A Closed-Loop Simulator of Long Term Care Systems for Elderly People*

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Abstract. Health costs associated with the long-term care of elderly people have increased in all European countries last years. In order to tackle this problem, some models have been proposed to provide integrated care services to elderly people. However, the use of these models can have long-term effects in the national healthcare systems and the use of computer-based simulation tools becomes necessary.
In this paper, we propose a simulator using as a starting point a holistic model of care systems for people that need long term care, the Sustainable Socio-Health Model (SSHM). The implementation of the simulator on the Jason multiagent platform allows the tool to include the human interactions, preferences and social abilities that take place between elderly people and the staff of healthcare systems (doctors, social workers and nurses). Also, the use of this multiagent platform provides the required scalability for simulating population sizes of different orders of magnitude. The closed-loop design of the proposed simulator allows to repeatedly simulate successive interactions of the considered population with the healthcare system. As a result, the simulator can forecast the long-term effects of different policies on the considered population as well as on the health system.

Keywords: Multiagent based simulation; long term care;social sustainability; elderly people.

1 Introduction

Technological and scientific advances have produced a society with an unprecedented high share of elderly people and people with chronic diseases [37]. As a result, the health costs associated with the long-term care of elderly people have increased. The substantial growth in health expenditures in European Union (EU) countries over recent decades has brought about serious problems for

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healthcare management [32] and finance [14], especially in Mediterranean countries like Spain, Portugal, Italy and Greece. One of the reasons for the sharp increase in health expenditure is the increasingly arbitrary distinction made between health and social care systems and the lack of integration of long-term care (LTC) services [28].

Some holistic models of care systems for people that need long term care have been proposed [20, 31]. These models aim not only to increase quality of life of elderly people, but also to perform a joint reorganization of health and social systems, in such a way that they can provide integrated services to elderly people with a lower cost. Among the existing models, some studies have shown the many positive features of *case management* methodology [27] with respect to other methodologies.

However, the use of these models at different scales can have long-term effects in different healthcare systems. In this sense, the European Commission has recognized the complexity in deciding health policies to assist people who require long-term care without knowing its consequences in the short, medium and long term [15]. In order to estimate these effects, the use of Information and Communication Technologies (ICT) simulation tools becomes necessary. In this way, the prediction of impacts of healthcare and social welfare policies would be greatly improved.

In this paper, we propose a computer-based simulator for integrated long-term care systems for elderly people. This tool simulates the Sustainable Socio-Health Model (SSHM) [20, 31], a holistic model based on a case management methodology developed for the people that need long term care in the Valencian region (Spain) [19] by Polibienestar Research Institute, and it consists of a multiagent based system developed using the *Jason* multiagent platform [5]. This paper shows the simulator architecture, the types of agents considered, their functionality and the information flow among them. The closed-loop design of the proposed simulator allows to repeatedly simulate successive interactions of the considered population with the healthcare system. As a result, the simulator can forecast the long-term effects of different policies on the considered population as well as on the health system.

The rest of the paper is organized as follows: Section 2 shows the related work about modeling long-term care systems for elderly people and multi-agent systems for simulating healthcare systems. Section 3 presents the implementation strategy, the multi-agent platform selected for the implementation, and the main details of the simulator of integrated long-term care systems for elderly people. Next, section 4 shows an application example of the simulator with real data. Finally, section 5 shows some conclusion remarks and future research work to be done.

2 Related Work

The optimization of healthcare systems both from the temporal and economic points-of-view involves the simulation of administrative and assistance processes.

Currently, it is still an open issue which type of simulation is best suited to healthcare systems modeling,[21, 6, 16] being the main options the Discrete Event Simulation (DES), System Dynamics (SD), and more recently Agent-Based Simulation (ABS), usually implemented as Multi-Agent Systems (MAS).

