Using Electronic Institutions for Hospitals Chronic Disease Management and Purchasing System

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Abstract. Use of multi-agent systems (MAS) in health-care domains is increasing. MAS is an appropriate technique for many medical domains due to the characteristics of the problems in this area. According to the World Health Organization (WHO) health care systems worldwide are faced with the challenge of responding to the needs of people with chronic conditions such as diabetes, heart failure and mental illness. Chronic disease management (CDM) is a systematic approach to improve health care for people with chronic disease. Electronic Institutions (EI), as agent technology, is considered a suitable paradigm for complex environments providing structured frameworks for multi-agent systems to regulate agents' interactions. In this paper we introduce the HCDMP System which is an electronic institution to improve the Hospitals Chronic Disease Management and Purchasing processes. HCDMP system provides a number of recommended services to the patients and aims to advance the self care as a well proven and highly effective means of improving the care of chronic diseases.

1 Introduction

In recent years there has been an increasing interest in integrating the organisational concepts into multi-agent systems with the purpose of considering organisation-centred designs of multi-agent systems [1]. Using multi-agent systems and lately electronic institutions in medical and health-care domains has recently amplified [2]. Electronic Institutions (EI) [3] are a system approach to implement interaction conventions for the agents who can establish commitments on an open environment. These agents can be either humans or computer software. The proposed EI in this paper for hospitals chronic disease management and purchasing system, HCDMP, is a good example of such efforts to tackle medical situations using agent technology and electronic institutions.

Chronic diseases are those that can only be controlled and not, at present, cured [4]. Living with a chronic disease has a significant impact on a person's quality of life and on their family. The frequency of such diseases increases with age. Many older people are living with more than one chronic condition and this means that they face particular challenges, both medical and social. The care of people with chronic conditions also consumes a large proportion of health and social care resources. People with chronic conditions are significantly more likely to see their GP (General Practice), accounting

for about 80% of GP consultations, to be admitted as inpatients, and to use more inpatient days than those without such conditions. The World Health Organisation (WHO) has identified that such conditions will be the leading cause of disability by 2020 and that, if not successfully managed, will become the most expensive problem for health care systems [5]. This confirms the global importance of chronic disease management (CDM).
HCDMP system aims to implement agent technology, using *Islander* tool [6], in chronic disease management and attempts to achieve better CDM through providing recommended services, by the responsible authorities, to the chronic patients.
The rest of this paper is structured in five sections. Section 2 is about chronic disease management and introduces some examples of successful CDM. In section 3 Electronic Institutions is explained followed by a full description of the HCDMP system in section 4. Section 5 presents the related work and Metastorm Manager's Edition Designer. Finally section 6 is about future work and conclusions.

2 Chronic Disease Management

Chronic disease is the biggest problem facing health care systems worldwide seems unarguable. They include diabetes, asthma, arthritis, heart failure, chronic obstructive pulmonary disease, dementia and a range of disabling neurological conditions. Chronic diseases are the ones which current medical interventions can only control not cure. The life of a person with a chronic condition is forever altered and sadly there is no return to normal. Chronic conditions have a profound effect on the physical, emotional and mental well-being of individuals, often making it difficult to carry on with daily routines and relationships. However, in many cases, deterioration in health can be minimized by good care. Chronic disease management (CDM) [7] is an approach to health care that emphasizes helping individuals maintain independence and keep as healthy as possible through prevention, early detection, and management of chronic conditions. Figure 1 shows the results of good CDM in UK, US and Canada where, first-class CDM led to significant achievements only within 4 years.

Three lessons from abroad

UK: Results of Castlefields Health Centre pilot of active management of conditions:
- 15% reduction in admissions for older people
- average length of stay fell by 31 per cent (from 6.2 days to 4.3 days)
- total hospital bed days used by this group fell by 41 per cent
- improved links between practice staff and other agencies in the community, leading to more appropriate referrals to other services and much faster response times for social services assessments

US: Veterans Administration, focus on improving chronic disease management:
- 50% reduction in bed-day rates from 1994-1998
- 35% reduction in urgent care visit rates
- moderate increase in clinic visits, tests and Consultations

Canada: Chronic disease management program
- 7% fall in unplanned and emergency hospitalisations from 1998 to 2002)

The reasons for this marked decline is attributed to a number of interventions focussed on better management of chronic disease including; *report cards; knowledge management; guidelines and protocols for patients and physicians; and learning from top performing physicians.*

Fig. 1. Results of good chronic disease management in United Kingdom and United States and Canada.

As it is shown in Figure 2, according to world health organization, in Spain in 2002 around 90% of all deaths were caused by chronic disease. This emphasises on the need for good CDM in Spain.

