Agent-based Modeling and Simulation Software Architecture for Health Care

Karam Mustapha and Jean-Marc Frayret
Polytechnic University of Montreal, Mathematical and Industrial Engineering Department
2500, Chemin de Polytechnique, Montreal, H3T 1J4, Canada

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Abstract: Health Care (HC) organizational structure and related management policies are essential factors of HC system. They can be tested through simulations in order to improve HC performance. To simplify the design of these simulations we have proposed a modelling approach based on an additional structure. The modelling approach considers the complexity of the modelling process, where in the various models are developed. This approach is organized according to two main abstraction levels, a conceptual level and a simulation level. We developed a computer simulation environment of patient care trajectories using the agent in order to evaluate new approaches to increase hospital productivity and adapt hospital clinical practice conditions for the elderly and patients with multiple chronic diseases. For that, we have developed a multi-agent framework to simulate the activities and roles in a HC system. This framework can be used to assist the collaborative scheduling of complex tasks that involve multiple personals and resources. In addition, it can be used to study the efficiency of the HC system and the influence of different policies.

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1 INTRODUCTION

Health Care (HC) is a rich domain for multifaceted simulation studies. The conceptual and architectural modeling is challenging due to the diverse and complex dimensions. In this domain, simulation generally aims at experimenting and testing management policies or organizational designs in a controlled environment in order to understand their economical, human and environmental consequences. This paper deals with the simulation of cancer patients' pathways.

Almost 88% of the Canadian population over the age of fifty1 (41 % women and 46 % men) will develop some form of cancer during their lifetime. Lung, breast, colon, rectal and prostate cancers represent more than half of all new cancer cases (52 %). Colon and rectal cancers are the third most common cancers among men and women and are considered the second leading cause of cancer death among men and the third among women.

With the aging population and the intricacy of the medical system, the management of HC activities has become increasingly complex. Therefore, simulation is a relevant tool to model this complexity and improve its operations. In particular, agent-based modeling and simulation significantly extend the capabilities of simulation approaches such as discrete-event simulation as discussed in the next section.

Providing high-quality care is a priority among health professionals. However, resources are limited and their utilization must be optimized in order to meet high quality standards and patients' unique profiles. Therefore, the challenge faced by HC providers and managers is to design organizational and medical processes that deliver the right treatment, to the right patient, at the right time using the right resources. Factors, such as socio-demographic and environmental characteristics, as well as the characteristics of the organizational and decision-making systems, can be used to simulate patient care trajectories, from their diagnosis to the end of the treatment.

In this paper, we propose to study the efficiency of organization decisions which aims at: i) describing the HC organization; ii) modelling and simulating the behaviours and decisions of its actors and iii) implementing these decisions and observe their local

[1]http://www.cancer.ca/~/media/cancer.ca/CW/cancer%20information/cancer%20101/Canadian%20cancer%20statistics/canadian-cancer-statistics-2013-FR.pdf

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and global effect on the HC, and iv) supporting each step with specific conceptual and software support.

This paper presents different objectives, the first objective presented requires the agent-based modelling and simulation of complex behaviours, decision-making processes and interactions between hospital staff and patients. The most appropriate technology to simulate these complex mechanisms is Agent-Based modelling and Simulation (ABS). The second objective is therefore to create and validate the patient agent model, which includes a physiological model of how the cancer evolves in time in response to specific treatments. Also, to simulate a large number of patients treated simultaneously with the same resources of the hospital; this step of the project is only concerned with the general behaviour of the patient agent, and how well it can be configured in order to simulate colon and colorectal cancer patients with different attributes. As for third objective, healthcare decision makers need reliable tools to support them in decision making for adapting policies to help cut costs or reduce waiting time, and to provide visualization which allows them to rehearse innovative ideas before they are implemented.

Contributing to aforementioned objectives, we aim to developing a computer simulation environment of patient care trajectories using the agent in order to evaluate new approaches to increase hospital productivity and adapt hospital clinical practice conditions for the elderly and patients with multiple chronic diseases. Ultimately, the simulation model will include: the physical health of the patient; the cognitive state of the patient; the psychosocial state of the patient; the hospital resources, staff and physicians. For that, we have developed a multi-agent architecture to simulate the activities and roles in a HC system. This architecture can be used to assist the collaborative scheduling of complex tasks that involve multiple personals and resources. In addition, it can be used to study the efficiency of the HC system and the influence of different policies.

First, this paper describes the general scope of this simulation project and presents an up to date ABS. Next, the general conceptual model of the simulation is described and finally simulation results are presented.

2 LITERATURE REVIEW

Many research projects are based on the agent paradigm to model and/or simulate complex systems. Indeed, this paradigm provides a tailored approach to model complex systems by explicitly addressing the study of the interactions and behaviours of their components. The design of HC agent-oriented models is a difficult task that requires the use of specific knowledge and skills. This section defines ABS and introduces a detailed analysis of ABS applications in the medical domain. Finally, this section also presents different ABS development framework.