Discrete Event Simulation (DES) has been widely used in modeling healthcare systems, and over the last 30 years several significant reviews of DES papers have been published.[21] DES mainly focus on modeling patient flows through hospital facilities, which is close to our scenario. The modeling of all the activities carried out in a hospital has not been developed yet, possibly due to the difficulty associated to deal with all the hospital activities within a single simulation model.[16] A straightforward solution generally adopted is to reduce the scope of the simulated domain, and in this sense, accidents and emergencies (A&E) units seem the most popular area for simulation modeling, since they are self-contained units and have easily observable processes during relatively short time periods. Thus, almost every year the Winter Simulation Conference proceedings include one or more papers on A&E simulations,[21] and there are numerous examples of papers focusing on this topic. citeFerrin07,Ruohonen06,Sinreich04,Miller04

Some authors have compared the use of DES and SD in health care.[8] They conclude that SD models are not well suited to detailed modeling, and they cope rather badly with stochastic variation, which is an important issue in the demand of emergency healthcare. In this sense, previous work had already tried to explain why DES is more useful than SD techniques[12]: the need for an individual patient focus, the importance of resource constraints, the primacy of clinical decision process, the power of animation and visualization for communicating with users, and the more realistic representation without restrictive mathematical assumptions.

On the other hand, System Dynamics (SD) has gained a wider acceptance in the simulation of mainstream health systems.Some authors have developed a SD model similar to ours in which they investigate future demand for social care services in a UK region from elderly people [13]. The aim of this model is to explore the significant challenges of an aging population (in the context of budget limitations) over the next five years, and to explore the effects of two possible interventions (new policies) to meet these challenges. However, the best known SD models for social care in the UK have been developed by a consultancy firm, the Whole System Partnership (WSP) [7]. These models have not been published in the academic literature, but full details can be found on the WSP website (www.thewholesystem.co.uk) and also as case studies on the MASHnet (2012).[28] One of these models was designed to review and explore different local reablement services[3] (in terms of both capacity and service models) and another one was developed to assist local authorities in implementing the UK's National Dementia Strategy for their own population.

Most of SD models take a "whole system" view, which is one of the key strengths of this simulation method, that offers a high level of aggregation. Typ-

[3] Understood as means of promoting independence, providing personal care, help with daily living activities and other practical tasks.

ically, SD models are not designed to yield exact numerical predictions, but to allow stakeholders to learn about their system and explore policy options by investigating the knock-on effects of different interventions. In order to model complex simulation scenarios, system dynamics have been also used in qualitative maps to help to identify new strategies and to facilitate the analysis and discussion in a logical structured way on a map [38]. Curiously, by doing so the SD model built seems to be approaching a typical DES scheme.

Finally, agent technology has emerged in the last years as a new and promising paradigm focused on the modeling, design and development of complex systems, and they have been used in many different areas.[2, 34–36] In health care real scenarios, it is very usual that the knowledge and data required to solve a problem are spatially distributed in different locations, which adds several constraints on the planning of coordinated actions. Furthermore, the provision of health care typically involves the coordination of several individuals (e.g. nurses, carers, social workers) with different skills and needs. Additionally, they are usually located at different places and usually lack the supervision of a single centralized coordinator.[24]

Multi-agent systems allow to model in a realistic way complex, heterogeneous and distributed systems and environments, by assigning an agent to each entity involved in the real-world environment. MAS have become nowadays a good alternative for improving the performance of the medical simulated scenarios in terms of interoperability, scalability and reconfigurability [30]. In this sense, classical computation paradigms fall short when trying to model an environment with such a variety of users and complex processes and interactions.[17]

From a computational point of view, planning and resource allocation represent areas in which the characteristics of agents-based solutions best fit.[10] In these areas many entities are modeled, ensuring a rich inter operation in order to execute efficient plans. Communication and coordination tasks are extensively exploited in these kinds of systems through the high level protocols included in agents (i.e. requests, queries, different kinds of negotiations, call for proposals, auctions, etc.). Agents also use a common terminology in the form of an ontology used to represent message contents, and therefore they may be considered as a very suitable basis to develop systems which faithfully model real communicative processes.

