Analysing the Electrical Patient Recruiting Agent system using the WIT trinity

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1 Introduction

In [5] a conceptual model is proposed for a new type of systems named Artificial Socio-Cognitive Systems (ASCS). In this paper we use the multiagent system described in [2] as an instance of an ASCS and deconstruct the system using the conceptual model of the so-called *WIT-trinity*. After the deconstruction we discuss the potential use the WIT could have had in the design phase of the system and outline potential for future development. First we will briefly describe the ASCS and ePCRN-Idea.

2 Artificial Socio-Cognitive Systems

As described in [5] ASCS are systems in which it is possible to *govern* the interaction of agents that are situated in a physical or artificial world by means of technological artefacts. The key element in this description is in the "governance" part that mediates between the world and the technological artefacts. It is an aspect worth distinguishing in ACSC because of the need to control the activity of complex individuals that are at the root of ASCS. The governance forms the institutional part of the system. In order to elucidate how such governance is achieved [5] propose the following tripartite view of ASCS:

View 1: The *world* system, $\mathcal{W}$, as the agents (both human and artificial) see it and relate to it.
View 2: An ideal *institutional* system, $\mathcal{I}$, that stipulates the way the system should behave.
View 3: The *technological artefacts*, $\mathcal{T}$, that implement the ideal system and run the applications that enable users to accomplish collective actions in the real world according to the rules set out in $\mathcal{I}$.

These three views are interrelated through three binary relationships (as depicted in Fig. 1). The institutional world corresponds with the real world by what is known

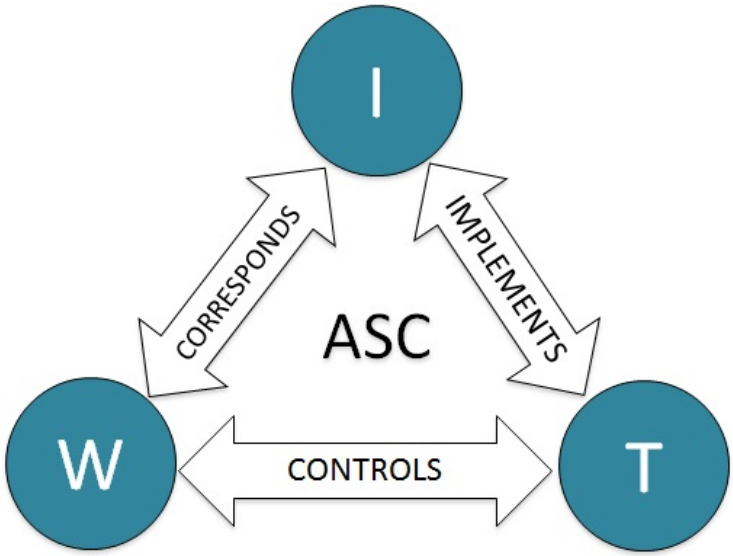

Fig. 1. The tripartite view of artificial socio-cognitive systems: The ideal system, $\mathcal{I}$; the technological artefacts that implement it, $\mathcal{T}$, and the actual world where the system is used, $\mathcal{W}$. After [4].

as a "counts-as" relationship [6, 1] by which (brute) facts and (brute) actions in the real world correspond to institutional facts and actions in the institutional world $\mathcal{I}$ only when these comply with the institutional conventions, in which case the institutional effects of those institutional actions carry over to have effects in the real world. Note that $\mathcal{W}$ is not the entire real-world, only that part of the world that affects and may be affected by the system. Secondly, the conventions and norms prescribed in the institutional world have their counterpart in the technological world in the sense that institutional conventions constitute a specification of the requirements of the system that is implemented in $\mathcal{T}$. In turn, the system, as implemented in $\mathcal{T}$ is what enables interactions (through a proper interface) in $\mathcal{W}$. Thus, the agents in $\mathcal{W}$ control the artefacts in $\mathcal{T}$, but also, we contend, this relationship is symmetric, in that by virtue of the percepts delivered via $\mathcal{T}$, the artefacts in $\mathcal{T}$ effect some control over the agents in $\mathcal{W}$. It should be noted that each of these three binary relationships needs to satisfy certain integrity conditions:

– The *corresponds* relationship needs: (i) to guarantee that the objects and concepts involved in the descriptions and functioning in $\mathcal{I}$ are properly associated with entities in $\mathcal{W}$; i.e., that there is a bijection between terms in the languages in $\mathcal{I}$ and objects and actions in $\mathcal{W}$. (ii) that the identity of agents in $\mathcal{W}$ is properly reflected in their counterparts in $\mathcal{I}$ and is preserved as long as the agents are active in the system, (iii) that the agents that participate in $\mathcal{W}$ have the proper entitlements to be subject to the conventions that regulate their interactions and in particular to fulfil in $\mathcal{W}$ those commitments that they establish in $\mathcal{I}$, and (iv) that the commitments that are established according to $\mathcal{I}$ are properly reflected in $\mathcal{W}$.

– The *implements* relationship needs to be a faithful programming of the institutional conventions so that actions and effects are well programmed, norms are properly represented and enforced, etc.
– Finally, the *controls* relationship needs to make sure that: (i) the technological artefacts work properly (communication is not scrambled, data bases are not corrupted, etc.) and (ii) inputs and outputs are properly presented and captured in $\mathcal{W}$, according to the implementation of the corresponding processes in $\mathcal{I}$. (iii) Algorithms and data structures in $\mathcal{T}$ behave as the conventions in $\mathcal{I}$ prescribe.

3 Case Study: ePCRN-Idea

In the following we present specific case study how disentangling socio-technological artefacts in the line of this integrated view - rather than an isolated analysis of the individual e.g. technological or social dimensions - enables a systematic comprehension of the recursive dependencies and influences of these different dimensions on each other.

Clinical trials are the gold standard by which the efficiency of medical interventions are evaluated. They involve the controlled testing of treatments on patients who match certain criteria, e.g. age, gender, condition. The stringent nature of these criteria, however, mean that many trials are unsuccessful in recruiting sufficient patients. A review of the UK Medical Research Council found that only 31% of trials actually recruited to their planned target, with 30–40% of costs arising during the recruitment phase alone [3], as discovering and contacting eligible potential recruits is logistically and legally challenging. Consequently, many research projects take far longer to complete than is desirable (or, in the worst case, not at all). *ePCRN-IDEA* [2] is a human-driven agent-based recruitment system for clinical trials. Figure 2 illustrates the architecture of the overall system, where arrows indicate the interactions between agents, i.e. the flow of information. To provide greater insight, the links are also annotated with example operations that occur through these interactions. Note that these are just examples and do not provide an exhaustive set of interactions.

The process of trial recruitment begins with the *Trial Designer Agent*. This is an agent that resides within the organisation of the *researcher*. The researcher is a human operator responsible for defining new trials. The Trial Designer Agent works with the researcher to generate an instantiation of the clinical trial model. The Trial Designer Agent then passes the newly created trial model to one or more *Trial Manager Agent*. Many of these exist throughout the healthcare system available in the country; typically, these would be distributed in a geographical sense. In the UK, for example, healthcare is split between multiple geographical management groups termed primary care trusts (each would have one agent). The Trial Manager Agents are responsible for coordinating in which clinics recruitment should be performed (for each trial). Once they have decided this, they pass the new trial model to a set of *Trial Recruiter Agents*. These exist on every GP's computer in every clinic. The Trial Recruiter Agent monitors the data entry by the GP to decide if any patient matches the eligibility criteria for the trials it is aware of. If a match is observed, the Trial Recruiter Agent generates a graphical pop-up asking the GP to recruit the patient. Obviously, this requires real-time access to patient information, which is provided by a *Patient Data Handler Agent*. This also

