Agent-Based Model as a Provider of Medical Services in Tijuana Mexico

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Abstract. The search for medical services to maintain family health remains a difficult goal to achieve because in addition family budget constraint is presented to desire to access the best possible medical services. The purpose of this paper is to present a model based on agents that analyzes a series of symptoms and sufferings, the results of this analysis allow provides a preliminary diagnosis of a patient. This model can be listing best options for medical service providers in Tijuana, Baja California, Mexico to prevent the erroneous self-diagnosis in the population of scarce resources. The model can help to create simulations of patient symptoms using computational tools and can predict in real time results with possible options of medical services to be attended. The model contains three main agents: Patient Agent, Medical Services Provider Agent and Content Medical Service Agent, the interaction of these agents supported by their Knowledge Base allow a finite and specialized search of suppliers in the health area. The use of agent-based models can reduce emerging costs derived from tests and errors in the real world.

Keywords: Modelling · Agents · Medical services

1 Introduction

Globally, main research lines of intelligent environments focus on systems operated by the end user; others focus on systems powered by autonomous agents, minimizing the user's cognitive load. This research represents the patient-user the option of knowing how much autonomy it maintains or how much it delegates to intelligent agents. Likewise, a Model Based on Agents is proposed that improves the ability to offer the adequate medical service based on the symptoms and conditions of the patient, allowing for adequate medical care.

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1.1 Medical Services

Nowadays, medical care plays an essential role in well-being and health of individuals. Medical Services promote and maintain the welfare (social, physical and mental) of people regardless of their social status. The medical services anticipate and take care of damages caused to health, maintaining protection against the risks that may be harmful to health.

Health requires constant maintenance by providing, diagnosing and treating diseases, medical services respond to this necessity, offering continuity of care by providing and understanding the specific needs of each patient. Proper medical attention allows patients to benefit from adequate attention promptly based on their symptoms or conditions. This article addresses in a different way how medical services can provide to patients based on their demands, as well as offering researchers an alternative to model medical care through multi-agent systems allowing abstraction of reality with the order to provide adequate medical services for the patient [1].

1.2 Agent Based Modelling (ABM)

The ABM is applied incrementally to empirical situations [2]. Its methodological advantage lies in the ability to explicitly simulate human decision-making processes considering a high degree of heterogeneity [3, 4].

The ABM has capabilities to deal with uncertainty in real-world actions using fuzzy logic techniques, approximate sets, Bayesian networks, etc. [5]. An agent-based on ABM can think and act like a human, can operate under autonomous control, perceiving their environment and adapting to changes to achieve specific objectives or goals [6]. In decision-making behavior, ABM outperforms simple if-then rules allowing for agents to learn and change behaviors in response to their experiences [7]. Even at the simplest level, an ABM consists of agents and the relationships between them and may have valuable conclusions about the system as a whole [8].

1.3 BDI a Practical Reasoning

The BDI theory tries to model the rationality of those actions taken by human beings in certain circumstances; this theory was developed by the philosopher Bratman [9]. A practical reasoning directed towards actions: towards process of deciding what to do. Unlike theoretical reasoning that is directed towards beliefs. This type of reasoning includes two activities: (I) Deliberation, that is, deciding which are the goals to be met, and (II) Analysis, related means, that is, deciding how the agent will achieve those goals. Both activities can be seen as computational processes executed by agents with bounded rationality.

2 Related Work

The existence of different research lines and applications using Systems Based on Agents in the realization of searches in different fields, can learn and perform searches based on established patterns [10]. The creation of intelligent systems allows performing specific activations of a specific context, allowing a comparison between the real world and the simulated world [11].

The autonomy feature offered by the agents allows to create reactive and personalized search assistants according to the preferences of the users, this allows information that is available to be accessed by searches derived from the combination of effective algorithms and techniques for the recovery of information improving the performance in the search for information [12].

The understanding of the processes among the elements involved is key allowing raise expectations offering quality information if these elements are represented in a Multi-Agent System, the simulated effectiveness is maximized through a virtual environment that can be contrasted in the real world [13].

3 Case Study

Modern and developed societies, with rare exceptions, have devoted considerable sums to the structuring of universal health service systems, with a strong public component, focused on the production and distribution of medical care. This dynamic was fostered in close connection with the technological fever of the "golden years," configuring so-called health industry, one of the most prosperous branches of economic activity in the world [14].