2.1 Agent-based Simulation

ABS is an abstract representation of reality that involves the elaboration of a descriptive model, which reproduces the behaviour of the system by modelling its components, including their decision-making capabilities and interactions patterns, as agents. An agent can be defined as an entity, theoretical, virtual or physical, capable of acting on itself and on the environment in which it evolves, and capable of communicating with other agents (Jennings et al., 1998).

Research in ABS is prolific. It is known under different labels, including multi-agent simulation, individual-based models and agent-based models. These tools are part of a more generic technology known as multi-agent systems; this domain of applications is much larger than simulation. In the literature, the concept of agent is generally defined as (Jennings et al., 1998) "…a computer system situated in an environment, which is a way autonomous and flexible to achieve the objectives for which it was designed."

In practice, the multi-agent paradigm is used at two levels: for modelling and for simulating. At the first level, it is required to create multi-agent models that (1) reproduce the naturally distributed structure of the studied systems, or (2) propose a representation of complex problems. Such models can be used for developing reactive, deliberative or hybrid agent models. The second level involves the simulation (i.e. experimentation with these models). Such a simulation may or may not be based on distributed software architecture. In other words, the operational simulation model is not necessarily multi-agent. It may be object-oriented or translated into other simulation languages (e.g. DEVS) (Quesnel et al., 2007)

2.2 Agent-based Simulation in the Health Care Domain

HC operation management is a domain that is well suited to ABS because it involves many people interacting with their own decision-processes. With agent-based modelling, it is possible to explicitly model these individuals and their interactions. However, although ABS is growing in the medical domain, applications to the real world are still rare ((Nealon and Moreno, 2003), (Devi and Mago, 2005)).

In the medical domain, (Mustafee et al., 2010) identifies 200 papers, in which simulation is used. More than 70% of these applications used Monte Carlo simulation, while 20% used Discrete-Event Simulation, less than 9% used System Dynamics, and finally only 1% used ABS.

For instance, (Stainsby et al., 2009) uses ABS to reorganize hospital emergency departments. Recently, several simulation techniques have been used in conjunction to capture different dimensions. (Knight et al., 2012) use DES and ABS to model a healthcare system, in which patients choose their hospital based on a linear additive service function of three factors (i.e., hospital reputation, travel distance, waiting time). Finally, (Figueredo and Aickelin, 2011) proposes one of the first systematic studies aiming at comparing SD and ABS based on a simple mathematical model of interactions between a tumour and immune cells. The authors concluded that both modelling paradigms are not always equivalent.

In most organizational simulations in the medical field, agents, whether patients, doctors or nurses are of reactive type and their behaviour is very specific to the purpose of the simulation. In (Kazar et al., 2008), the author discussed the introduction of a multi-agent system into the medical field, which helps the management take decisions and actions, and also ensures the communication and coordination by reducing the errors of diagnosis and treatment, and by improving time required for the medical resources, and other medical departments. However, (Kanagarajah et al., 2010) (Laskowski et al., 2009) use simulation in order to analyse the performance of an emergency department in different configurations. In these studies, agents are used to model resources that move through the hospital with predefined process time. In (Jones and Evans, 2008), modelling deals mainly with the different types of treatment associated with their time and resource requirements, which then become predefined in the simulation. Only patient's arrival time and resource availabilities change dynamically. In these models, the agents travelling times within the hospital is predefined. However, it can also be dynamically computed in the simulation as in (Zhang and Yao, 2010), which models the evacuation of a hospital undergoing a fire, or in (Krizmaric et al., 2005) that use simulation to study different transport configurations for clean and dirty equipment in the hospital.

Also, some authors proposed the concept of an online medical service system for internet users using a multi agent system, the user can get access to the details of the closest and best health care system such as hospital, medical clinic, etc. (Gupta et al., 2012). However, (Han et al., 2006) used the medical sensor modules with combinations of wireless telecommunication technology based in the multi-agent system. The papers (Iantovics, 2008) (Gupta and Mukhopadhyay, 2012), proposed a hybrid system with human and artificial agent members. (Gupta and Mukhopadhyay, 2012) proposed an operational algorithm to describe the operations of a hybrid multi agent system based intelligent medical diagnosis system called Clinical Diagnosis System (CDS) (Gupta and Pujari, 2009). Also, (Mahmud et al., 2009) presented hybrid architecture of a multi-agent consultation system for obesity oriented health problems.

Some authors propose a multi-agent oriented learning environment aimed at learning using a positive approach to perform diagnostic reasoning and modelling of a domain (Rosa et al., 2003). In (Chao and Wong, 2009), the authors proposed the model of practical data mining diagnostic which intends to support real medical diagnosis by two emerging technologies - data mining (Zhang et al., 2005) and multi-agent system (Foster et al., 2005)(Klusch et al., 2003). In the next section we present the patient agent models.