There are many examples of MAS systems for modeling different health systems. Some representative examples are the K4Care system,[1, 23, 3, 22] aimed to represent the coordination between different health care partners, or the Domino framework,[18] an open proposal designed to create smart DSSs using BDI agents. A part of the framework is designed to react to general inputs (signs and symptoms) and the other part is designed to observe the consequences of those actions and adapt the current management. Other proposals[4, 25] show the representation of healthcare systems through intelligent software agents.

A very recent review of the MAS technology applied to healthcare briefly summarizes those MAS which have been applied in real settings, such as hospitals or medical organizations.[24] The first example is CARREL, which includes different kinds of agents as surgeons (who formalize the requests for organ transplants), analyzers (who validate all the parameters according to the patient's data) and other kinds of agents. The simulated scenario introduces negotiation among agents to achieve a transplantation plan. In addition, a Database Agent stores all details related to the assignment of pieces, as the regulatory norms mandate.[11] The second example is a research project focused on the deployment of multi-agent systems for solving planning problems in health, Medical Information Agents (MIA).[9] In this example, the MAS performs the planning of the diagnostics, surgeries and hospital beds. At any moment, the chosen treatment can change based on a new diagnosis, and planned treatments can be re-scheduled due to emergencies. The main goal of this project is to design a multi-agent system that achieves a more efficient planning in this very dynamic environment.

Beyond the methodology used to implement the simulation models, all of them are built in order to help in the decision making process, but unfortunately many of them have not been finally implemented nor validated. Although simulation analysts can generate quick solutions, the time spent in collecting and analyzing the necessary input data is generally too long. Furthermore, the model validation represents another time consuming task, since many real data needs to be gathered. Since timing may be crucial for the healthcare decision makers, the required response time may add a hard constraint to the execution time required by the simulation tool.

3 LTCMAS: Long Term Care Multi-Agent Simulator

The Sustainable Socio-Health Model (SSHM) consists of a joint reorganization of health and social care services to respond to people requiring long-term care [20]. The model focuses, among other things, on the creation of case management teams and the implementation of new care pathways with the aim to achieve significant savings and efficiency in the healthcare system [31]. It monitors new care pathways in primary care systems to improve the efficiency of social and health care for elderly people with LTC needs through the case management methodology.

The simulator should provide not only results for both the population and the healthcare system as a whole, but also results for different groups of agents and healthcare resources (e.g. hospitals, primary care centers, etc.) and even for each agent present in the scenario (e.g. patients or healthcare professionals). Given these requirements, Multi-Agent Simulation (MAS) seems the best strategy for developing the simulator, since the behavior of agents in the simulation can represent the behavior of actors in the SSHM, with the interaction between actors represented as messages between the agents. The outcomes of such simulations are not always obvious from their set-up, allowing the emergence of different phenomena as a result of different of individual behaviors. Therefore, we have selected MAS as the appropriate strategy for implementing the SSHM simulator. We have denoted this simulator as LTCMAS, that stands for Long Term Care

Multi-Agent Simulator. Specifically, we have selected *Jason* [5] as the multi-agent platform for implementing the LTCMAS. The main reason is that Jason provides several infrastructures to execute a MAS following either a centralised or a distributed architecture, providing the necessary scalability when the size of the population to be simulated reaches high orders of magnitude.

The LTCMAS includes three kinds of agents, one for each kind of entity in the SSHM: *patients*, *professionals* of the health system, and the *case management team (). Patients* are the population being considered in each simulation, in this case elderly people. Each agent of type *patient* holds all the personal information describing her/his medical situation. *Professionals* of the health system are doctors, nurses or social workers in charge of screening patients and selecting candidates to enter the SSHM. The patient's personal and medical information will be used by these *professionals* to screen the patient and decide whether she/he is derived to the *case management team* or not. Patients not eligible are derived to the conventional healthcare system and, thus, they do not enter the simulated system. When they are selected, though, the CMT acts as the committee in charge of designing a pathway for each of them depending on his/her personal and medical information.