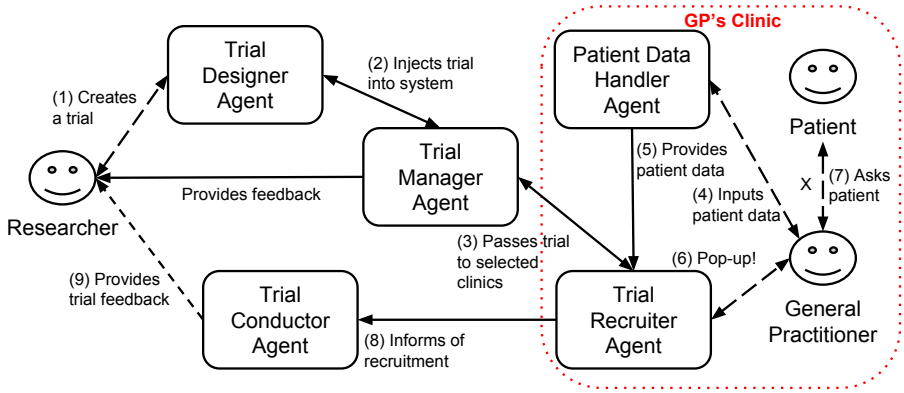

Fig. 2. Recruitment system architecture

sits on the GP's computer, but is owned and managed by the company that controls the patient's medical records.[5] Once someone has been recruited, an *Trial Conductor Agent* is contacted to initiate the trial with the patient. In the simplest case, this might involve retrieving information (e.g. a blood pressure reading), whereas in other cases it could involve complex interventions (e.g. drug treatments) accompanied by proactive data collection. The system has been installed in more than 50 clinics with more than 120 clinicians involved. We have been successful in initiating three (diverse) clinical trials within the system, with 811 patients being recruited for these trials, exceeding normal recruitment figures.

4 Mapping the Case Study to the W-I-T Dimensions:

Along the lines of the tripartite view of ASCS the case can be disentangled along the views of the world $\mathcal{W}$, institutions $\mathcal{I}$ and technological artefacts $\mathcal{T}$. $\mathcal{W}$, i.e. the world view, is represented by several of the components of our case study. This includes the humans in the system such as the GP, the patient and the researcher. Likewise, the office or entity executing the actual clinical trials is part of the real world.

The digital entities enabling the recruitment process are part of the technical view. This dimension includes the two software agents (Trial Managing Agent, Recruitment Agent) as well as the patient data handling system.

The design agent is not part of the technical dimension, but is considered belonging to the institutional dimension of WIT. The reason for this categorization is that the research design constitutes an institutional fact of scientific practice. Another institution can be found when considering the doctor patient relationship (marked as x in the diagram) that is an institutional in the sense that is follows a standardize pattern of conduction by both parties involved. This particular institution is affected by the implementation of the system, both in terms of a change of routines of interaction (additional

[5] In the UK, several commercial vendors provide Electronic Health Record databases that perform this function. Clinics are largely free to select their preferred one.

questions from the GP to the patient which need to be asked during the appointment) as well as well utilization of new technology for storing and communicating information. A final institution we identify in the case study is the GP practice itself, whose organizational structure and processes are reorganized by the information.

Concerning the *controls relation between $\mathcal{W}$and $\mathcal{T}$*, the condition (i) that the technological artefact works properly is satisfied need to be shown for the trial managing agent, the recruitment agent and the patient data handling system. Correct functioning of the trial managing agent is secured by the trial designer agent, who provides input and controls the output of the system. Controlling the output secures that system functions as intended. The recruitment agent is controlled by the trial conductor, whereas the patient data handler is under control of the GP. Moreover, it is obvious that in the initial phase of implementing a technological system bugs may occur in every technological system. In such case it is important that people (in $\mathcal{W}$) handling the system can communicate with the systems engineer. Thus the design of relations *within $\mathcal{W}$*is essential for a proper relation between $\mathcal{W}$and $\mathcal{T}$.

Condition (ii) that the input and output is properly presented is decided ultimately by the question whether the system is factually used by the GP in everyday practice. Here ease of using, design of the user interface and the time needed to get acquainted with the system and how much time it occupies in the practical use. The same holds for the patient data handler. However, this is a more established system.

Condition (iii) that $\mathcal{T}$behaves according to the standard in $\mathcal{I}$need to be secured by the software engineer developing the system. The primary focus to increase success and speed of clinical trials is ultimately derived from the standards of medical ethics to save human life and the fact that clinical trials are the gold standard to achieve the goal of medical progress which in turn contributes to achieve the goal of medical ethics.