3 PATIENT AGENT MODELS

In the literature review, we have presented various research based on the definition of methodologies to guide the designers in the development of multi-agent models in general. However they present a number of weaknesses related to modelling HC, and their simulation, for example, at present, there is no generally accepted health care ontology for generating and analysis of medical or health care information. This makes it difficult to communicate between several systems developed in different areas. Also, other limitations related to the framework can be synthesized by the following: (i) the absence of an approach which ensures the passage of the conceptual level to the implementation level; (ii) the transition from design to implementation is costly in time and development efforts; (iii) consideration of the organization; (iv) multi-modelling and v) time management.

In this study we proposed a modelling approach based on an additional structure to consider the complexity of the modelling process, where in the various models is developed. The real system is first represented by the HC domain and then the overall modelling approach is based on an incremental approach in which different models are developed. As shown in Figure 1, the expert's fields of intervention are specified including different models: conceptual modelling and simulation oriented agents.

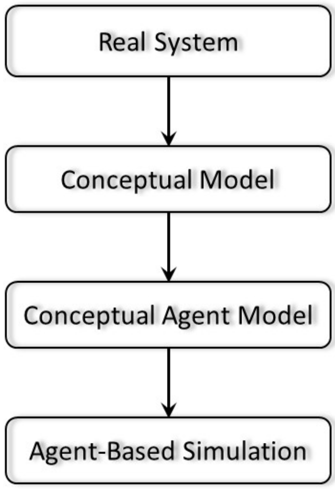

Figure 1: A schematic of the Modelling Process.

In the process of modelling and simulation patient trajectory, the model distinguishes three main steps: the conceptual modelling, the conceptual agent modelling, and operation modelling (Simulation Oriented Agents - SOA).

The patient is the central actor of the HC system or real system. It interacts with many resources, including physicians, nurses and equipment. Its dynamic condition is the main driver of resource utilization, and its reaction to treatment defines the system quality level. In order to design such an agent, different models are proposed to describe its place in the overall system, and its complex behaviour.

Conceptual modelling is based on several models specifying the nature of the agents and the architecture of multi-agent system. In the following, it is for the programmer to operationalize the conceptual model agent. Each agent identified at the conceptual level is specified and implemented according to the constraints related to the development environment. It is always for the programmer, to take into account the technical constraints ignored at the simulation. Thus, the multi-agent system will be deployed in a software environment enabling its execution to conduct simulation experiments.

The conceptual modelling and conceptual agent modelling are described next. With regard to operating step, it will be addressed in the next section on the architecture simulation support.

3.1 Conceptual Model

The general conceptual model proposed in this study defines the main interactions between the patient and its environment (Figure 2). It is composed of four dimensions and includes different aspects of the patient, its environment, and the HC system. These dimensions are related to physiology of the patient, the psychosocial state and support of the patient, the decision processes and the resources used to treat the patient. The links between the different aspects identified within these four dimensions represent their mutual dependencies. The central part represents the patient agent. The other parts represent the hospital staff involved in the treatment selection, as well as patient support (e.g., family members, nurses) (for more details see the reference (Gilli et al., 2014)).

Psychosocial dimension: The psychological dimension includes an emotional model of the patient agent and its social influences, especially in the form of support from family members and nurses. This model describes a response to specific situations and will eventually contribute to measuring the patient quality of life during treatment.

Physiological Dimension: this dimension includes both the patient's health model (its general physical and health condition) and its cancer evolution model. Both are affected by treatment in different manners, while influencing each other. In practice, this dimension includes on the one hand, the absolute physiological state of the patient and cancer, and, on the other hand, the perception of this state obtained from observations (e.g., analysis, scans, and biopsies). While the initial information is not necessarily known, the subsequent information can be out-dated, and more or less accurate. Finally, in this model, the patient health model is influenced by his or her emotional model.

Decision Dimension: This dimension includes both the patient's and the physician's decision models. It represents the main actors' decision-making processes and preferences that contribute to treatment selection and treatment implementation. It is the part of the conceptual model that directly contributes to the decision and implementation of patient care trajectories. Here, the patient decision model is influenced by its health and emotional models, while the physician decision model is influenced by the patient cancer and health models. The patient decision model also contributes to plan each individual treatment according to the system resource availabilities.

System Dimension: The system dimension represents the virtual hospital resources and processes.