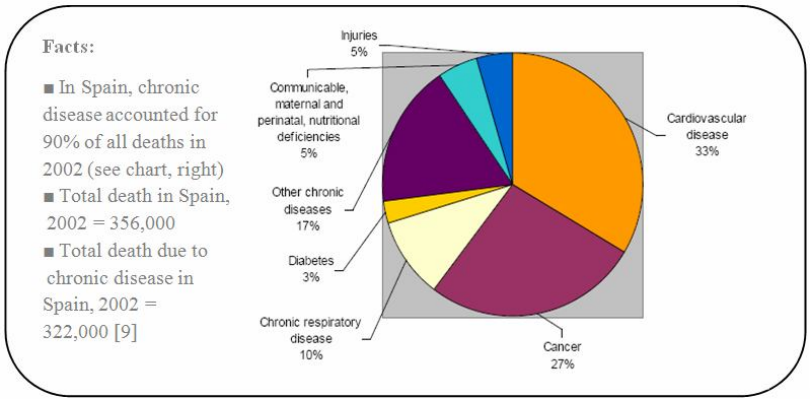


Fig. 2. Deaths by cause for all ages in Spain in 2002

3 Electronic Institutions

Multi-agent systems (MAS) are collections of autonomous intelligent entities that collaborate in the joint resolution of a complex problem. These kinds of systems are appropriate in many medical domains because of the quality of the problems in this area. Such agent-mediated medical systems can manage complex tasks and have the potential to adapt to unexpected events.

Electronic institutions [3] [8] are based on three main elements: a Dialogical Framework, a Performative Structure and a set of Normative Rules [9] [10]. However in this paper the normative rules are not discussed.

The *Dialogical Framework (DF)* defines the valid illocutions that agents can exchange as well as the language and ontology they use. Moreover, it defines the participant roles within the EI and their relationships. Each role defines a pattern of behaviour within the EI, and any participant agent is required to adopt some of them. In the context of an EI there are two types of roles, *internal* and *external* roles. The internal roles can only be played by what are called *staff* agents which are those related to the institution.

For each activity interactions between agents are articulated through agent group meetings, called *scenes*, using well-defined communication *protocols*. As a result, all agent interactions that take place in an EI exist within the context of a scene. In addition, the protocol of each scene models the possible dialogues among roles instead of agents. One of the features of the scenes is that they allow agents either to enter or to leave a scene at certain particular moments (*states)* of an ongoing conversation depending on their role. A scene protocol is specified by a directed graph, where nodes represent the different conversation states and arcs are labelled with illocution schemes or timeouts that allow the conversation state evolve. Hence, at each point of the conversation, electronic institution defines what can be said, by whom and to whom.

As a scene models a particular multi-agent dialogic activity more complex activities can be specified by establishing relationships among them illustrated in the *Performative Structure (PS).* In other words, the activities represented by PS can be shown as a collection of multiple, concurrent scenes. In a PS agents move from scene to scene, constrained by the rules defining the relationships among the scenes. Moreover a PS

can be thought as a network of scenes in which, the *initial* and *final* scenes determine the entry and exit points of the institution respectively.

4 Hospitals Chronic Disease Management and Purchasing (HCDMP) System

HCDMP System is an electronic institution in a hospital environment using agent technology which, in order to help chronic patients provides the followings to the patient home address by post:

1. *Guidebooks:* including patient education about self management of their illness, for example helping them to understand what to do, how to adjust their medication dose, and how and when to use health care.
2. *Prompts and Reminders:* for when they should be doing something and attending for care.
3. *Support from a knowledgeable patient:* introducing knowledgeable patients (with their consent) in the same living area, and broader networks including attending practices as part of a group of patients with the same condition.

It is clear that self management is not simply a matter of providing information to patients, it is a range of different things; however according to the UK Department of Health's Economic and Operational Research division the above self care supports work the best.

