.2 Assistants

will not be able to understand unless this new command is added by a developer, which limits its usefulness for the particular use cases that want to be solved in this project.

Another consideration or limitation in the use of these tools is the cost per time and amount of data processed in the cloud servers available in the corresponding provider (Fig. 18.2).

18.3 Methods and Materials

In order to be able to manage the manufacturing companies with the proposed flow, the next module requires [4] that needs to interact with each other to complete the proposed flow as show in Fig. 18.3:

- Voice to text agent.
- Translation to English agent.
- Natural Language Processing agent.
- Classification of result tokens.
- Search token into the propose business model agent.
- Agent to return related information found, if the request is related to DML-Read.
- If the request is related for DML-Delete, Update or Create last user information, save data to be validate for authorize business actor of involve areas in the correspondent UI environment.
- If the request is related to DDL, save data to be validate for authorize business actor of process involved areas.

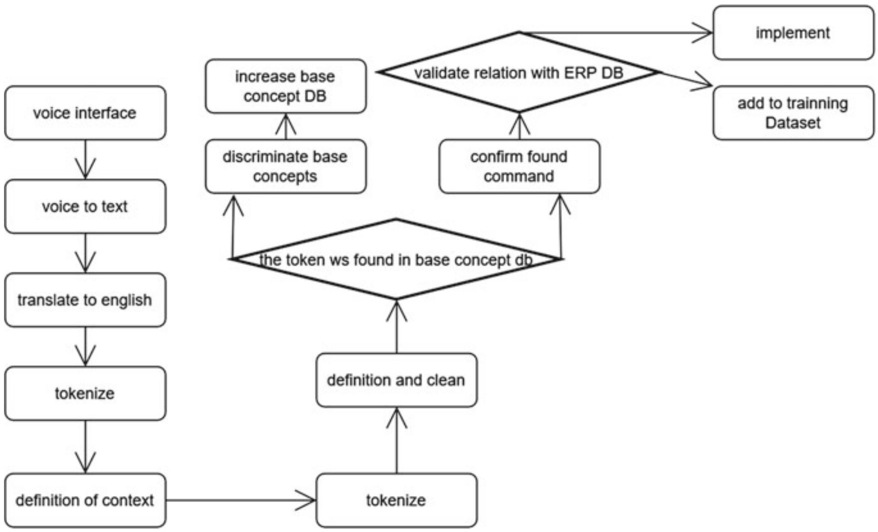


Fig. 18.3 Complete general flow

18.4 Multi-agent System

18.4.1 Voice to Text Agent

Nowadays, there exists several voices to text tools that the system can adopt to be part of the proposed algorithm, and the consideration to use one or another will depend on diverse factors such as

- Budget—to buy or rent the local or cloud server to deploy the solution.
- Infrastructure—can be simplified if an Iaas is rented to deploy the solution
- Usage—depending on the business, usability and available complement services are needed as ISP and network infrastructure.

However, considering that the area of natural language processing has been widely studied, this paper focuses on some agents associated with the process with the main objective of analyzing the feasibility of implementing these models in manufacturing companies to contribute to the advancement in the area of 4.0 organizations than the NLP algorithms itself.

Next, you can find some of the available tools with their considerations to implement (Fig. 18.4).

- Voice assistants
  - Pros: The existing providers such as Amazon Alexa, Apple Siri, Microsoft Cortana, and google have in the first place a very robust infrastructure to offer different functions such as noise suppression modules, NLP analysis to filter

Fig. 18.4 Assistants

semantic, grammar, and lexical accidents to name a few of the multiple tools. In second place, it provides support that released continues update to fix incidents feed by the big amount of information provide by the immense users that those companies have.
- Cons: Based on the Alexa skill developer tools, we can point out that the entries are limited to the predefined intents making the complex business request entry by the business administrator pass directly to the proposed application without the analysis filters decreasing the potential benefits of this assistants. As second consideration, the constant dependency of ISP will add a potential variable problem to the business, and in third place, the cost increase for the entry node hardware (echo, dots..) and the process and analyze servers usage can be considerable.

- Speech recognition API
  - Pros: depending on the used API or library, the cost could vary from the one generated while using a voice assistant as the mentioned Assistants section. There are some communities that also help to support and constantly release new updates to the current private and public APIs as can be seen with the Spacy Library [7]. The second advantage of implementing an API is that some of them offer offline Libraries that can be downloaded to interpret the voice entries without a constant ISP connection.
  - Cons: The support and available tools are limited, extra the noise considerations by the usage of not specialize voice entry interfaces, previous language accidents corrections will rely on a self manage server creating more steps in the supporting process of the deployment. The extra cost of the servers that will save and process a big company requests of the need micro services with the correspond library or the improvements of the trained corpus will depend of constant Internet services.

18.4.2 Translation

The google translate and the spacy.lang module in spacy libraries allow the translation of any language to the destination language defined as dest, and particularly for this case, we used English as follows used English corpus [5]:

18.4.2.1 Google

```
from googletrans import Translator

translator = Translator()
my_context =  str(translator.translate
    (my_context_esp, dest="en").text)
```

18.4.2.2 Spacy

```
from spacy.lang.es import Spanish

nlp = Spanish()
```

18.4.3 Natural Language Processing

18.4.3.1 Tokenization

The recent Google Bert algorithm considers tokenization as the process to split the full-text entry into a word array separating the prefixes, roots, and suffixes that will help in the times and conjugation management (Fig. 18.5).

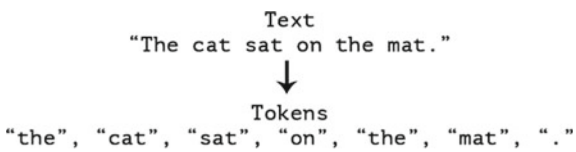


Fig. 18.5 Tokenization

18.4.4 Embedding

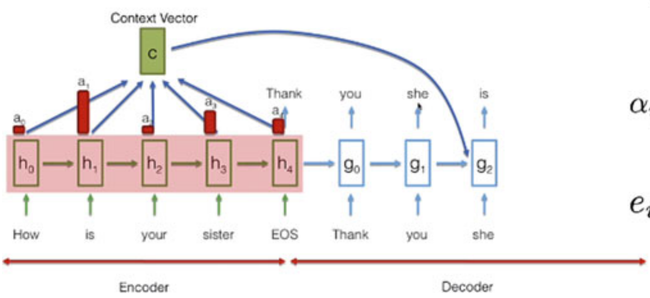
The second part of the process, a numerical value is assigned to each token defined in the tokenization phase, however, these numerical values are not trivial. The values defined in the embedding layer were determined as part of the Bert algorithm based on their meaning with respect to other words, so words that have a certain relationship in meaning with each other would be expected to have a normal value between 0 and one. Approximate to each other, however, given that the statements tend to define the words by context, an independent definition is not practical, so a method called transformation is used as the third stage of analysis [2]:

18.4.5 Transformer

The third part of the NLP using Bert consist in implementing the convolution algorithm in the analysis of meaning of phrases base in context using the Stanford Question Answering Dataset making matrix to analyses the meaning values relations between the words in the sentences. This particular layer was the main reason to consider the usage of Bert algorithm over other libraries as Spacy for the capability to specialize the convolution analysis of particular production contexts (Fig. 18.6).

18.4.6 Metadata Interaction

As the main objective of the present work is the implementation of the NLP Bert algorithm into a complex business infrastructure, it is important to consider that the next process after the transformer process that will result in a dictionary that query the base concept tables to find pre-defined relations and will create records



$$c_i = \sum_j \alpha_{ij} h_j$$

$$\alpha_{ij} = \frac{\exp(e_{ij})}{\sum_k \exp(e_{ik})}$$

$$e_{ij} = a(g_{i-1}, h_j)$$

Fig. 18.6 Transformer

in the meta data table and the defines tables, values with type of data and values in them as record inside other tables show in Fig. 18.8. The proposed model to interact with the metadata is based on the framework methodology, in which we save the tables information into a table that keeps the fields relations allowing to increase the database vertically and query it; as can be seen in Fig. 18.9, implementing SQL not related database that can support the type of next types of data:

- string
- double
- boolean
- object

Even the more detailed definitions need to be considered to secure the data integrity, the proposed database, however, represents the general considerations that can be taken to interact with the metadata as needed in this ERP model.

18.5 Experiments and Results

The system was originally pre-trained in 3 layers, first, the Bert Algorithm itself has trained the tokenization values as part of the dataset of the algorithm, the second layer of the algorithm is trained using the worldpiece with 30522 articles and the wikipedia corpus with more than 1,728,146 articles. The third layer in the trainning process uses The Stanford Question Answering Dataset SQuAD2.0, which combines 100,000 questions in SQuAD1.1 with over 50,000 unanswerable questions written adversarially by crowdworkers to look similar to answerable ones (Fig. 18.7).

The pre-trained codes were tested by giving an assertivity under tpu processors of 88.5% in the trainning process and 84.6% in the testing process.

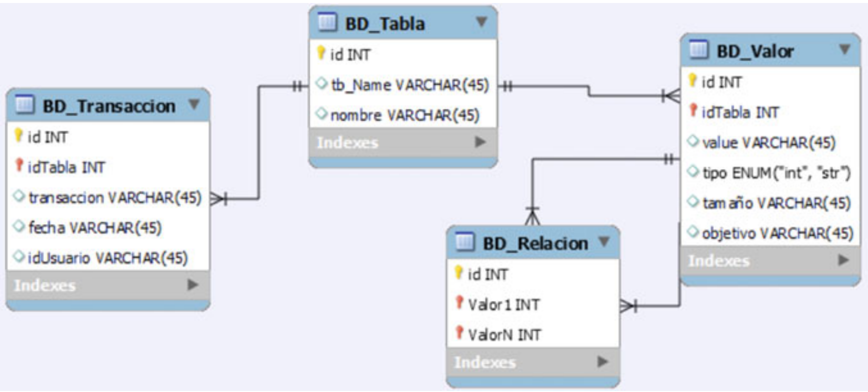


Fig. 18.7 Scheme of model adjustment

This particular project Experiments consisted in taking sentences that were pass to the system to determinate if it was capable to assert fix question related to the information that wants to be look for in the correspondent data base as:

18.5.1 Sentence Defined as Sample

My employee number is 20702, we need to know the quantity of products created in the line of production 3 during the first turn of January 15, 2022.

18.5.2 Questions Defined as Sample with Desire Response

- Who is consulting data? Employee number 20702
- What data is requested? The quantity of products created in the line of production 3
- which period of time wants to be consulted? First turn of January 15, 2022

The proposed system with production related information was tested by giving an assertivity under tpu processors of 42.5% in the trainning process and 37.6% in the testing process.

	Squad 1.1	Production Context
trainning	88.5%	42.5%
testing	84.6%	37.6%

18.6 Conclusions

Even though the paper represents mostly the important points related to the NLP, the thesis and research were also focus in the consideration that most be take in the implementation of this tool and It is important to consider that since the system is potentially scalable both horizontally and vertically, a module should be considered to control computing and storage capacity. In the same way, to complement the services that manufacturing companies require, this project could, although it is not developed, incorporate a communication mechanism. For productive control, it must allow the communication of devices through Scada, TCP/IP, OPC.

18.7 Recommendations

Current computer systems capable of processing machine learning algorithms should preferably have TPUs designed precisely with this, however, it is possible, although not very optimal, to work under other processing structures such as GPUs and CPUs [6]. The Squad dataset used was a 1.1 version and nowadays the version 2.0 is available that allows to find information in a context that doesnt necessarily include the specific words neither in the questions or the contexts, so that better results are expected with that versions.

References

1. codegrepper Corp. python speech to text spanish. Code Answer. https://www.codegrepper.com/code-examples/python/python+speech+to+text+spanish
2. Davidson, S., Yamada, A., Mira, P.F., Carando, A., Gutierrez, C.H.S., Sagae, K.: Developing NLP tools with a new corpus of learner Spanish (2020). https://aclanthology.org/2020.lrec-1.894.pdf
3. Explosion AI, various, February 2015, “spaCy 101: Everything you need to know”. https://spacy.io/usage/spacy-101
4. Kim, H.S., Chang, M.H., Lee, H.J., Park, K.S.: A comparison of classification performance among the various combinations of motor imagery tasks for brain-computer interface. In 2013 6th International IEEE/EMBS Conference on Neural Engineering (NER). IEEE (2013). https://doi.org/110.1109/NER.2013.6695965
5. Moreno-Jimenez, L.G., Torres-Moreno, J.M.: Megalite: a new Spanish literature corpus for NLP tasks (2021). https://www.researchgate.net/publication/348968894_Megalite_A_New_Spanish_Literature_Corpus_for_NLP_Tasks
6. Vivek, G.: How to add jobs to cron under linux or unix. https://www.cyberciti.biz/faq/how-do-i-add-jobs-to-cron-under-linux-or-unix-oses

Chapter 19
Use of Multi-agent System to Classify Control EEG Signals: A Preliminary Study

Francisco Sierra, Rosario Baltazar, Anabel Pineda, Miguel-Ángel Casillas, Claudia Díaz, and Martha-Alicia Rocha

Abstract The potential use of EEG data along with a Multi-Agent System can offer great benefits to the medical and technological area, and this conjunction is used to provide electronic device control through a BCI that can contribute to elderly people or with motor disabilities as well. This work-in-progress paper focuses primarily on the feature discrimination of an EEG dataset that follows the motor-imaginary paradigm, by applying classification techniques and comparing the accuracy between them will allow us to select the best technique to identify between four different classes, finally those trained datasets will serve as supervised learning data, as reference for real-time EEG signal acquisition, and to program commands.

F. Sierra · R. Baltazar (✉) · M.-Á. Casillas · C. Díaz · M.-A. Rocha
Instituto Tecnológico de León, Av.Tecnológico s/n 37290, León, GTO, Mexico
e-mail: rosario.baltazar@leon.tecnm.mx

F. Sierra
e-mail: fp.sierra218@gmail.com
URL: http://www.itleon.edu.mx

M.-Á. Casillas
e-mail: miguel.casillas@leon.tecnm.mx

C. Díaz
e-mail: claudia.diaz@leon.tecnm.mx

M.-A. Rocha
e-mail: marthaalicia.rocha@leon.tecnm.mx

A. Pineda
Instituto Tecnológico de Matamoros, Carretera Lauro Villar Kilometro 6.5, Tecnológico, 87490 Heroica Matamoros, Tamps, Mexico
e-mail: anabel.pineda@itmatamoros.edu.mx
URL: https://www.itmatamoros.edu.mx

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_19

19.1 Introduction

These days technology advances by leaps and bounds, so it is very important to assertively use the technological tools that are within our reach, using them to benefit a large part of the population. According to the 2020 Population and Housing Census carried out by INEGI [1] (acronym in Spanish of National Institute of Statistics and Geography), of the total population in the country of Mexico (126,014,024), 5.7% (7,168,178) of the population has a disability and/or a mental problem or condition. The most reported activity with difficulty among people with disabilities and/or mental conditions is walking, going up or down (motor disability), with 2.9 million people (41%). It is necessary for this group of people to rejoin the activities of daily life.

In the field of computer science, the analysis and processing of biomedical signals is commonly used for monitoring, diagnosis, and control. In this research, the electroencephalographic signals will be specifically handled, this signals contains useful information and are acquired through Brain-Computer Interface (BCI) systems. These multi-agent systems are mainly used to extract desired characteristics of human brain activity in order to obtain information which can be used to control electronic devices. For the treatment of these signals, it is generally carried out in four stages: Signal Acquisition, Pre-processing, Analysis and Extraction of Characteristics and Classification [2].

The purpose of this working-progress document is to show how it is possible, through the use of intelligent agents, software tools and classification techniques, to discriminate brain signals for application in device control. This multi-agent system is based on the motor-imaginary paradigm. This paradigm is related to neuronal processes and is considered a dynamic mental process, in which the person internally simulates a motor task without movement of any muscular body segment. Using this paradigm through classification techniques will allow us to determine imaginary movements of a person in order to use them to control external devices.

19.2 Related Work

For the elaboration of this work, it was necessary to carry out an in-depth investigation of several authors with projects focused mainly on the area of intelligent Agents in health, well-being, and human development environments. Some of the most relevant are mentioned:

The article *"A comparison of classification performance among the various combinations of motor imagery tasks for brain-computer interface"* compares the classification performance among the various combinations of motor-imagery tasks, toward the multi-dimensional control of motor-imagery BCI. On this article, an EEG motor imagery data set of 99 subjects is used. The author considered using two techniques for feature extraction, Common Spatial Patterns (CSP), and Linear

Discriminant Analysis (LDA), these were applied to extract features and to classify motor-imagery tasks. Also 10×10 fold cross validation was used to evaluate classification accuracy through large data set. For two-class discrimination, was compared the classification accuracy of the results between the different combinations: both feet and one hand, and both hand and one hand [3].

People with motor and neurological deficiencies tend to have very little control over parts of their body and great difficulty walking. So the author of this research worked on the development of solutions based on assisted technology that can provide accessibility and mobility. An intelligent wheelchair is an example of this type of technology. However, its use without proper training can be dangerous due to its nature when performing movements; therefore, a wheelchair simulator games can be a good tool for training people with severe disabilities. The EEG signals can be used as a source of information that allows communication between the brain and an intelligent system. This research aimed to develop a computer model to categorize electroencephalogram signals for the control of a virtual wheelchair using motor-imagery of the left and right wrists, both wrists and both feet. Electroencephalogram signals were acquired through the eegmmidb database -EEG Motor Movement/Imagery Data-set, captured by the BCI2000 system, this signal samples are from 10 individuals, and were used to validate the model. The techniques used are serviceable, making possible its use in three-dimensional simulation environments for the virtual intelligent wheelchair controlled by a brain-computer interface [4].

Another research found, is named “Acquisition, processing and classification of EEG signals for the design of BCI systems based on movement imagery” whose objective is to introduce the fundamentals of BCI systems based on motor-imagery. So data acquisition has been carried out with passive Ag/Cl electrodes and a g. USBamp amplifier 256 Hz. Three feature extraction methods developed in Biosig were used. In the classification block, a FLD (Fisher Linear Discriminant) has been used. To generate the feedback, the Simulink module is used. A total of six volunteers participated in this study consisting of two sessions of movement imagination of one of their hands. The experiments were carried out with the company’s BCI equipment [5].

And finally, one of the most recent works on BCI and EEG signals, in this paper focuses on classification of motor imagery in Brain Computer Interface (BCI) by using classifiers from machine learning technique. The BCI system consists of two main steps which are feature extraction and classification. The Fast Fourier Transform (FFT) features is extracted from the electroencephalography (EEG) signals to transform the signals into frequency domain.

Due to the high dimension of data resulting from the feature extraction stage, the Linear Discriminant Analysis (LDA) is used to minimize the number of dimension by finding the feature subspace that optimizes class separability. Five classifiers Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Naïve Bayes, Decision Tree, and Logistic Regression are used in the study. The performance was tested by using Dataset 1 from BCI Competition IV which consists of imaginary hand and foot movement EEG data. As a result, SVM, Logistic Regression, and Naïve Bayes classifier achieved the highest accuracy with 89.09% in AUC measurement [6].

19.3 Methods and Materials

19.3.1 Multi-agent System

The communication systems through which brain signals are transmitted to the outside world through non-natural forms (like neuromuscular, hormonal, etc.) are the BCI (Brain-Computer Interface) systems. These systems detect the presence of electrical signals in brain activity (measured in microvolts) which, by processing them, can be used as control commands [7, 8].

The main stages in a BCI system are shown in Fig. 19.1.

19.3.2 EEG Data Acquisition Agent

For this research, an Open-Access database is being used. This dataset is named *EEG Motor Movement/Imagery Data-set*. The database file format is .EDF (European Data Format) which is a standard file format designed for exchange and storage of

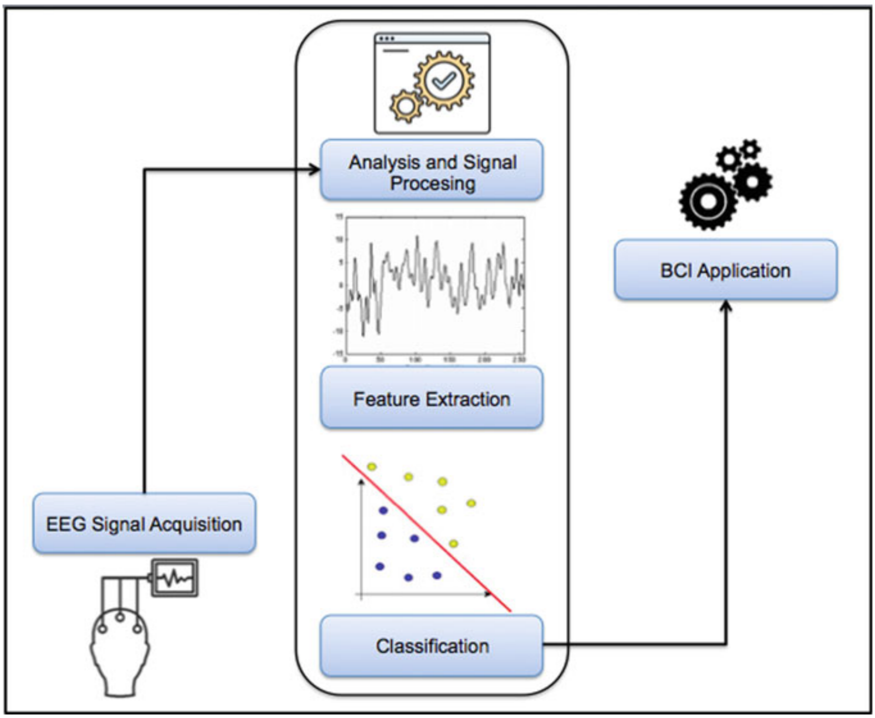


Fig. 19.1 General scheme of the EEG-BCI system

multichannel biological and physical signals. It was recorded using the BCI2000 system. The main features of this dataset are 109 healthy volunteers without any specific requirements, with due consent of all subjects before the experiment. A total of 12 sessions, each session last 2 min, and three runs of each of the four following tasks were performed:

- When a target appears on either left or right side of the screen, the volunteer opens and closes the corresponding fist.
- If a target appears on either left or right side of the screen the volunteer imagines opening and closing the corresponding fist.
- The volunteer opens and closes either both fists if a target appears on top of the screen or both feet if the target is on the bottom.
- If a target appears on either, top or bottom of the screen, the volunteer imagines opening and closing either both fists if the target is on top, or both feet if the target is on the bottom.

The number of sessions determined are a relatively small source of variance, on average 1%. However, this 1% does not mean that the three sequential recordings runs with the same EEG system and the same subject were nearly identical. Rather, there is no systematic bias of Motor-Imagery amplitudes, based on the number of recordings for the same subject and the same system [9].

The database consists of 64 channels in total, which only 9 were selected for use, this decision made is due that on the International System 10/20 we located the parietal and frontal area, is in this part of the brain where the higher electrophysiological activity occurs.

The nine electrode positions selected correspond to the Alpha (8–13 Hz) and Beta (14–30 Hz) brainwave frequency bands [10, 11] (See Fig. 19.2).

19.3.3 EEG Signal Treatment Agent

19.3.3.1 Analysis and Signal Processing

Brainwaves frequency bands are patterns of electrical activity produced by a person's nervous system. These signals have a very low amplitude (measured in micro volts), and depending on the activity carried out by a person, these signals are generated at different frequencies and locations in the brain. The frequency bands widely used are Delta ($0.1-4$ Hz), Theta ($4-8$ Hz), Alpha ($8-13$ Hz), Beta ($14-30$ Hz), and Gamma ($30-63$ Hz). These frequency bands are also called Brain Rhythms. The pre-processing of signals is carried out using EEGLAB, a MATLAB Toolbox under free BSD license, for processing data from electrophysiological signals, this toolbox supports various database file formats, and allows us to load the dataset in .EDF (European Data Format) file format which is a standard file format for biological multi-channel signals. This software gives us the possibility to eliminate the noise

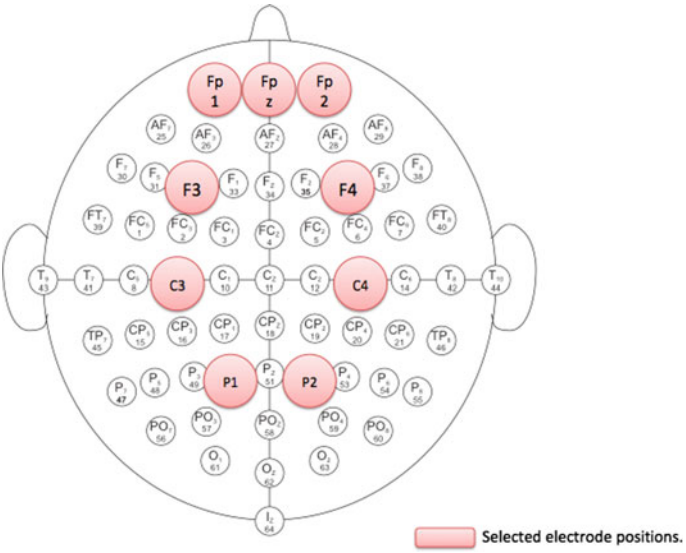


Fig. 19.2 International 10/20 system for electrode placement

(artifacts) of the EEG signals that we select and remove the channels that do not interest us [12].

This research is based on the motor-imaginary paradigm which comes from electrophysiology, an area of research that is responsible for analyzing and studying the electrical processes that take place in different organs of our body, this paradigm is an effective tool since when imagining some motor movement, activity is triggered electricity that is of importance to us to register. This paradigm shares a structure very similar to the actual execution of the movement [13].