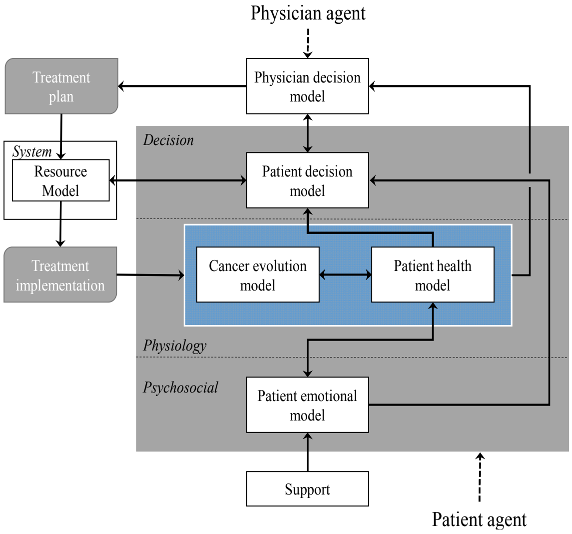

Figure 2: General conceptual model.

When a physician requests a type of treatment, it must be planned according to the hospital priority, the workload of the resources required for this kind of treatment, as well as the preferences of the patient. The different sub-models of these dimensions influence each other in order to emulate the general relationships between the patient, his/her cancer, the medical staff, and the patient's support. The relationship between the patient and the hospital processes and resources are addressed through the dynamic specification of the treatment program into the care trajectories, which defines how the patient interacts with the different resources for his/her treatment and tests/scans. The next section focuses on the conceptual agent model.

3.2 Conceptual Agent Model

The conceptual agent model must determine a number of properties of the previous conceptual model. Focusing mainly on aspects of design and analysis, the conceptual agent model integrates the major concepts of agent, role, service and relationship, defined as:

- The agent is an active entity of the environment;
- The role is played by the concept of an agent;
- A service is a function performed by an agent;
- A relationship is an interaction between entities.

The concepts behind the conceptual agent model are defined through a meta-model. This meta-model defines as precisely as possible all the concepts involved in a conceptual agent model and semantic relationships. The conceptual agent meta-model is formalized by the UML class diagram shown in Figure below.

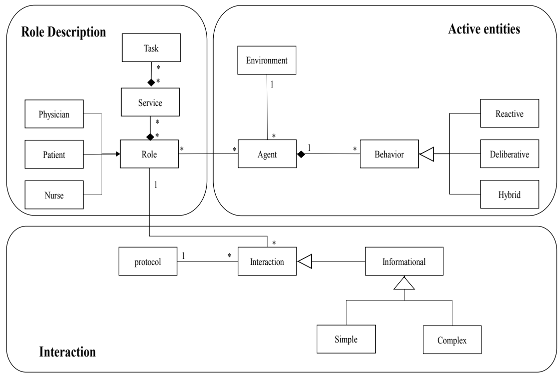

Figure 3: Conceptual agent model.

In this conceptual model an agent plays different roles. The same role can be played by several agents. A role provides services, while a service may require a task. Relationships can develop between roles. There are two sub-types of interactions, simple and complex interactions (informational). The simple relationship is an exchange of information to complete tasks, the distribution of tasks or the sharing of knowledge and the complex relationship for example assumes that agents must coordinate their actions in order to combine their skills to solve complex tasks. An interaction composed protocol. Finally, there are several types of agents: reactive (If the simple behaviour is required, a type of stimulus-response behaviour is sufficient), deliberative (If decision making and negotiation are needed, it will be the capacities of a deliberative agent to perceive its environment and the behaviour of other agents), hybrid (Reactive behaviour and deliberative behaviours are needed. For example, an agent "smart" capable of interacting with another agent when disruptive events occur). In the next section we present the Simulation of Care Pathways for Patients (SiCaPP).

4 SIMULATION METHODOLOGY (SICAPP)

The objective of this section is to present the software solution restraint to accompany the process design and Simulation of Care Pathways for Patients (SiCaPP) for colon and rectal cancer treatment by integrating the functional and software requirements, and based on multi-agent modelling.

SiCaPP represents an implementation solution for the conceptual agent model and is characterized by:

- Specification, the agents' behaviour in appropriate languages to the granularity of agents, it is to describe how the agent should behave during the simulation without prejudging how they will actually be implemented (language programming, simulation language, environment, etc.)
- The specification of interactions between agents which results in dynamic simulation. These interactions will have different implementation issues that are involved as agents of a same environment.

The simulation environment aims both to facilitate the handling of models and supervise their implementation in order to exploit their results. To support the simulation design process different conceptual software needs should be treated. These needs can be summarized into two main categories:

- Needs related to the field study of HC
  As mentioned in the previous section, the HC complex systemimpose many constraints. It involves modelling and simulating the system according to their decision-making level and operational implementation. In fact, the processes nature, calculations or decision-making implemented processes method requires a large variability of representation behavioural of entities in a HC. This is translated by expressed models in adapted modelling languages, which must be possible to integrate, that is to say make or consistently maintain at a conceptual and simulation level. The multi-agent paradigm seems affordable.
- Needs related to simulation
  The nature of the simulation of HC, as well as taking into account the foregoing need, leads to a distributed simulation load on one or more simulators. Since the simulation word is set, the time issue becomes unavoidable and is necessary in a simulator. We need to synchronize the agents in the simulator to avoid inconsistent behaviour of the simulation as a whole and therefore the results of simulations erroneous (Fujimoto, 2000). This problem is not specific to the simulation of HC and has already been posed.

