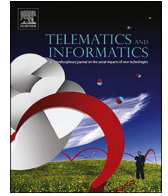


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## Developing a multi-agent platform supporting patient hospital stays following a socio-technical approach: Management and governance benefits

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### ABSTRACT

Most of the caregivers working in hospitals are highly skilled and educated work force. Even if they are supported by administrative staff, part of their time still consists of administrative procedures or trying to empirically fill or retrieve agendas on the basis of real-time constraints. Similarly, patients waste time waiting for adequate treatments so they occupy slots (beds) in hospitals while their hospitalization is not a necessity. This leads to huge wastes of resources for the hospital that has to hospitalize and prioritize patients in more effective need of care and monitoring. In order to ensure real-time patient support during its entire stay in the hospital (in terms of bed occupancy, appointments with doctors and/or for medico-technical exams) as well as to furnish a central solution open for future IT integration we propose, in this paper, to build a Multi-Agent System (MAS) based software solution. The latter has been built following a socio-technical approach; it maps, at runtime, the working processes of a Belgian hospital. Processes have been modeled in a patient-centric way in order to identify most relevant stages and bottlenecks in bed, cares and medico-technical exams management; real-time data transmission allows to update and re-optimize slots statuses as well as schedules. Also, data analysis (i.e., business intelligence) functions are supported by the MAS implementation for decision making/taking. Further than the proof of concept that shows the managerial support of the software solution, the MAS modules' benefits to the overall hospital strategy is studied. The latter shows the relevance of the solution to the hospital's governance.

### 1. Introduction

Healthcare institutions are nowadays facing a lot of challenges. Among their strategic objectives, they primarily need to furnish high quality care to patients but also to, at least, break even from a financial point of view. Their mission to society is important and complex so that tools and procedures need to be optimized to furnish an adequate added value. One of the strategies that can be used in order to sustain this long term plan is the use of *Information Technology (IT)*. For instance, (Yen and Bakken, 2012; Payne et al., 2013) highlight that IT is (notably) able to increase efficiency, quality, safety of medical care, data analysis, cost-effectiveness and fairness in healthcare.

Following (Varshney, 2009), *pervasive healthcare is the conceptual system of providing healthcare to anyone, at any time, and anywhere*

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by removing restraints of time and location while increasing both the coverage and the quality of healthcare. Various IT technologies supporting treatments or healthcare processes can support this system. In order to furnish their full potential, these technologies need to be successfully integrated in the hospital environment but also need to be easily integrated with other technologies and be scalable (Cresswell et al., 2017). With more and more connected objects available at an ever decreasing price, the amount of heterogeneous technologies possibly of benefit for healthcare services will continue to grow leading to an even bigger challenge for (pervasive) healthcare.

Currently used software systems in hospitals are often too old and closed to ensure software collaboration/integration (Bergenti and Poggi, 2010). Acting as IT consultants and researchers, the authors have studied the processes and IT infrastructure of a Belgian hospital. At the start of the research, the information systems of this hospital were obsolete and not coupled nor integrated. These systems were connected with a central database coming from the reorganization of multiple other (previous) datastores having different purposes and linked together in a “do it yourself” way, a common problem in healthcare institutions notably highlighted by Bergenti and Poggi (2010). It was thus poorly conceived and not fully normalized so that history and consistency were not ensured. A new normalized and centralized database needed to be developed from scratch; the latter would be the central point where data is stored in a standard and unified way and will constitute a potential source for data analysis. Moreover, previous information systems only supported parts of the processes of the hospital so that a lot of work was still done manually. All this has negative consequences on the fulfillment of the hospital long term strategy. The governance board consequently wished for a new integrated IT system notably offering openness for later evolution to connected technology, the highest possible process support but also allowing exploitation of the data for business intelligence. Globally, The project was seen as an opportunity to reach a higher alignment between the hospital’s business objectives and the supporting IT infrastructure.

Facing all these challenges, we have decided to develop a central software platform following a socio-technical approach (see Davis et al., 2014). The software development, within its first increment, targets the support of the bed management process of the hospital. All the roles involved in the hospital work progress are stakeholders of this process and it constitutes their means of coordination. Bed management has been for a long time identified by the various hospital services and *Care Units (CU)* as the main bottleneck for a global optimization of the entire set of operational processes (see for example Hall (2012); Shi et al. (2015); Maloney et al. (2007)); it constituted the root cause of inefficiency in the hospital: e.g., *unoccupied beds, transfer to other hospitals when beds are not available, patients waiting in their bed for medical exams during prohibitive delays*, etc. No place must be wasted in order to avoid financial loss but simultaneously the services offered must be kept at highest standards since the stake is life and death. Global real-time coordination and analytics must be offered for this critical business process to increase the overall managerial efficiency and progress towards the overall strategic objectives. Also, future connected devices (e.g. beds) are likely to furnish more data potentially useful for planning. These devices must be easily integrable in the coming software system.

The objective of the paper is not to document runtime processing like scheduling algorithms but to show how a socio-technical approach can be followed to develop an IT system aligned with, on the managerial side, the hospital operational processes, and, on the governance side, the organizational strategy. The software development stages (analysis, design and implementation) presented mainly focus on the processes aiming *the optimal repartition of patients in the slots (i.e., the beds) of the various CUs*; the followed modeling and design approaches are very representative of how IT can be aligned within the organization. We call this particular software module the *bed planner*. Other aspects like *the management and analysis of appointments both for hospitalizations, simple (doctors) consultations or medico-technical exams* (called the *Medico Technical Exams Management App*), *the management and analysis of the medical and administrative files of the patients* (called the *Care Unit Management App*) and *the automatic billing of the patient medical services* (called the *Billing Processor*) are also part of the core processes supported by the platform but are not the focus of the present presentation. The scientific approach and validity (in order to answer the research question) is nevertheless the same for these other aspects because they have been built following the same socio-technical approach and evaluated with the same tools.

The main contribution of the paper is thus to show how a Multi-Agent System (MAS) based platform mapping the behavior of the hospital processes at runtime can be built using a socio-technical approach. Such an approach leads to operational benefits, an IT system mapping, at runtime, the behavior of the real life organizational processes. We also mention it leads to building a centralized database that can be later exploited for datawarehousing as well as the identification of the key elements for data analysis. It finally leads to governance benefits, through an alignment with the long term organization’s strategic objectives.

The processes modeled to develop the software solution are centered on the patient. It is indeed the key stakeholder to be satisfied for bed management. The analysis provided in this paper mostly focuses on tracing the benefits of the platform to the management and governance of the hospital. As far as governance is concerned, the overall long term strategy of the hospital has been depicted in terms of goals so that the contributions of the software modules on these goals could be traced. In line with the special issue theme, the economic, social and cultural benefits of the platform are notably highlighted.

The paper is structured as follows:

- Section 2 depicts the research question, research method and the data collection. The aim of the collected data is to model the hospital as a socio-technical organization and to build a MAS out of it;
- Section 3 exposes the technical choices for the development of the software solution;
- Section 4 positions the paper with respect to previous scientific work and contributions;
- Section 5 relates the most important stakeholders for ensuring pervasive healthcare through agent software supported bed management;
- Section 6 exposes the modeling of organizational processes for interfacing with the patient using the *i\** socio-intentional framework (Yu et al., 2011). This modeling of the current situation allows to build a complete and consistent basis for positioning the

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