An artifact is an interference in a signal that overlaps and hides the signal resulting from brain activity, an example of an artifacts can be blinking eyes, heartbeat, or some unintentional gesture in some part of the body (e.g., clenching the jaw, swallowing saliva, etc.).

19.3.3.2 Feature Extraction

Due to the fact that the brain signals are non-stationary and because of a low signal-to-noise ratio generated, processing these signals becomes difficult, and therefore the use of Fourier Transforms is not feasible, this is why Wavelet analysis techniques are needed, so we can delimit frequencies of interest in brain signals and effectuate its correct interpretation. The characteristics of a Discrete Wavelet Transform to identify the time-localized events makes it perfectly suitable for the biomedical signals. For the feature extraction we use a Tool-Box provided by MATLAB called *Wavemenu*, which allows us with the use of Discrete Wavelet Transform, to decompose into two low-pass signals using scaling function, choosing the family of Daubechies of

6Th decomposition level, whose objective is to obtain their coefficients [14]. The coefficients of low-pass filters correspond to the scaling function and the coefficients of high-pass filters correspond to wavelet function; it is needed to apply statistical functions to these coefficients to obtain our vector of characteristics [15, 16].

19.3.4 Classification Agent

For classification tasks, was decided to choose Weka software, which is a free license platform that mainly provides a variety of tools for classification, regression and clustering tasks, also includes several machine learning algorithms for data mining problems. This research is carried out with the intention of implementing the support vector machine learning algorithm in its final version [17, 18]. At the moment two supervised classification methods were used in this research: K-NN and Naive-Bayes [19].

19.3.5 BCI Application

The contribution of this research, which lies in the classification of signals following the paradigm of motor-imagination, has a very wide range of applications, both in the medical and technological areas. In the field of medicine, it provides tools that can be of great importance for the sector of the population with some type of motor disability, as well as the elderly population that finds it difficult to move. In the field of artificial intelligence, it provides theory and knowledge to understand the procedures carried out by the human brain when executing activities that involve moving, as well as using multiple agents in a BCI system to find different techniques that provide better results and therefore can benefit the scientific community [20].

19.4 Experiments and Results

This experimentation was done by following the model adjustment scheme, Fig. 19.3, which works in a similar way to the general scheme except that the BCI application module is excluded. This scheme is mainly focused on training the chosen classification methods with the Physionet dataset, although it can work with different EEG databases as long as the file format is compatible with the EEGLAB toolbox.

The preprocessing was done with the EEGLAB toolbox, providing several methods to remove all kinds of artifacts from the data set, the one used it is known as ICA (Independent Component Analysis), this method assumes that signal sources are instantaneously linear mixtures of cerebral and artifactual sources, so can decompose observed signal into independent components (ICs). Once ICs are extracted from

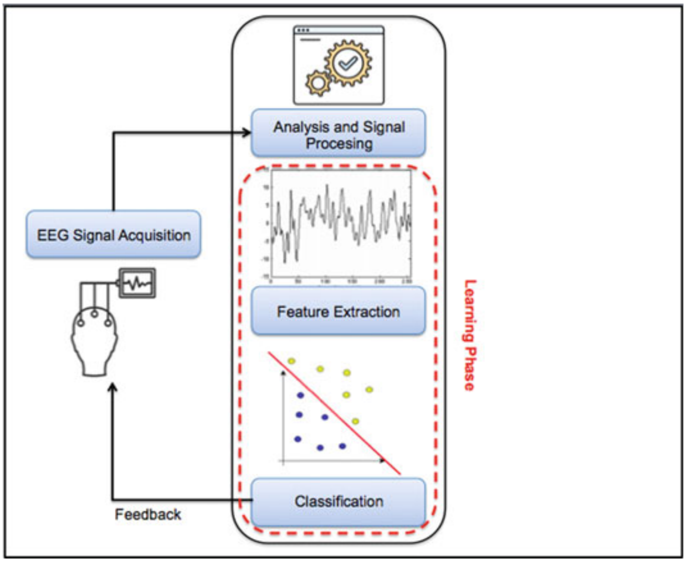


Fig. 19.3 Scheme of model adjustment

original signals, the clean signal is reconstructed by discarding ICs contained artifacts, without losing any integrity of the database signals, also unwanted frequency channels were removed, to focus only on the signal channels that are needed.

The data set was exported in .txt format and imported into the MATLAB command line for the next phase. For this next step, it is necessary to convert the .txt file to .mat format to use it to analyze and extract its features, the signal decomposition was performed through the Wavemenu Toolbox, using the multi-signal analysis which allows us to analyze several signals at the same time. Now in the Toolbox interface the Daubechies1 wavelet transform was applied with a decomposition level of 6 [21].

Once the signals are decomposed, we obtain as a result different coefficients that by applying statistical functions we can obtain a vector of characteristics to be used in the discrimination of signals. This vector is made up of data functions such as the mean, median, standard deviation, min range, max range, and absolute mean, we know in advance to which class the signals belong.

We export this vector of features in .CSV format and label it by adding the class feature, this for its discrimination through the Weka software, using the KNN and Naive-Bayes classification techniques [22].

These classifiers are bi-class; therefore, the one-versus-all technique was used because our data is multi-class. In this one-versus-all strategy, four classifiers are created:

- The first one that distinguishes between opening and closing the left fist and the rest.
- The second that distinguished between opening and closing the right fist and the rest.

Table 19.1 Results comparison

Classification method	Accuracy (%)	Mean squared error
K-Nearest Neighbor (2 K-Folds)	91	0.2948
K-Nearest Neighbor (Training Set)	98	0.0098
K-Nearest Neighbor (Split 50 %)	96.2	0.14
Naive-Bayes (2 K-Folds)	82.38	0.3871
Naive-Bayes (Training Set)	88.74	0.3362
Naive-Bayes (Split 50 %)	82	0.3572

- A third that distinguished between opening and closing both fists and the rest,
- A fourth that distinguished between opening and closing both feet.

When classifying a movement, the four classifiers would be executed and the one that received the highest score would be chosen. In general, if we have N different classes, we will need N classifiers.

Table 19.1 shows the accuracy percentages during the classification performed with the feature vector. The percentages show us that the most effective technique used is the K-Nearest Neighbor, showing a more significant precision compared to the Naive-Bayes.

Considering that feature extraction was used using the Daubechies Wavelet of order 6. This family of wavelets is well known for its orthogonality property and its efficient implementation of filters. The Daubechies wavelet of order 6 was found to be more appropriate for EEG data analysis with motor imagery. However, to obtain a clearer comparison, with more optimal results, it is planned in the future to use different orders of the Daubechies family.

Because Naive Bayes is a linear classifier while K-NN is not, it tends to be faster when applied to big data. By comparison, K-NN is typically slower for large amounts of data, due to the calculations required for each new step in the process.

In these tests, K-NN turned out to be more accurate in signal classification, mainly because as the value of k in K-NN increases, the error rate decreases. It was tested until the ideal K value was reached. Naive Bayes will generally show more accurate results if the decision boundary is linear, elliptical, or parabolic.

19.5 Conclusion

In this paper, a model with the integration of different intelligent agents was proposed, which has the potential to be used to control different electronic devices, thanks to the capacity of coupling with different intelligent agents, which combined with a user interface can reach to be used in different fields of work and automation projects.

We are currently working so that this multi-agent system can extract electroencephalographic signals in real time, with the intention that it can be used with any BCI headband in any situation and place. In addition, it is planned to add more different classification methods so that the reliability of the system is the most rigorous in terms of precision.

Acknowledgements To CONACYT, for their support during the study of the master's degree. To PhD. Rosario Baltazar and the research committee for their contribution to this preliminary study.

References

1. Discapacidad, I.: Estadísticas a propósito del día internacional de las personas con discapacidad (Datos Nacionales). Comunicado de Prensa Num. 713/21. (pp. 1–5). 3 de diciembre (2021)
2. Sun, L., Feng, Z.R.: Classification of imagery motor EEG data with wavelet denoising and features selection. In: 2016 International Conference on Wavelet Analysis and Pattern Recognition (ICWAPR), pp. 184–188 (2016). https://doi.org/10.1109/ICWAPR.2016.7731641
3. Kim, H. S, Chang, M.H., Lee, H.J., Park, K.S.: A comparison of classification performance among the various combinations of motor imagery tasks for brain-computer interface. In: 2013 6th International IEEE/EMBS Conference on Neural Engineering (NER), pp. 435–438. IEEE (2013). https://doi.org/10.1109/NER.2013.6695965
4. Pinheiro, O.R., Alves, L.R., Romero, M.F.M., de Souza, J.R.: Wheelchair simulator game for training people with severe disabilities. In: 2016 1st International Conference on Technology and Innovation in Sports, Health and Wellbeing (TISHW), pp. 1–8. IEEE (2016). https://doi.org/10.1109/TISHW.2016.7847792
5. Rodríguez Bermúdez, G., García Laencina, P.J., Brizion, D., Roca Dorda, J.: Adquisición, procesamiento y clasificación de señales EEG para diseño de sistemas BCI basados en imaginación de movimiento (2013). https://doi.org/10317/3295
6. Isa, N.M., Amir, A., Ilyas, M.Z., Razalli, M.S.: Motor imagery classification in Brain computer interface (BCI) based on EEG signal by using machine learning technique. Bull. Electr. Eng. Inform. **8**(1), 269–275. (2019). https://doi.org/10.11591/eei.v8i1.1402
7. Angrisani, L., Arpaia, P., Casinelli, D.: Instrumentation and measurements for non-invasive EEG-based brain-computer interface. In: 2017 IEEE International Workshop on Measurement and Networking (MN), pp. 1–5. IEEE (2017). https://doi.org/10.1109/IWMN.2017.8078383
8. Wang, Y., Wang, R., Gao, X., Hong, B., Gao, S.: A practical VEP-based brain-computer interface. IEEE Trans. Neural Syst. Rehabil. Eng. 234–240 (2006). https://doi.org/10.1109/TNSRE.2006.875576
9. Melnik, A., Legkov, P., Izdebski, K., Körcher, S.M., Hairston, W.D., Ferris, D.P., König, P.: Systems, subjects, sessions: to what extent do these factors influence EEG data? Front. Hum. Neurosci. **11**, 150 (2017)
10. Goldberger, A., Amaral, L., Glass, L., Hausdorff, J., Ivanov, P.C., Mark, R., Stanley, H.E.: PhysioBank, PhysioToolkit, and PhysioNet: components of a new research resource for complex physiologic signals. Circulation **101**(23), e215–e220 (2000). https://doi.org/10.13026/C28G6P
11. Schalk, G., McFarland, D.J., Hinterberger, T., Birbaumer, N., Wolpaw, J.R. BCI2000: A general-purpose brain-computer interface (BCI) system. IEEE Trans. Biomed. Eng. 1034–1043 (2004). https://doi.org/10.1109/tbme.2004.827072
12. Iversen J.R., Makeig S.: MEG/EEG data analysis using EEGLAB. Magnetoencephalography: From Signals to Dynamic Cortical Networks, pp. 391–406. Springer, Berlin (2014). https://doi.org/10.1007/978-3-642-33045-2_8

13. MacIntyre, T.E., Madan, C.R., Moran, A.P., Collet, C., Guillot, A.: Motor imagery, performance and motor rehabilitation. Prog. Brain Res. 141–159 (2018). https://doi.org/10.1016/bs.pbr.2018.09.010
14. Georgoulas, G., Georgopoulos, V.C., Stylios, C.D.: Speech sound classification and detection of articulation disorders with support vector machines and wavelets. In: 2006 International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 2199–2202. IEEE (2006). https://doi.org/10.1109/IEMBS.2006.259499
15. Subasi, A., Gursoy, M.I.: EEG signal classification using PCA, ICA, LDA and support vector machines. Expert. Syst. Appl. 8659–8666 (2010). https://doi.org/10.1016/j.eswa.2010.06.065
16. Medina Salgado, B., Alvarez López, R.: Caracterización de Señales EEG mediante Wavelet Packet y Entropía Difusa para tareas de imaginación motora. Ingeniería, pp. 226–238 (2017). https://doi.org/10.14483/udistrital.jour.reving.2017.2.a04
17. Chaisaen, R., et al.: Decoding EEG rhythms during action observation, motor imagery, and execution for standing and sitting. IEEE Sens. J. **20**(22), 13776–13786 (2020). https://doi.org/10.1109/JSEN.2020.3005968
18. Guler, I., Ubeyli, E.D.: Multiclass support vector machines for EEG-signals classification. IEEE Trans. Inf. Technol. Biomed. **11**, 117–126 (2007). https://doi.org/10.1109/TITB.2006.879600
19. Sharmila, A., Geethanjali, P.: DWT based detection of epileptic seizure from EEG signals using Naive Bayes and k-NN classifiers. In: IEEE Access, vol. 4, pp. 7716–7727 (2016). https://doi.org/10.1109/ACCESS.2016.2585661
20. Murugappan, M., Ramachandran, N., Sazali, Y.: Classification of human emotion from EEG using discrete wavelet transform. J. Biomed. Sci. Eng. 390 (2010). https://doi.org/10.4236/jbise.2010.34054
21. Jahankhani, P., Kodogiannis, V., Revett, K.: EEG signal classification using wavelet feature extraction and neural networks. In: IEEE John Vincent Atanasoff 2006 International Symposium on Modern Computing, pp. 120–124 (2006). https://doi.org/10.1109/JVA.2006.17
22. Sabancı, K., Koklu, M.: The classification of eye state by using kNN and MLP classification models according to the EEG signals. Int. J. Intell. Syst. Appl. Eng. **3**(4), 127–130 (2015). https://doi.org/10.18201/ijisae.75836

Chapter 20
Online Social Networks and Psychological Experiences: Analysis of Youth Perceptions Through Data Mining

Bogart Yail Marquez, Arnulfo Alanis, Ángeles Quezada, and Irving Diaz-Hernandez

Abstract Various research articles referring to social networks agree that excessive use of these can lead to psychological problems in users, whether they are emotional problems, identity problems, or self-acceptance problems, among others, being the addiction of young adolescents toward social networks, the most common problem when talking about their prolonged use. The analysis that is intended to be carried out with this research will be carried out through information on the population of the city of Tijuana, Baja California, Mexico with young people between the ages of 12 and 25. This research will begin by revealing general aspects of social networks, mentioning their advantages as a personal, work, or school tool, and then analyze the negative impact that social networks have on young people with a data mining analysis.

B. Y. Marquez · A. Alanis · Á. Quezada · I. Diaz-Hernandez (✉)
Departamento de Sistemas y Computación, Maestría en Tecnologías de Información, Instituto Tecnológico de Tijuana, Tijuana, México
e-mail: irving.diaz@tectijuana.edu.mx

B. Y. Marquez
e-mail: bogart@tectijuana.edu.mx

A. Alanis
e-mail: alanis@tectijuana.edu.mx

Á. Quezada
e-mail: angeles.quezada@tectijuana.edu.mx

B. Y. Marquez
Av Castillo de Chapultepec 562, Tomas Aquino, 22414 Tijuana, B.C, México

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_20

20.1 Introduction

20.1.1 Problem Statement

The present investigation will consist of knowing the consequences of prolonged use of social networks and how they come to affect young people and adolescents by analyzing the response of how users are familiar with this technology. This is to recognize the impact that social networks can cause and be able to make an application for smartphones that can help to reduce the possible consequences of this addiction.

Social networks have become a medium used by most people who have access to the network, including the youngest who may not know how to limit their consumption, which has consequences that affect their lives [1] every day. Social networks carry numerous benefits; however, the negative impact it has caused on young people and adolescents is something alarming that must be addressed as soon as possible [2]. The addiction to social networks is talked about more often than usual, and this is caused by prolonged use of them. Truly, the excessive use of social networks is not harmful since many people use them as a tool for work or school. The problem arises at the time an addiction develops by these. The excessive use of social networks can alter the user's way to relate to their environment, to the point of interfering with other daily activities and even disturbing their interpersonal relationships [3]. There are known cases in which users can spend long periods on social networks, the short- or long-term effects of which can cause alterations in their sleeping and eating schedules. In some cases, a distortion of language can be developed, such as cacophony, which refers to mistakes made when speaking that damage the statement or speech[4].

Teenagers with less self-control are more vulnerable and are the ones who use technology the most [5]. Among the most recognized causes of addiction to social networks are low self-esteem, personal dissatisfaction, depression, hyperactivity, and even a lack of affection, a lack that adolescents often try to fill with virtual acceptance.

20.1.2 Justification

In the academic field, the fast growth of new information technologies, and especially their usefulness in face-to-face and distance education, makes them necessary when attending school. To socialize with your social circle, as a means of communication to assign or prepare tasks, these and many more are reasons that have made social networks indispensable in education, therefore a thorough analysis must be made of the consequences that prolonged use of these not only for leisure but as an academic communication tool can cause too.

In terms of communication, social networks play a great role today, whether to schedule appointments, communicate messages, leave messages, request, or provide information, these are some of the reasons why social networks have come to stay in our lives. However, abusing these functions can cause problems in the youngest, completely forgetting that live communication can be harmful in some cases; therefore, a study must be done to evaluate the situations in which this can occur.

In the sociocultural, it is notorious that social networks have been adopted as a measure to express themselves in a sociocultural way. New social and cultural trends, fashion, new types of art, social movements, etc. are the different ways in which social networks have been involved in the sociocultural. Although, some cultural trends or social issues have turned out to be controversial due to damages caused to third parties and even to the same. This situation must be reviewed to verify the existence of a relationship with the prolonged use of social networks or even an addiction, or if it is a different matter.

Young people and adolescents use them as a means of entertainment, which generates satisfaction, fun, and excitement. This is due to the satisfaction of constantly viewing new content. Currently, getting together with friends involves being on social networks during these meetings, whether it is to take a souvenir photo, show publications, etc. What should be considered is whether this is completely invading the minds of young people to the point of forgetting how to socialize with friends without the use of a social network.

ICTs are a tool that has helped the new generations to a great extent, the benefits they have provided are numerous and they have facilitated various tasks that previously seemed difficult. The new generations, that is, the young people, the adults of the future, are the ones who have access to them more easily, so it is necessary to review whether the prolonged use of social networks has a negative impact or not on young people and adolescents. With the information collected by this research, in the future, the software will be developed which will help reduce the use of social networks for non-essential activities and report on the problem, as well as proposed solutions through a web page.

20.2 State of the Art

20.2.1 Introduction

Over the years, it has been observed that as the Internet expanded from its beginnings to the present, social networks began to take on a fundamental part of the lives of users around the world.

From the social networks of the past such as Myspace, Hi5, and Buzz [6] to the current giants of the industry such as Facebook, Twitter, and Tiktok, they have been able to see the changes that users have had during all these years, so it is You who can compare the behavior of users and the changes they have undergone over time since at first social networks were used more as a hobby than as a means of communication [7]. That is why the research carried out more than 10 years ago would not yield the data that can be obtained today due to the lifestyle that has changed among young people and adolescents.

Apart from everything mentioned above, the popularity of today's social networks should also be highlighted, since the difference between the number of people who, for example, had Myspace, Hi5, and Buzz in 2010, compared to the number of users who only have Facebook, is very large. Today, by far, Facebook has managed to monopolize the use of social networks in such a way that most young people and adolescents have a user on Facebook.

An investigation carried out regarding the use of social networks and mobile phones among male and female university students, regarding the daily hours of use and addictive behavior to social networks, by a sample population of 466 people, 60% men and 40% women, through surveys, a direct relationship was found between the relationship to social networks and addiction to smartphones. Smartphones every day become a necessary tool for students and workers, mostly due to their capabilities to provide communication between users of telephone services or social networks, which contributes to the excessive use of social networks [8].

20.3 Methodology

20.3.1 Methodological Approach

This research seeks to see and understand the impact that the prolonged use of social networks can cause on young people, finding out the negative consequences that can bring, fulfilling the characteristics of a descriptive investigation. To gather the necessary data, electronic surveys were carried out on multiple young people during times of pandemic, where the use of social networks increased due to confinement. The information obtained from it will be used for an upcoming investigation that seeks to help solve the problem.

The individuals who will participate in this study will be gathered in social network groups that integrate young people from the city of Tijuana, Baja California Norte, with ages ranges between 12 and 25 years, this age range was decided since it was determined that users within the range are more vulnerable to the content of social networks. According to the official INEGI website, there are 907,800 adolescents between men and women in the age range between 12 and 25 years.

Therefore, the survey will be carried out with a sample of 385 adolescents.

To carry out the investigation, numerous digital articles will be used, which address the subject from different points of view, carried out in the last decade. However, the information that articles can provide becomes limited to a certain extent, so the survey will be used as a procedure for collecting information, which will be carried out through online forms.

The survey will be closed using the Likert scale since it is ideal for measuring a person's reactions, attitudes, and behaviors.

The reason why the survey was chosen as the collection instrument is due to the ease of implementation.

20.4 Results and Analysis

20.4.1 Methodological Approach

We were able to obtain information from 410 people who responded to our virtual survey (see Fig. 20.1).

We use the age question to check that the results we use are within the age range stated in our population sample. The graph shows the number of respondents of a certain age along with their corresponding percentage of the total. The ages of the respondents ranged from 12 years to 28, the majority (49 people) who answered the survey were 23 years old (12%) and the minimum (16 people) were 12 years old (3.9%) (Table 20.1).

20.4.2 Random Forest (RF)

The Random Forest is used for practices within Machine Learning, and it is an algorithm that generates a tree of multiple decisions and averages them to obtain a more accurate prediction [9, 10].

For example, get repeatedly (N times) and select a random sample with substitution from the training data sets, $X = x_1, x_2\ldots, x_n$ concerning the result $Y = y_1, y_2, \ldots, y_n$. For $i = 1,\ldots, N$ random samples, with one substitution, n trains the X and Y data; expressed in X_i, Y_i. Train the regression and classification tree fi on X_i, Y_i. The RF model can be presented as

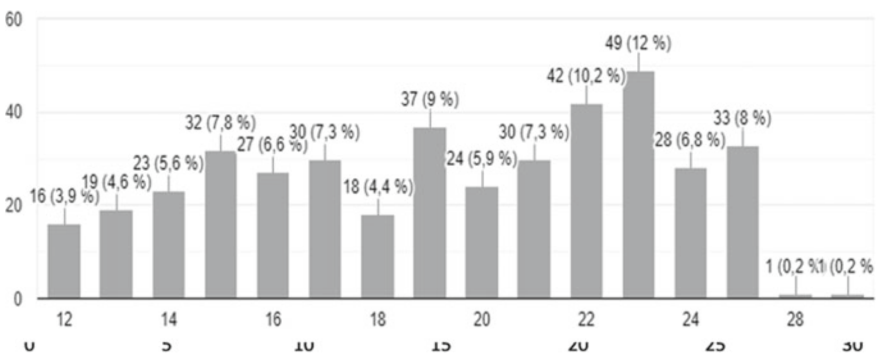


Fig. 20.1 Percentages of those surveyed according to age

Table 20.1 The questions to be asked for data mining analysis

Questions
1. Age?
2. Approximately how much time do you spend a day on social networks?
3. What do you use social networks for in your day-to-day life?
4. Do you think fake news posts on social media affect your day?
5. How productive do you think the time you spend on social networks is?
6. How entertaining do you find the content you consume on social networks?
7. How necessary are social networks in your daily life?
8. Do you think that social networks can affect mental health?
9. Do I feel self-conscious about posts on different social networks that idealize the perfect lifestyle?
10. Does seeing posts from users I consider more attractive affect my self-esteem?
11. Have I had serious conflicts with my parents, siblings, friends due to the use of social networks?
12. Do you think that your daily activities may be affected using social networks?
13. What social network do you use the most in your day-to-day life?
14. Do you think that the absence of social networks can affect your mood?
15. Have you lied to your parents about the amount of time you spend on social media?
16. Have you missed an important event in your life by giving priority to your social networks?
17. Have you felt guilty about the time you spend on social networks?
18. Have you tried to reduce the time spent on social media but can't?
19. Would you be able to leave social networks for at least one day?
20. At what age did you start using social networks?

$$\hat{y} = \frac{1}{m}\sum_{j=1}^{m}\sum_{i=1}^{n} w_j(x_{i,}x)y_i \tag{20.1}$$

Being $W(x_i, x') = 1\ k'$ if x_is one of the points k on the same leaf as x´, otherwise it would be 0.

Random forest (or random forests)' is a combination of predictor trees such that each tree depends on the values of a random vector tested independently and with the same distribution for each of these. It is a substantial modification of bagging that builds a large collection of uncorrelated trees and then averages them (Fig. 20.2).

The algorithm to induce a random forest was developed by Leo Breiman and Adele Cutler, and Random forests are their trademark [11]. The term comes from the first proposal for Random decision forests, made by Tin Kam Ho of Bell Labs in 1995 [12]. The method combines the idea of Breiman bagging and random selection of attributes, introduced independently by Ho, Amit, and Geman, to build a collection of decision trees with a controlled variation.

The selection of a random subset of attributes is an example of the random subspace method, which, according to Ho's formulation, is a way of carrying out the stochastic discrimination proposed by Eugenio Kleinberg. Using the Random forest algorithm, we use the question as a dependent variable: How productive do you think the time you spend on social media is?. And when the algorithm is applied, it generates the following decision tree (see Fig. 20.1) (Table 20.2).