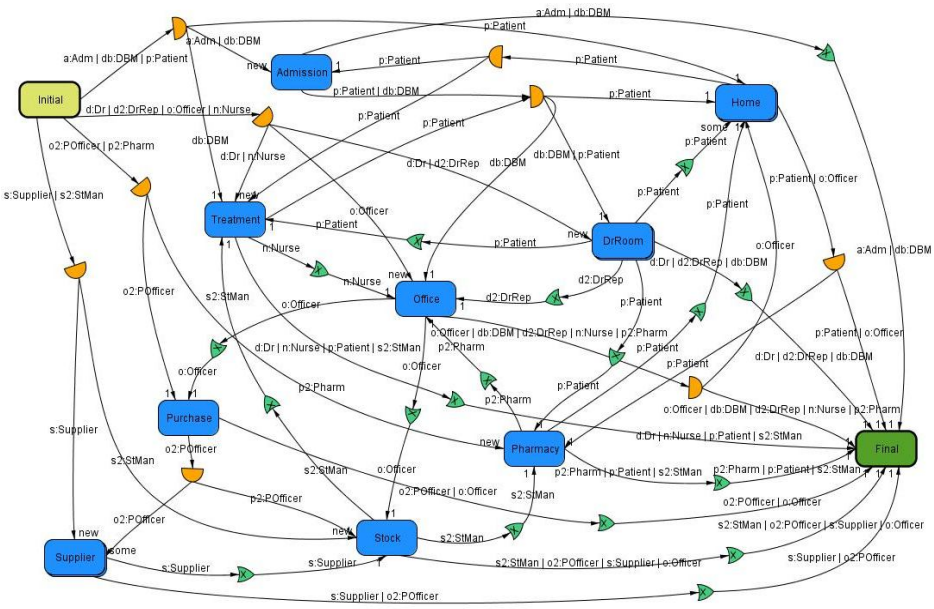


Fig. 3. HCDMP System Performative Structure: illustrates how scenes are connected through arcs and how agents move between them.

Figure 3 shows the performative structure of the HCDMP system. Scenes and roles of this electronic institution are as follow:

- Scenes: Initial, Admission, Home, DrRoom (doctor room), Office, Treatment, Pharmacy, Purchase, Stock, Supplier, Final.

- Roles: Adm (admitter), DBM (data base manager), Dr (doctor), DrRep (doctor representative), Nurse, Patient, Pharm (pharmacist), Officer, POfficer (purchase department officer), StMan (stock manager), Supplier.

Agents enrol to the Institution at the *"Initial"* scene and as it can be seen they move between the scenes depending on their roles. Initially the *Patient*, after enrolment, goes to the *"Home"* scene where all the patients, as external roles, are assumed to stay. From Home patient moves to the *"Admission"* to register and requests an appointment to visit a doctor. Figure 4 illustrates the admission scene protocol (can be thought as the inside of Admission scene) where, the *Adm* (Admitter) requests the patient for his/her *ID* (Identification number) which will be checked if it is recognised by the system as a current patient. If the ID is *accepted* and the patient is a current patient who already has a *patientFile*, then an appointment will be given to the patient to visit his/her doctor. However; if the ID is *notAccepted* then the Adm requests the patient to fill an *applicationForm* which will be processed by the Admitter. If the applicationForm is accepted then an appointment will be issued for the patient to visit his/her doctor, and the *DBM* (DataBaseManager) will be informed about the new patientFile by the Adm. Otherwise the patient is informed that he/she is notAccepted and goes to the *Final* state of the protocol to leave the Admission scene and returns to the Home scene.

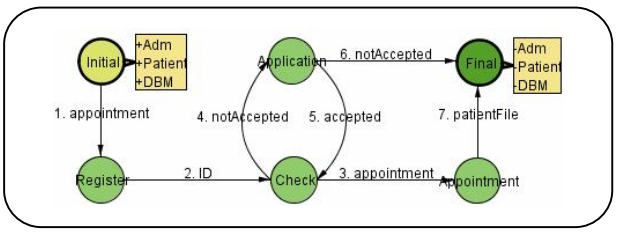


Fig. 4. Shows the Admission scene where, nodes represent protocol states and arrows indicate the transitions. Also rectangles show what roles can enter or leave.

Following the performative structure, if the patient is given an appointment then goes to the *"DrRoom"* scene to visit his/her *Dr* (doctor), where the doctor in order to know the patient requests for the patientFile from DBM. Then Dr requests the patient *howCanIHelp* and patient informs the Dr from his/her problems/disease. There are two different protocols for this scene, one for the *current* hospital patients and another for the *new* patients to the hospital. Depends on the chosen protocol by the system for new or current patients, Dr asks different questions from the patients (i.e. about patient *diseaseHistory?* from New Patients, or if current patient *useMedicationOnTime?*, *contactOtherPatients?* and *happyWithServices?*). Dr then informs the patient with the *DrInstruction4P* (doctor instruction for patient) and also provides *DrInstruction4O* (doctor instruction for Office) to the *DrRep* (doctor representative). Afterwards, patient from DrRoom scene depends on DrInstruction4P moves either to Home, *"Pharmacy"* or *"Treatment"* scene. And DrRep from DrRoom moves to *"Office"* scene to inform the Officer of the DrInstruction4O.