However, condition (iii) of the controls relation is constraint by several sometimes contradictory norms and institutions which are specified in the *implements relation between $\mathcal{T}$and $\mathcal{I}$*. This concerns issues such as protection of private data, time schedule of the GP necessary for an effective doctor-patient relation, or trial priorities. Many of the issues cannot be answered by yes or no. However, at least data protection needs to be secured by the technological implementation and it need to be secured that the trial recruiter agent produces a proper match between the trial and patient characteristics. For this purpose it is essential that the access to patient data works properly, i.e. that the recruiter agent selects all or as much as possible eligible patients but only those, and at the same time fulfils the condition of protection of private data.

To investigate whether the *corresponds relation between $\mathcal{W}$and $\mathcal{I}$* is satisfied, it need to be shown that the conditions (i) (iv) are fulfilled. Concerning (i), a bijection between $\mathcal{W}$and $\mathcal{I}$need to be demonstrated. For instance, it needs to be shown that the trial manager agents are geographically distributed in the world to sufficiently cover e.g. the whole UK and sufficiently coordinate the allocations of patients to trials. This proves that the goal of the system, which is ultimately derived from $\mathcal{I}$, is factually realized in $\mathcal{W}$. Likewise if a successful implementation of the system reduces costs for recruitment will realize the institution of economic optimization.

Condition (ii) that identity of $\mathcal{W}$is preserved while agents are active in the system concerns correct handling of patient data. The test runs indicate that this is the case.

Examining condition (iii), in particular the entitlements of the patient are highly sensitive. Primarily the GP is responsible that these entitlements are respected, i.e. that the well-being and the privacy of the patient is guaranteed.

Concerning condition (iv) that commitments from $\mathcal{I}$are properly reflected in $\mathcal{W}$in particular the GP and the researcher have to be considered. It can be stated that the technological system supports the commitment of the researcher. Prime goal of the system is to increase efficiency of research, i.e. to encourage the commitment of the researcher to the institutional goal of scientific progress. This has to be realized given the constraint to respect the commitment of the GP to factually realize in $\mathcal{W}$the commitment to the institutional standards for doctor-patient relationships. Thus it needs to be investigated whether the system saves time for the consulting dialogue or whether further time gets lost.

5 Discussion

Certainly the overall objective of the information system utilised as case study is the optimisation of clinical trials. However, perceiving it in the context of the tripartite view of ASCS allows disentangling the recursive interrelations in which such an information system is placed when put into practice rather than optimising GP practice, clinical research, or the technological performance of the systems in isolation. We have classified entities, one arrow and all boxes of the case study. It has to be noted that institutions were in basically all elements, but normally not explicit. While far from being comprehensive, this first analysis provides a test case to study the two recursively related questions of (i) how the tripartite view of ASCS gives advice to system design and refinement from the perspective of the physical world and institutional facts and (ii) how the implementation of the system in the environment of the physical world and institutional facts gives rise to changes of this environment. For instance, the effect on the institutional setting of GP practice (additional questions to ask in the doctor patient relations) might have an effect on the acceptance and performance of the system as well as the system might have an effect on the effectiveness of the doctor patient relations and acceptance of this institution from the side of the patient. On the other hand, if it becomes an institution that the patient gets a 'feeling' of being involved in a research community might have an effect on the effectiveness and acceptance of clinical research.

The ePCRN-Idea system has many institutions governing the interaction among the various actors of the system, as well as governing the acting that such actors can take with regards to resources accessible to them. For example, patient data is a very sensitive type of information that requires extra security measurement when being communicated. For such reason, patient data in the system under analysis is always kept inside GPs' clinics (marked as a red box in Fig 2). Another example of an institution is the constraint that the manager agent impose on the recruiter agent in that the latter is obliged to follow the trials priorities imposed by the former when selecting the trial to inform a particular GP of. These institutions and many more are considered in the original system design but are kept implicit. Once they are separated into a separate entity, they become clearer and easier to reason about and modify.

Also, by separating users of the system from the technology that enable system usability, we can clearly observe the implication that each part have on the other part. Based on the result of the deployment of the system, we can clearly observe that the used technology has helped increasing the number of recruited patient for clinical trial. This can be seen as a very positive effect on the world achieved through the technology. However, consultation between GPs and patients are usually short and highly demanding. So, adding the extra task of recruiting the patient during consultation makes it even more stressful. This has an implication that the technology needs to have a very minimal time demands. The technology also need to be efficient, which may be achieved by learning the model of GPs behaviour and interest, so only notify them once they have extra time and only about trials that they are interested in.

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