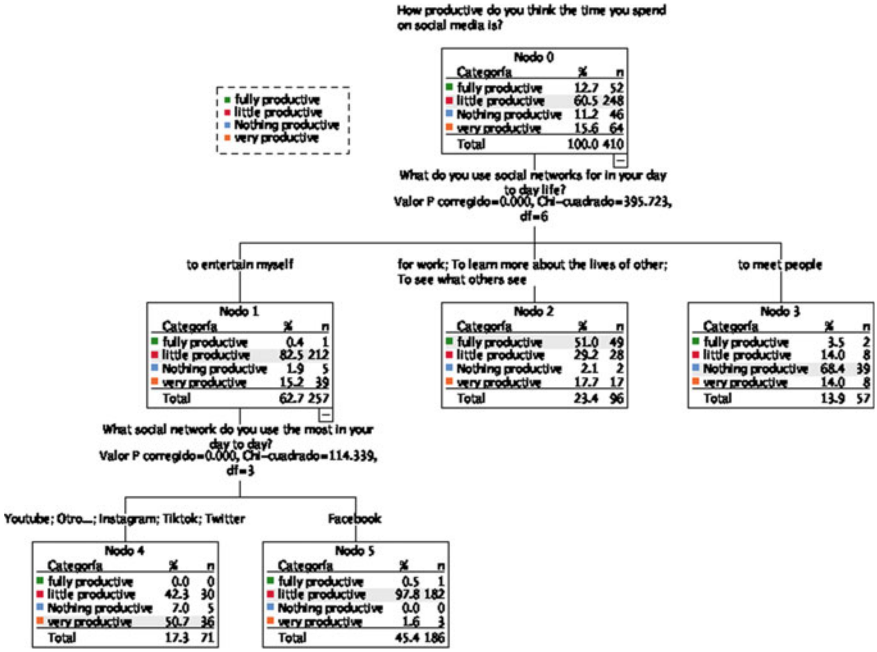


Fig. 20.2 Random forest—using the question as a dependent variable: How productive do you think the time you spend on social media is?

Table 20.2 Growth method: How productive do you think the time you spend on social media is?

	Nothing productive	fully productive	little productive	very productive	percent correct
Nothing productive	39	2	0	5	84.8%
fully productive	2	49	1	0	94.2%
little productive	8	28	182	30	73.4%
very productive	8	17	3	36	56.3%
Percentage global	13.9%	23.4%	45.4%	17.3%	74.6%

In many problems, the performance of the random forest algorithm is very similar to that of boosting, and it is simpler to train and tune. Therefore, the Random Forest is popular and widely used (Fig. 20.3).

The graph represents the statistics of how many people use social networks per day.

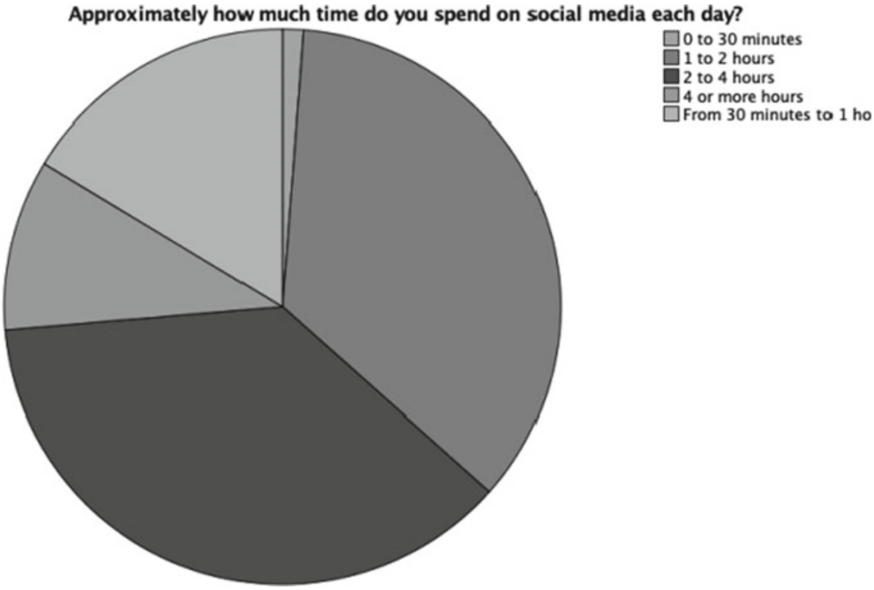


Fig. 20.3 The graph represents the question: What social network do you use the most in your day to day?

This graph shows that most of those surveyed use social networks for around 1 to 4 h (72.5%); however, one thing to keep in mind is that of the 410 people surveyed, 41 people use social networks excessively, going since 4 h of use a day.

At the time of starting with the problem, the system iterates an N number of times making tree structures randomly from the collected data, once each of the possible paths in search of results is obtained, the ability to obtain the result is obtained, of regression and classification type, using the mode for a classification problem, and the mean in case of a regression problem (Fig. 20.4).

Each of the trees created based on the collected samples will be assigned a vote, with the most voted prediction being the one used within the algorithm and will be defined as the final prediction.

The consequences of prolonged use of social networks can be interpreted as mostly psychological, generating ideas that are usually false about the perception of oneself as a person, compared to what they usually see on social networks. In turn, another consequence is the need to consume content from social networks to maintain a stable state of mind.

The different consequences of the excessive use of social networks by young people and adolescents are self-esteem problems, detachment from reality, lack of interest in responsibilities, and addiction to social networks (Fig. 20.5).

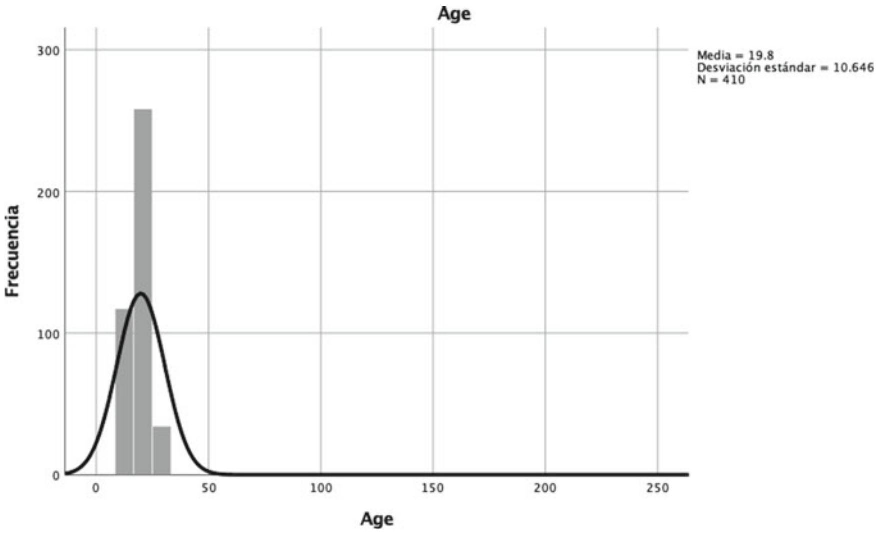


Fig. 20.4 The mean and standard deviation according to age

The obtained results in the surveys and the research carried out about the problems caused by social networks allow us to affirm that social networks are harmful to the user's mental health, and most of them are not aware of it, on the other hand, even being conscious, they fall on the temptation of the immediate and diverse entertainment that they offer.

20.5 Conclusions

In most cases, this excessive use may be caused by a discipline that was not instilled that will limit the use that young people give to social networks, likewise, this lack of attention in this aspect is very serious, since most of the respondents answered that they began to use social networks at a very young age, we are not dictating a discipline who can lead to addiction more easily. Addiction to social networks can cause problems not only in self-esteem but also in the personal performance of the individual, whether it is not only in studies or in the workplace but also in how they relate to the world, since the idea of the world that social networks can give to them, can alter the perception of reality. It can also be concluded that the people surveyed spend at least 2 h or more on social networks in 70.5% and only the rest of the people measure themselves more with the use of social networks.

Based on the results, we can say that people are using social networks excessively, and taking awareness is necessary to avoid depending on social networks.

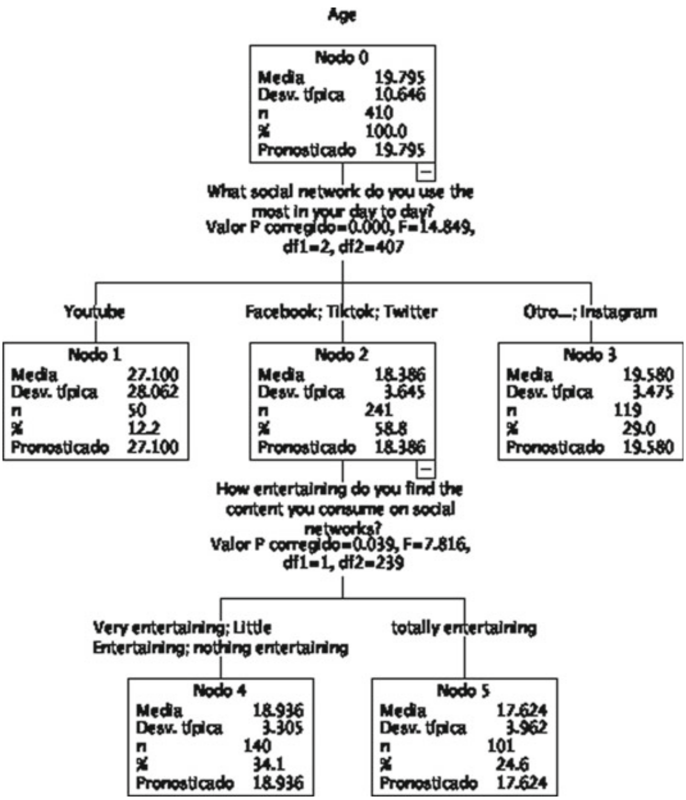


Fig. 20.5 Random forest—age with the use of social networks

References

1. Garton, L., Haythornthwaite, C., Wellman, B.: Studying online social networks. J. Comput. Commun., **3**(1), JCMC313 (1997)
2. Greenhow (2011) Online social networks and learning. Horizon
3. Lefebvre, R.C., Bornkessel, A.S.: Digital social networks and health. Circulation **127**(17), 1829–1836 (2013)
4. Hackworth, B.A., Kunz, M.B.: Health care and social media: Building relationships via social networks. Acad. Heal. Care Manag. J., **7**(2) (2011)
5. Hur, M.H.: Demographic, habitual, and socioeconomic determinants of Internet addiction disorder: an empirical study of Korean teenagers. Cyberpsychology Behav. **9**(5), 514–525 (2006)
6. Deepmala, M., Khan, T.M.: Social Networking Sites: its Applications and Implication in Libraries
7. Masciantonio, A., Bourguignon, D., Bouchat, P., Balty, M., Rimé, B.: Don't put all social network sites in one basket: Facebook, Instagram, Twitter, TikTok, and their relations with well-being during the COVID-19 pandemic. PLoS ONE **16**(3), e0248384 (2021)
8. Arab, L.E., Díaz, G.A.: Impacto de las redes sociales e internet en la adolescencia: aspectos positivos y negativos. Rev. Médica Clínica Las Condes **26**(1), 7–13 (2015). https://doi.org/10.1016/j.rmclc.2014.12.001

9. Ullah, I., Raza, B., Malik, A.K., Imran, M., Islam, S.U., Kim, S.W.: A churn prediction model using random forest: analysis of machine learning techniques for churn prediction and factor identification in telecom sector. IEEE access **7**, 60134–60149 (2019)
10. Islam, S., Amin, S.H.: Prediction of probable backorder scenarios in the supply chain using Distributed Random Forest and Gradient Boosting Machine learning techniques. J. Big Data **7**(1), 1–22 (2020)
11. Wei, D., Qiao, L., Hao, M., Feng, H., Peng, X.: Reliability prediction model of NAND flash memory based on random forest algorithm. Microelectron. Reliab. **100**, 113371 (2019)
12. Kumar, A., Sinha, N.: Classification of forest cover type using random forests algorithm. In Advances in Data and Information Sciences, Springer, pp. 395–402 (2020)

Chapter 21
Implementation of an Intelligent Agent for Decision Making Tasks in the Hanoi Towers

Daniel Velázquez, Arnulfo Alanis, and Rosario Baltazar

Abstract In the field of neuropsychology, it is common to use physical, analog tests to evaluate different cognitive functions. Due to recent world events, the need for technologies to adapt and contribute with digital adaptations that can be relied upon has increased. In this research project, a small team of researchers combined efforts to develop software that could accurately measure outcomes from the Tower of Hanoi test, which include the number of moves and the time taken to finish the task, so that it could be used safely, efficiently, and remotely. While the digital adaptation served its purpose, there appears to be a subjective component that some could find more satisfactory in the physical implementation, although the efficacy of the test remained high.

21.1 Introduction

It is estimated that there are over 366 million people that suffer from ADHD globally in 2020 with an estimated 5% of children who suffer from that condition [1]. Treatments are varied and have advanced with time, but the global pandemic brought on by COVID-19 has lessened the treatments and timely detection that many would have normally had. Additionally, medication that is usually prescribed for ADD/ADHD

D. Velázquez (✉)
School of Psychology, CETYS University, Calz Cetys 813, Lago Sur, C.P 22210 Tijuana, Baja California, Mexico
e-mail: daniel.velazquez@cetys.mx

A. Alanis
Systems and Computer Department, Technological Institute of Tijuana, National Tech of México, Calzada Del Tecnológico S/N, Tijuana, BC, México
e-mail: alanis@tectijuana.edu.mx

R. Baltazar
Technological Institute of Leon, National Tech of México, Av. Tecnologico s/n, León, Guanajuato, Mexico
e-mail: rosario.baltazar@leon.tecnm.mx

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_21

can have limited results in several patients or are not affordable for some. The object of this paper is to propose a system for remote interventions that can be followed up on from a distance, using a mix of traditional and digital methods to continue monitoring the progression of treatment over a period. This proposal will have extended benefits once it is implemented and can serve as a blueprint for future interventions in the fields of psychology and technology, further implementing collaborations between the two fields.

21.2 Attention Deficit Disorder

Attention Deficit Disorder is one of the most prevailing problems with children in Mexico and in the world at large, with an estimated 2 million children diagnosed with it in the country alone [2]. It is characterized by symptoms of inattention, impulsivity and hyperactivity that interfere with the social, occupational, or academic functioning of the person. The first description of recognition of symptoms was in 1798 by Alexander Crichton [3] who was the first person to describe two types of problems related with inattention, the first being a disorder of distraction, describing inconsistency with the attention faculties of the mind and a lack of persistence or concentration. He also referred to it as a disorder of a lacking energy which is not consistent with current diagnostic research and interpretations.

Treatment for ADHD commonly utilized is pharmacological medications, which can include stimulant and non-stimulant drugs. While not all patients who have ADHD will benefit from their use for a variety of reasons, it is likely that a doctor or psychiatrist will recommend their use to see if they can benefit from it after an initial trial that can last from two to four weeks, the amount of time it takes for medications to take effect in the patient.

The assessment of ADHD continues to be a controversial topic within the psychological and psychiatric communities. The purpose of a diagnosis is to be able to determine if the combinations of signs and symptoms a person presents mean a specific diagnostic or if it can be attributed to another set of circumstances or explanations. The expert goes on to obtain pertinent information from a variety of sources to corroborate information and get enough data to validate the diagnosis. In the case of children, this usually means interviews with their parents and teachers. Ultimately, an accurate diagnosis of ADD/ADHD means that there is no other explanations of the symptoms of hyperactivity, inattention, or impulsiveness.

The causes of ADHD can be limited primarily to hereditary factors and the post birth environments. It is likely that when diagnosed, the parents of a child with ADD or ADHD discover that they themselves also have it. Pennington and Ozonoff [4] have said that the disorder is based in a general deficit of executive functioning or one or more domains of executive functions. Dehn [5] defines these functions as mental processes that are responsible for the regulation of cognitive functioning during behaviors that guide purpose, directed to solving problems and reaching goals. The most common way to approach this diagnosis is by detecting it at an early age and giving medication for treatment. Many parents and children find it difficult to follow these treatments for a variety of reasons, including the side effects and the cost of medications.

21.3 Executive Functions

The term "executive functions" is still relatively new in neuroscience. The father of neuroscience, Luria [6], referred to the three units of brain functions as

- Arousal-motivational system
- Receiving, storing, and retrieving information system
- Programing, controlling, and verifying system

The last one is considered very important for different brain functions such as cognitive flexibility, planning, self-regulation, monitoring, working memory and inhibitory control [7].

The best way to define executive functions is to think about it as a psychological construct, something that cannot be observed or measured directly but can be inferred from behaviors related to mental processes [8]. Such behaviors then must be measured in much defined ways that technological applications have done with more precision than human observation has done before. While this in not meant to suggest that human observation cannot or will not continue in the future, it does suggest that it can be combined with machine-based learning and algorithms to make it a more complete process that can guarantee patients have more accurate measurements and assessments when being diagnosed or as part of research studies.

21.4 Emotional Regulation

Children who have ADHD can have difficulties with managing their emotions and controlling their impulses. These terms are sometimes defined by some authors as hot and cold functions. The cold functions were described previously but the hot ones are related to contexts where emotions, motivation, and tension can mediate immediate and delayed gratification [9], something that people with ADHD have trouble with, some researchers speculating that this has something to do with dopamine releases [10]. The feedback programmed in computer games and applications can help with a more frequent feedback loop between the behavior and what is seen on the screen.

Much can also be said about the potential benefits that a good emotional regulation system can have in a child's day to day interactions. When a child with ADHD plays a board or video game and loses, they can have a negative reaction towards the result, not properly managing their emotions and leading to negative attitudes and behaviors.

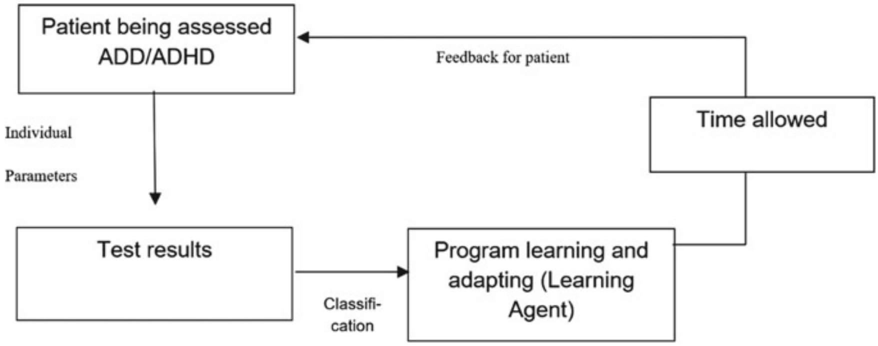


Fig. 21.1 Detects that the time has elapsed in a test

21.5 Intelligent Agents

As is related to health fields, intelligent agents are used to perceive environments and respond to them so that any changes continue to satisfy their designed objectives. Their performance or growth depends on what they learn and the nature of their programming. They are usually described in terms that can be like those of computer programs but can be classified in a variety of ways depending on their capabilities [11].

The easiest of these to explain remain the simple reflex agents, which react to a condition to then act. For example, if a program detects that the time has elapsed in a test, it can lock itself, rendering further interactions invalid until reset. Another variation of this is to set several attempts in a test and force a number of movements or a set number of tries per attempt while maintaining the time variable fixed, so after a set of time elapsed there would be an indicator that the task must be restarted, to avoid letting the user try to "guess" his way to an answer, leading to more careful consideration of each of his attempts at solving a problem, as shown in Fig. 21.1.

21.6 Telehealth

As with any unique and unforeseen circumstance, these times of difficulties also come with unique opportunities, such as the advances in the field of Telehealth, particularly during the COVID-19 Pandemic [12]. There are technologies that did not exist before that provide patients and health professionals with wider options for treatments. While there are still limitations to the accuracy of diagnosis and interventions that come from not being able to see a person completely or from interference from a low Wi-Fi signal, the advantages are quickly becoming apparent. There is a zero risk of transmitting COVID during a remote session and additionally, and there are time and money savings that patients can benefit from scheduling sessions from a distance [13]. A particular benefit that comes from remote screenings and evaluations is in access to specialists that come from a wider net that the one the patients can previously get in contact with. Initially, this was the promise of telehealth, getting people connected with doctors who were out of the patient's coverage area.

The challenge remains to be able to develop techniques and applications that can be adapted to the unique needs of telehealth. Telemedicine and telehealth can be used to assist with evaluations and assessments of patients remotely and further research into decision making algorithms that supports these processes will become invaluable to the field, as the pandemic continues and beyond.

21.7 Tower of Hanoi

The tower of Hanoi [14] is an instrument that lets an examiner evaluate a subject's capacity to solve complex problems while having to formulate a plan of action that leads to a solution. The usefulness of the tower has been seen in previous studies that deal with planning and executive functions [15]. The origin of the tower comes from around the year 1882, although an exact date is unknown [16]. The test is somewhat easy to apply and score and can be modified for different tasks. In its physical form, it uses 3 vertical posts, starting with an occupied post with wooden discs of different sizes, from large or small. The discs must be moved from one place to another, respecting the rules of movement, which only allow one disc to be moved at a time and no large disc may be placed on top of a smaller one.

The challenge with remote applications was resolved by developing a digital version of the test using Unity. There has been research made with the implementation of new technologies and the areas of assessment with positive results, as children are motivated using computers and robots in areas such as psychology and education [17]. This version of the test complies with all the requirements that the physical version has but allows precision time keeping and no errors in the number of moves that a person uses with the inputs. Additionally, it can be modified from 3 to 10 discs, although only 3 to 5 were used in the trial.

The tower is then used to obtain a baseline of a person's capacity to plan and solve problems and is saved directly to the software where a detailed report can then be obtained. Future measurements can then be compared to establish new baselines, measure progress, or analyze data regarding an intervention between applications.

21.8 Proposal

As this project involves minors, there was a formal review by the Internal Ethics Committee of CETYS University, Tijuana Campus. A consent form was redacted, and there were no conflicts of interest found in the study. A formal letter of acceptance was given in January of 2022 giving the project the verdict of Approval for purposes of research.

In an initial trial, there would be a digital and a physical presentation of the tower that would be used to measure the efficacy and precision of both techniques. For this to be implemented, there would be a parallel development of a digital app that could focus on reproducing the qualities of the Tower of Hanoi at the same time facilitating a remote implementation. Ease of use, movement detection and registration and exporting of the data acquired where among the principal tasks that the application had to do to be considered useful in this trial. The physical model is the standard use model that is used traditionally when applying this test. The user would have free access to the application once the trial is complete, so they could continue to try and better their results and time, as the app could continue to grow and adapt, making it possible that in the future there could be variations on the challenge, based on the number of discs, starting position of the discs and their colors.

The tower of Hanoi is relatively easy to solve when there are only 3 discs to move from one post to another. When the number of discs increases, so does the difficulty. For this project, two phases were considered: in phase 1, the agent “AgNd-TDAH” was implemented and in phase 2, the physical version. In both cases, the underlying mechanism and theory of the tower were used. The model for the intelligent system is composed of 4 modules, where the first module is the one where the child-user profile is created, once captured, the test is applied using a telehealth module (designed to use the test online), followed by the “AgNd-TDAH” model, during this process of learning and deduction by the user, as they try and solve the puzzle, a csv file is created with the information from the application, as seen in Fig. 21.2.

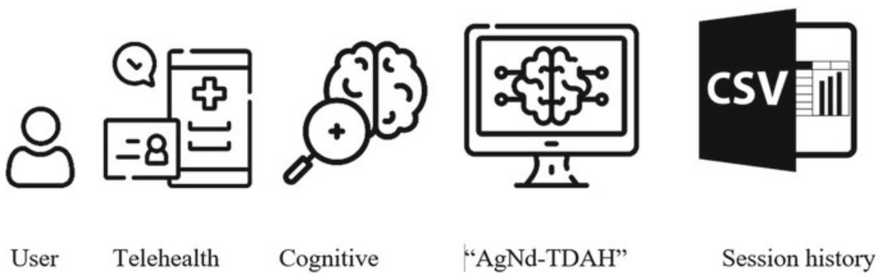


Fig. 21.2 Telesaud intelligent system model

21.9 Using Recursiveness

This is a common problem in programing, when trying to explain recursiveness. If the discs in the tower are numbered from 1 to n, if we name origin to the first pile of discs, destination to the third and auxiliary to the intermediate one, and denominate the function as Hanoi, with origin, auxiliary and destination as parameters, the algorithm for the function will be as is described in Fig. 21.3.

Where:

- N represents the discs
- NA, NB, NC, ND discs of different colors
- (v{Z}) first post
- (v{M}) second post
- (v{Y}) third post

The number of minimum movements to solve the problem in this mode is de $2n - 1$, with n being the number of discs [17]. It is worth mentioning that for these movements to be correct, the agent needs to make a series of decisions and rules established by the tower of Hanoi protocols (time to start, total number of movements and incorrect movements), based on the level of difficulty that was established prior to the session. This can be modified based on the needs of the child-user or the needs of the professional.

The "AgNd-TDAH" agent will be responsible for covering the learning objectives, in relation to the abilities and the tasks that the child-user has, this agent will then function as a great asset, while also helping professionals in the health field, monitoring the movements during a session.

Rule 1	If {N}=0 the go to *origin*
Rule 2	If {N} = 1 & ({NA}-red) then move {N}(v{Z}) to (v{Y})
Rule 3	If {N} = 1 & ({NB}-blue) then move {N}(v{Z}) to (v{Y})
Rule 4	If {N} = 1 & ({NC}-green) then move {N} (v{Z}) to (v{Y})
Rule 5	If {N} = 1 & ({ND}-yellow) then move {N} (v{Z}) to (v{Y})
Rule 6	If {N} > 1 then move {N−1} {N} (v{Z}) to v{M}, considering (v{M=Z}) & (v{Z=M}) & move the n-ésimo N of n-th (v{Z}) to (v{Y}) & move (n−1,N) of (v{M to Y}), considering (v{Z=M}) and (v{M=Z})
Rule 7	If *origin* then finalize

Fig. 21.3 AgNd-TDAH agent rules

21.10 Methodology

Each participant would initially be described as the task that must be completed, with no supplies at hand. They would be given the task to be imagined with only 3 disks and asked if the follow along with the instructions as given. If there is expressed or perceived confusion, there would be a second explanation with visual help. When the participants are ready, they are presented with the Tower of Hanoi in Digital Form. A second group follows the same instructions but are presented the Physical Form. After successfully or unsuccessfully completing the tests, the participants are thanked for their time and given a follow up appointment in no less than two weeks' time to repeat the test but inverting the roles, that is, if the participant started with the Digital Form, they would be asked to complete the Physical one. The two-week time between applications would result in enough time passed to as not fully remember the solution to the task, but it is recognized that once it is presented, there will be some familiarity, no matter the length. Posttest, a short questionnaire is applied where the participants are asked the following questions, depending on if is the first or second time, they are taking the Tower of Hanoi task:

1. Did you find the test to be easy or difficult?
2. Did you enjoy the test?
3. Did you think you did well on the test?
4. Which test do you think is better, the physical or digital version?
5. Did you prefer the physical or digital version of the test?