The information included in each patient agent is the following one: Identification number within the healthcare system, Age, Gender, Social and health scores extracted from the referral protocol [31], Flag indicating whether the patient has a caregiver or not, Type of caregiver (if any) (relative, employee, etc.), Caregiver availability (full, nights and weekends, etc.), Number of medicines consumed, Health techniques required by the patient (e.g. number, who carries them out (i.e. health or non-health staff), periodicity, etc.), number of hospital admissions, and Agent constraints on the use of some health or social resources.

By means of the patient's identification number, the previous information is expanded with data stored in the health system databases. This data corresponds to more technical information (possibly unknown to the patient) recording, for instance, the prior utilization of the different healthcare system facilities, their efficacy, efficiency and other information. *Professionals* and the *Case Management Team* are currently considering the following aspects when assessing patients in the LTCMAS: Pathology and state of the illness, dependency score obtained from the Barthel test [26], cognitive state score obtained from the Pfeiffer test [29], caregiver burden score obtained from the Zarit test [39], and the Resources already being used by the patient (e.g. chronic care hospital, home help service, etc.).

The LTCMAS is designed for providing a temporal evolution of the health state of patients as a result of the application of the pathways designed by the CMT. These changes affect the patient's data stored in the agents as well as in the health system databases, thus closing the loop and allowing to further simulate new iterations of patients interacting with the healthcare system until their decease. That is, when the pathway finishes, each agent re-enter the system by returning to the CMT. Depending on his/her situation after the pathway, he/she is assigned a new pathway, and this process is repeated until he/she dies.

We have considered statistic data from the Spanish National Statistics Institute as well as the Valencian regional government and a work on statistical incidence of pulmonary illnesses on health [33], in order to assign probabilities of worsening the health of patients after covering each pathway.

The time unit considered for the LTCMAS is one day, that is, this the shortest period of time that can be simulated. An iteration of a given patient consists of a complete interaction of that patient with the system. This iteration starts when the patient visits the primary healthcare center to be seen by a professional of the health system (i.e. a doctor, a nurse or a social worker). In that interaction, the professional screens the patient by means of a referral protocol consisting on a screening test containing 19 items [31]. If the screening test results in a health score greater than 10 points and, at the same time, in a social score greater than 15 points, then the patient is led to the case management team. If a lower score is obtained from the screening test, then patient is led to the conventional healthcare system and the iteration ends. The duration of the pathway in each iteration depends on the patient's dependency degree (DD) value, varying from 3 months if it is high (the CMT will review the patient's state and assign a new pathway within a shorter time) to 12 months if the patient is independent.

The Case Management Team is the entity in charge designing the *pathways* that patients will follow, that is, the set of healthcare and social facilities they will use. These facilities will be selected among the existing ones in a list of available resources that CMT can use. The CMT should combine one or more resources in the list according to a set of *pathway rules* that define which resources better fit the personal and medical circumstances of a patient. The list of available resources contain both social and healthcare resources. Each resource can be assigned either as a binary resource or as a multi-level resource. Binary resources are those resources that can either be fully used by the patient (Yes) or not used at all (No). Multi-level resources are those resources that can have four possible degrees of use: Not used (No), Low Intensity (LI), Medium Intensity (MI), and High Intensity (HI). The social resources currently assigned by our system are the following ones:

- *Home Help Service, domestic housework (HHSd)*: This resource consists of a professional caregiver making domestic housework for the patient at the patient's home. It is assigned as a multi-level resource.
- *Home Help Service, personal care (HHSp)*: It consists of a professional caregiver helping the patient at home in personal tasks of different types (e.g. moving, hygiene, etc.). It is also assigned as a multi-level resource.
- *Day Center (DC)*: This resource refers to a center for the outpatient treatment of the older people and it is assigned as a multi-level resource.
- *Nursing Home (NH)*: It consists of a center designed to serve as a stable communal home for elderly people and it is assigned as a multi-level resource.
- *Remote Care (RC)*: It corresponds to the emergency service for elderly people with health and social risks who live alone. It is assigned as a binary resource.
- *Technical Aids (TA)*: This resource refers to the acquisition of any type of technical material (e.g. a crane) and it is treated here as a binary resource.