The goal of obtaining medical services is to maintain health. Achieving this objective depends in part on the services offered and the way they are organized in a region.

Specialized medical services have become an important activity for the private sector, ranking third regarding economic units registered in the city of Tijuana. Proper diagnosis, treatment, and prevention are promoted through the appropriate management of different conditions. Obtaining information quickly stimulates the efficient management of the process of obtaining medical attention, translating into a reduction in the duration of the process, thus promoting an efficient prognosis of the disease.

The importance of giving access to the population of these specialized services is important since in Mexico there has been a tendency of the population towards prevention, for which the demand for these services has been increasing, particularly in Baja California, besides the Foreign market adds to domestic demand.

The proliferation of establishments that provide medical care in the northern border of the country has been attributed to the development of a medical management model observed in Tijuana and Mexicali, becoming a case of success and an example for the rest of the country. During 2014 the economic spill in the state of Baja California for medical tourism was 673 million dollars, estimating an influx of visitors from the neighboring country in search of attention by order of 4.7 million people [15].

4 Modelling Medical Care Process

The design of a conceptual model depends importantly on knowledge of the study context, as well as on the perception of the modeler. We know that a model allows us to reduce the complexity of the study context and serves as a guide to represent difficult scenarios emerging on reality, likewise, it allows the generation of hypothetical cases helping to analyze and contrast different possibilities, to give the response to the problems raised. The model presented in this research is based on MAS, allowing elements involved to have autonomy in their interactions, beliefs, desires, and intentions, helping to solve problems.

4.1 Agents Modelling

We represent an abstraction of the real world using an agent; we motivated on this paradigm because the agents are entities that allow us to emulate rational behavior based on humans. Additionally, we used de Belief, Desire and Intention Paradigm (BDI) [9], in each agent, so that has more reasoning to do actions. Also, the agent can help the patient to accomplish a task such as find the best hospital and doctor for his correct treatment.

In our research we define agents based on the context of Medical Care, the proposed model is composed by three main agents Patient Agent (PA), Medical Services Provider Agent (MSPA), Content Medical Service Agent (CMSA). In the next part, each agent is defined and its interactions.

4.1.1 Formalization of Medical Care Process Agents

The formalization of the elements that compose the model helps to understand in details its properties. The formalization of methods is used to understand the wide variety of complex behaviors that an agent can exhibit. Each agent has three main elements Beliefs, Desires an Intentions, allowing them to have to reason similar to humans. In the next Fig. 1 is represented by its elements.

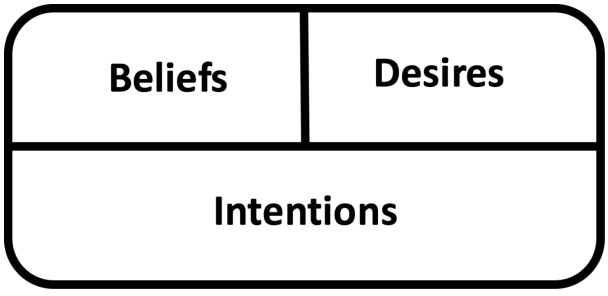

Fig. 1. A representation of BDI Agent

The following is a formalism, which is, defined a representation for BDI agents.

The Patient Agent (PA), is a Patient representation, is who has pain, symptoms, discomfort, this agent manifests its condition and requires medical care.

El PA is defined by a tuple of 3 elements:
A PA agent is a tuple of 3 elements:

$$\Pi = <\Omega, \Gamma, Y> \quad (1)$$

where:

1. Ω is the finite set of base beliefs. Each PA belief is represented by the emerging Symptoms
2. Γ is the finite set of base desires; Each PA desire is represented by find cure of Symptoms
3. Y is the finite set of intentions. Each PA intention is a stack of plans to execute requests or searches in order to find adequate medical services according its symptoms (Fig. 2).