21.11 Results and Discussions

Due to the ongoing pandemic, the development of the software was timely and was able to be implemented in a pilot study of 10 children between the ages of 9 and 12 years of age, divided in two groups because of the pandemic (more will be added in the future). No difficulties were reported in the use of the software and the results are accurate and comparable to the physical use of the tower. While there is a loss of the tactile component of the test, it is a short application that leads to less distractibility compared to when using the wooden discs. Additionally, the app version of the test is completed more quickly than the physical version. Whatever differences can be observed between the two are subjective and seem to be equivalent in results and methodology.

21.11.1 Future Interventions

In the future, the test will continue to be used in circumstances where remote applications are needed and especially with unvaccinated children that are more at risk of getting sick. Also, the accuracy of the measurements cannot be overstated as an error in time or movements required can be the difference between diagnosis and prognosis.

Of course, results are still preliminary and are still considered a starting point for further research. In the future, the test will expand its age range to include a broader group on people while also increasing the number of participants to a larger number as the pandemic permits it, in this specific case, another trial of tests is planned for September 2022, after which there will be a comparison to physical applications of the tower to be sure of its validity as well as establishing the use of apps to help in the fields of psychology and neuroscience, helping diminish the barriers and distrust of technology in both fields.

References

1. Rowland, A., et al.: The prevalence of ADHD in a population-based sample. J. Atten. Disord. **19**(9), 741–754 (2015)
2. Sauceda García, J.M.: Trastorno por déficit de atención con hiperactividad: un problema de salud pública. Rev. Fac. Med. **57**(5), 14–19 (2014)
3. Palmer, E.D., Finger, S.: An early description of ADHD (inattentive subtype): Dr. Alexander Crichton and mental restlessness (1798). Child Psychol. Psychiatry Rev. **6**(2), 66–73 (2001)
4. Pennington, B.F., Ozonoff, S.: Executive functions and developmental psychopathology. J. Child Psychol. Psychiatry **37**, 51–87 (1996)
5. Dehn, M.J.: Essentials of Processing Assessment, 2nd edn. Wiley (2014)
6. Luria, A.: The Working Brain. Penguin Books (1975)
7. Ardila, A., Fatima, S., Rosselli, M.: Dysexecutive Syndromes. Springer (2019)
8. Uttal, W.R.: The New Phrenology: The Limits of Localizing Cognitive Processes in the Brain. MIT Press (2010)
9. Collette, T., van der Linden, M., Laureys, S., Delfiore, G., Degueldre, C., Luxen, A.: Exploring the unity and diversity of the neural substrates of executive functioning. Hum. Brain Mapp. **25**(4), 409–423 (2005)
10. Blum, K., et al.: Attention-deficit-hyperactivity disorder and reward deficiency syndrome. Neuropsychiatr. Dis. Treat. **4**(5), 893–918 (2008)
11. Monaghesh, E., Alireza, H.: The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. BMC Public Health **20**(1), 1193 (2020)
12. Russell, J.S., Norvig, P.: Agents and Enviroments in Artificial Intelligence: A Modern Approach, pp. 34–35. Pearson (2010)
13. Chauhan, V., et al.: Novel coronavirus (COVID-19): leveraging telemedicine to optimize care while minimizing exposures and viral transmission. J. Emerg., Trauma, Shock **13**(1), 20–24 (2020)
14. Simon, H.: The functional equivalence of problem solving skills. Cogn. Psychol. **7**(2), 268–288 (1975)
15. Sang-Hu Kim, A.: Performance of the Tower of Hanoi and its Relationship to the Prefrontal Cortex Activity. Springer (2018)
16. Hinz, A., et al.: The Tower of Hanoi-Myths and Maths, pp. 6–7. Springer (2018)
17. Resing, W.C.M., Vogelaar, B., Elliott, J.G.: Children's solving of 'Tower of Hanoi' tasks: dynamic testing with the help of a robot. Educ. Psychol. **40**(9), 1136–1163 (2020)
18. Petković, M.: Famous Puzzles of Great Mathematicians, p. 197. AMS Bookstore (2009)

Part IV
Agent-Based Modeling and Simulation

Chapter 22
A Systematic Review About Requirements Elicitation for Multi-Agent Systems

Willian Samuel Gerstberger, Iderli Pereira de Souza Filho, and Gilleanes Thorwald Araujo Guedes

Abstract Requirements elicitation is the first stage of the requirements engineering, and it is essential to discover the stakeholders' needs for any software, including multi-agent systems. This particular kind of software is composed by agents, autonomous and pro-active entities, which can collaborate among themselves to achieve a given goal. However, multi-agent systems have some particular requirements that are not normally found in other software. Taking this into consideration, this paper aims to determine the actual state of the elicitation techniques for multi-agent systems by means of a systematic review, highlighting how these techniques work, their strengths and weaknesses and its support to the BDI model.

22.1 Introduction

Agents are software processes that can perform autonomous actions and are able to interact and communicate with other agents in order to achieve the goals imposed on them [1]. Software agents are a software paradigm that provides agent abstractions for the development of heterogeneous, distributed systems [2]. The usage of agents has become one of the most effective ways to deal with complex systems [3].

Within the context of developing multi-agent systems, there is a research area where agents are based on the Belief Desire Intention (BDI) model. When applying this model, agents are modeled based on their beliefs, desires, and intentions. The BDI model provides a practical approach to developing intelligent agent systems [4].

W. S. Gerstberger (✉) · I. P. de Souza Filho · G. T. A. Guedes
Pampa Federal University, Campus Alegrete, Rio Grande do Sul, Brasil
e-mail: williangersteberger.aluno@unipampa.edu.br

I. P. de Souza Filho
e-mail: iderlisouza.aluno@unipampa.edu.br

G. T. A. Guedes
e-mail: gilleanesguedes@unipampa.edu.br

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_22

However, developing this kind of system brought its own challenges for the software engineering area, which led to the emergence of AOSE (Agent-Oriented Software Engineering). AOSE aims to adapt software engineering techniques for multi-agent system development [5].

One of the subareas of Software Engineering is the Requirements Engineering. This area has the purpose of eliciting, analyzing, specifying, and validating the requirements of a given system [6]. Regarding requirements elicitation, the requirements for a system do not arise naturally, instead, they need to be engineered and have continuing review and revision [7]. These authors also state that inadequate, incomplete, inconsistent, or ambiguous requirements are numerous and have a critical impact on the quality of the resulting software.

This kind of problem typically happens because the stakeholders, who are the source of the requirements, often assume that such requirements are obvious and not mention them, and the software engineers must actively elicit requirements rather than merely relying on stakeholders to tell them what they want [8]. A major task of requirements engineering is to have the stakeholders validate their requirements to ensure that the requirements completely and correctly specify their needs.

Requirements elicitation is the first stage of requirements engineering, and it is essential to understand the problem the software must solve. Elicitation is fundamentally a human activity, in which the stakeholders are identified and through interviews and other techniques their needs are put in the form of requirements [6].

Considering the importance of requirements elicitation to any system, including multi-agent systems, this work aims to present a systematic literature review that has the intention to verify what are the requirement elicitation techniques for multi-agent systems, as well as how they are applied and if they cover requirements related to the Belief-Desire-Intention (BDI) model. In addition, this work can be used by researchers seeking to identify which technique would best fit a given situation in the context of requirements elicitation, as well as, the strengths and weaknesses of each technique highlighting possible new research areas.

This paper is organized as follows. Section 22.2 contains the background. Section 22.3 presents the protocol used in our systematic review. In Sect. 22.4, the elicitation techniques found in this review are described. Section 22.5 presents the possible threats to the validity of our research, together with the mitigation of these threats. Finally, we present the conclusion and future works.

22.2 Background

22.2.1 Requirements Engineering

Requirements engineering involves all lifecycle activities devoted to requirements elicitation, analysis, specification, and validation [6].

Requirements elicitation involves activities that must allow for communication, prioritization, negotiation, and collaboration with all the relevant stakeholders, and it must also provide strong foundations for the emergence, discovery, and invention of requirements as part of a highly-interactive elicitation process [9].

22.2.2 Multi-agent Systems and BDI (Belief-Desire-Intention) Model

Multi-agent systems are composed of autonomous entities, known as agents. These agents can collaboratively solve tasks with flexibility due to their inherent ability to learn and make decisions in an autonomous way [10]. Moreover, agents can assume roles within the system, Cossentino in [11] defines an agent role as a part of the agent's social behavior that is characterized by having a goal and/or providing a service. The objective of each role is to contribute to the achievement of a part of the organization requirements in which the agent is linked.

Belief-desire-intention (BDI) is one of the most popular models for developing rational agents based on how humans act and based on the information derived from an environment [12].

A BDI agent has three types of mental attitudes, which are belief, desire, and intention. Beliefs are information about an agent's itself, other agents, and the environment that the agent is located. Desires (goals) express all possible states of affairs, which might be achieved by an agent. A desire is a potential trigger for an agent's actions. Simply, desires are often considered as options for an agent. Lastly, intentions represent the states of affairs in which the agent would try to achieve [13].

22.3 Systematic Review Process

Our review follows the process proposed by Kitchenham [14], which describes the processes for a systematic literature review. As our main objective, with this review, we seek to understand the state of the art of requirements elicitation techniques for multi-agent systems, thus seeking to understand how these techniques were proposed, in which context they are applied and, mainly, if any technique supports the requirements elicitation for multi-agent systems with emphasis on the BDI model.

22.3.1 Research Questions

In order to identify elicitation techniques, we established three research questions that aim to guide our review, which are as follows:

Q1: How are requirements elicitation techniques for multi-agent systems applied?
Q2: What are the features required for eliciting multi-agent requirements that support the BDI model?
Q3: Which studies present a new elicitation technique and which adapt techniques from previous approaches?
The first research question (RQ1) seeks to find, preferably with practical examples, how a software engineer should apply the elicitation techniques found. The second research question (RQ2) was defined to identify the main characteristics in relation to requirements elicitation with emphasis on the BDI model. Finally, with the third research question (RQ3), we aim to discover which techniques are new and which parallels can be drawn from a technique that adapts something from an old technique.

22.3.2 *Identifying and Selecting Primary Studies*

To perform the search, only databases that have a web search engine that allow the use of custom Strings. The string was adapted following the characteristics of each database. The selected databases were, Association for Computing Machinery (ACM) Digital Library, Engineering Village (Ei Compendex), IEEE Xplore, and Scopus. In Fig. 22.1, we show the generic String used in the basis.

22.3.3 *Inclusion and Exclusion Criteria*

After establishing the search string, inclusion criteria (IC) and exclusion criteria (EC) were defined to assist in the screening process of studies returned in the search process. These criteria are fundamental, as they will help to reduce the number of studies returned and will guide the selection of relevant works in the search. We define that, for example, if a study is classified in only one IC, it will be included as a primary study and if a study is associated with at least one EC, it will be excluded.

In our review, the inclusion and exclusion criteria are as follows: IC1: The study must present or propose at least one technique for eliciting requirements for multi-agent systems; IC2: The study presents a comparison of requirements elicitation techniques for multi-agent systems; EC1: The study is not related to multi-agent systems; EC2: The study is not related to requirements elicitation; EC3: The study

```
(Multiagent OR multi-agent OR Agent-based OR "Multi agent") AND ("early
requirements"OR "requirements elicitation"OR "requirements elicit"OR
"requirements acquisition"OR "elicitation process"OR AORE)
```

Fig. 22.1 Generic string used in the review does not present any technique for requirements elicitation; EC4: The study is not written in English; EC5: The study has less than six pages; EC6: Studies available only in the form of an abstract, slideshow, poster, short paper, or conference introduction article; EC7: Study not available for download.

22.3.4 Studies Quality Assessment

Quality criteria were also defined, which aim to qualitatively compare the relevance of one study with another and also to classify the works that were selected according to the inclusion criteria. Works with less than 2.5 grades were excluded. Each of the following quality criteria is evaluated by the researcher, with each question given a weight of 2.5 and therefore, the total score can result: 0 to 2.4 (bad); 2.5 to 4.0 (good); 4.1 to 5.0 (very good). The quality criteria are as follows:

QQ1: Is there any kind of empirical evaluation?

Yes: The study applied an empirical evaluation, for example, a case study or an experiment.

Partial: The study only mentions an empirical evaluation.

No: No empirical evaluation was mentioned.

QQ2: The requirements elicitation technique supports the BDI model or assists in eliciting specific requirements for the BDI model.

Yes: The elicitation technique supports the BDI model or helps elicit specific requirements for the BDI model.

Partial: The specification technique only cites the BDI model.

No: The BDI model is not supported.

22.3.5 Conducting the Review

As shown in Fig. 22.2, four steps were defined for the selection of studies: (i) execution of the search string in the bibliographic databases; (ii) removal of duplicate studies; (iii) application of inclusion and exclusion criteria to works; and (iv) reading and extracting information from the studies resulting from step (iii).

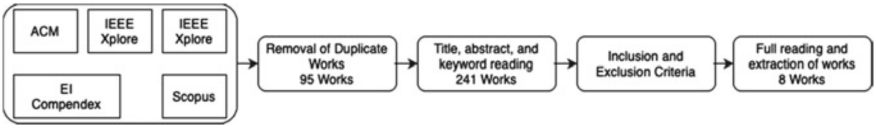


Fig. 22.2 Systematic review conducting process

22.3.6 Analysis of Results

To apply the Studies Quality Assessment, the eight works selected and considered promising were thoroughly read.

Firstly, we can highlight the work of Wilmann and Sterling [15], which was the only work that was refused, as in addition to the technique not supporting requirements elicitation for the BDI model, it also did not present any case study.

The rest of the works got a score of 2.5 because they present a case study, but as in the work by Wilmann and Sterling [15], they also do not support the elicitation of requirements for the BDI model.

To make sure that all possible techniques were found, we also carried out a snowballing by checking the references of the works considered accepted. The snowballing was performed following the protocol proposed by Wohlin [16].

The only results obtained with the conduction of the snowballing were two papers with different titles, but which present the same technique already presented in the selected work by Sen and Jain [17].

Our objective with the accepted works was to extract which elicitation technique they use, as well as which artifacts are generated to save information about requirements. When we look at the proposed research questions, we can infer the following answers.

RQ1—As we performed an in-depth study of each technique, we chose to present a summary containing the application details of each technique, described in Sect. 22.4.

RQ2—The works returned by the systematic review were not sufficient to answer this question, considering that none of the techniques found is intended to elicit requirements for multi-agent systems aimed at the BDI model. We know that agents based on the BDI model must have the basic characteristics that are, beliefs, desires, and intentions, but no study was able to present a way to elicit these characteristics.

RQ3—Based on the results of the systematic review, we found only two studies that adapt techniques from a previously created technique. The works by Miller et al. [18] and Waishiang et al. [19] adapt issues that are found in Sterling's [15] work, which introduces the Homer technique. The remainder of the studies presents new techniques that are not based on any other studies we found.

22.4 Current Elicitation Techniques for Multi-Agent Systems

The first study that addressed elicitation specifically for multi-agent systems was proposed by Ruiz et al. [20]. In this work, the authors present guidelines for raising initial requirements for multi-agent systems. These guidelines are composed of roles, objectives, and relationships between roles. The main premise of this methodology is the decomposition of complex systems.

This approach focuses on understanding the perspective of observing the behavior of a given system, so the software engineer must be able to connect all components detected as a result of their interactions and dependencies. The proposed guidelines are divided into three aspects: identification of roles, specification of role interactions, and identification of goals.

The use of this technique is interesting as it is intended to serve as a starting point for requirements engineering. Using these guidelines, it is possible to identify the roles and its inputs and outputs, the role interaction specification and also the goal specification. However, to elicit more complex system issues, it would be necessary to establish a relationship with another technique, keeping the initial requirements raised as a starting point. We also found that it is assumed that the analyst using this technique has prior knowledge of the problem, which is often not the case.

In another work, Oliveira et al. [21] propose a technique whose main objective is to elicit the intentionality (interests and motivations) of agents. Therefore, it is necessary to identify the owners of the objectives and sub-objectives. As a point to be discussed, the authors' general idea is that actions change states and states are objectives.

The proposed technique brings as its main contribution the elicitation of agents' goals and subgoals by a method based on the Language Extend Lexicon, which follows the idea that actions point to goals.

The authors assume that identifying the actors is a relatively simple task, since they are frequently mentioned in documents or interviews, so the big problem is to elicit the intentionality of the actors. A suggestion to mitigate this problem would be the participation of stakeholders in the elicitation process. As the application of the technique is not simple, the participation of stakeholders could take place through a brainstorm before the application of the technique.

In the work of Sen and Jain [17], the authors state that the correct extraction of objectives is possible through a method involving the maximum participation of stakeholders. The technique presented by the authors seeks to be agile and serves to elicit soft goals using the Agent Based Goal Refinement process. The ABGR process is done in several sessions of Sprints, and the activities proposed in each session are: Develop; Wrap; Revise and Adjust. After each Sprint session, an output is generated from the activity card compiler algorithm. Each output generated must contain a greater number of elicited subgoals showing its link with its predecessor.

Before starting the activities with the stakeholders, an analyst will carry out the planning activity, which aims to prepare an initial list of objectives. All stakeholders involved in the elicitation will receive this list and must assign an integer value in ascending order to all available objectives based on priority. After this step, the analyst using the activity card compilation algorithm, developed by the authors themselves, receives the list with the priority order of the objectives.

As the technique seeks to be agile following sprints already defined, its great contribution is that it will always be applied systematically, regardless of the context of the multi-agent system.

Although the technique proves to be effective, when we take into account the case study that had a total of 104 new subgoals elicited, some important points should be considered. While the analyst presents an initial list of objectives, the stakeholders involved in the elicitation must have a high degree of understanding of the scope of the problem, as they are fundamental for the success of the elicitation. The development of a software following the rules of the proposed algorithm must also be taken into account, considering that the authors did not provide any source code and neither were any tools that serve this purpose.

It is not clear during the authors' work how the agents' roles responsible for the elicited goals and subgoals are elicited, although this is not a difficult task, once the goals and subgoals have been elicited.

Another work that focuses on elicitation for multi-agent systems is the work of Fuentes-Fernández et al. [22]. According to these authors, the Requirements Elicitation Guide (REG) is a multi-question questionnaire that contains the specialized knowledge that developers need to obtain information about their multi-agent systems, human environments and their mutual influences.

The knowledge raised with the technique takes the form of requirements described in diagrams, which are the sum of text plus a UML-AT diagram. The REG questions are divided into four areas: (I) Means and ends; (II) Environment; (III) Learning, Cognition and Articulation; (IV) Development. Each area has different aspects and each aspect has a specific number of questions, totaling 170 questions in the end.

Some concerns are raised by the authors, for example, case studies show that certain analysts only seek to apply the REG, forgetting that they are encouraged to use all possible techniques and knowledge to ensure that no relevant information is ignored. The authors also explain that not all REG questions make sense in a given environment and analysts must first perform a careful analysis of when each question is useful. With this technique, it is possible to elicit the agent roles, the goal and sub-goal that the agent roles are responsible for and also the agent roles' actions.

In Hill's [23] work, the author addresses the elicitation of initial requirements for multi-agent systems through the Transaction Agent Modeling (TrAM) technique, which incorporates the use of conceptual graphics.

The first step in eliciting requirements with this technique is capturing the main goals of the project and modeling them in a conceptual graph. In parallel to the creation of the models, the software engineer must think in terms of domain, such as the names of concepts and relationships, and to help build a logical basis, questions such as why, what and how should be asked. Through the generated graphic, it is possible to identify the agent roles and their goals.

It is unclear what would be the best method to assist in the extraction of requirements, as in the beginning, where the main objectives of the system should be captured. It is also unclear whether the elaboration of graphs can be taught to the stakeholders.

The work of Miller et al. [18] brings some evolutions to the HOMER technique [15]. Contextualizing, the process of applying HOMER can be described using organizational metaphors, such as hiring new employees to elicit customer requirements. This style of elicitation proposes to discover more easily the roles of agents, the communication between them and their objectives within the system.

During the application of Miller technique, the main activities of the system must first be raised, so that a set of questions are then carried out for each activity raised. The questions are divided into sections, and each section is responsible for eliciting certain aspects of the system.

In this work, we can find a set of improvements when compared to the first version of the HOMER technique, highlighting the greater number of questions to be answered by the stakeholders, which facilitates collecting more details about the requirements to be raised, and the improvements in relation to the lack of systematic methods for eliciting agent-oriented requirements. However, the greater number of questions also brings a downside, as they must be repeated for each activity raised at the beginning of the elicitation, thus making the elicitation process very repetitive and tiring, especially for stakeholders.

Finally, in another work that brings characteristics of the HOMER technique, Waishiang et al. [19] present an elicitation technique called eHOMER, which transforms mathematical models into a context of multi-agent systems through a series of questions, which in turn are based on the HOMER elicitation technique. These questions aim to identify elements in mathematical models that correspond to specific agent-oriented characteristics.

This work adopts the organizational metaphor of the HOMER technique. With the metaphor, it is only possible to elicit a function that will always be associated with a person or some position, while the eHomer technique can bring the characterization of elements of complex systems in domains such as biology, where humans, non-human organisms, and environmental entities constitute a complex system.

22.5 Threats

During the planning and execution of this review, some factors were characterized as threats to the research validity. The potential threats are discussed to orient the interpretation of this work:

1. Construct Validity: The reliability of the search string defined to select relevant works can be a threat to the construct. To minimize this threat, the string was calibrated with the execution of several tests and the area expert was consulted about the most used terms.

2. Internal Validity: A possible threat could have arisen from the individual interpretation of each researcher, something that could have led to the exclusion of relevant studies. To minimize this threat, a researcher with experience in this area was consulted to reach a consensus about the acceptance of the identified studies.
3. Coverage Validity: Regarding the possible papers that were not captured by our String, we carried out a snowballing trying to find more relevant papers.

22.6 Conclusion

In this review, we answered the research questions about how elicitation techniques for multi-agent systems exist and how they are applied and also which studies present a new elicitation technique and which adapted techniques from previous approaches.

After summarizing all the works considered promising, five new techniques proposals and two proposed techniques that are evolutions of previous techniques, we can observe some interesting points. First and most important, we identify that none of the techniques found can elicit specific requirements for the BDI model. It is known that an agent based on the BDI model must have belief, desire and intention, but no technique can do it and does not intend to elicit such characteristics.

Some of the techniques found can be considered difficult to be applied and also unintuitive. As an example, the Miller et al. [18] technique can be considered complex as the interviewer must pass by several stages during the elicitation interview. We also noticed that none of the found techniques is willing to carry out a feasibility test for the use of multi-agent systems.

We observed that within the requirements engineering, the elicitation area has a big gap, especially when related to multi-agent systems and mainly with the BDI model. This gap creates an opportunity for new elicitation techniques to be created.

That said, as a future work, we will propose a new requirements elicitation technique for multi-agent systems that can also cover the characteristics of the BDI model. The process of developing this technique is already underway, and is being tested in different multi-agent systems. We also intend to extend this technique in such a way that it encompasses all the development life cycle of multi-agent systems with focus on the BDI model.