5 SICAPP ARCHITECTURE

SiCaPP architecture presents different services, these services includes the following information: agents' management, time management, and inter-agent communication.

The agents' management provides all the functions needed to manage the life cycle of agents addressing, functions such as launch and stop. It allows for example, adding, changing, or deleting the agents dynamically, it maintains a directory of these agents taking particular account of the simulator in which they operate. Secondly, the inter-agent communication presents different communication languages like ACL message and provides the communication between agents in the environment. It can also manage a directory like yellow pages integrating information on the capabilities and/ or agent played roles of the simulation. Finally, the time management is rarely mentioned in mutli-agent, of the fact that the distributed nature of the simulation is often more conceptual than software. Thus, time management is implicitly centralized on the reactive multi agent system and is not managed in the deliberative systems if not in relative terms.

In this architecture, we also define a different role that includes the following information:

- A set of actions that can be performed, i.e. a patient role is to approve action prescribed by physician.
- A set of protocols, which describe how this role should interact with other roles.
- A set of goals.

The SiCaPP system is organized into different packages (Figure 4), packages include:

- User interface: It is a GUI-based logic which enables the user to generate, simulate patients and show simulation results graphically.
- Database: It is used to register generated patients and the simulation results.
- Patient population: It generates patient's population; this information includes aspects of a patient's personnel information and physical health such as treatment plan, medication and diagnosis.
- Patient simulation: Controlled by physicians who decide whether diagnostics are to be accepted, perform medical and surgical interventions, provide prescriptions, and perform chemotherapy and radiotherapy treatment in collaboration with nurse.
- Treatments protocols: It describes a method to be used during the treatment (e.g. drug, medical treatment) or a medical research study.
- Treatment plan: This package is used to choose a treatment trajectory plan for patients based on the epidemiological studies and real data.

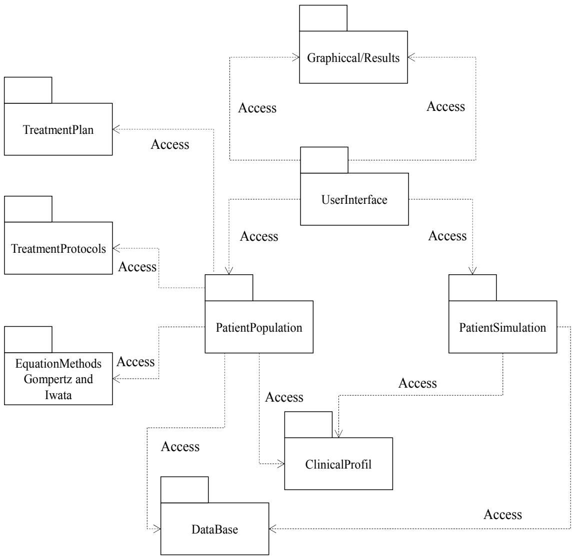

Figure 4: SiCaPP Architecture Diagram.

- Equation methods: it contains different sets of mathematical equations used in our model, e.g. gompertz model which describes the evolution of the main tumour from the appearance of the first cancerous cell to a larger tumour, iwata (Iwata et al., 2000) (Gilli et al., 2014) model which is used to describe the evolution of metastases.
- Clinical profile: It is used to check the physical and psychological state of the patient, it is based on different notions e.g. depression, status performance, sleep disturbance and fatigue. We are using the epidemiological studies and Jewish Hospital real data.

6 SICAPP KERNEL

Medical information of a patient is one of the most sensitive types of information; this information includes aspects of patient's personnel information and physical health such as treatments, medicines and diagnosis. A patient may be treated by any number of physicians or nurses but they must all belong in the team which is responsible for this patient. A physician can treat any number of patients and maintain the medical history for each patient.

The patient is considered as a composed class to calculate tumour evolution using mathematical models. Tumour growth is based essentially on population-based models (Verga, 2010). Also this class is used to verify the stage before and during the treatment (diagnosis step). Each patient has a medical profile; this profile contains a record of all treatments used within the medical group. If the patient has been treated in any facility within the same medical group, we will have an existing patient record and a medical history for the patient; this may need to be updated. A treatment instance is created for all patients admitted and updated throughout the patient's stay. The treatment will subsequently be added to the patients' medical record upon patient discharge.