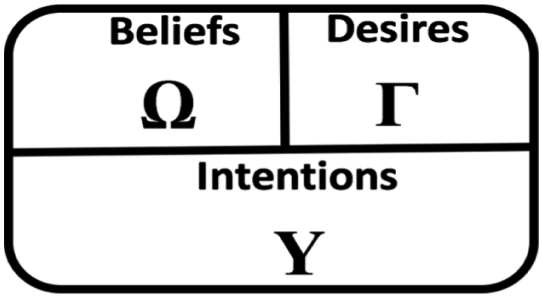

Fig. 2. A representation of Patient Agent (PA)

The Medical Services Provider Agent (MSPA). Is the Medical Services expert representation, analyze the symptom form filled, after this analyses using its Knowledge Base search the best results, based on Patient' Symptoms.
A MSPA agent is a tuple of 3 elements:

$$\Sigma = <\Theta, \Delta, \Phi> \quad (2)$$

where:

1. Θ is the finite set of base beliefs. Each MSPA belief is a selection and analysis of the kinds of symptoms that have the PA.
2. Δ is the finite set of base desires; Each MSPA desire is represented by the search of adequate medical service based on symptom belief of PA.
3. Φ is the finite set of intentions. Each MSPA intention is analyze based on the Knowledge Base to find the best option of medical services, request to CMSA the service a deliver to PA the adequate result (Fig. 3).

The MSPA knowledge Base is based on a Fuzzy Logic paradigm in the Patient Symptoms and Suffering to handle the emerging uncertainty to offer the adequate medical services. We had identify the involved linguistic variables for the input 'Symptom' (Strong, Medium, Weak), for the input 'Suffering' (Strong, Medium, Weak)

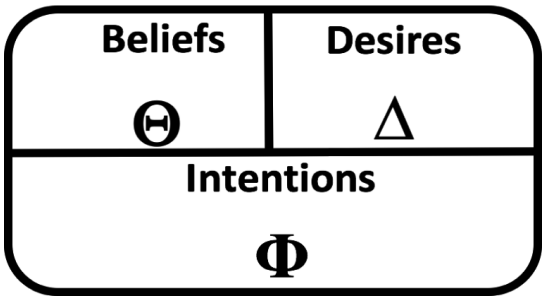

Fig. 3. A representation of Medical Services Provider Agent (MSPA)

and for the output 'disease Type' (RequiredMedicalService1, RequiredMedicalService2, RequiredMedicalService3, RequiredMedicalService4, RequiredMedicalService5, RequiredMedicalService6, RequiredMedicalService7, RequiredMedicalService8 and RequiredMedicalService9).

We defined 9-inference IF-THEN rules covering all linguistic variables. The proposed FIS is flexible and permits the addition or deletion of rules; this can be seen as an advantage as it can be adapted to different contexts or, if different variables exist, can be increased (Table 1).

Table 1. Inference fuzzy rules of MSPA.

Nu	Inference rules
1	If (Symptom is Strong) and (Suffering is Strong then (diseaseType is RequiredMedicalService1)
2	If (Symptom is Strong) and (Suffering is Medium then (diseaseType is RequiredMedicalService2)
3	If (Symptom is Strong) and (Suffering is Weak then (diseaseType is RequiredMedicalService3
4	If (Symptom is Medium) and (Suffering is Strong then (diseaseType is RequiredMedicalService4)
5	If (Symptom is Medium) and (Suffering is Medium then (diseaseType is RequiredMedicalService5)
6	If (Symptom is Medium) and (Suffering is Weak then (diseaseType is RequiredMedicalService6)
7	If (Symptom is Weak) and (Suffering is Strong then (diseaseType is RequiredMedicalService7)
8	If (Symptom is Weak) and (Suffering is Medium then (diseaseType is RequiredMedicalService8)
9	If (Symptom is Weak) and (Suffering is Weak then (diseaseType is RequiredMedicalService9)

The Content Medical Service Agent (CMSA). Is the container of Medical Services having a Data Base with content related to Medical Services constantly upgrade its

database to have the Medical Services upgraded, this agents response to MSPA requests.
A CMSA agent is a tuple of 3 elements:

$$\Lambda = <\vartheta, K, \Psi> \tag{3}$$

where:

1. ϑ is the finite set of base beliefs. Each CMSA belief is represented by MSPA requests based on the results of medical service required.
2. K is the finite set of base desires; Each CMSA desire is represented by search in its data base best medical services based on MSPA requests.
3. Ψ is the finite set of intentions. Each CMSA intention is find and response to the MSPA with best Medical Services found in its Data Base, this agent build a stack with results of medical services, the top of the stack is the first option and so on in order to cure the disease.

The following Fig. 4 illustrates the Model in general as well as the interactions of the agents involved within the Medical Care Process.