References

1. Wooldridge, M., Ciancarini, P.: Agent-oriented software engineering: the state of the art. In: Agent-Oriented Software Engineering. Springer Berlin Heidelberg, Berlin, Heidelberg (2001)
2. Gan, K.S., Anthony, P., Chin, K.O., Hamdan, A.R.: Enforcing social semantics in FIPA-ACL using spin. In: Agents and Multi-agent Systems: Technologies and Applications 2019, pp. 3–13. Springer, Singapore (2020)
3. Gelaim, T.Â., Hofer, V.L., Marchi, J., Silveira, R.A.: Sigon: a multi-context system framework for intelligent agents. Expert Syst. Appl. **119**, 51–60 (2019)

4. Xu, M., Bauters, K., McAreavey, K., Liu, W.: A formal approach to embedding first-principles planning in BDI agent systems. In: International Conference on Scalable Uncertainty Management, pp. 333–347. Springer, Cham (2018)
5. Shehory, O., Sturm, A.: Agent-Oriented Software Engineering. Springer-Verlag Berlin AN (2016)
6. Buarque, P., Fairley, R.: Guide to the Software Engineering Body of Knowledge (SWEBOK (R)): Version 3.0. IEEE Computer Society Press (2014)
7. Van Lamsweerde, A.: Requirements Engineering: From System Goals to UML Models to Software, vol. 10. Wiley, Chichester, UK (2009)
8. Firesmith, D.: Common requirements problems, their negative consequences, and the industry best practices to help solve them. J. Object Technol. **6**, 17–33 (2007)
9. Aurum, A.: In: Wohlin, C. (ed.) Engineering and Managing Software Requirements, vol. 1. Springer, Heidelberg (2005)
10. Dorri, A., Kanhere, S.S., Jurdak, R.: Multi-agent systems: a survey. IEEE Access **6** (2018)
11. Cossentino, M., Hilaire, V., Molesini, A., Seidita, V. (eds.): Handbook on Agent-Oriented Design Processes. Springer Berlin Heidelberg (2014)
12. KC, U., Chodorowski, J.: A case study of adding proactivity in indoor social robots using belief–desire–intention (BDI) model. Biomimetics **4**(4) (2019)
13. Kardas, G., Tezel, B.T., Challenger, M.: Domain-specific modelling language for belief–desire–intention software agents. IET Softw. **12**, 356–364 (2018)
14. Keele, S.: Guidelines for performing systematic literature reviews in software engineering. Vol. 5. Technical report, Ver. 2.3. EBSE Technical Report. EBSE (2007)
15. Wilmann, D., Sterling, L.: Guiding agent-oriented requirements elicitation: HOMER. In: 5th International Conference on Quality Software 2005 (QSIC 2005). IEEE Xplore (2005)
16. Wohlin, C.: Guidelines for snowballing in systematic literature studies and a replication in software engineering. In: Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering, pp. 1–10 (2014)
17. Sen, A.M., Jain, S.K.: A visualization technique for agent based goal refinement to elicit soft goals in goal oriented requirements engineering. In: Second International Workshop on Requirements Engineering Visualization (REV 2007). IEEE (2007)
18. Miller, T., Lu, B., Sterling, L., Beydoun, G., Taveter, K.: Requirements elicitation and specification using the agent paradigm: the case study of an aircraft turnaround simulator. IEEE Trans. Softw. Eng. **40**(10) (2014)
19. WaiShiang, C., YeeWai, S., Nizam, S., CheeWyai, L.: Agent oriented requirement engineering for lake mathematical modelling: preliminary study. J. Telecommun., Electron. Comput. Eng. (JTEC) **8**(2) (2016)
20. Ruiz, N., Giret, A., Botti, V.: Early requirement guidelines for multiagent system modeling. In: IEEE Workshop on Distributed Intelligent Systems: Collective Intelligence and Its Applications (DIS'06). IEEE (2006)
21. Oliveira, A., do Prado Leite, J., Cysneiros, L., Cappelli, C.: Eliciting multi-agent systems intentionality: from language extended lexicon to i* models. In: XXVI International Conference of the Chilean Society of Computer Science (SCCC'07). IEEE (2007)
22. Fuentes-Fernandez, R., Gomez-Sanz, J.J., Pavon, J.: Requirements elicitation and analysis of multiagent systems using activity theory. IEEE Trans. Syst., Man, Cybern.-Part A: Syst. Hum. **39**(2) (2009)
23. Hill, R.: Agency and the virtual campus: the TrAM approach. In: 2010 International Conference on Intelligent Networking and Collaborative Systems. IEEE (2010)

Chapter 23
Implications of the Exact Time Use for the Simulation of Business Processes' Costs with the TDABC Approach

Michal Halaška and Roman Šperka

Abstract Business process simulations provide a flexible approach to analyze business processes through simulation experiments using various 'what if' questions. Many business process simulation tools provide means for assessment of quality and efficiency of business processes; however, the possibilities of cost dimension simulation are being neglected. The focus of this research is on the use of exact times of business process activities for simulations of organizational costs and thus on cost simulations at the operational level. Furthermore, this research addresses the implications of exact times used on simulations of organizations' costs. Finally, we address the possibilities of contemporary business process simulation tools for the simulation of organization costs using exact activity times. To do this, we postulated two research questions. To answer these research questions, we first analyze the real-life event log that represents the loan application process and the estimated probability distributions of the duration of the process activities based on the exact times recorded in the log. Secondly, we analyzed capabilities provided by selected business process simulation tools towards simulation of business processes' cost with TDABC approach.

23.1 Introduction

Cost accounting is a form of managerial accounting that aims to capture a company's total cost of production by assessing its variable and fixed costs. Controlling is a part of cost accounting. It provides data for operational planning, among others. The basis for this is a complete recording of all costs incurred in the financial accounting. To make sense of costs, they are being separated into different cost groups. Among the

M. Halaška (✉) · R. Šperka
School of Business Administration in Karvina, Silesian University in Opava, Univerzitni namesti 1934, 733 40 Karvina, Czechia
e-mail: halaska@opf.slu.cz

R. Šperka
e-mail: sperka@opf.slu.cz

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_23

most important cost groups belong direct and overhead costs, and fixed and variable costs. Grouping on fixed and variable costs is not important for the ABC (Activity-Based Costing) or TDABC (Time-Driven Activity-Based Costing) approach, unlike grouping on direct and overhead costs. Traditional costing systems ignore the critical role of time, which can affect the expected profits' inefficiencies caused by bottlenecks [1]. According to Barber et al. [2], direct costs are easily traceable to cost objects (e.g., direct labour, direct expenses, equipment rental, etc.), while indirect costs cannot be easily traced to cost objects (e.g., office equipment, maintenance, utilities, etc.). To determine the costs of individual cost units, it is necessary to distribute the total incurred costs as they reflect the individual cost units. With changes in the cost structure of organizations, higher ratios of overhead costs and involvement of different technologies [3, 4], it is necessary to consider used processes and related activities, cost factors and process costs through analysis of business processes at the operational level. Especially, since in today's highly competitive markets, organizations need to utilize all possible advantages. It is widely accepted that organizations using older functional paradigm have difficulties to succeed in the present market conditions [5].

The sustainability of an organization is related to its ability to promptly adapt to the ever-changing market conditions. To this day, there is still growing interest towards tools that simulate the process before the changes get actually enforced. Simulation techniques are used to simulate complex systems such as business processes due to holistic view of them today. Thus, simulations allow us to analyze costs at the operational level as well. There are three main requirements related to business process simulations [6]: (1) process control flow, (2) data flow, and (3) organization. Generally speaking, there are three different approaches to business process simulations [7]: (1) discrete event simulations, which are based on the concept of entities, resources and block charts describing entity flow and resource sharing; (2) system dynamics, which represents processes in terms of so-called stocks; and (3) agent-based modelling and simulation, where active elements of the modelled system are represented by software agents. These agents are specific in a way that they are programmed to follow some behavioural rules and autonomously interact with each other and make their own decisions, which replicates the complexity of the system. While agent-based modelling and simulation and discrete event simulation are bottom-up approaches, thus building the simulation model of business process from lowest level of abstraction, system dynamics applies so-called top-down approach. According to Dumas et al. [8], business process is a sequence of activities in which execution results in specific outcome. TDABC assigns business's costs to individual activities which are building components in analysis and modelling of business processes. Costs of particular activities are furthermore aggregated into the cost of the whole process. The advantage of this method compared to others is the effort of evaluating each single activity instead of evaluation based on allocation bases.

Research in this paper explores the implications of exact times use for simulation of business processes' costs. In this paper, we postulated two research questions: (1) is it possible to use the exact times of process activities for simulation of costs of cost objects using TDABC approach, and (2) is it possible to use contemporary business process simulation tools for simulation of organizations' costs using TDABC approach. The remainder of this paper is organized as follows. Section 23.2 presents an introduction to the ABC approach and TDABC, respectively. Section 23.3 briefly introduces process mining, its fundamentals and required data. The following section presents research methodology, and the next section presents the results of our research. Finally, we conclude and discuss our results.

23.2 Time-Driven Activity-Based Costing

Generally, it is not easy to allocate indirect costs; thus, they are being allocated based on two steps: (1) they are aggregated under one or more cost pools and (2) then assigned to products on the basis of one or more cost drivers (e.g., direct labour) [9]. The process of cost allocation determines different costing techniques. Activity-based costing is based on three assumptions [4]: 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 [9, 10]. ABC focuses on overhead of individual activities and allows for the allocation of overhead costs to operations that brought about these costs. First, it assigns overhead costs to activities and then to products, orders or customers, based on consumption of individual activities [11–13]. Moreover, the 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 [14, 15].

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 [16, 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 was shown by several researchers, TDABC can bring positive results and better representation of company's costs. According to Everaert et al. [11], the breakthrough lies in the time estimation, where the time required for performing the activity for each case is estimated. The 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 [12, 17]. Although 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 [18]. 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 the complexities of business transactions by using time equations reflecting the time involved in a particular process [19], as time drivers are easier to maintain than transaction drivers used in ABC systems [4]. The model also removes activity pools and the use of quantity-based resource-activity cost drivers [16].

23.3 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. Information systems that record required data are increasingly appearing in medium and small companies, together with raising interest in 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 [20, 21]. None of the discovery techniques guarantees that the discovered model really corresponds to the original process or if it fully represents the behaviour discovered in the data. Therefore, it is necessary to verify that the discovered process model is of proper quality [22]. The essence of process enhancement is the extension or improvement of existing process models using information from the log of the monitored process [23]. Deviance mining is a group of techniques that attempts to discover the reasons for discrepancies in business process records and/or process models [8]. Online or operational support allows one to analyze processes in a real time using combination of a pre-mortem and post-mortem data, where the pre-mortem denotes data from pending cases and the post-mortem data from terminated cases [22].

The data required for PM analysis have to be extracted from operational systems like, 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 an 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 the MXML format. However, due to several encountered limitations, a new standard event log format named XES was created. Nevertheless, there are other formats like, e.g., CSV files, or even software specific FXL files, etc.

23.4 Methodology

To answer the first research question, we use complex real-life process of financial institution. Namely, it is the loan application process. The loan application process is represented by the publicly available event log [24]. The log contains more than 13,000 cases, which are formed by 262,200 events, each having nine attributes. Furthermore, 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 processing of work items of applications. The overall workflow of the process is as follows: after applying, small number of applications is controlled for fraudulent behaviour, the rest of them are controlled for completeness, after that the application is pre-accepted and processed. Some applications are cancelled, and the offer is sent to the rest of the customers and the contact with customer follows. In case that the customer accepts the offer, the application is assessed, and the loan is approved. In some cases, after the assessment of the application, further contact with the customer might be required to complete the application.

The log is available in XES format. Before we applied process mining techniques, we prepared the logs for its application. 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 neither cases nor events were removed from the log based on these attributes. We analyzed the prepared log using Apromore[1] to get a better understanding of the process, as it is crucial for TDABC costing systems. Apromore allows us to discover the BPMN process model from the log and subsequently exports it for simulation purposes. Moreover, Apromore uses one of the best process discovery techniques called split miner [21]. Based on the discovered process model, we identified activities contained in the log and used exact times recorded within the log to determine the best fitting probability distribution of activity durations. We were considering following probability distributions as they are typically supported by business process simulation software: gamma distribution, normal distribution, lognormal distribution, exponential distribution and Weibull distribution. The best-fitting distribution for each activity

[1] Apromore—process mining tool. http://apromore.org/platform/tools/. Accessed 13 Jan 2022.

was selected based on the Kolmogorov–Smirnov statistic, the Cramer–von Mises statistic and the standard deviation. For the occurrence of new cases, we considered only Poisson distribution. For fitting the probability distributions, we used R package ‘fitdistrplus’.

To answer the second research question, we analyze capabilities of selected contemporary business process simulation tools with regards to simulation of business processes’ costs. The first criterion for selection of business process simulation tools is used of modelling language. In our research, we focus on BPMN. A significant part of the literature that addresses the business process simulation uses Petri Nets, which are preferred to other modelling techniques due to their rigour and clear formalism [25]. However, many simulation techniques and tools have been supporting the BPMN modelling language lately, as it is being recognized as the standard process modelling language. Moreover, there are other important elements of the process in addition to the flow of activities such as, e.g., data and organizational perspectives. Furthermore, BPMN is much more user friendly than, e.g., Coloured Petri Nets. The purpose of the research is not to provide comprehensive list of capabilities of all business process simulation tools towards cost dimension. Thus, the second criterion is recognition of chosen business process simulations. Based on our criteria, the following business process simulation tools were selected: Bizagi Modeler, Bimp, BonitaSoft, IBM WebSphere BPM.

23.5 Results

Figure 23.1 presents the discovered process model representing the loan application process in 2012. To discover the process model, we used following parameters in Apromore: activity filter is equal to 100%, trace filter is equal to 60% and parallelism filter is equal to 100%. Figure 23.2 presents the extract of black oval in Fig. 23.1. In Fig. 23.2, one can see that the process model is enhanced with averages of processing and waiting times. Waiting time refers to a period of time in which a work item is waiting for further processing. Processing time refers to the time period in which a work item is being processed. Figure 23.2 shows just one activity, as it serves an illustrative purpose.

The time perspective of the process and simulation model is crucial for the TDABC approach. There are two ways to build the TDABC model. First, we go through so-called time equations (see Eq. 23.1):

Fig. 23.1 Discovered process model—2012 log

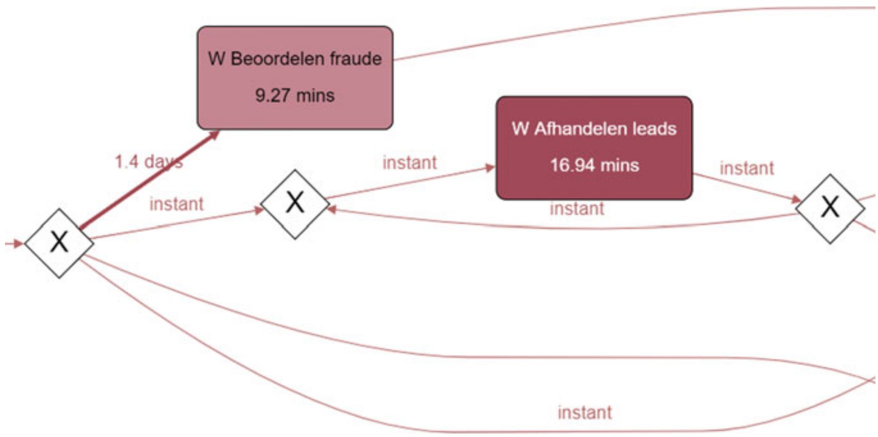


Fig. 23.2 Extract of black oval in Fig. 23.1 (activity 'W_Afhandelen leads' with average processing time of 16.94 min)

$$t_{E,A} = \sum_{i=0}^{n-1} \beta_i x_i, \text{ where} x_0 = 1 \tag{23.1}$$

$t_{E,A}$ … time required for executing event E related to activity A,

β_i … time consumed per unit of time driver i, β_0 constant amount of time required for activity A,

x_i … i-th time driver,

i … number of time drivers needed to run activity A.

However, estimation of each time driver determining the durations of all activities of the analyzed process might prove difficult. In Table 23.1, we present an alternative approach to that of time equations. Nowadays, business processes increasingly supported by technologies, and thus a large amount of data are recorded describing such processes. If the recorded data contain timestamps marking the start and completion of process activities, one can use the durations of each activity contained in the log for estimation of probability distributions instead of basing the TDABC model on

Table 23.1 Best fitting distributions and estimated parameters of activities of analyzed event log

Activity	Distribution	Parameters
W_Afhandelen leads	Gamma	60*rgamma(1,0.3234,0.0191)
W_Completeren aanvraag	Exponential	60*rexp(1,0.1042)
W_Nabellen incomplete dossiers	Exponential	60*rexp(1,0.0781)
W_Nabellen offertes	Exponential	60*rexp(1,0.1144)
W_Valideren aanvraag	Weibull	60*rweibull(1,0.7339,16.1139)
W_Beoordelen fraude	Exponential	60*rexp(1,0.1042)

Table 23.2 Cost-related simulation capabilities of selected business process simulation tools

Capabilities	Bizagi	BIMP	BonitaSoft	WebSphere
Activity	X	X	X	X
Resource	X	X	X	X
Branching	X	X	X	X
Arrival rate	X	X	X	X
Processing time	X	X	X	X
Waiting time	X	X	X	X
Probability distributions	X	X	X	X

time equations. In Table 23.1, column 'Parameters' presents functions[2] of estimated probability distributions based on exact processing times retrieved from event log. Functions are also adjusted to proper units by multiplying by '60', as probability distribution might fit better after proper modification of units of processing times.

As is presented in Table 23.2, selected business process simulation tools provide functionalities for use of the TDABC approach. In Table 23.2, activity refers to the cost of processing an activity; resource refers to hourly cost of each resource; branching refers to probabilities of outgoing branches; arrival rate refers to probability distribution specifying start of new cases; processing time refers to time spent in execution of an activity; waiting time refers to time activity has to wait for resources to be executed; probability distributions refer to supported probability distributions. If we are able to use exact times through probability distributions (duration of instance if each activity) and we know the cost rate of each activity (as simulation resource) in the process, we are able to apply a TDABC approach within business process simulation. There are differences in the implementation of different capabilities of selected business process simulation tools presented in Table 23.2, e.g., different tools have available different probability distributions; they differ in the amount of resource types that are possible to assign to each activity; implementation of branching of process workflow; etc.

23.6 Conclusions

Based on the results presented in Sect. 23.5, we are now able to answer research questions. To answer the first research question, if it is possible to use exact times of process activities for simulation of costs of cost objects using the TDABC approach. We show that it is possible to use exact times of process activities by estimating of probability distributions of durations of processing times of process activities.

[2] 'fitdistrplus' R package. https://cran.r-project.org/web/packages/fitdistrplus/fitdistrplus.pdf. Accessed 13 Jan 2022.

To answer the second research question, if it is possible to use contemporary business process simulation tools for simulation of cost of business processes using the TDABC approach. We show that contemporary business process simulation tools provide functionalities that allow us to simulate the costs of business processes using the TDABC approach.

The advantage of use of exact times and estimations of processing times of activities, respectively, is that it might not be always possible to determine each time driver of all of the process activities to be able to discover time equations required for TDABC model. Moreover, if one combines the TDABC approach with business process simulations, it is possible to assess the costs in the context of waiting times of activities and resource utilization. This approach is applicable at end-to-level of the process through discrete event simulations. However, at the level of individual process instances, the simulation requires not only workflow of the process but also process logic. At the level of individual process instances, hybrid simulation approach of discrete-event simulation and agent-based simulation would be more appropriate. In the future research, we are going to explore in more detail further integration of business process simulations, TDABC and process mining, as process mining bridges the business process simulations and TDABC approach at the implementation level.

Acknowledgements This paper was supported by the Ministry of Education, Youth and Sports Czech Republic within the Institutional Support for Long-term Development of a Research Organization in 2022.

References

1. Zhuang, Z.-Y., Chang, S.-C.: Deciding product mix based on time-driven activity-based costing by mixed integer programming. J. Intell. Manuf. **28**(4), 959–974 (2017)
2. Barber, K.D., Dewhurst, F., Pritchard, M.C.: Cost allocation for business process simulation models. Proc. Inst. Mech. Eng, Part B: J. Eng. Manuf. **220**, 695–705 (2006). https://doi.org/10.1243/09544054JEM379
3. Popesko, B., Papadaki, Š., Novak, P.: Cost and reimbursement analysis of selected hospital diagnoses via activity-based costing. E+M Ekon. Manag. **18**, 50–61 (2015). https://doi.org/10.15240/tul/001/2015-3-005
4. Afonso, P., Santana, A.: Application of the TDABC model in the logistics process using different capacity cost rates. J. Ind. Eng. Manag. **9**(5), 1003–1019 (2016)
5. Tallon, P.P.: A process-oriented perspective on the alignment of information technology and business strategy. J. Manag. Inf. Syst. **24**, 227–268 (2007). https://doi.org/10.2753/MIS0742-1222240308
6. van der Aalst, W.M.P.V., Nakatumba, J., Rozinat, A., Russell, N.: Business process simulation: how to get it right. In: International Handbook on Business Process Management. Springer-Verlag (2009)
7. Halaška, M., Šperka, R.: Is there a need for agent-based modelling and simulation in business process management? Organizacija **51**, (2018)
8. Dumas, M., la Rosa, M., Mendling, J., Reijers, H.: Fundamentals of Business Process Management. Springer-Verlag, Berlin (2018)
9. Jeyaraj, S.S.: Activity based costing vs volume based costing: relevance and applicability. Int. J. Manag. **4**(2), 39–46 (2015)

10. Popesko, B.: Activity-based costing application methodology for manufacturing industries. Ekon. Manag. **13**(1), 103–114 (2010)
11. Everaert, P., Bruggeman, W., Sarens, G., Anderson, S.R., Levant, Y.: Cost modeling in logistics using time-driven ABC: experiences from a wholesaler. Int. J. Phys. Distrib. Logist. Manag. **38**(3), 172–191 (2008)
12. Bruggeman, W., Everaert, P., Anderson, S., Levant, Y.: Modeling logistics costs using time-driven ABC: a case in a distribution company. https://www.researchgate.net/publication/24125837_Modeling_Logistics_Costs_using_Time-Driven_ABC_A_Case_in_a_Distribution_Company (2005). Accessed 15 Jan 2021
13. Lu, T.-Y., Wang, S.-L., Wu, M.-F., Cheng, F.-T.: Competitive price strategy with activity-based costing – case study of bicycle part company. Procedia CIRP **63**, 14–20 (2017)
14. Tse, S.C., Gong, M.: Recognition of idle resources in time-driven activity-based costing and resource consumption accounting models. J. Appl. Manag. Account. Res. **7**(2), 41–54 (2009)
15. Kaplan, A.L., Agarwal, N., Setlur, N.P., Tan, H.J., Niedzwiecki, D., McLaughlin, N., Burke, M.A., Steinberg, K., Chamie, K., Saigal, C.S.: Measuring the cost of care in benign prostatic hyperplasia using time-driven activity-based costing (TDABC). Healthcare **3**(1), 43–48 (2015)
16. Ratnatunga, J., Tse, M.S.C., Balachandran, K.R.: Cost management in Sri Lanka: a case study on volume, activity and time as cost drivers. Int. J. Account. **47**(3), 281–301 (2012)
17. Keel, G., Savage, C., Rafiq, M., Mazzocato, P.: Time-driven activity-based costing in health care: a systematic review of the literature. Health Policy **121**(7), 755–763 (2017)
18. Namazi, M.: Time driven activity based costing: theory, applications and limitations. Iran. J. Manag. Stud. **9**(3), 457–482 (2016)
19. Stout, D., Propri, J.M.: Implementing time-driven activity-based costing at a medium-sized electronics company. Manag. Account. Q. **12**(3), 1–11 (2011)
20. Leemans, S.J.J., Fahland, D., van der Aalst, W.M.P.: Discovering block-structured process models from incomplete event logs. In: Ciardo, G., Kindler, E. (eds.) Application and Theory of Petri Nets and Concurrency. Lecture Notes in Computer Science, pp. 91–110. Springer, Berlin (2014)
21. Augusto, A., Conforti, R., Dumas, M., la Rosa, M., Bruno, G.: Automated discovery of structured process models from event logs: the discover-and-structure approach. Data Knowl. Eng. **117**, 373–392 (2018)
22. van der Aalst, W.M.P.: Process Mining: Data Science in Action. Springer-Verlag, Berlin (2016)
23. Yasmin, F.A., Bukhsh, F.A., Silva, P.D.A.: Process enhancement in process mining: a literature review. In: CEUR Workshop Proceedings, vol. 2270, pp. 65–72. CEUR, Aachen (2018)
24. van Dongen, B.: BPI challenge 2012. 4TU.ResearchData. Dataset. https://doi.org/10.4121/uuid:3926db30-f712-4394-aebc-75976070e91f. Accessed 21 Jan 2021
25. Cartelli, V., Di Modica, G., Manni, D., Tomarchio, O.: A cost-object model for activity based costing simulation of business processes. In: 2014 European Modelling Symposium, pp. 221–226 (2014). https://doi.org/10.1109/EMS.2014.41

Chapter 24
Coping with Diverse Product Demand Through Agent-Led Type Transitions

Martins Obi, Chris Snider, Lorenzo Giunta, Mark Goudswaard, and James Gopsill

Abstract Additive Manufacturing (AM) machines are a highly flexible manufacturing capability capable of producing a wide range of products. One feature that enables this is the ability to change materials in a relatively short time. For example, Fused Deposition Modelling (FDM) printers can be quickly and easily reconfigured to print in different materials such as PLA, ABS, and Nylon. Facilities that, therefore, employ Additive Manufacturing (AM) machines have the underlying capability to be flexible and responsive to diverse product demand. However, as jobs require different machine configurations for fabrication, methods need to be developed to assist facilities in deciding whether to and when to transition machines from one type of production to another to maximise overall system performance. In this paper, we explore how agent-based control can provide flexibility and responsiveness in manufacturing facilities. A model of a single fabrication workshop was created using AnyLogic, comprising multiple machines and incoming jobs of varying required machine configuration. The modelling shows responsiveness to spikes in demand when machines are able to request a change in configuration, although the penalties associated with reconfiguration cause poor performance when changes occur frequently. When not willing to change configuration, spikes in demand cause the system to become unstable and unable to meet changes in demand.

M. Obi · C. Snider (✉) · L. Giunta · M. Goudswaard · J. Gopsill
University of Bristol, Bristol, UK
e-mail: chris.snider@bristol.ac.uk

J. Gopsill
The Centre for Modelling & Simulation, CFMS, Bristol, UK

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_24

24.1 Introduction

Modern manufacturing processes are complex and yet, well-defined structures that require smart and intelligent mechanisms to handle product demand [1]. Of particular interest to this paper is Additive Manufacturing (AM). AM is a flexible manufacturing process with machines able to handle jobs with different materials and complex and varied geometries [2]. As a result, AM has seen rapid growth across the prototyping and end-use product sectors [2].

