Agent-based Intelligent Collaborative Care Management

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ABSTRACT
The aim of our research is to provide a unified model for the composition and management of consumer care services. We identify design, composition, distribution and management as key stages of this model and propose an Intelligent Collaborative Care Management (ICCM) System as its realisation. The distribution and management stages are implemented as multi-agent systems. Agents in the distribution stage carry out domain-specific negotiation and distribution processes for the assignment of tasks in the care plan. Through the agents in the management stage, we introduce the notion of "failure prevention" and "adherence support" in contrast to "failure recovery" in planning. The key to failure prevention is to identify what has to be carried out to prevent care plan failures. The healthcare domain is used to demonstrate the ICCM system.

Categories and Subject Descriptors
I.2.11 [**Computing Methodologies**]: Artificial Intelligence—Multi-Agent Systems

General Terms
Distribution/Assignment Problem, Agent based systems, Service oriented computing

Keywords
e-Health, Failure Prevention, Adherence Support, Planning

1. INTRODUCTION
The aim of our project is to propose a unified model for managing the provision of care to consumers across the full life cycle of care delivery and the realisation of that model using service oriented architectures. We identify four key stages in collaborative care, namely: design, composition, distribution and management as illustrated in Figure 1. This work includes the following research contributions:

- Identification and formalisation of domain-independent, key concepts in collaborative care management.
- Unification of the key concepts in goal-directed, multi-agent systems and context-dependent service oriented architectures [1].
- Introduction of a context-dependent, goal-driven service composition technique.
- Development of a framework for domain specific service (task) negotiation and assignment.
- Development of a framework for plan adherence support and failure prevention (as opposed to failure recovery).

The last two points above are addressed in the distribution and management stages using multi-agent systems. The innovation of the distribution stage is that the agents carry out a domain specific negotiation and distribution process for task assignment as opposed to generic negotiation processes. In addition, the domain specific negotiations can change or ground certain parts of the care plan. The management stage introduces the notion of "adherence support" and "failure prevention" for uncertain domains with incomplete knowledge.

We focus on the healthcare domain, specifically chronic disease management as an example of a complex consumer care management system to demonstrate ICCM [2].

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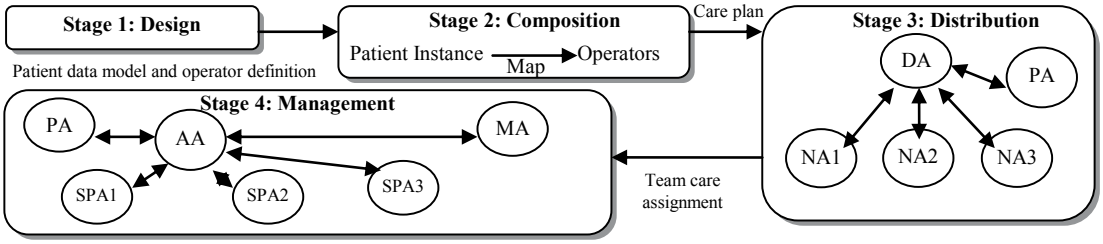

Figure 1. ICCM architecture.

2. ICCM IN HEALTHCARE

The design stage introduces a way to specify the domain by defining the properties of the consumer (data model), the services available in the domain (operators) and the compositional properties of those operators. For the healthcare domain, the data model specifies a patient's clinical information. The operators define, in a context-sensitive, goal-directed formalism (similar to BDI agents), the care services that can be provided by healthcare professionals. In particular, an operator specifies a desired service (goal), service selection criteria (context) and the sub-services (sub-goals) that, in the given context can be composed to yield the desired services. The design stage also may apply domain-specific constraints to the set of possible solutions. For example, two services may exclude, cause or require each other; some may be repeatedly applied (e.g., visits to a podiatrist).

The composition stage carries out patient-based service composition by selecting a set of goals relevant to the medical conditions of the patient. The selected set of goals is referred to as a care plan for the given patient. A care plan is a set (or network) of goals, where each goal is associated with a particular service (task), provider type, time of service and possibly other parameters.

The distribution stage consists of a multi-agent system to assign specific service providers (e.g., a specific doctor, podiatrist, educator) to carry out the goals in the care plan. This multi-agent system consists of two types of agents: a Distributor Agent (DA) and Negotiation Agents (NAs). The DA initiates the process of distributing the goals (tasks) and NAs negotiate on behalf of real providers. The DA considers proposals made by the NAs in assigning goals (e.g., see [3]). The DA and NAs use a domain-specific negotiation process and their negotiations can alter or ground parts of the care plan such as goals, repeat frequencies and starting dates.

The management stage introduces the notion of "adherence support" and "failure prevention" for uncertain domains with incomplete knowledge. It consists of a multi-agent system with two main types of agents: Adherence Agents (AAs) and a Management Agent (MA). AAs proactively decide what interventions are required to help patients and providers adhere to the care plan. These interventions, called *failure prevention mechanisms*, add a new step to the traditional plan execution process. In particular, they extend the process

select applicable plan → execute → recover from failures if any

to a new form incorporating a "failure prevention" step:

select applicable plan → (proactively) execute failure preventive mechanisms → execute → recover from failures if any

The distribution and management stages assume a dynamic world and decentralised decision making, whereas the design and the composition stages assume an initial static assessment of the world and a centralised planning process. In both the composition and distribution stages, we assume fixed goals and a fixed consumer (patient) profile. However, in the distribution stage, the selection of service providers depends on prevailing conditions and on information known only to the service providers themselves. In the management stage, the status of service providers and the consumer (as well as the external environment) is dynamic. Also, it is not possible to rely on the consumer or any service provider to carry out their planned commitments.

3. DEMONSTRATION

The demonstration runs through each stage of the ICCM process. We consider the following interactions with the system:

- Design stage: add and/or alter patient data model and/or operators using the service developer user interface.
- Composition stage: make requests for the creation of care plans for patients.
- Distribution stage: the negotiations between the DA and the NAs of different service providers and final agreement to be part of the care team.
- Management stage: failure prevention scenarios performed by agents.

The scenarios to be demonstrated include:

1. Remind patients to make appointments with providers for due procedures if they have not made the appointment within the due time frame.
2. Remind patients about forthcoming visit to a provider.
3. Monitor whether patients have visited the provider for due appointments and if not identify remedial mechanisms to keep the care plan valid.
4. Remind patients when their medication renewals are due.
5. Alert doctors about over and under use of medications.
6. Alert doctors if there are deviations in measurements such as blood glucose, blood pressure and body weight of patients beyond acceptable range.

This integrated platform enables us to examine the mechanisms of "adherence support" and "failure prevention" for uncertain domains with incomplete knowledge.

4. REFERENCES

1. H. Schmidt, B. Kramer, I. Poernomo, and R. Reussner, Radical Innovations of Software and Systems Engineering in the Future, in Lecture Notes in Computer Science, chapter Predictable Component Architectures Using Dependent Finite State Machines. 2004, Springer-Verlag: Berlin, Germany. p. 310-324.
2. D. Bu, E. Pan, D. Johnston, J. Walker, J. Adler-Milstein, D. Kendrick, J. M. Hook, Caitlin M. Cusack, D. W. Bates, B. Middleton, The Value of Information Technology-Enabled Diabetes Management. 2007: Healthcare Information and Management System Society (HIMSS).
3. C. Guttmann, M. Georgeff, and I. Rahwan, Collective iterative allocation: Enabling fast and optimal group decision making. International Journal of Web Intelligence and Agent Systems. to appear in 2010.