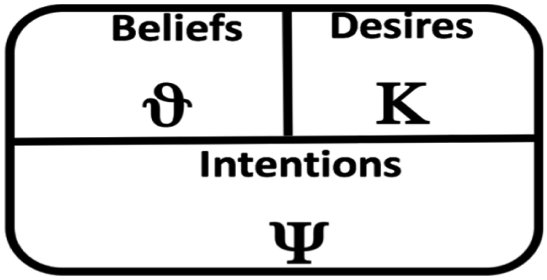

Fig. 4. A representation of Content Medical Service Agent (CMSA)

The Fig. 5. represents, all agents embedded in a context of Medical Care Process. This process is defined by a series of steps described below:

1. Patient Feels the Symptom
2. Patients seek Medical Care
3. Patient fill Symptom Form Provided by MSPA, "PA Provides the needs"
4. Patient brings Symptoms Form to MSPA
5. MPSA analyze the symptom form filled using its Knowledge Base, once have the best results, starts the request to CMSA
6. CMSA receive the MSPA Request a search in its Data Base, the best Medical Services based on MSPA request. (Constantly the CMSA check the Medical Service Environment (MSE) for Medical Service Updates) and upgrade its databases.
7. CMSA response to the MSPA with the best results and secondary results

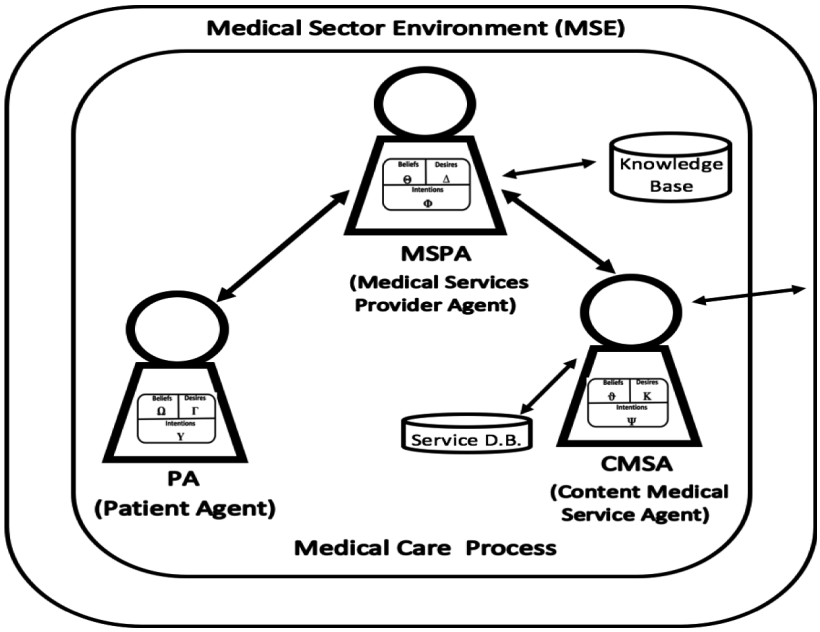

Fig. 5. Representation of Medical Care Process

8. MSPA receive the CSMA results and register these results to make historical user register
9. MPSA send to the PA the best secondary results of Medical Services
10. PA receive the results of Medical Services according to its symptoms

5 Conclusions

Many models have focused on building architectures with reasoning capabilities; the proposed article offers to the model based on agents, representing abstractly the provision of medical services based on the symptoms and sufferings of the patient. The proposed model defines an environment of medical care, where three main agents are considered, the interaction and the integration of these agents allow to study possible scenarios that may arise in the real world allowing offering the adequate average service based on the symptoms and sufferings of the patients.

Additionally, the use of agents motivates this research, because these agents can be intelligent, these entities emulate or simulate rational mental processes, behaviors such as the patient, doctor, and the expert in medical services.

6 Future Work

Derived from the complexity of medical care in Tijuana, Mexico, it is required that the model have more intelligent agents, the interaction between agents can be maximized adding different scenarios of the emergency level, the model will be manipulated to be attended allowing a closer approximation to reality. The agents will be programmed in

a technology platform and will include artificial intelligence in its reasoning. Additionally, based on the proposed BDI aided by the Fuzzy Logic Type-2 we will create fuzzy perceptions allowing an adaptation to patients needs. The model will have patterns of perception, processing, and representation of knowledge to act in consequence of the emergence of the system.

Likewise, the use of Multi-Agent Systems will allow supporting the personalized, intelligent interaction and an active environment allowing to create complex adaptive systems configured according to the patient.

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