6.1 Generate Population of Patients using SiCaPP

Based on epidemiological studies and the real data, two different methods are used to generate the population of patient. Figures below show a state chart for the class to generate a virtual patient population. Firstly this class generates the age and gender using the epidemiological studies (Figure 5) alternatively we can extract this information from real data (Figure 6). Secondly, based on the age and gender we choose the cancer type (two types are available: colon and rectal) and stage. Alternatively we can also extract this information from real data. Finally, we use the gompertz model to determine the tumour size in mm and we can calculate the stage using the iwata model. If the stage obtained is different using both models we have to re-determine the stage again and repeat the same procedures. In case stage results are matching, population generated is registered in the data base.

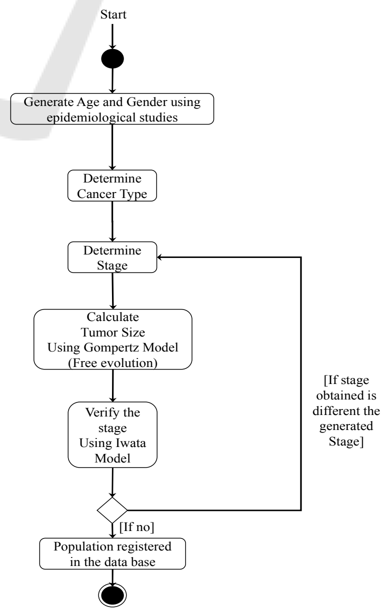

Figure 5: Generate population using the epidemiological studies.

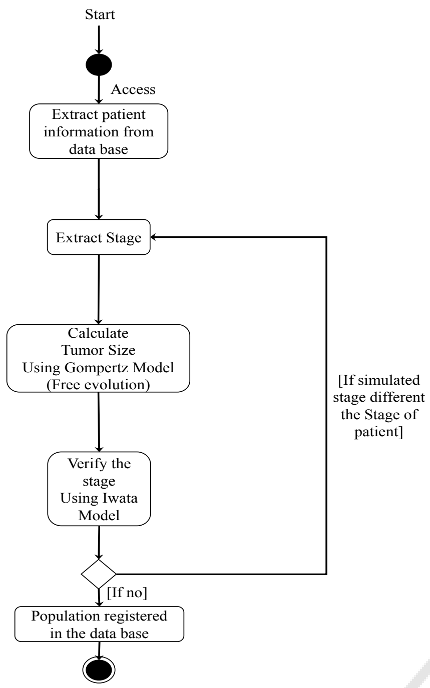

Figure 6: Generate population using the real data.

6.2 Select Treatment Plan using SiCaPP

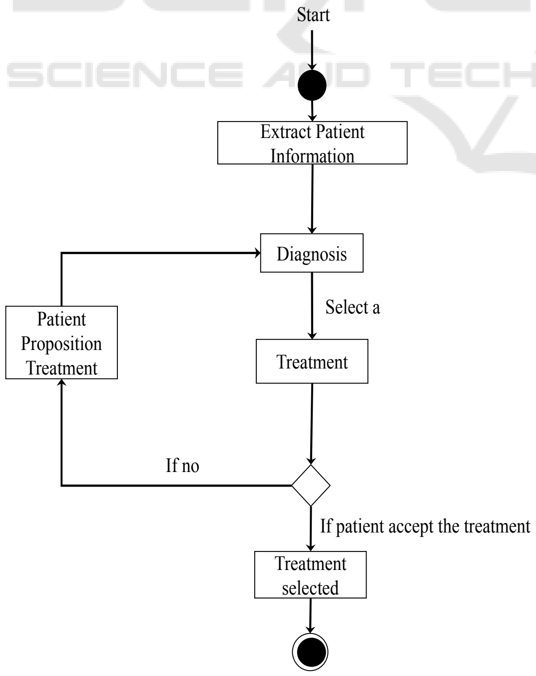

Figure 7: Select treatment plan.

Figure 7 shows a state chart for the treatment class which is responsible for generating a treatment plan for each patient. This treatment is defined by the physician. The patient has to perform some diagnosis which enables treatment plan choosing. When the patient approves the treatment, the following information must be stored in the generated file to be used in the simulation step. In case the patient rejects the treatment, the physician has to choose another type of treatment in collaboration with the medical team and patient.

6.3 Treatment Trajectory using SiCaPP

The figure below shows a state chart of class used to treat patients who have colon or rectal cancer. This treatment is created by the physician. First of all, the patient should be examined prior each treatment or session of treatments such as radiotherapy or chemotherapy. This is needed to evaluate the physical and psychological state of this patient and determine the stage of the cancer. After this evaluation the physician will be able to verify the patient's ability to continue treatment or suspend it for some period until the patients state is re-evaluated or the treatment is adjusted (for example change the dose of the medication). During treatment, the patient may need to undergo more examinations if it is necessary or if the physician has any concerns.