On the other hand, all healthcare resources are binary resources, and they are the following ones:

- *Primary Care Center (PCC)*: These are the health centers where patients are first seen. Hence, there is one of these centers in each village or neighborhood in a city.
- *Outpatient Consultants Center (OCC)*: Being assigned this resource means using a medical specialties center.
- *Day Hospital (DH)*: This resource corresponds to hospitals for certain treatments in which patients stay during the day while spending the night at home.
- *Home Hospital Unit (HHU)*: This resource refers to the situation in which some doctors and/or nurses from hospital go to the patient's home to make some treatments.
- *Acute Care Hospital, outpatient service visit (ACHo)*: This resource corresponds to those hospital sections devoted to treat medical specialties such as: medical post-surgery, monitoring, or preliminary diagnosis.
- *Acute Care Hospital, short stay unit (ACHs)*: This resource consists of the patient being assigned a short stay at an acute care hospital.
- *Chronic Care Hospital (CCH)*: This resource are hospitals for patients requiring long-term healthcare.
- *Mental Health Unit (MHU)*: This resource offers health mental services for outpatients.

The pathway rules used by the CMT to design the patient's pathway can be divided into two groups, general rules and meta-rules. The general rules are applied first to design a tentative general pathway. Then, the meta-rules are used to modify this pathway and adjust it to the concrete situation of that patient (e.g. by considering the resources already being used). The general rules are based on four criteria:

Dependency degree (DD): It is obtained from the score of the Barthel test [26]. A classification as independent corresponds to a score between 0 and 39 points, a degree of low dependency corresponds to a score between 40 and 85 points, and a degree of high dependency corresponds to a score between 86 and 100 points.

Cognitive problems (CP): A patient is considered to suffer from cognitive problems if the score obtained in the Pfeiffer test [29] is equal or greater than 8 points.

Clinic complexity (CC): A low CC means that the patient does not require any sanitary technique. A medium CC means that the patient requires either one or more sanitary techniques provided by non-sanitary staff, or just one sanitary technique provided by sanitary staff while his medicine consumption is lower than the average in this context (equal or less than 9 medicines [31]). A high CC means that either the patient suffers from an illness in its terminal stage, or she/he requires 2 or more sanitary techniques provided by sanitary staff, or she/he just needs one sanitary technique provided by sanitary staff but his medicine consumption is higher than the average in this context (greater than 9 medicines).

Suitable caregiver: A patient is considered to have a suitable caregiver when she/he has a caregiver whose age is lower than 75 years. Additionally, if the patient suffers from a high dependency degree (DD), the caregiver should be available at any moment of the day. If the patient's DD is low, then the caregiver's availability should cover nights and weekends. Only if the patient is independent the caregiver can have a different availability (e.g. some hours on alternate days or weeks). Otherwise, the patient is not considered to have a suitable caregiver.

Taking into account these four criteria, Table 1 shows the general rules applied by the LTCMAS. Thus, for example, if the case management team receives a patient that has a suitable caregiver, with a low dependency degree, and with a medium clinic complexity, then the pathway that the CMT first assigns to that patient includes attention in her corresponding primary care center (PCC) and a low intensity degree of personal home help service (HHSp(LI)). The rest of general rules in Table 1 can be similarly understood by using the criteria and resource definitions provided above. For the sake of clarity, resources not being assigned do not appear in the table.

Table 1. General rules applied by the LTCMAS.