AM has also shown itself to be responsive. During the outbreak of COVID-19, Personal Protective Equipment (PPE), ventilators, and other equipment for remote working experienced increased demand. It was then AM that initially responded to tackle the demand with conventional production and supply chain processes following soon after. Without AM, there would have been more moments during the early stages of the outbreak where key workers would have been left without PPE leaving them at considerable risk. Having identified that AM-enabled facilities[1] have the capacity to be flexible and highly responsive to diverse product demand [3], the attention then turns to the methods employed in managing the jobs through the facilities. Research has shown that most of these facilities work on manual first-come first-serve methodologies. In addition, there are few who employ job scheduling tools, such as Ultimaker's Digital Factory. However, these are often proprietary solutions that limit their connectivity to a subset of AM machines. The hypothesis is that considerable gains in productivity, responsive and flexibility can be achieved through improvements to job scheduling. In particular, where machines need to transition between different types of job to meet demand yet doesn't not compromise itself with the cost of transitioning (e.g., changing the filament material from PLA to ABS). To explore this, we adopt an agent-based approach to mimic a facility with 15 machines able to manufacture three types of job. This could represent three different materials, for example. Jobs of each type are submitted to the manufacturing facility and must be printed on a machine of corresponding type. The machines have the capability to print any job but must switch types to print those of a non-corresponding type. This incurs a change penalty. The contribution of this paper lies in exploring the performance of the system under a big demand scenario, and the variation in performance dependent on the conditions by which a machine may switch its configuration to align with incoming jobs (termed switching *types*)—i.e., how controlling switching behaviour may enable better overall system performance.

The paper is structured as follows. Section 24.2 discusses the related work on agent-based AM systems. Section 24.3 presents the agent-based approach taken to represent an AM facility and determine machine transitions. Section 24.4 describes the numerical experiment with Sect. 24.5 containing the results. Section 24.6 then discusses the results and future work to explore the potentials of altering willingness for a machine to change types to tackle big demand especially for outbreaks such as Covid-19. The paper then concludes with the key findings from the study (Sect. 24.7).

[1] For example, workshops, makerspaces, libraries, and hobbyists.

24.2 Related Work

To provide context to this paper, this section provides a brief overview of work in coordinating modelling of agent-based AM systems using rule-based Logics and the Architecture of the system.

Manufacturing scheduling and control is often centrally managed through hierarchical and centralised structures, managing structure through decomposition and simplification. The needs of manufacturing systems in the twenty-first century include heterogeneity of software and machines, interoperability, open and dynamic structures, scalability, and fault tolerance [4]. In addition, recent additive manufacturing systems are beginning to shift focus from production maximisation and standardisation to cost reduction and mass customisation [5]. To enable the maximisation of cost and reduce the loss of productivity in such systems, an extensive knowledge of logics is important [6]. The use of agent-based systems to model additive manufacturing has been explored in various studies [5, 6] and revealing the dynamic capabilities of agent-based systems in developing responsive manufacturing systems.

Multi-agent systems (MAS) view the supply chain as a network, composed of individual nodes, each one representing an agent. In turn, each agent represents an individual decision-maker within the supply chain [8]. In the case of a MAS adapted for AM, these nodes would represent the printers; this is because they act individually to select jobs while continuously sharing information with one another [9, 10]. This continuous communication between agents is vital to the functioning of the MAS, allowing them to respond appropriately to the state of the network. Since each agent is independent, each agent can autonomously attempt to optimise for a specific parameter, such as, for example, number of jobs processed or lead time. Nonetheless, as a collective network the MAS attempts to achieve the same goal, the production of AM parts [8].

However, despite all the agents in an MAS acting independently, the network itself need not be decentralised. The organisation of the network can be hierarchical or centralised [8]. This allows for the adoption of a client–server model, which allows for a centralised job queue, simplifying the development of the inter-printer communication [11]. Each printer agent, acting as a client, communicates with a server to view the jobs. The server contains a list of the jobs being submitted to the network and allows the printers to be aware of which jobs have been already selected. The use of a centralised location simplifies both the submission of jobs and the inter-agent communication, while still allowing the printers to independently make decisions on the jobs to select.

In summary, the development of a co-ordinated-dynamic AM system using agent-based approach requires features some rule-based logics. Moreover, a communication architecture where agents can interact to execute jobs based on their capabilities is needed.

24.3 Agent-Led Type Transitions

Research shows that agent-based approaches have the potential to be fault tolerant and highly reactive [12, 13] thus possessing the capacity to be dynamic within a coordinated system. Agent-based approaches may be implemented in facilities as AM machines with heterogeneous capabilities can be added, removed, maintained, and modified regularly. However, while machines are typically able to print in multiple materials, there is a non-zero time cost associated with any reconfiguration, and as such frequent changing of machines across types of job may greatly decrease system performance and increase overhead. While it logically stands that the ability of machines to adapt to a big demand scenario may increase performance, the dynamics present when also considering a non-zero cost of flexibility must be investigated. Modelling and simulation are here deployed to gain an insight into how these switches can occur, and the optimum switch characteristics for the system to maximise responsiveness to the increased product demand.

The agent-based model used to represent an AM facility and examine machine-led type transitions featured two populations of agents—*Machines* and *Jobs*. *Machine* agents represent the AM printers in the facility and are aware of their 'type'. Machines are assigned a 'type' when they are created. The type could define the material in which they are configured to print, for example. A *Machine* agent is able to print any job submitted to the facility, however, it has to be of corresponding type otherwise a change of type penalty occurs, for example, to change filament.

The *Job* agents represent individual jobs that need to be manufactured and possess the necessary manufacturing information. *Job* agents are assigned a type on creation. *Types* here represent the material in which the job must be printed (i.e. PLA, ABS, Nylon), where a machine must be configured to corresponding *type* for printing to occur (i.e. the corresponding material must be loaded, and corresponding manufacturing parameters must be set). A direct communication architecture is developed between the machine and the job agents in the system.

The system is configured to depict a co-ordinated (Machine-led) system (Fig. 24.1) where the *Machine* agents initiate and communicate directly to the *Job* agents. In this communication strategy, the *Machine* agents lead on the discussion and may either accept a job of their corresponding type, or may make the decision to switch modes and allow selection of an alternative job type. The decision to switch modes is determined by the proportionality of job types within the system, with the required proportion to demand a switch taken as the independent variable within the study. In this way, should the proportion of jobs of a single type increase relative to other types above a given threshold (here termed *switch ratio*), the logic allows machines to change their configuration and focus on the dominant job type.

Jobs are created according to steady-state or step-change demand profile. For the former, jobs of each type have equal likelihood of creation in each timestep, with likelihood itself defined such that a steady-state capability is achieved (i.e. average time in system remains constant). Step-change demand mimics a big demand scenario in which the likelihood of creation of jobs of a single type increases relative to other

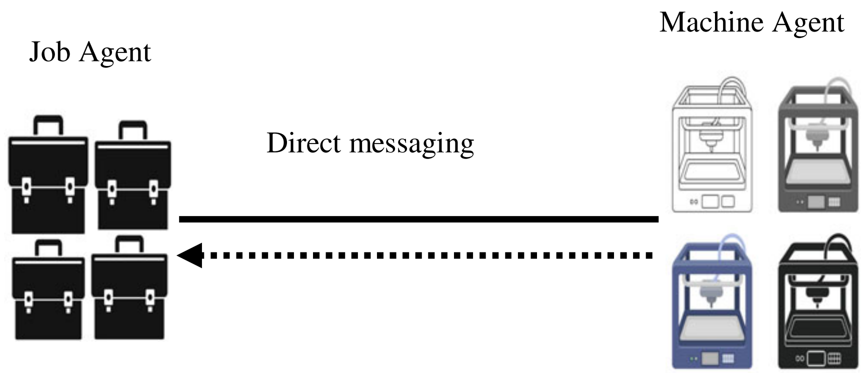
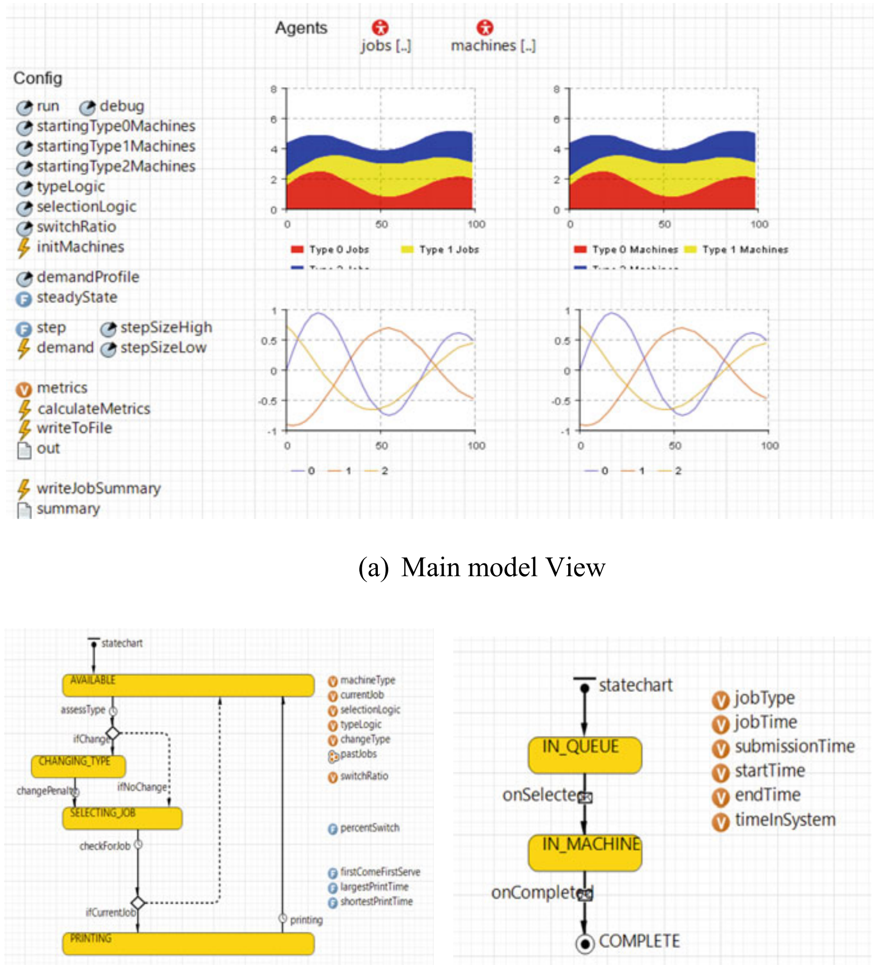


Fig. 24.1 Agent communication

types for a given time period, before reversion back to the steady-state value. Here, interest lies in the interplay between the step-change profile, threshold proportionality to switch modes, and the ability of the system to return to steady-state capability.

Machine agents select jobs from their corresponding type using a First-in-first-out (FIFO) selection logic, with simulation of alternative logics (i.e. shortest print time, earliest due date) considered future work. The Model was developed using AnyLogic and configured as a co-ordinated—dynamic manufacturing system. Figure 24.3 shows the main model view (in this case, the system) and features the agent populations, parameters, variables, and metrics that will be captured during simulation. Figure 24.2b shows the *Machine* agent first exists in the AVAILABLE state before it proceeds to check if it is commissioned to switch modes by assessing its type. Since the system is configured to work all week for 24 h/day the *Machine* agents then checks the job type with the largest demand in the *Jobs* agents and, should the proportionality of the largest job type be above a given threshold, then enters the CHANGING TYPE state where it switches mode to that predominant type. In such cases, a change penalty is administered representing the logistics involved in changing print materials. The Machine agent then moves to exist in the SELECTING JOB state where it selects the job based on a predefined rule-based logic and issues a communication 'selected' to the selected jobs. It then moves to the PRINTING state where the manufacture of the selected job is carried out based on the distributed print time. When the manufacture is completed, the *Machine* agent returns a 'completed' message to the *Job* agent.

Figure 24.2c shows the *Job* agent, which is submissive. When the job agent is created, it enters the IN QUEUE state and listens to receive communication from the *Machine* agent on whether it is selected or not. On receipt of the 'selected' message, it moves the job to the IN MACHINE state. The *Job* agent remains in this state until it receives a 'completed' message from the *Machine* agent manufacturing the job.



(a) Main model View

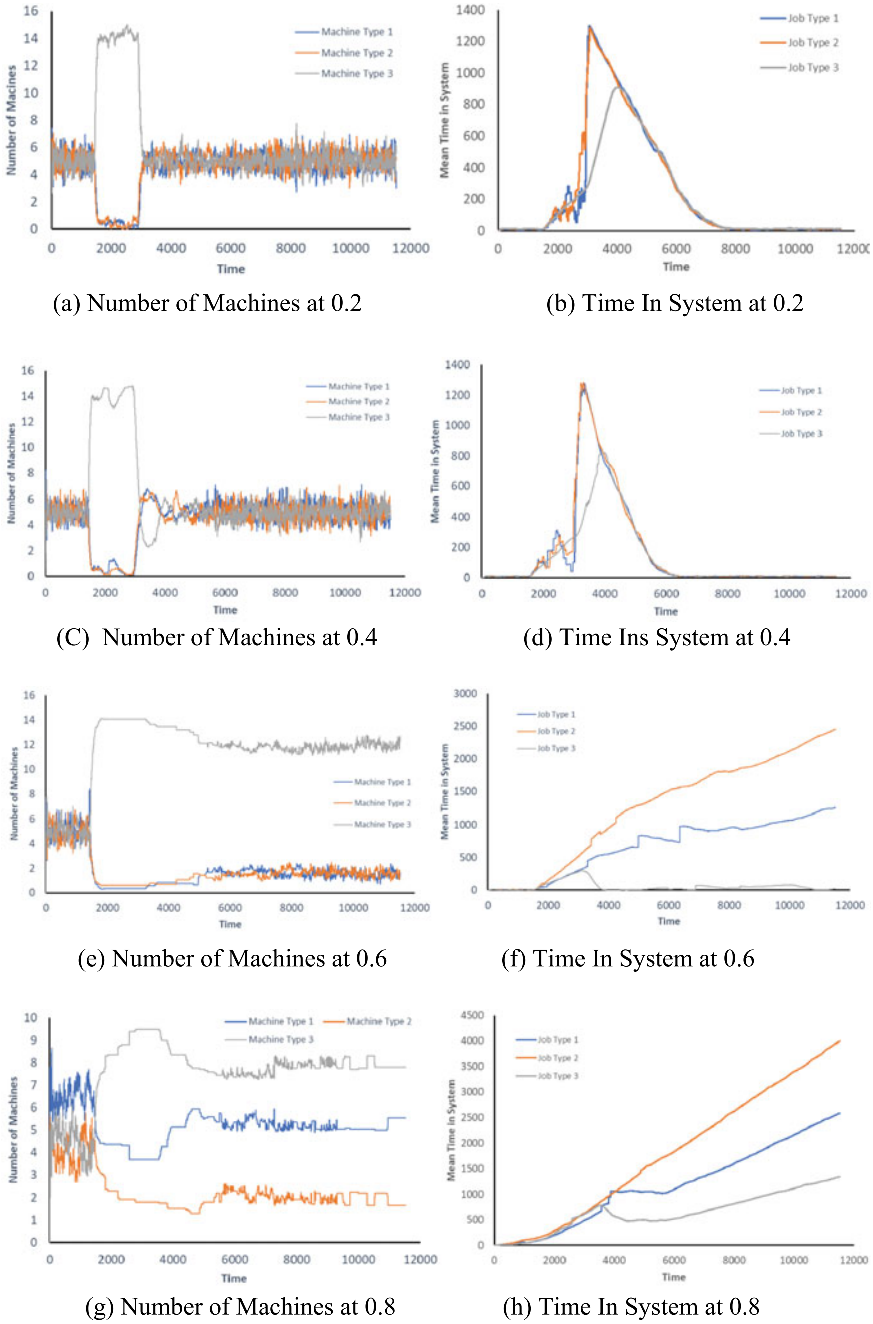
(b) Machine Agent

(c) Job Agent

Fig. 24.2 Modelling in any logic

24.4 Experiment

The experiment mimicked a fabrication facility (termed 'workshop') operating 24 h over 7 days, approximately representative of a typical Makerspace or industry printing facility.. Three machine types and three corresponding job types were considered, with 15 machines assigned equally across the types (i.e. 5 machines of each) on initiation. Jobs were assigned to one of the three types on creation. All jobs submitted to the workshop could be manufactured by any of the machines, if of corresponding type. Eight days were simulated with an infinite availability of materials and a 10 min



(a) Number of Machines at 0.2

(b) Time In System at 0.2

(C) Number of Machines at 0.4

(d) Time Ins System at 0.4

(e) Number of Machines at 0.6

(f) Time In System at 0.6

(g) Number of Machines at 0.8

(h) Time In System at 0.8

Fig. 24.3 Agent-led transition in response to a step-change in demand penalty for material changeover. No downtime, maintenance or chance of failure was added to the model. While assigned a type on creation, machines could switch types should the proportionality of waiting job type change beyond pre-defined thresholds. This threshold was defined as a *switch ratio*, whereby machines first scanned types of all waiting jobs, and changed their type to that of the predominant job type if it exceeded a given proportion of all waiting jobs. Simulated thresholds included 80% (i.e., change to the predominant type if 80% or higher of the total waiting jobs are this type), 60, 40, and 20%. Machines selected jobs according to FIFO selection logic.

Jobs were created according to a demand profile as described in Sect. 24.3. Initially, jobs of each type were created with a likelihood of 5% chance in any given timestep. This profile remained for the start of the week (Monday). A step-change profile was then created in a single job type by increasing likelihood of creation to 30%for a single day (Tuesday), before returning to 5% for the remainder of the week. Job submission only occurs within the open hours of the workshop on a random triangular distribution. The job prints time distribution featured a minimum, mode, and maximum of 20, 60, and 300 min, respectively.

The performance of the system was measured by a rolling average of time in system of jobs across each type in the preceding two hours, and the number of machine-type switches per time step. At each timestep, the number of machines switching to tackle the spike in demand of any job type is collated and their time in system calculated (Start Time—Submission Time). The average time in system and number of machines switching across runs were collated and plotted against the model run time. The model was run 20 times for each simulation case (i.e. each switching threshold), with results averaged across the cases.

24.5 Results

Figure 24.3 shows the baseline performance of switching machines within a flexible AM system with the existing coordinated system. Subfigures show the effect of altering switch ratio—the proportion of jobs of a single type required for a machine to switch to the corresponding type. At a switch ratio of 0.2, the system shows a rapid response to the increased demand of job type 2. The machines also returned to the steady state after dealing with the demand on Tuesday. We also observe that the time in system (Fig. 24.3b) for job types 0 and 1 increased to above on Tuesday which suggests that job types 0 and 1 submitted same day (Tuesday) were left unattended until the spike in demand of job type 2 was tackled, thus bringing the time in system back to its steady state.

Figure 24.3c shows the response from the machine agent transitioning at 0.4 switch ratio and exhibits a similar response to the baseline. We observe that the machines are willing to switch to tackle the spike in the demand of job type 2. The willingness of machine 0 and 1 to switch may be hypothesised as being proportionate to the expected proportions of jobs (i.e. the 40% is close to the expected proportionality 33.3% of the job types) thus, the system is highly responsive to deviate from the steady state. This is also shown in the corresponding time in system (Fig. 24.3d) which depicts an overload of the system with job types 0 and 1.

Figure 24.3e shows the results from having the switch ration set at 0.6 and reveals a different profile from earlier switch ratios. The machines are keen on responding to the spike in demand of job type 2 while ignoring the other job types. After tackling the demand, machine types 0 and 1 never reached 60% of the total number of machines, hence, the machines do not change back to Types 0 or Type 1. This implies that the number of job types 0 and 1 continue to increase, thus, raising their average time in system (Fig. 24.3f).

Figure 24.3g shows similar trend with the switch ratio of 0.8, however, with the exception that there is a reduced willingness of machine types 0 and 1 to switch into machine type 2. This is suggestive of their unresponsiveness to the spike in demand of job type 2. Figure 24.3h further reveals the impact of the unresponsiveness to the time in system of the various job types. An increased time in system of job type 2 is shown in comparison to the previous simulated switch ratios.

24.6 Discussion and Future Work

The result shows that agent-based modelling shows viability in achieving steady-state production for AM. However, while AM machines have the capability to print different materials, there is a non-zero cost of reconfiguration that must be considered when jobs require different materials for their fabrication (are of different *types*). This work investigated different degrees of willingness to transition from one machine type (i.e. material configuration) to another defined by the proportionality of different job types waiting to be printed. Furthermore, the study identifies that while the transition of machines to other types allows for increased responsiveness to big demand scenarios, the willingness to change affects emergent system performance.

- If machines are not able to change, they are not able to react to big demand.
- If they can change, but with resistance, (controlled by high proportionality threshold), they will clear the jobs with big demand, but to the detriment of other job types.
- If able to change freely, then they can efficiently clear the job type experiencing big demand while also managing other job types.
- When eager to change, machines will clear all jobs and return to steady state but suffer the effects of accumulation of change penalties.

Thus, this work, therefore, implies an optimal set of switching characteristics, likely related to the proportionality of incoming jobs, at which the system is best able both to support steady-state demand and a big demand scenario. Future works will include to validate the concept of Agents transition through real-world testing of the switching ratio suitable to model an optimum system, difference in demand profiles, switch ratios and selection logics and identifying the balance of parameters to deal with big demands and step changes most efficiently.

24.7 Conclusion

Agent-based modelling offers a unique potential to model how AM systems can transition to build a co-ordinated-dynamic and responsive system by using rule-based logics and switch ratios. Additive manufacturing has proven to be a relevant manufacturing strategy for both prototyping and end-use products for most facilities that adopt their use. We have shown that transition time and switch ratios would contribute to creating a balance in the system, thus allowing the system to respond to the high demand and return to its equilibrium state otherwise noted as the steady state. This work has further revealed that to realise such balanced co-ordinated-dynamic systems, the optimum switch ratios fall between 0.4 and 0.6, enabling the system to return back to steady state after tackling big demand of any product type.

References

1. Ma, A., Nassehi, A., Snider, C.: Anarchic manufacturing. Int. J. Pro. Res. **57**(8). https://doi.org/10.1080/00207543.2018.1521534
2. Sculpteo.: The State of 3D Printing 2021
3. Gopsill, J., Goudswaard, M., Snider, C., Johns, J., Hicks, B.: Achieving responsive and sustainable manufacturing through a brokered agent-based production paradigm. Smart Innov. Syst. Technol. **262** (2022). SIST: 24-33
4. Qiao, B., Zhu, J.Y.: Agent-based intelligent manufacturing systems: a state-of-the-art survey. Nanjing Hangkong Hangtian Daxue Xuebao/J. Nanjing Univ Aeronaut Astronaut. **33**(1), 1 (2001)
5. Lu, Y., Xu, X., Xu, J.: Development of a hybrid manufacturing cloud. J. Manuf. Syst. **33**(4), 551–66 (2014). https://doi.org/10.1016/j.jmsy.2014.05.003
6. Darmoul, S., Pierreval, H., Hajri-Gabouj, S.: Using ontologies to capture and structure knowledge about disruptions in manufacturing systems: an immune driven approach. In: IEEE International Conference on Emerging Technologies and Factory Automation, ETFA (2011)
7. Goudswaard, M., Gopsill, J., Ma, A., Nassehi, A., Hicks, B.: Responding to rapidly changing product demand through a coordinated additive manufacturing production system: a COVID-19 case study. In: 9th Manufacturing Engineering Society International Conference (MESIC 2021) (2021)
8. Caridi, M., Cavalieri, S.: Multi-agent systems in production planning and control: an overview. Prod Plan Control **15**(2), 106–118 (2004)
9. Guo, Q., Zhang, M.: A novel approach for multi-agent-based Intelligent manufacturing system. Inf. Sci. (Ny) **179**(18), 3079–3090 (2009)
10. Tang, H., Li, D., Wang, S., Dong, Z.: CASOA: an architecture for agent-based manufacturing system in the context of industry 4.0. IEEE Access **6**, 12746–12754 (2017)
11. Oluwatosin, H.S.: Client-server model. IOSR J. Comput. Eng. **16**(1), 57–71 (2014)
12. Khan, Z.A., Khan, M.T., Ul Haq, I., Shah, K.: Agent-based fault tolerant framework for manufacturing process automation. Int. J. Comput. Integr. Manuf. **32**(3), 268–277 (2019). https://doi.org/10.1080/0951192X.2019.1571235
13. Ma, A., Nassehi, A., Snider, C.: Anarchic manufacturing: implementing fully distributed control and planning in assembly. Prod. Manuf. Res. **9**(1), 56–80 (2021). https://doi.org/10.1080/21693277.2021.1963346

Part V
Multi-Agent Systems in Transportation Systems

Chapter 25
A Normative Multi-objective Based Intersection Collision Avoidance System

Maha Riad and Fatemeh Golpayegani

Abstract Coordination of vehicles' behaviour is critical at intersections to avoid collisions. Intersection management is even more challenging when it is required to avoid collisions and address multiple objectives such as improving the traffic flow and decreasing vehicles' travel time simultaneously in real time. Normative multi-agent systems enable the development of centralised collision avoidance techniques by synthesising and applying traffic norms in real time. However, they do not take into account the impact of the synthesised norms on other objectives that must be met by the system. In this paper, the proposed normative multi-objective based intersection collision avoidance system is based on a hybrid norms synthesising (HNS) model that avoids collisions using run-time synthesised norms. HNS enables the vehicles to synthesise local norms, considering their local traffic flow, which results in decreasing their waiting time and creating a smoother traffic flow while avoiding collisions at the same time. The simulation results show that HNS outperforms the state-of-the-art algorithm IRON in various scenarios.

25.1 Introduction

Intersection management remains a challenging area of research due to the high number of accidents occurring at intersections. As reported by the U.S. Federal Highway Administration in 2020, 50% of accidents that resulted in fatal injuries happened at or close to intersections [3]. The coordination of the behaviour of vehicles is crucial in intersection management for collision avoidance [11].