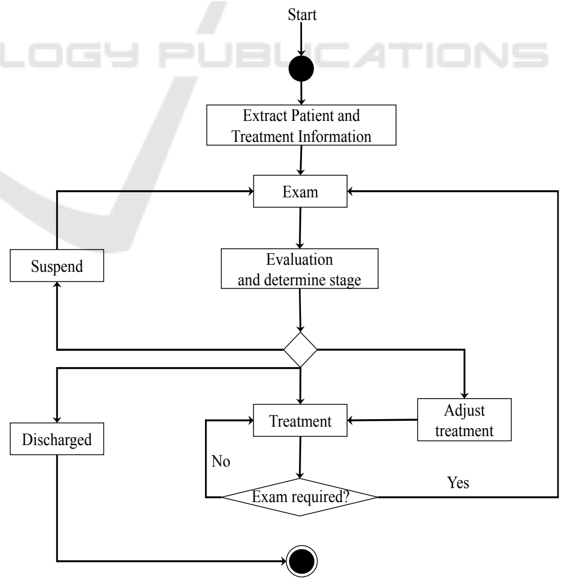

Figure 8: Treatment phase.

7 VALIDATION

The first objective was to validate our modelling and simulation oriented agents; the results of the simulation are presented above in figure 8. These simulations should allow us to validate our simulation platform for executing further simulations that involve treating patients with colon and rectal cancer. The input data of the simulation and the results are stored in a database, which was added into our simulation platform.

To do that, we carried out different experiments, using the Java eclipse software package with a 3,5GHz Intel Core i7 processor and 32 Go of RAM. More specific, we used the JADE platform (Java Agent Development Framework). JADE it's a MAS development environment complies with the FIPA very diffused and included a set of tools included facilitating various MAS development phases (Rimassa et al., 1999). The experiment aims at assessing the ability of the model to replicate the results of real studies with specific treatment protocols. In order to compare the simulation results with actual data, we used the results for the real patients after treatments. The treatments results are classified by survived or not.

7.1 Experiment and Generate the Virtual Population

In this experiment, we must calibrate the model's parameters. In order to do this ABS, we use the Jewish Hospital real data, which allows us to validate our model during the different type of treatment. The real data include 773 patients who have colon and colorectal cancer. However, among these patients there are just 56 patients that have a complete profile, more precisely that they have the stage, type of treatments, and the results after treatments which characterized by survived or not. Each of these patients have different types of information (or different profile), like stage, age, cancer type, type of treatment, and the protocol received by patients for different treatments. Patients in the protocol received two daily doses of chemotherapy treatment continuously without rest periods.

Figure 9 explains the contents presented in the Jewish Hospital real data. Firstly we present the percentage of patients (male and female) who have Colon and Rectal Cancer in our real data, secondly we present just the percentage of patients who have a colon and rectal cancer with complete profile and output results, and finally we present the percentage of output results which is classified by Survived or not.

To start our simulation, we must create several populations of virtual patients based on the Jewish

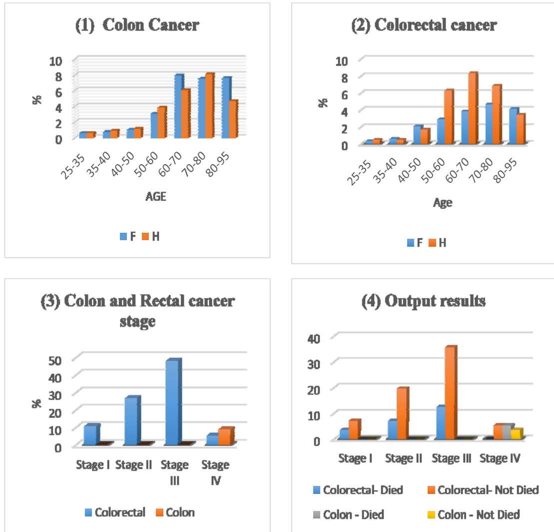

Figure 9: Real Data Analyses.

Hospital real data. Firstly the user can be select one real patient from the data base to generate the following 100 virtual patients (or more) who have a similar real patient profiles and same treatment plan. During the generation of patient profiles we used the Gompertz model which describes the evolution of the main tumor from the appearance of the first cancerous cell to a larger tumor (we determine the stage and the tumor size of the population generation). Then, we use the iwata model to describe the evolution of metastases. In case the stage obtained and real patient stages are matching, the population generated is registered in the data base and we can prepare the simulation step. However, we must generate the various parameters used by mathematics equations as Gompertz model and iwata model. The model was calibrated for one protocol.

Table 1: Real data and Population generation information.