In the Pharmacy scene patient requests for his/her prescription from *Pharm* (pharmacist).

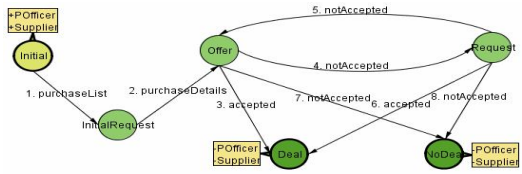
However if the Dr diagnoses that patient needs extra care then the patient goes to the Treatment scene to stay in the hospital until the patient either fully recovers and leaves the hospital to Home, or dies.

In Office scene DrRep informs the *Officer* of the DrInstruction4O including: *PatientID, PatientName and recommendedServices* for the patient. Then officer requests the

patientFile from DBM in order to process the doctor recommendations and provide *services* to the patient including: *guidebooks, reminders, similarAreaPatients* (please note that the similarAreaPatient details are released by the patients consent, asked in registration form) *and recommendedOrganizations.* (recommendedOrganizations are the organizations which might be able to provide extra help for the patients. i.e. psychiatrists) Officer then moves to the Home scene to inform the patient about the services he/she will receive. Officer also moves to the *"Purchase"* scene to inform the *POfficer* (purchase department officer) about the *purchaseList* (purchaseList, prepared by the Officer, is a list of requested products by the Pharmacy and Treatment department). In addition Officer has to move to the *"Stock"* scene to inform the *StMan* (stock manager) of the requested products (mainly medicine) for Pharmacy and Treatment scenes. These products will be delivered later by the StMan to the Pharmacy and Treatment scenes.

In Home scene patient in informed by the Officer about the services including similarAreaPatients details who are patients with the same disease and condition and are willing to help other patients. These patients using this information can contact each other and discuss their problems and help each other. This is highly recommended by doctors to introduce patients with similar conditions to each other. Patients then can request other patients for *Consultation* including: their *problems, DrInstructions* and the *services* they receive.

In Purchase scene Officer informs the POfficer of the purchaseList including: *items, quantity*. POfficer then informs the Officer of the *purchaseDetails* including: *price, productInfo, deliveryTime and quantity.*



1	(request (?x POfficer) (?y Supplier) (requirePurchaseList ?purchaseLists))
2	(inform (?x Supplier) (?y POfficer) (requirePurchaseDetails ?purchaseDetail))
3	(inform (?x POfficer) (?y Supplier) (accept))
4	(failure (?x POfficer) (?y Supplier) (requirePurchaseDetails ?purchaseDetail))
5	(failure (?x Supplier) (?y POfficer) (requirePurchaseDetails ?purchaseDetail))
6	(inform (?x Supplier) (?y POfficer) (accept))
7	(failure (?x POfficer) (?y Supplier) (dontAccept))
8	(failure (?x Supplier) (?y POfficer) (dontAccept))

Fig. 5. Shows the Supplier scene, the protocol states and the messages using Fipa agent communication language [11].

As it can be seen in figure 5, which shows the *"Supplier"* scene protocol (can be thought as the inside of Supplier scene), POfficer requests the purchaseList from the Supplier (message #1) and Supplier informs the POfficer of the purchaseDetails (#2) including requested *items, price, productInfo,deliveryTime and quantity*. If this purchaseDetails is accepted by the POfficer (#3) then the purchasing process is completed but, if the purchaseDetails is notAccepted by the POfficer then it informs the Supplier of the failure to accept the purchaseDetails and requests a modified

PurchaseDetails to come to an agreement with the supplier (#4) where, if it is accepted by the Supplier (#6) then the business is done. Otherwise the Supplier informs POfficer of another modified PurchaseDetails modified by the supplier (#5). If it is accepted by the POficer (#3) then the purchasing process is completed, but if it is notAccepted then the Supplier will be informed about the failure to accept the supplier offer until it sends another modified PurchaseDetails. This can be done as many times between the POfficer and Supplier until they either come to an agreement (#3 or #6) or refuse to do more business (#7 or #8). In the Stock scene POfficer informs the *StMan* (stock manager) of the *purchase* including *items, quantity* and *productInfo*. Then Supplier moves to the Stock scene in order to deliver the purchased products and informs the StMan of the *deliverProducts*. StMan then informs the POfficer of the deliverProducts.