	Suitable Caregiver (SC)		
DD	Low CC	Medium CC	High CC
Independent	PCC	PCC	PCC
Low DD	PCC	PCC+HHSp(LI)	PCC+HHSp(MI)
High DD	PCC+HHSp(MI)	PCC+HHSp(MI)+ DC(LI)	PCC+HHSp(MI)+ DC(MI)
	Not Suitable Caregiver (SC)		
DD	Low CC	Medium CC	High CC
Independent	PCC+RC	PCC+RC	PCC+RC
Low DD	PCC+RC+HHSd(LI)	PCC+HHSd(MI)+DC(LI)	PCC+HHSd(LI)+ HHSp(LI)+DC(MI)
High DD or CP	PCC+NH(LI)	PCC+NH(MI)	PCC+NH(HI)

After a first tentative pathway has been assigned by using the previous general rules, it is adjusted by sequentially applying the following set of meta-rules:

1. If the patient has important cognitive problems (i.e. a score of 8 points or more in the Pfeiffer test) and she/he has a caregiver, then, the HHSp resource is added to the pathway or its intensity is increased by one degree if it was already present. When the HHSp resource is already at its maximum degree (HI), the DC resource is in turn added or increased.

2. If the patient does not have important cognitive problems but she/he has a caregiver with an intense burden (i.e. a score of 56 points or more in the Zarit test [39]) then, both the HHSp and HHSd resources are added to the pathway, or their intensities are increased by one degree if they were already present. If either the HHSp or HHSd resources are already at their maximum degree (HI), then the DC resource is in turn added or increased.
3. If the patient is already using the DH resource, then this resource is kept in the patient's pathway.
4. If the patient is already using the ACHs resource and his/her clinic complexity is high, then this resource is kept in the patient's pathway. In the case of a low or medium clinic complexity, she/he is only assigned the CCH resource. In any case, the rest of resources are removed from the pathway.
5. If the patient is already using the CCH resource, he/she exclusively this resource in his/her pathway, and the rest of resources are removed from the pathway.
6. If the patient was previously using ACHo and both the DD and the CC patient's criteria are high, then the ACHo resource is replaced by the OCC resource. If any of this two criteria is not scored as high, then the patient remains using the ACHo resource, which is added to the pathway.
7. If the patient was previously using OCC, then the OCC resource is replaced by the PCC resource in the pathway, provided that the patient's clinic complexity is low. Otherwise, the OCC resource is also added to the pathway.
8. If the patient is already using HHU, then this resource is added to the pathway, whereas the PCC resource, if present, is removed.
9. If the patient fulfills the next three conditions: first, he/she has a high DD; second, he/she is assigned to either the HHU resource or to the HHSp resource with a high intensity degree; and third, he/she has not been assigned to any of NH, DC, CCH or ACHs resources. Then (if the three conditions are fulfilled), the TA resource is added to the pathway.
10. If the patient was previously using MHU, his/her dependency is not high and he/she has not been assigned to any of NH, CCH or ACHs resources, then, the MHU resource is added to the pathway.

Finally, once the pathway has been fully designed then it is proposed to the patient. At this stage, she/he can reject those resources that do not fit his/her personal constraints. For instance, a patient might refuse using the day center due to economic issues. Thus, the set of resources actually used by a patient are the remaining resources in the pathway, after having discarded those that are marked as rejectable.

4 Application Example

We have tested the performance the simulator can provide by simulating different populations during different periods of time. For comparison purposes, we have considered two different alternatives for each simulation: the application of the SSHM to the considered population (we have denoted this option as "SSHM"), and the usual healthcare treatment that is applied to standard patients (extracted from the Valencian regional government). We have denoted this latter option as "No SSHM". Due to space limitations, we show here the results for a representative example. It consists of a population of around five hundred people with the features shown in a experimental project carried out in Burjassot (Valencia) [31]. The results provided by LTCMAS for the SSHM option have been fully validated by the real data obtained in that experiment, ensuring the correctness of the simulator. The example shown here considers a simulation of a 5 year period. Although we could have simulated other period lengths, we considered that it is long enough to allow the SSHM to provide significant differences with the standard healthcare system for a population of 500 patients.

Since the SSHM considers 6 social resources and 8 health resources, it has been impossible to show the evolution in the use of all these resources. Due to space limitations, we show here the evolution computed for those resources that had experience the biggest differences between the standard healthcare system and the SSHM.

