

**A DECISION SUPPORT SYSTEM FOR HOSPITAL EMERGENCY
DEPARTMENTS DESIGNED USING AGENT-BASED TECHNIQUES**

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ABSTRACT

This paper presents the results of an ongoing project whose objective is to develop a model and a simulation that, used as decision support system, aids the heads of hospital emergency departments (ED) to make the best informed decisions possible. The defined ED model is a pure Agent-Based Model, formed entirely of the rules governing the behavior of the agents that populate the system. Two distinct types of agents have been identified, active and passive. Active agents represent people, whereas passive agents represent services and other reactive systems. Actions and interactions of agents are represented using Moore state machines. The model also includes the communication system and the environment in which agents move and interact. The simulation has been implemented using NetLogo and it has been used to evaluate the potential benefits of the derivation to primary care services of those patients who attend ED without requiring an urgent attention.

EXTENDED ABSTRACT

The increasing demand of urgent care services, the overcrowding of hospital emergency departments (ED) and the limited availability of economic resources are phenomena shared by health systems around the world. The emergency department may well be one of the most complex and fluid units of a hospital, consuming a large portion of the budgets of the Healthcare System. However, patients often feel neglected and that the service is overcrowded. The resource planning of ED is complex because its activity varies depending on time, day of week and season. For this reason the ability to simulate special situations (i.e. the impact of a pandemics on the demand received by ED) can be useful for the efficient use of resources.

There are no standard models to describe a complex systems. Simulation becomes an important tool for modeling this kind of systems that include many elements, a large amount of interdependencies among such elements, and/or a considerable variability (Babin et al. 2011). Discrete event simulation (DES), system dynamics (SD) and agent-based modeling and simulation (ABMS) are the main three approaches used when simulating healthcare systems. There are a large body of literature describing the use of DES and SD models in ED studies, but the use of ABMS for this purpose is reduced, although

healthcare systems are based on human actions and interactions that can be more properly modeled with ABMS than with DES (Escudero-Marin et al.2011).

The Research Group in Individual Oriented Modeling of the University Autonoma of Barcelona, in cooperation with a ED team of the Hospital of Sabadell (an Spanish hospital that attend an influence area of 500,000 people, receiving 160,000 patients/year in its ED), is carrying out an ongoing project whose general objective is to develop a model and a simulation that, used as decision support system (DSS), aids the managers of the ED to allow additional knowledge of physician staff, resource optimization, and alternatives for decreasing the patients Length of Stay, amongst other situations. The work is being developed applying an iterative and spiral methodology, divided in cycles of 5 phases (system analysis; model design; simulator implementation; simulator execution and results analysis; simulator validation). Once a cycle is completed, based on the conclusions obtained during the analysis and validation phase, the model is updated and a the next cycle is carried out. The process is repeated until the objectives are achieved.

After finishing the second cycle an Agent-Based Model for ED has been obtained, in which the system behavior emerges as result of local level actions and interactions. Such model describes the complex dynamics found in an ED, representing each individual and entity as an agent. Two distinct kinds of agents have been identified, active and passive. *Active agents* represent the persons involved in the ED such as patients and ED staff (admission staff, nurses, doctors, etc). *Passive agents* represent services and other reactive systems that have a remarkable influence on the behavior of the ED, such as the information technology (IT) infrastructure or diagnostic services used for performing tests. State machines are used to represent the actions of each agent, taking into account all the variables that are required to represent the many different states that such individual (a patient, a member of hospital staff, etc) may be in throughout the course of the time in a hospital emergency department. The change in these variables, invoked by an input from an external source, is modeled as a transition between states. In order to control the agent interactions the model also includes the communication between individuals, modeled as the Inputs that agents receive and the Outputs they produce, and the physical environment in which agents interact, modeled as a series of interconnected areas (admissions zone, triage boxes, waiting rooms, or consultation suits) in which interactions take place.

With the aim of verifying and validating the model a simulation has been implemented using the agent-based simulation environment NetLogo, a high level platform particularly well suited for modeling complex systems developing over time. The verification and validation process was carried out with the participation of the ED team of the Hospital of Sabadell and let conclude that both, model and simulation, represent correctly an ED. The simulator has been used for carrying out and experiment to evaluate the potential benefits of the derivation to other units of the Health Care System (ambulatory and primary care services) of those patients who go to the emergency care service without requiring an urgent attention. The results obtained show how the derivation of non-urgent patients allows to improve the ED performance indicators (Patients Length of Stay, Number of patients attended, etc), or what is the same, let to achieve the same level of the performance indicators with less ED staff.

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