5 Related work

The aim of this paperwas to specify a Business Process Management (BPM) setting in terms of a Multi-agent organisational environment using Islander tool. Specifically, to use the EIDE environment, developed by the Artificial Intelligence Research Institute (IIIA-CSIC), to model a business process management example. As a result Hospitals Chronic Disease Management and Purchasing System was developed using Electronic Institutions and Islander tool explained in sections 3 and 4. This approach and similar techniques are employed by *Metastorm* [12]. Metastorm offers market-leading software for Business Process Management (BPM).
Metastorm Manager's Edition Designer is the main tool used to create a process and the *maps* and *forms* required to define and implement the procedure. In addition Designer is used to build the business rules that are used to automate business processes. Studying Metastorm software illustrates that *maps* are equivalent to *performative structures* in Islander as well as *forms* equivalent to *Ontologies*. Metastorm Designer is used to create models of business processes in which an electronic *folder* (equivalent to *scene* in Islander) is passed from *stage* (*state*) to stage within the process. At each stage *actions* may be taken either automatically or by individuals or groups. Please note that actions are comparable to the *protocols* of Islander tool.
Also *Prometheus Design Tool* [13] similar to Islander is a graphical editor for designing agent systems. There are three design phases in Prometheus:

- *System specification:* in which *actors* (human or software) are identified and *roles* (identified by *goals, percepts* and *actions*) are described and captured.
- *High-level (architectural) design*: in which similar to the performative structure in Islander, an overall structure of the system is described using a system overview diagram. The *protocols* are defined in this phase too.
- *Detailed design*: in which the internals of each agent are developed.

Islander and Prometheus Design Tool, both are used to develop various aspects of specifying and designing a system using an agent oriented approach and to support the design and development of multi-agent systems.

6 Conclusions and Future work

In this paper we described how important the chronic disease management was and how a good management could make significant improvements. According to WHO about 90% of all deaths in Spain in 2002 has been due to chronic disease. This emphasises on the importance of CDM in Spain.

Agent technology is appropriate for many medical domains, including chronic disease management, as they are collections of autonomous intelligent entities that collaborate in the joint resolution of a complex problem. We introduced and explained HCDMP system. An electronic institution which can help chronic disease management and purchasing processes of the chronic departments in hospitals.
As future work we plan to implement the agents of HCDMP model and try some experiments using aBuilder (agent builder) and AMELI software.

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References

1. Luck, M., McBurney, P., Shehory, O., Willmott, S. *Agent Technology: A Roadmap for Agent Based Computing*. AgentLink (ISBN 0854328459) 2005.
2. Javier Vázquez-Salceda "Normative Agents in Health Care: Uses and Challenges", *AI Communications* vol. 18 n. 3, pp. 175-189. IOS Press, 2005.
3. Marc Esteva, Juan A. Rodríguez-Aguilar, Carles Sierra, Pere Garcia and Josep L. Arcos, "On the Formal Specification of Electronic Institutions" in the book *Agent-mediated Electronic Commerce: the European AgentLink Perspective*, Lecture Notes in Artificial Intelligence, pp. 126-147, Springer-Verlag, 2001.
4. Department of Health: Improving Chronic Disease Management: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4075214.
5. World Health Organization Report: http://www.who.int/chp/chronic_disease_report/en/
6. Marc Esteva, David de la Cruz and Carles Sierra. "ISLANDER: an electronic institutions editor" in Proceedings of the First International Joint Conference on Autonomous Agents and MultiAgent Systems (AAMAS 2002), pp. 1045-1052, Bologna, 2002.
7. Chronic Disease Management: http://www.health.gov.bc.ca/cdm/
8. Carles Sierra, Juan Antonio Rodríguez-Aguilar, Pablo Noriega, Marc Esteva, and Josep Lluís Arcos, "Engineering multi-agent systems as electronic institutions" in *European Journal for the Informatics Professional*, V(4) N. 4, pp. 33-39, 2004.
9. Gaertner, D., García-Camino, A., Noriega, P., Rodríguez-Aguilar, J.A., Vasconcelos, W. "Distributed norm management in regulated multi-agent systems" In Sixth International Joint Conference on Autonomous Agents and Multiagent Systems. (AAMAS'07), May 2007.
10. Jordi Campos, Maite Lopez-Sanchez, Juan A. Rodriguez-Aguilar, Marc Esteva. "Formalising Situatedness and Adaptation in Electronic Institutions". In Coordination, Organizations, Institutions and Norms in Agent Systems (COIN). Workshop at AAMAS'08 Portugal, pp.103-117, 2008.
11. Fipa agent communication language: http://www.fipa.org/repository/aclspecs.html
12. Metastorm BPM: http://www.metastorm.com/products/mbpm.asp.
13. Prometheus Tool: http://www.cs.rmit.edu.au/agents/pdt/docs/PDT-Manual.pdf