Figure 1 shows the temporal evolution of the considered population in the use of the OCC resource (medical specialties center). The plot labeled as "No SSHM" shows the evolution of the population using the standard healthcare system, while the plot labeled as "SSHM" shows the evolution if the SSHM is applied. This figure shows that the evolution in the use of this resource significantly differs from the first months, showing plots with different shapes. Thus, at the end of a 5-year simulation, the standard healthcare system would assign this resource to 70 patients, while the SSHM would have assigned this resource to around 38 patients. Since this is a high-cost resource, the benefit of applying the SSHM could be significant.

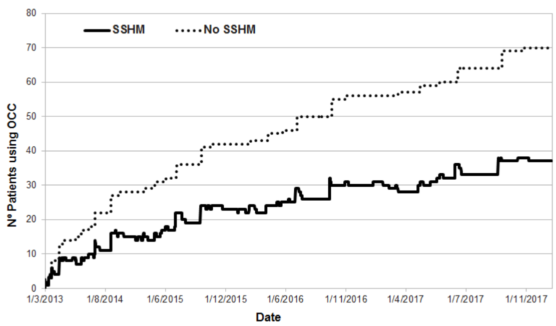

Fig. 1. Evolution in the use of the OCC resource.

Figure 2 shows the temporal evolution in the use of the ACHs resource (short stay at an acute care hospital). In this case the shape of the plots are even more different, showing greater differences. Thus, at the end of the five-years period the number of patients using this resource is around five if the SSHM is applied, in front of more than 50 patients in the standard healthcare system.

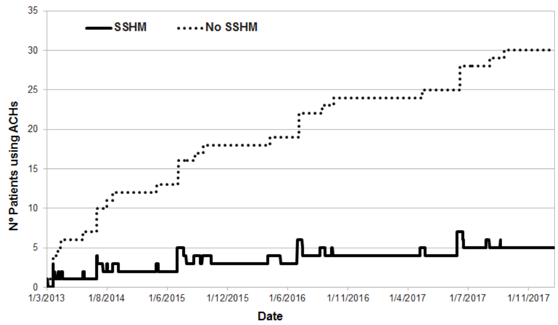

Fig. 2. Evolution in the use of the ACHs resource.

Finally, Figure 3 shows the temporal evolution in the use of the HHS resource (Home Help Service, that is, a professional caregiver making both domestic housework and personal tasks). The different plot shapes still remain in this case, but now the plots are exchanged, experiencing a faster increase the plot corresponding to the SSHM. This behavior can be explained because the SSHM stimulates the use of social resources instead of healthcare resources whenever possible, and people prefer stay at home as much as possible, instead of being in a hospital.

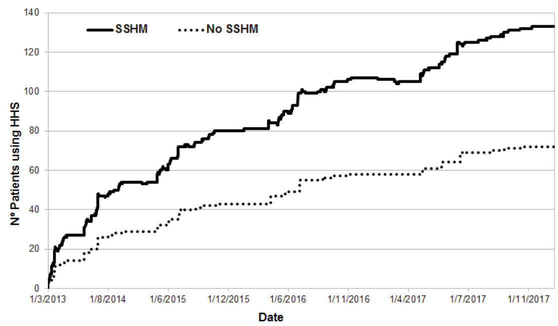

Fig. 3. Evolution in the use of the HHS resource.

These figures show that LTCMAS can be used to determine the infrastructures that a given population of elderly people will require in the long term, according to the social and healthcare policy that is applied.

5 Conclusions and Future Work

In this paper, we have proposed a closed-loop simulator for the long-term care of elderly people. This tool consists of a multiagent system simulating a holistic model of care systems for people that need long term care. The closed-loop design of the proposed simulator allows to repeatedly simulate successive interactions of the considered population with the healthcare system. The application example show that the simulator can forecast the long-term effects of different policies on the considered population as well as on the health system. The key issue for the closed loop design has been the access to real statistical data from Spanish government institutions.

As a future work to be done, we plan to adapt the tool for simulating another health and social systems in Europe, in order to make a comparative study.

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