Reservations methodologies, optimisation techniques and normative multi-agent systems are the main works in the vehicles coordination context [8, 11]. In reservation methodologies a central control unit manages a schedule of the vehicles crossing the

M. Riad (✉) · F. Golpayegani
School of Computer Science, University College Dublin, Dublin, Ireland
e-mail: maha.riad@ucdconnect.ie

F. Golpayegani
e-mail: fatemeh.golpayegani@ucd.ie

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_25

intersection [5, 6, 14]. The central unit collects reservation requests from vehicles; to allocate available slots in the intersection for them. Although the reservation schema technique can ensure collision prevention, it neglects social norms such as giving way to emergency vehicles. It is challenging for current reservation techniques to incorporate norms, because of their dynamic nature, which results in the appearance of new norms and the update or the disappearance of existing norms. This makes their addition as a static set of rules difficult. Accordingly, it is essential to have a dynamic technique that would enable online norms synthesising.

Optimisation techniques address the system's objectives and avoid collisions by considering travel time in their optimisation problem formulation [13, 15, 16]. However, the fact that they eliminate collisions by adding their relevant attributes as constraints makes this technique inappropriate for real run-time applications which can dynamically change. For example, in real time, the entrance of one of the roads may be temporarily closed, in which routing vehicles to it after leaving the intersection may result in a collision.

Normative multi-agent systems (NorMAS) are also used to model and coordinate the behaviour of the vehicles. NorMAS integrate norms concepts in multi-agent systems (MAS) [2]. MAS represent systems in the form of autonomous agents that can cooperate or compete on resources [4]. Agents perform actions to reach their objective(s). In the intersection management methodologies used in [1, 7, 8, 10], vehicles are represented as agents performing a 'Go' or 'Stop' action till reaching a final destination. They use norms to avoid accidents in run time. For example, the norm of stopping if there is another vehicle just in front of the driver is created (synthesised) by the system central unit and then communicated to the vehicles to apply it to avoid collisions. This technique facilitates dynamicity as norms are synthesised and revised in run time and any changes such as temporary road closure can be handled. Although NorMAS contributions work as promising techniques for avoiding collisions in run time addressing the drawbacks of the reservation and optimisation techniques, they do not coordinate norms compliance and agents' objectives achievement (except for our previously proposed centralised norms synthesising mechanism in [10]). Moreover, they rely on a centralised architecture and do not give vehicles(agents) flexibility to synthesise norms. To address these gaps, in this paper, we tackle collision avoidance by coordinating the behaviour of vehicles while considering reaching the objectives of the system using a hybrid mechanism. We propose a hybrid norm synthesising model (HNS) that is a multiobjective multi-agent system used for run-time intersection management. The hybrid mechanism relies on a set of central norms synthesised by the system's intersection manager (central unit) and a set of local norms synthesised by the vehicles. HNS works on satisfying three main goals:

- **Avoiding vehicle accidents** by using behaviour management and central norms synthesising using case-based reasoning technique.
- **Addressing system's objectives and preferences**, such as decreasing the average waiting time of vehicles and giving priority to emergency vehicles in the norm reasoning process. A utility function is used for meeting these objectives.

- **Decreasing each of the vehicles waiting time** by the support of local synthesised norms created by the vehicles themselves.

25.2 Problem Formulation

Consider an intersection of two orthogonal roads $R1$ and $R2$. Each road has two lanes facilitating two entry points and two leaving points as shown in Fig. 25.2. At each time-step, the set of travelling vehicles T is extended by a number of new vehicles E_n, which enter from randomly selected entry points to the grid. Each of the travelling vehicle v_i is modelled as an autonomous agent that can perceive its local context $v_i(lc)$ and global context $v_i(gc)$. The vehicle v_i's local context $v_i(lc)$ includes the vehicles that are situated in front, left and right of it and their heading directions. For example, in Fig. 25.2, the local context of v_8 is

$v_8(lc) = \{left(east), front(north), right(-)\}$

While in the global context the vehicle perceives its neighbours' local context $v_6(lc)$ and $v_7(lc)$ as well. $v_8(gc)$ is:

$$v_8(gc) = \{left(east), left'sLeft(west), left'sFront(west), left'sRight(west), front(north), front'sLeft(-), front'sFront(north), front'sRight(-), right(-), right'sLeft(-), right'sFront(-), right'sRight(-)\}$$

There is an intersection manager CNS which is used as a central unit that can communicate with vehicles, perceive their local context and decide their next action ac, which can be 'Go' or 'Stop'. The main aim of both the intersection manager and the vehicles is to avoid collisions. Moreover, the intersection manager has two system objectives, which are: S_{o_1} decreasing the average waiting time of vehicles and S_{o_2} decreasing the total waiting time of emergency vehicles. Furthermore, the vehicles have an objective of minimising their stopping/waiting time V_{o_1}.

25.3 Hybrid Norm Synthesis Model

A hybrid norm synthesis (HNS) multi-agent model is proposed for intersection management. The hybrid mechanism of HNS is represented by integrated norms synthesising process carried out by a central norm synthesiser (CNS) and the travelling vehicles. CNS synthesises central norms CN, and the travelling vehicles synthesise local norms LN using their vehicle synthesiser and reasoner (VSR) unit (see Fig. 25.1). The construction of HNS is based on the following assumptions:

- CNS can monitor all vehicles and have global knowledge.
- Each travelling vehicle is aware of all the synthesised norms.

- Each travelling vehicle can perceive the heading direction, context and applicable norms of its three neighbouring vehicles. For example, in Fig. 25.2, v_4 perceives the corresponding knowledge of v_3 and v_{11}, and can deduce that in front of it is empty.

HNS has three main responsibilities: (a) collision avoidance, (b) achieving system's objectives and (c) achieving vehicles' objectives. These responsibilities are addressed using the following three main processes, respectively:

25.3.1 Central Norm Synthesis

Run-time collision avoidance is carried out by HNS central norm synthesiser (CNS) using case-based reasoning algorithm. Case-based reasoning is a machine learning algorithm that models new changes in the form of cases and compares them against construed cases from old experiences and finds solutions accordingly [9]. In each time-step, CNS starts by detecting new accidents using traffic cameras and stores them in a set of accidents (check Fig. 25.1). Then, for each accident, the vehicles which were involved in the accident are marked as the responsible vehicles and stored in a set RV excluding any vehicle that was stationary prior to the accident time-step (i.e., the vehicles responsible for the accident are the ones that were moving before the crash happens). Afterwards, the local context and action of each responsible vehicle v_i in RV set is retrieved. For example, if the position of vehicle v_4 prior to the collision was as seen in Fig. 25.2, then its local context $v_i(lc)$ will be $left(west)$,

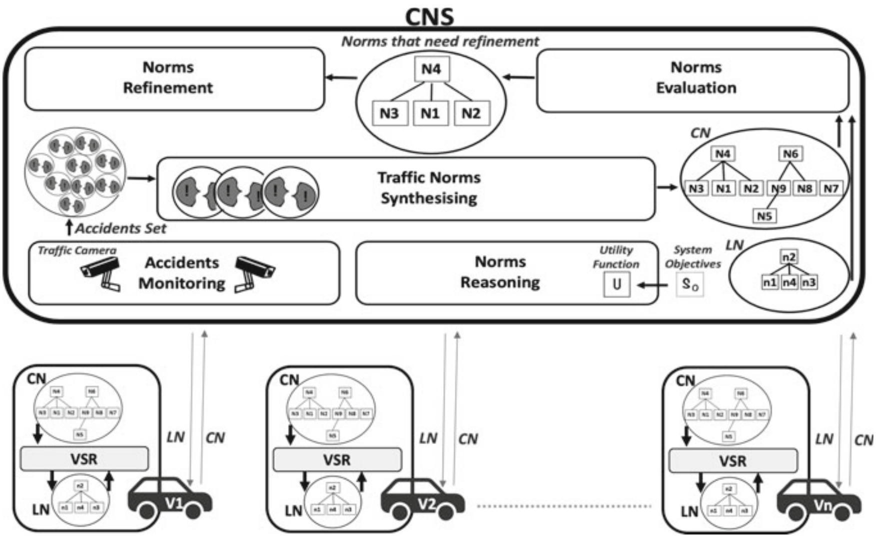


Fig. 25.1 Hybrid norm synthesis model (HNS)

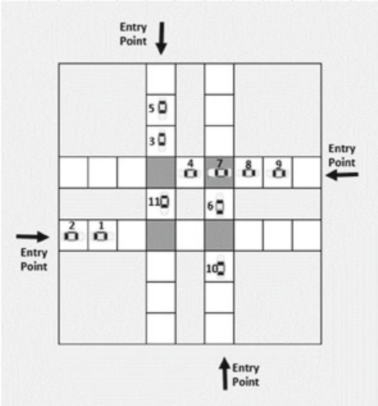


Fig. 25.2 Two orthogonal roads intersection

$front(-)$, $right(west)$, and its action will be 'Go', which is the action prior to the collision. Using both the vehicle's local context and action, a norm is created. The norm is composed of a pre-condition that represents a case (i.e., vehicle's context) that should be satisfied to apply the norm and a deontic operator. The deontic operator in this example will be a prohibition for action 'Go'. Central synthesised norms by CNS are communicated at the end of each time-step to travelling vehicles in T, so they can be aware of the norms they have to apply to avoid future collisions. In addition, CNS will inform all the vehicles of any local norms that are communicated to it as well (as it will be discussed in Sect. 25.3.3). Finally, CNS evaluate and refine the norms (inherited from IRON, a state-of-the-art work [8]).

25.3.2 Utility Function

The utility function proposed in [10] is used in CNS when a decision is needed to choose the most suitable norm when more than one norm can be applied simultaneously(unmatchable norms). For example, when two vehicles are crossing the same intersection and both decide to apply a norm that prohibits the 'Go' action. This utility function is constructed based on the system objectives which are: decreasing the average waiting time of vehicles S_{o_1} and decreasing the total waiting time of the emergency vehicles' S_{o_2}. In other words, the used utility function quantifies the impact of a vehicle's norm compliance on the objectives of the system.

Algorithm 1 VSR

```
1: for each t do
2:     Get v(gc)
3:    LN_a ← getLocalApplicableNorm(v(gc))
4:    if LN_a = null then Get v(lc)
5:       CN_a ← getCentralApplicableNorm(v(lc))
6:       if CN_a ≠ null then
7:          N_a ← getNeighApplicNorms(v(gc))
8:          if N_a = null then
9:             v(ac) ← Go
10:             if NoCollision then
11:                createLocObligNorm(v(gc), v(ac))
12:             else createLocProhNorm(v(gc), v(ac))
13:             end if
14:          else applyNorm(CN_a)
15:          end if
16:       else performAction('Go')
17:       end if
18:    else applyNorm(LN_a)
19:    end if
20: end for
```

25.3.3 Local Norm Synthesis

Synthesising central and local norms are the basis of our hybrid approach. After the CNS synthesises the central norms that are used for avoiding collisions it communicates them to the vehicles. However, the vehicles do not adopt the norms directly, instead, they carry out Algorithm 1 in their vehicle synthesiser and reasoner (VSR) unit. They check if they can create more enhanced norms (local norms) that can assist in reaching their objectives. For example, if a vehicle received a central norm that prohibits the 'Go' action when there is another vehicle in front of it, this norm will always guarantee that the vehicle avoids collision. However, applying the norm will not be optimum in case the vehicle is in a situation similar to vehicle v_2 in Fig. 25.2, as in the following time-step the cell in front of v_2 will be empty and there will be no need to apply the norm. Therefore, stopping or prohibiting the 'Go' action will not be the optimum choice in this situation. Using Algorithm 1 the vehicles synthesise local norms (if there is a possibility for enhancement). The vehicles rely on a wider level of knowledge which is perceiving their neighbours' contexts to deduce the next actions of their neighbours. In Algorithm 1, each vehicle starts by perceiving its global context $v_i(gc)$ and checks the local norms LN set for applicable norms LN_a (see Algorithm 1, line 3). If no local norm was found, the vehicle checks if there is any central applicable norm in the central norms CN set. If a central norm was found, lines 7 to 15 are executed. If no applicable central norms were found for the neighbours, this means that all neighbours can move in the next time-step and that the vehicle does not need to 'Stop'. So, the vehicle sets its action to 'Go' and if its action was successful with no collisions, a new local norm is created to obligate the

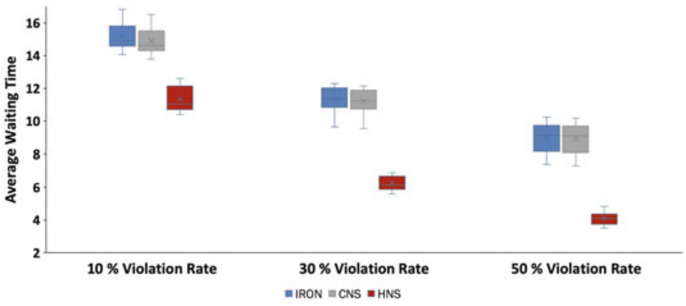


Fig. 25.3 Average waiting time

'Go' action in that global context (see line 9). Else, if a collision occurred, a new local norm is created to prohibit the 'Go' action. In line 14, if any of the vehicles' neighbours has applicable central norms (i.e., will stop in the next time-step) then the central applicable norm is applied normally and no local norms are synthesised. Also, if no applicable local or central norms were found, a normal 'Go' action is carried out (see line 16). If a vehicle synthesised a new local norm and updated its LN set, it sends it to the CNS to update the LN set it stores and to communicate the new norms to the rest of the travelling vehicles as seen in Fig. 25.1.

25.4 Simulation

HNS is compared with IRON, which is a central run-time norm synthesiser that showed its efficacy to avoid collisions at the traffic junction and decrease the vehicles' average trip time [8]. Compared to HNS, IRON has three limitations: (1) It does not involve agents in the norm synthesising process. (2) It synthesises norms that do not support fairness. For example , if vehicles v_3 and v_4 in Fig. 25.2 collided in the intersection cell, IRON will only synthesise one norm either $\{left(west), front(-), right(west)\}$, Prohibit(Go) or $\{left(east), front(-), right(-)\}$, Prohibit(Go). If the first norm was synthesised, the lane that included v_4 will always be delayed than the lane that included v_3. (3) It does not coordinate the systems objectives and the norms (Fig. 25.3).

25.4.1 Experiment Setup

Two-crossing orthogonal roads, represented by a 19×19 grid are simulated using SUMO [12]. The roads consist of two lanes in which the vehicles travel. The vehicles aim to avoid collisions while travelling and specifically at the intersection cells, the grey cells in Fig. 25.2. Four entry points are specified for the vehicles entrance to the system, with a random rate of 2–8 vehicles per time-step. When all entry points are occupied the waiting time for the vehicles to be entered is counted as the 'Entering waiting time of the vehicles' . The vehicle speed is constant and no acceleration or deceleration is allowed. The vehicles are only permitted to 'Go' or 'Stop'. SUMO default algorithm for intersection management is overridden by HNS algorithm.

The vehicle's final destination is decided randomly at the beginning of the trip by the system. If vehicles collided they are removed from the simulation and added to the queue of the entering vehicles to the system, however, their waiting time and travelling time are not reset and are counted towards their final figures when reaching the final destinations successfully.

25.4.2 Evaluation Metrics

To represent a real-world situation, different violation rates are considered. Violation rates represent the fraction of vehicles that do not apply the recommended norms and make decisions independently. We have considered 10, 30 and 50% violation rates in our simulation scenarios. The violation rates are used to understand the impact of applying norms on the number of collisions, and subsequently the total travelling time, waiting time and entrance waiting time of the vehicles:

- **Average waiting time of vehicles:** the average number of stops that each vehicle perform till reaching its final destination.
- **Total collisions:** the total number of collisions that takes place per time-step in the simulation.
- **Collisions out of violations:** the number of collisions that occurs because a vehicle has violated a norm
- **Actual collisions:** the number of collisions that happened when there was no applicable norm or when a collision has occurred although a vehicle applied a norm at a particular time-step.

To monitor the capability of HNS in using the available slots in the road via the synthesised local norms, the following metrics are considered:

- **Rate of applicable norms:** the ratio of the vehicles that have applicable norms to the total number of travelling vehicles at a particular time-step.
- **Rate of entered vehicles:** the ratio of the number of new vehicles entering the travelling grid to the total number of vehicles that were ready for entrance at this time-step. For example, the system may randomly choose to insert six vehicles in the next time-step but only two might find free entry points, so the rate will be 2/6.

25.4.3 Results

The results reported in this section are the moving average per 50-steps of the average of 10 runs simulation for 10, 30 and 50% violation rates. **Actual Collisions:** As shown in Figs. 25.4, 25.5 and 25.6, the number of actual collisions for both HNS and IRON decreases over time as the system learns from the accidents and synthesises norms until the system converges (i.e., when reaching zero accidents). This shows HNS and IRON capability to avoid collision over time under various violation rates.

Total number of collisions: Because of the **collisions out of violations**, the total number of collisions in both methods does not decrease. Consequently, when the violation rate increases in an environment, the total number of collisions increases. The results also show that the number of total collisions in HNS is higher than IRON, which is because the higher number of vehicles with applicable norms in HNS and accordingly higher number of collisions out of violations. This happens because the

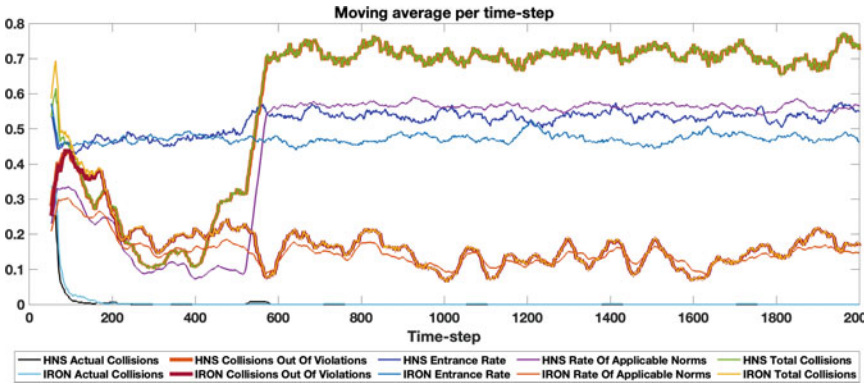


Fig. 25.4 HNS VS IRON using 10% violation rate

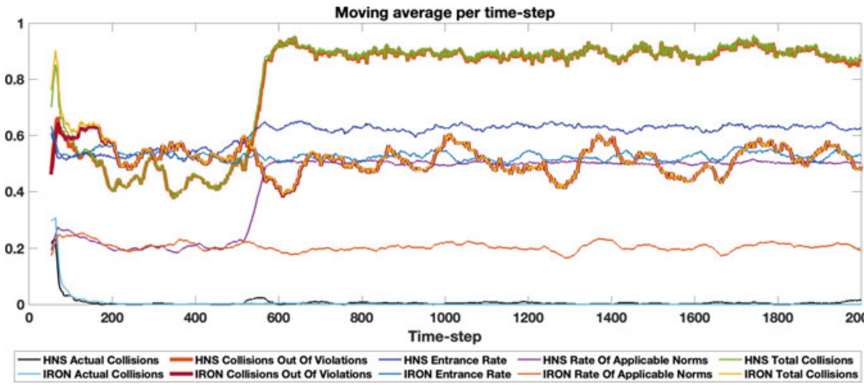


Fig. 25.5 HNS VS IRON using 30% violation rate

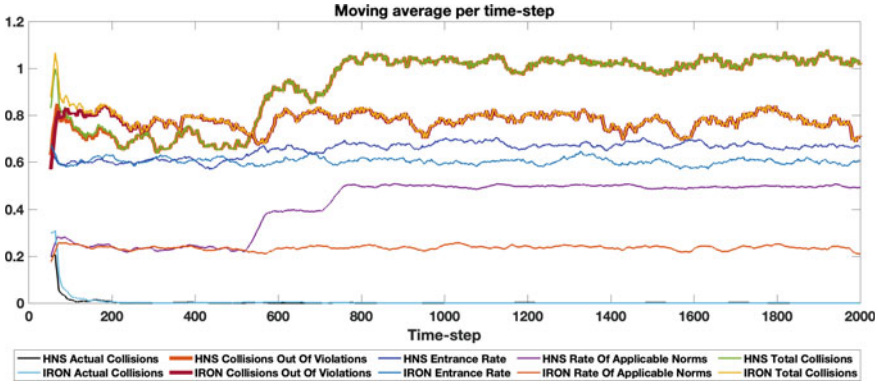


Fig. 25.6 HNS vs IRON using 50% violation rate

local norms synthesised by HNS enable the vehicles to utilise the available cells and consequently a higher density of vehicles is experienced, which leads to a higher number of potential accidents and a higher number of norms to apply. The interesting conclusion here is that HNS is able to handle high traffic density.

The rate of vehicles with applicable norms: From the rate of vehicles with applicable norms per time-step produced by IRON, a high discrepancy can be found between the results of the 10% and 30% violation rate scenarios when compared to HNS. This indicates that violating synthesised norms in IRON does not always result in collisions. In other words, applying some of the norms is not always necessary, as violating them would not produce any collision. As an example, in Fig. 25.2, IRON synthesis a norm to prohibit vehicle v_2 from moving in the next time-step because there is vehicle v_1 in front of it. However, vehicle v_1 has an empty cell in front that will move to in the next time-step. When such a norm is violated, no collision occurs because the destination cell of vehicle v_2 is already available. Accordingly, the probability of harmful violated norms (i.e., norms that when violated produce collisions) increases when the violation rate increases and so in the number of collisions out of violations in IRON increases.

Vehicles' entrance rate: The entrance rate in HNS is higher than IRON in all scenarios. This is the result of synthesised local norms in HNS, as vehicles are enabled to utilise the empty cells which facilitate a higher rate of grid entrance of vehicles, and consequently lower entrance waiting time is achieved. **Average waiting time:** The average waiting time of vehicles in the 10 runs is plotted in Fig. 25.3. Results show that the lowest average waiting time is achieved by HNS when both central and local norms are synthesised. This is because the local norms allow the vehicles to violate a central norm when a specific global context is perceived that would allow the vehicle to 'Go' without colliding. Additionally, it is shown that CNS outperforms IRON even when only central norms are synthesised. This is because CNS prompts only one vehicle to apply a norm when there is more than one vehicle in the same context willing to apply 'Stop' norm. Moreover, the vehicle chosen by CNS to apply the norm is determined based on having the maximum utility.

25.5 Conclusion

In this paper, we presented a novel hybrid norm synthesising (HNS) model for intersection management using normative multi-agent systems. HNS reaches three main objectives: (1) avoid accidents by applying central norms that represent traffic behaviour aspects, (2) address system objectives in coordination with norms such as decreasing the average waiting time of vehicles while avoiding collisions and (3) decrease the vehicles' waiting time and creates a smoother traffic flow using local norms. Results of simulated scenarios on SUMO show that HNS avoids collisions and decreases vehicles' waiting time by at least 23% when compared by IRON a state-of-the-art norm-based model. As future work, we aim to have a decentralised approach for intersection management that overcome the challenge of single point of failure in centralised systems. Additionally, HNS can be extended to include an adaptable global and local contexts based on traffic situations. The simulation scenarios can also be extended to include a real map with real traffic load.

References

1. Bailey, J.M., Golpayegani, F., Clarke, S.: Comasig: a collaborative multi-agent signal control to support senior drivers. In: 2019 IEEE Intelligent Transportation Systems Conference (ITSC), pp. 1239–1244. IEEE (2019)
2. Dastani, M., Dix, J., Verhagen, H., Villata, S.: Normative multi-agent systems (dagstuhl seminar 18171). Dagstuhl Rep. **8**(4), 72–103 (2018)
3. Federal Highway Administration, U.S.: Intersection Safety (2020). https://highways.dot.gov/research/research-programs/safety/intersection-safety. Accessed 01 March 2021
4. Golpayegani, F., Dusparic, I., Clarke, S.: Using social dependence to enable neighbourly behaviour in open multi-agent systems. ACM Trans. Intell. Syst. Technol. (TIST) **10**(3), 1–31 (2019)
5. Huang, S., Sadek, A.W., Zhao, Y.: Assessing the mobility and environmental benefits of reservation-based intelligent intersections using an integrated simulator. IEEE Trans. Intell. Transp. Syst. **13**(3), 1201–1214 (2012)
6. de La Fortelle, A.: Analysis of reservation algorithms for cooperative planning at intersections. In: 13th International IEEE conference on intelligent transportation systems, pp. 445–449. IEEE (2010)
7. Mashayekhi, M., Du, H., List, G.F., Singh, M.P.: Silk: A simulation study of regulating open normative multiagent systems. In: IJCAI, pp. 373–379 (2016)
8. Morales, J., Lopez-Sanchez, M., Rodriguez-Aguilar, J.A., Wooldridge, M.J., Vasconcelos, W.W.: Automated synthesis of normative systems. In: AAMAS, vol. 13, pp. 483–490 (2013)
9. O'Mahony, E., Hebrard, E., Holland, A., Nugent, C., O'Sullivan, B.: Using case-based reasoning in an algorithm portfolio for constraint solving. In: Irish conference on artificial intelligence and cognitive science, pp. 210–216 (2008)

10. Riad, M., Golpayegani, F.: Run-time norms synthesis in multi-objective multi-agent systems. AAMAS, COINE (2021)
11. Rios-Torres, J., Malikopoulos, A.A.: A survey on the coordination of connected and automated vehicles at intersections and merging at highway on-ramps. IEEE Trans. Intell. Transp. Syst. **18**(5), 1066–1077 (2016)
12. SUMO: https://www.eclipse.org/sumo/
13. Wu, J., Perronnet, F., Abbas-Turki, A.: Cooperative vehicle-actuator system: a sequence-based framework of cooperative intersections management. IET Intell. Transp. Syst. **8**(4), 352–360 (2013)
14. Zhang, K., Zhang, D., de La Fortelle, A., Wu, X., Gregoire, J.: State-driven priority scheduling mechanisms for driverless vehicles approaching intersections. IEEE Trans. Intell. Transp. Syst. **16**(5), 2487–2500 (2015)
15. Zhu, F., Ukkusuri, S.V.: A linear programming formulation for autonomous intersection control within a dynamic traffic assignment and connected vehicle environment. Transp. Res. Part C: Emerg. Technol. **55**, 363–378 (2015)
16. Zohdy, I.H., Kamalanathsharma, R.K., Rakha, H.: Intersection management for autonomous vehicles using iCACC. In: 2012 15th International IEEE Conference on Intelligent Transportation Systems, pp. 1109–1114. IEEE (2012)

Chapter 26
Development of a Transport Model Dedicated to an Agent-Based Simulation of Land Use

Simon Gorecki, Seghir Zerguini, Nathalie Gaussier, and Mamadou Kaba Traore

Abstract In order to limit greenhouse gas emissions, urban travel is a central point of interest for metropolises as part of their actions in favor of ecological transition. MUST-B is a land use transport interaction (LUTI) model that simulates the location choices of households and jobs. It models and simulates the interaction both of the population of an agglomeration through its residential choices with activities and jobs, but also the different modes of transport to satisfy daily mobility. This tool based on the agent-based paradigm makes it possible to apprehend the complexity of an urban territory from individual behaviors giving rise to collective phenomena. In this article, we concentrate on the "transport" part of the tool, show how the elaboration and the calibration of this model are done, and study an example of its reaction to a variation of setpoints.