	Jewish hospital real data							Population generation					
	PN	St	CT	Sug	Rad	Ch	Op	PN	S	CT	Sug	Rad	Ch
Experiment 1	1	II	Col	No	No	Yes	S	100	II	Col	No	No	Yes
Experiment 2	1	IV	Col	No	No	Yes	NS	100	IV	Col	No	No	Yes
Experiment 3	1	II	Col	No	No	Yes	S	100	II	Col	No	No	Yes
Experiment 4	1	III	Col	Yes	No	Yes	S	100	III	Col	Yes	No	Yes
Experiment 5	1	IV	C	Yes	No	No	S	100	IV	C	Yes	No	No

To validate our work, we select five patients with different profiles to show the effectiveness of our model. The table below represents the Jewish Hospital (patients selected) and the population generation. This table presents the patient Number (P), the stage (St), the type of cancer (CT: Colon (C) or Colorectal (Col)), the different treatments (like surgery (Sug), Radiotherapy (Rad) and Chemotherapy (Ch)) and the Output results (Op) (Survived (S), or Not Survived (NS)). However, the real data and the population generation have the same profile.

7.2 Calibration and Simulation Results

In order to calibrate the model for the configuration of the real hospital data, we first need to estimate the impact of each parameter on the results based on their role in the model. For example, the percentage of progressive disease is only defined by the parameter of the Gompertz evolution, the parameters of the chemotherapy E0, and Absorption and Dose. There are other parameters such as m, α and the maximum and minimum size of the tumor in the selection of the virtual population (Gilli, et al., 2014). Thus, to calibrate the model, we proceed by trial-and-error, using a dichotomy approach to set each parameter and replicate the results of the hospital data as best as possible. Concerning the duration of the simulated treatments, the median duration reported in both studies was used for the corresponding tests. The final values of the parameters for each calibration are shown in Table 2. Concerning the parameter Absorption, it has been set equal to its defined in (Van Cutsem et al., 2000) value, while the average value of α2 was taken in (Heun et al., 2011).

Table 2: Calibration Parameters.

	Experiment				
	1	2	3	4	5
Parameters	**Average (Standard deviation)**	**Average (Standard deviation)**	**Average (Standard deviation)**	**Average (Standard deviation)**	**Average (Standard deviation)**
m	$6*10^{-8}$ $(3*10^{-9})$	$6*10^{-8}$ $(3*10^{-9})$	$6*10^{-8}$ $(3*10^{-9})$	$6*10^{-8}$ $(3*10^{-9})$	$6*10^{-8}$ $(3*10^{-9})$
α2	0,66 (0,03)	0,66 (0,03)	0,66 (0,03)	0,66 (0,03)	0,66 (0,03)
P	0.87	0.87	0.87	0.87	0.87
E0	$3,1*10^{-3}$	$3,1*10^{-3}$	$3,1*10^{-3}$	$3,1*10^{-3}$	$3,1*10^{-3}$
Absorption	0,6	0,6	0,6	0,6	0,6
Dose	> 0.45	> 0.45	> 0.45	> 0.45	> 0.45

In figure 10 below we compare our simulation results with the results presented in the real hospital data which are classified by survived or not.

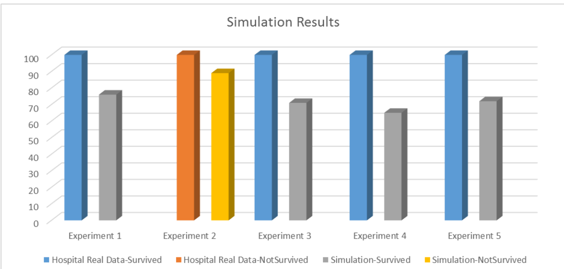

Figure 10: Comparative analysis.

8 CONCLUSION AND FUTURE WORK

The HCs is becoming increasingly complex. In the search for their performance, modelling/simulation becomes necessary. This modelling/simulation of HCs needs multi-modelling with the use of different formalisms or representation paradigms. The agent's oriented approach we showed to be relevant, including the consideration of behaviour of various actors of HC. Our research has focused on the definition of a modelling approach for agent's oriented simulation of HC, with the main objective to allow a more organizational modelling/agents oriented simulation of HC.

For this we have developed a simulation platform for the implementation of the conceptual model and implementation of multi-agent system. This platform used a simulation platform based on a specific simulation environment (JADE). This simulation allowed us to analyse the presented simulation behaviour in the HC system. We have conducted with our simulation platform several simulations of the HC allowing the study of several relevant scenarios.

The validation phase described in this paper gives very important results to reality reproduce, but it is preliminary. Indeed, validation must be detailed with more specific data for each patient and have a better model calibrated than just on population averages, before integration in the simulation platform. Thus, validation with a more specific method, reflecting the better use of the model in the simulation platform, is required. This requires much more detailed data in the treatment of each patient, to be provided by the Jewish General Hospital in Montreal.

To complete the simulation platform, it will take the next step in this focus on the most important part will be the "Patient health model", because it will determine the impact of patient treatment side effects that is an important aspect of treatment against cancer. Indeed, the fight against cancer advanced by chemotherapy can be seen as a balance between enough drugs for reducing cancer, but not too much to not kill the patient.

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