26.1 Introduction

Nowadays, people are constantly pushing the limits of mobility in their urban travel. This phenomenon added to the demographic growth trends leads to the mechanism of urban sprawl [1]. In order to limit greenhouse gas emissions and meet international commitments (such as HORIZON EUROPE [2] or COP23 [3]) and fight against global warming, the French government has implemented a series of plans to limit

S. Gorecki (✉) · M. K. Traore
University of Bordeaux, IMS, UMR 5218, 33400 Talence, France
e-mail: simon.gorecki@u-bordeaux.fr

M. K. Traore
e-mail: Mamadou-kaba.traore@u-bordeaux.fr

S. Zerguini · N. Gaussier
University of Bordeaux, CNRS, BSE, UMR, 6060, 33600 Pessac, France
e-mail: seghir.zerguini@u-bordeaux.fr

N. Gaussier
e-mail: nathalie.gaussier@u-bordeaux.fr

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2_26

and optimize pollution. The MUST-B project is funded by a region of France and a group of actors (such as laboratories, universities, etc.). It aims to develop a modeling and simulation platform to support local authorities in the ecological transition of their territories. Various sectoral policies can be simulated by the MUST-B platform, such as transport pricing, the creation of new structuring transport infrastructures, the energy renovation of the existing housing stock, urban renewal, the creation of a green belt, scenarios of energy price increases, and population growth in the territory under consideration. For each of the simulated policies, MUST-B will take into account the constrained household expenses (home-work mobility, housing, …) and the socio-spatial issues of energy vulnerability of the considered policy.

In this article, we will first present brief state-of-the-art tools used for land use transport interactions (LUTI) in order to highlight our proposal. For the second time, we will present the MUST-B platform, and this will be done in two parts. The first part details the land use part, and the second part details the transport model. Then, a case study will be presented to show the calibration and use of the transport model. Finally, a conclusion on the tool and future perspectives.

26.2 State of the Art

We can observe in state of the art several LUTI tools [4]. Their objectives are to study interactions between transport and urban development.

Wegner et al. list in [4] about 20 models which are compared according to a grid based on nine characteristics: (1) Their unified or composite structure made of several subsystems; (2) The complete or partial integration of the transport system; (3) The theoretical foundations (models based on auctions, expected utility, equilibrium, etc.); (4) The modeling paradigm of time and space management; (5) Dynamic simulated; (6) Parameterization and validation of the model; (7) The operationality; (8) Application of the model.

Generally, all existing LUTI models have been developed from a single discipline point of view. In [5], Hassan et al. present URBANSIM, a land use and transportation model designed from an urban planning point of view applied to the Seoul Metropolitan Area. In [6], Alex et al. propose a land use and transportation model algorithm focused on regional economic issues named RELU-TRAN. This tool is mainly based on the economist discipline because it was designed to simulate metropolitan economy and land use for cities such as Chicago (study case in the article). In [7], Jean et al. detail a French LUTI model (PIRANDELLO) oriented engineering and focused on the Paris area. Sustainable development can also be an orientation of simulation because it was the subject of a French national call for projects (see PLAINSUDD in [8]) that led to the MOSART numeric platform applied to a city. Finally, Antoni et al. present in [9], MOBISIM, a geography-oriented LUTI model designed for the simulation of the complexities of daily and residential mobility in an urban air space.

Starting from the observation of the complexity of the urban phenomenon, we chose rather to work on a multidisciplinary approach (geography, planning, urbanism, economy, engineering) [10] allowing us to describe the mechanisms of the urbanization phenomenon. All these mechanisms have the particularity of being linked to group phenomena (populations, jobs, transport, economy, etc.). This is why another of the proposals of the MUST-B platform compared to the state of the art is to use the paradigm of agent-based simulation.

26.3 An Agent-Based Multi-sectoral Simulation

As we can see in Fig. 26.1, MUST-B is composed of two parts. The left one is an agent-based simulation that manages land use through several disciplines. It is composed of two populations of agents: households and workplaces.

Both agents' population are in competition regarding the building land potential. They are also in concurrence between them: a household agent is in competition with all other household agents because they all need housing. The behavior of an agent is linked with his *Utility* function:

$$U_z = \alpha_1 AC_z + \alpha_2 NO_z + \alpha_3 * SL - FE_z * SL_z - P_z * SL_z$$

Utility U_z is the result of a calculation used for each agent of the simulation [11]. The objective of this function is to represent the "well-being" of a household or the "performance" of a workplace. The unit of Utility is monetary (€). During the simulation, every agent (household and workplace) has one main objective: to maximize its *Utility* value.

Utility function is composed of several members:

– Accessibility, defined by $\alpha_1 AC_z$, is composed of two elements. An accessibility value (AC_z) and a parameter (α_1). Depending on whether the calculated Utility is for a workplace agent or household agent, the accessibility will be different. The household accessibility is a unique value attached to each zone and represents the

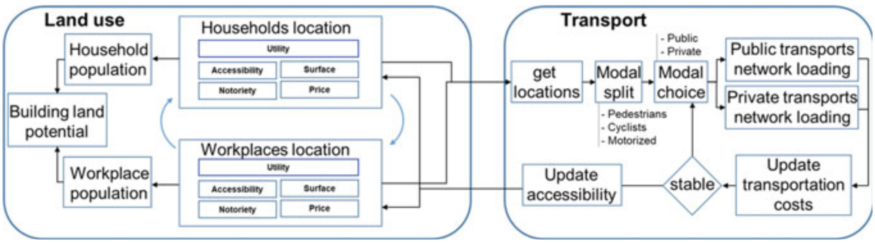


Fig. 26.1 MUST-B architecture

access to work. If a zone provides easy access to jobs (by private, public, or non-motorized modes), its accessibility will be high. On the other hand, workplace accessibility is a unique value attached to each zone and represents the access to employees for companies. The more easily a company can access employee fleets, the better its accessibility will be.

The role of the parameter (α_1) is to convert accessibility value to monetary value (€).

- Notoriety, defined by $\alpha_2 NO_z$, is composed of two elements. The notoriety of each zone (NO_z): the ability to provide services to households and workplaces of the zone. And a parameter (α_2) to convert notoriety value to monetary value (€).
- Surface area $\alpha_3 * SL$ is composed of a parameter α_3 that convert surface into monetary value, and the size of the living space (housing for a household and industrial space for a workplace). This element will determine if the size of an apartment is important for an agent, or not. If for a workplace/household, the size of the housing is important, then the α_3 will be high.
- Energy bill $FE_z * SL$ must also be considered in the calculation of the Utility. The average energy bill per square foot is evaluated for each zone in the simulation. This average is multiplied by the surface of the agent's dwelling to obtain an overall bill.
- Housing price $P_z * SL_z$ is also considered based on area multiplied by the average estate price per square meter of the inhabited area.

During the simulation, all agents are in competition and try to maximize their own *Utility* value, until natural balance: when all agents reached their maximum. Some members of the equation are modulated by parameters (α_n), and distributed among a Gaussian function which creates heterogeneity among the agent populations. For example, if a household prefers a large living space to the detriment of accessibility to services, its α_3 parameter will be bigger than the average, and its α_2 parameter will be smaller than the average.

During the execution process, some parameters are constantly updated (such as average prices per zones), however, some others (like accessibility) need a parallel execution to be updated. Periodically, the accessibility of each zone must be updated by the transport model. Agent-based simulation time is paused, and transport model simulation is executed in order to feed the agent population.

26.4 Transport Model

The right side of Fig. 26.1 is a transport model that simulates travel in a city. This module takes into input the matrix location of households and workplaces (simulated by the land use model) and gives an output accessibility value for each zone (this accessibility is used by agents through the *Utility* function).

As we can see in Fig. 26.1, the transport model is divided into four several steps: flow generation, flow distribution, modal choice, and traffic assignment.

26.4.1 Flows Generation and Distribution

This section is related to the two first steps: flow generation and flow distribution. After the matrix retrieval phase, the transport model has the location of every household in the city, and the location of their jobs. From this matrix, transport flows from one zone (source zone called "*i*") to another (destination zone called "*j*") are generated from the following formula:

$$F_{ij}^{TM} = k * \frac{P_i * E_j}{r_{ij}^2}$$

Defining the number of flows F_{ij}^{TM} from i to j is based on the Newton universal gravitation law. The (k) parameter is the gravity of the system: it is a parameter used to modulate the number of flows generated. The rest of the formula is composed of the number of households in the source zone (P_i) multiplied by the number of workplaces in the destination zone (E_j), divided by the distance (empty distance, without considering congestion) between zone i and zone j squared (r_{ij}^2).

Then comes a data cleaning step. Trips of less than 1 km are considered to be made on walking (so they will not saturate the road network). Trips between 1 and 3.5 km are considered as done by bike. Inter-zone travel (when $i = j$) is also considered only by bikes and walking. The rest of the flows (travels up to 3.5 km) will be made by motorized modes (MM). Motorized modes are divided into two categories through a modal choice phase (the third step). Based on a formula, a part of the population will prefer to use public transport $\left(F_{ij}^{TC}\right)$, the other part will prefer private vehicles $\left(F_{ij}^{VP}\right)$.

Modal split formulas involve a new concept that is important to detail before going any further: trip costs. Transportation costs are a means of making a choice between two transportation modes (public or private). Users will seek to minimize their transport costs, which will create competition between modes. The longer, more unpleasant, and more congested a trip is, the more expensive it will be, and the less it will be attractive. However, the less a mode is used, the more efficient it is, which lowers its cost, and generates again attractiveness. This opposition is designed to be self-balanced.

$$C_{ij}^{VP} = V_t * tt_{ij}^{VP} + (CC + CK) * dC_{ij}^{VP} + C_j^{\text{stat}} C_{ij}^{TC}$$
$$= V_t * \left[1 + \tau\left(\frac{F_{ij}^{TC}}{C_{ij}^{MM}}\right)^{\tau'}\right] * tt_{ij}^{TC} + \text{Tarif}^{TC}$$

Cost of travel by private vehicle between zone i and zone j $\left(C_{ij}^{VP}\right)$ is composed of time travel by private vehicles between zone i and zone j $\left(tt_{ij}^{VP}\right)$ multiplied by the value of time (constant (V_t)) plus an estimate of the costs of using the vehicle:

total distance traveled between i and j $\left(d_{ij}^{VP}\right)$, multiplied by vehicle wear costs per kilometer (CK), plus fuel costs per kilometer (CC), plus the average parking costs in the destination zone j $\left(C_j^{Stat}\right)$.

Cost of travel by public vehicle between i and j $\left(C_{ij}^{TC}\right)$ contains time travel by public vehicles $\left(tt_{ij}^{TC}\right)$ multiplied by the value of time $\left(tt_{ij}^{TC}\right)$ degraded by a load factor:

$$1 + \tau\left(\frac{F_{ij}^{TC}}{F_{ij}^{MM}}\right)^{\tau'}$$

This formula is designed to simulate the decrease of interest for this network in case of strong affluence. Indeed, in public transport, users present in a bus/tramway/metro do not increase the traffic time. A bus filled with 20 or 80% will take the same time to go from one point to another. However, a bus with an 80% occupancy rate implies a loss of attractiveness (few spaces, inconvenience caused), which cannot be measured by a degraded time. Thus, this decrease of interest mechanism has been added to the public transport cost formula by considering the load of this network. The two parameters of the above formula (τ and $\tau^{'}$) allows for calibrating and obtaining a self-balancing algorithm.

These two costs are used in the modal choice formulas.

$$F_{ij}^{VP} = \frac{F_{ij}^{MM}}{1 + e^{\mu\left(C_{ij}^{VP} - C_{ij}^{TC}\right)}} F_{ij}^{TC} = F_{ij}^{MM} - F_{ij}^{VP}$$

Determination of the number of flows through the private vehicle network $\left(F_{ij}^{VP}\right)$ is a fraction of the number of flows through motorized modes $\left(F_{ij}^{MM}\right)$. The numerator is 1 + exponential μ multiplied by the cost difference between private and public: $C_{ij}^{VP} - C_{ij}^{TC}$. The number of flows through a public network will be the rest: all flows that were not included in the fraction.

Once the modal choice is made, each flow has been assigned a travel mode. But this is only an attribution, they have not traveled yet. The next phase consists in simulating all these trips, considering congestion, degradation of travel times, and distances. All these constraints will lead some agents to rethink their travel modes, which is what we will see in the next part.

26.4.2 Transport Assignment

After the modal choice is made, the different trips are simulated over the real network of the city. With the Open Street Map [12] database, the system has access to road length and maximum speed which allows us to simulate private and public roads, and the transport system of the city. The simulation of each of the F_{ij}^{VP} flows and F_{ij}^{TC} flows are done during the "loading" phase of Fig. 26.1.

Public and private network transports are loaded in two separate graphs. In a transportation graph, vertices are intersections and edges are short roads (also called links). Information contained in an intersection is the list of roads that are connected to it. Information contained in a link is its length, capacity, and crossing time (based on maximum speed). During the simulation, this crossing time will be degraded by a formula:

$$tt_l = tt_l^0 \times \left[1 + a\left(\frac{\sum q}{C_l}\right)^b\right]$$

Time to cross a link l, (tt_l) is defined by its empty crossing time and tt_l^0 is the distance/max speed limit. This value is multiplied by a congestion law BPR [13] $1 + a\left(\frac{\sum q}{C_l}\right)^b$ which increase the crossing time according to its occupation ratio. The more this link will be used by vehicles, the longer it will take to cross the section (thus simulating congestion). a and b are parameters that allow us to define the sensibility of a road to handle the traffic. The capacity of the link is represented by C_l, and $\sum q$ is the sum of flows that are currently on the link. If $\frac{\sum q}{C_l} = 1$, that mean the road is loaded to 100% and the time to cross value will increase according to the BPR function in order to simulate the congestion phenomenon. As we can see in Fig. 26.2, four road types have been defined:

The graphic in Fig. 26.2 shows the behavior of the four types of roads defined in the simulation. Road number 1 (blue in Fig. 26.2) is the one that has the best reaction to vehicle overload: multi-lane main road on the outskirts of a city, with loading of 100%, time to cross will be up to ×1.25.

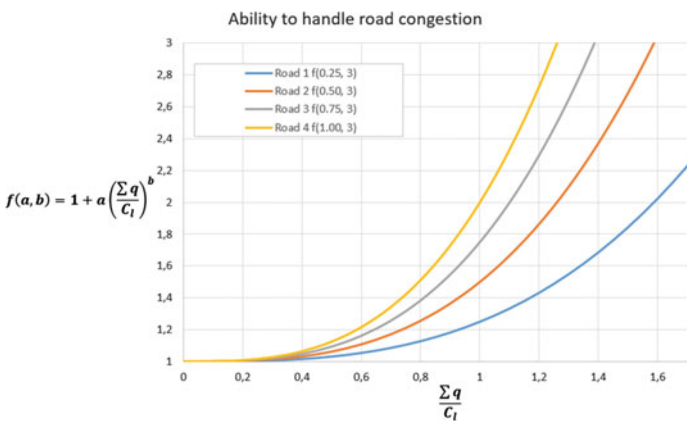


Fig. 26.2 Road sensitivity congestion

Once we have detailed the behavior of a road, we can explain the flow affectation mechanism. The simulation is based on the Dijkstra algorithm [14], still among each VP and TC graph. The objective here is to determine for each origin–destination flow (OD) the shortest path in terms of duration.

Each time a flow has to be added to the network (a flow is a trip from a departure zone i to an arrival zone j), the Djikstra algorithm computes the shortest path (in terms of time) to reach zone j from zone i. It returns a set of edges that form a route that connects i and j in the shortest time. The algorithm increments the occupation parameter q of each of these routes, and we update their crossing times according to the above formula.

The number of flows to be assigned on the network can be up to 500000, they are not done one by one, but by slices. The algorithm carries out the assignment of all the network zone by zone in 10 slices. So, for example, the beginning will be done in the following way: the algorithm recovers 1/10 of the flows going from zone 1 to zone 2, calculates the shortest path, and loads all these routes with 1/10 of the flows between z1 and z2. Then it recovers 1/10 of the flows going from zone 1 to zone 3, calculates the new shortest path, assigns 1/10 of these flows, and so on, for all i-j flows, 10 times. In the end, all the flows will be added to the network. Between each route assignment, Dijkstra's algorithm is updated so that the progressive loading of roads can impact the decisions made by Dijkstra.

Depending on the geographical layout, roads of the network will be more or less saturated, which will impact the accessibility of each area (an area close to jobs will be considered by the model as "easy to access", while an area far from jobs will be considered as "hard to access"). Our model simulates congestion and degrades travel times (and distances) accordingly. At the end of the private and public transport simulation, the model loops back to the modal choice. According to previous transportation assignment, some agents will prefer to switch modes. The modal choice + transportation simulation loops until natural balance.

Finally, after these steps, new costs are updated and modal accessibility is calculated for each transportation means according to:

$$AC_i^{VP} = \sum_j e^{-C_{ij}^{VP}} \quad AC_i^{V} = \sum_j e^{-C_{ij}^{V}} \quad AC_i^{TC} = \sum_j e^{-C_{ij}^{TC}} \quad AC_i^{MP} = \sum_j e^{-C_{ij}^{MP}}$$

Once each modal accessibility is calculated, the transport model can determine the transport accessibility value to each zone (this accessibility is used in the Utility function of Chapter 3).

$$AC_i^{\text{Trans}} = \frac{\sum_j F_{ij}^{VP}}{\sum_j F_{ij}^{TM}} AC_i^{VP} + \frac{\sum_j F_{ij}^{TC}}{\sum_j F_{ij}^{TM}} AC_i^{TC} + \frac{\sum_j F_{ij}^{V}}{\sum_j F_{ij}^{TM}} AC_i^{V} + \frac{\sum_j F_{ij}^{MP}}{\sum_j F_{ij}^{TM}} AC_i^{MP}$$

Once this general availability is calculated, it is exported and pushed back in the land use simulation.

26.5 Study Case and Validation

SIMUTEC platform is used in different territories; in this document, we take the example of the Bordeaux Urban Area (AUB). The AUB is divided into 42 zones according to a minimal threshold of population and jobs per zone and geographical constraints which constitute delineations (waterways, railways, motorways, ring roads, etc.). These 42 zones are derived as follows:

– Zone 1–Zone 13 (BX): center of the city. Lots of public transportations and roads can be quickly saturated;
– Zone 14–Zone 28 (PC): small ring of the city. Inside a large ring road, access to public transportations;
– Zone 29–Zone 42 (GC): outside of the ring road. Few access to public transportation.

In this configuration, we first established a reference situation. This situation represents the city in its normal state. The objective of this contribution is to observe changes in results consistent with changes in the parameters of the simulation. To do this, we do the first simulation with some parameters. Then, for the second time, we modify one parameter and we observe changes in results. In our case, we observe the impact of a fuel price (CC) increase. In the normal state simulation, the price is fixed to a value, and in the comparative situation, this price will be increased significantly.

In this paper, we focused on the transportation model, which will provide an accessibility update of each zone to each agent. It is therefore the results of the transport model that we will observe: the accessibility of each zone in Fig. 26.3. For more clarity, we aggregate the output data into macro-zones (BX, PC, and GC) detailed above.

In (2) of Fig. 26.3, we can observe an important decrease of accessibility in center of the city (BX) and inside the ring road (PC). However, outside the ring road has suffered a slight loss, but less important than the others. As expected, the increase in fuel costs caused a decrease in global accessibility: traveling through the AUB is

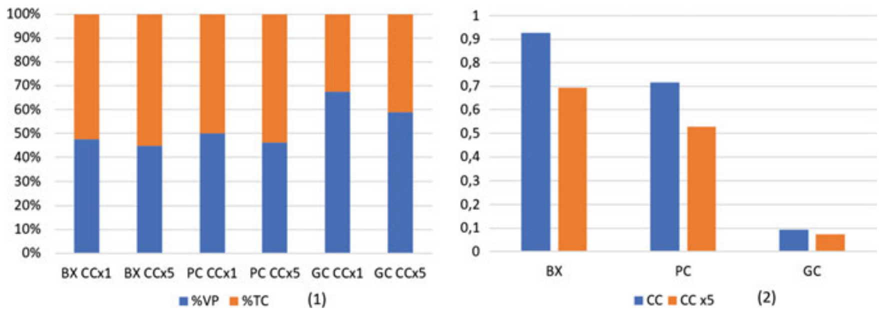


Fig. 26.3 SIMUTEC—Transport model results

less accessible for agents of households and workplaces. This will be reflected in the first parameter of the Utility function of workplaces and households.

Moreover, we can also observe the modal choices made by the agents in the simulation in (1). This observation is also done by comparing the two situations (CC costs as normal vs CC costs increased). As expected, in a normal situation (normal CC), private vehicles (VP) are used more and more as one moves away from the city center. Increasing the value of fuel, thus decreases the attractiveness of private vehicles, which in turn increases the use of public transport.

26.6 Conclusion

In this article, we focused on the transport model part of the MUST-B platform. We first demonstrate the original characteristic of the tool: transdisciplinary (association of multidisciplinary researchers such as economics, urban planning, geography, transport, computer science, etc.) that allowed us to consider specificities of the different disciplinary fields related to the urban phenomenon. And in another hand the capacity of his transport model to be accurate and also transdisciplinary (variety in the means of transport, considering public networks, congestion, secondary routes, energy constraints, inconvenience, etc.).

Agent-based modeling and simulation have made it possible to get the complexity of the city from individual behaviors, bringing to light collective behaviors that are difficult to access either by intuition or by analytical calculation.

Much remain to be done with the integration of new mechanisms such as the impact of COVID19 on urban life or the democratization of remote work which influences transportation and lifestyle choices. Other perspectives remain in the introduction of neural networks to complexify the behaviour of human agents.

References

1. Newman, P., Kenworthy, J.: Sustainability and cities: overcoming automobile dependence (1999)
2. Horizon Europe.: https://www.horizon-europe.gouv.fr/
3. COP23.: https://cop23.unfccc.int/fr
4. Wegener, M.: Overview of land use transport models. J. Discrete Algoritm. (JDA) **5** (2004)
5. Hassan, M., Joo, Y., Jun, C.: A review of the development and application of urbansim integrated land-use and transportation model. Int. J. Urban Sci. **14** (2011). https://doi.org/10.1080/12265934.2010.9693686
6. Anas, A., Liu, Y.: A regional economy, land use, and transportation model (RELU-TRAN©): formulation, algorithm design, and testing. J. Reg. Sci. **47**, 415–455 (2007). https://doi.org/10.1111/j.1467-9787.2007.00515.x
7. Delons, J., Coulombel, N., Leurent, F.: PIRANDELLO an integrated transport and land-use model for the Paris area (2008). https://hal.archives-ouvertes.fr/hal-00319087
8. PLAteformes numeriques INnovantes de Simulation Urbaines pour le Developpement Durable.: https://anr.fr/Project-ANR-08-VILL-0001

9. Antoni, J.-P., Vuidel, G.: MobiSim: un modèle multi-agents et multi-scalaire pour simuler les mobilités urbaines (2011)
10. Zerguini, N., Seghir ;. Gaussier: MUST-B : Un modèle LUTI multidisciplinaire au service de la complexité du phénomène urbain. Can. J. Reg. Sci. Revue Can. Sci. Rég. **43**, 50–59 (2020). https://doi.org/10.7202/1083293ar
11. Gaussier, N., Zerguini, S., others: MUST-B: a multi-agent LUTI model for systemic simulation of urban policies. Groupe de Recherche en Economie Théorique et Appliquée (GREThA) (2019)
12. OpenStreetMap.: http://www.openstreetmap.fr/
13. Roads, U.S.B. of P.: Traffic assignment manual for application with a large, high speed computer. US Department of Commerce, Bureau of Public Roads, Office of Planning, Urban (1964)
14. Dijkstra, E.W.: others: a note on two problems in connexion with graphs. Numer. Math. **1**, 269–271 (1959)

Author Index

G. Jezic (eds.), *Agents and Multi-Agent Systems: Technologies and Applications 2022*, Smart Innovation, Systems and Technologies 306,
https://doi.org/10.1007/978-981-19-3359-2