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Enhancing Patient-centered Palliative Care With Collaborative Agents

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***Abstract*—In this paper, we propose the use of an agent-based architecture to enhance workflow system capacity to support interprofessional, patient-centred palliative care delivery. This paper outlines the concept of palliative care and describes how agents can be used to assist care providers to address the needs of the patient and family. Our architecture is illustrated in a diagram and the agents are described in terms of the services they provide, and the dependencies among them. The dependencies determine the information flow, which facilitates the communication and collaboration among the patient and care providers.**

***Keywords*-Agent-based Modelling; Patient-centred Healthcare; Palliative Care; Collaboration; Team Approach**

I. Introduction

The work described in this paper is part of a large research and development project that is being conducted by our interdisciplinary research team, which includes researchers in computer science, information systems, and nursing, and involves an ongoing collaboration with palliative care stakeholders, such as healthcare administrators, palliative care clinicians, other healthcare providers, and a software engineering industry partner. The project is developing an information and workflow system that involves two streams, one to enhance collaborative, patient-centred, palliative care, and one for senior care. This paper focuses on the palliative care stream.

The provision of palliative care typically involves a number of caregivers, distributed across a variety of settings for care, who make decisions based on the information available to them and the results of healthcare interventions which themselves need to be coordinated. To facilitate better access to knowledge for decision-making and improve the coordination of healthcare activities, we propose the use of autonomous agents. An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own goals [4]. More specifically, agents typically have the following four characteristics [13]: *autonomy*: agents have some degree of control over their actions and can work without intervention of humans; *social ability*: agents can coordinate their actions and cooperate with other agents to achieve their goals, using a common language to communicate with each other; *reactivity*: agents can perceive their environment and respond to environmental changes; *proactiveness*: agents can act on their own initiative to achieve their goals instead of simply reacting to the environment.

Software agents can be viewed as assistants to stakeholders (patients, caregivers, managers, etc.) in a healthcare setting. In this article, we present an agent-based architecture that facilitates the delivery of patient-centred palliative care. Section II describes the details of patient-centred palliative care. Section III outlines an agent-based architecture that supports the objectives of Patient-centred palliative care. Section IV gives a conclusion.

II. Patient-centred Palliative Care

Palliative care refers to the physical, psychological, spiritual and practical care given to patients and their families when they are dealing with the issues associated with serious illness. As patients are usually part of a family, when care is provided, the patient and family are treated as a unit. The main focus of palliative care is to ease the suffering of the patient and his or her family and to help them to cope with their difficulties. The patient's needs and priorities for care are at the core of care provision; therefore it is called patient-centred care. This contrasts with traditional models of care that are typically illness focused, provider driven, or determined by the care setting. Palliative care is ideally delivered by an interdisciplinary care team. The composition of the team varies and is determined by the nature of the patient/family needs and issues, which often fluctuate over the course of the illness. Team members may include:

- the patient/family,
- the patient's primary care and specialist providers,
- formal caregivers with the skills needed to implement the plan of care and deliver the chosen therapies,
- informal caregivers who may be family or friends,
- community resources acceptable to the patient and family (e.g., spiritual supporters, volunteers).

Figure 1 gives a view of many of the care providers who may compose a palliative care team. The patient/family is at the centre of care, and there is a combination of caregivers with different areas of knowledge and expertise that may be

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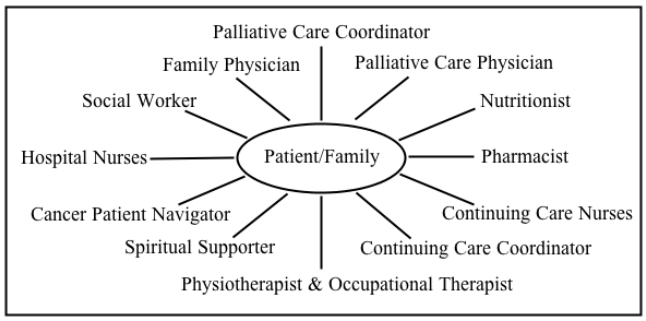

Figure 1. A Patient-Centered Palliative Care Team

involved at different points in course of the illness, to meet the particular care needs.

In a recent study [6] conducted by members of our team, palliative care professionals identified a few key functions desirable for a palliative care information system. A Careflow Management System (CfMS) [7] is being developed by our team to streamline work processes and reduce manual steps. More specifically, the CfMS integrates: (i) workflow management tools to aid the design, assessment, management, and monitoring of the complex processes, (ii) ontologies to structure the data into a knowledge base which can be used to guide the workflow, (iii) verification tools to ensure processes are designed and executed in accordance with their specifications [9]. Several specific challenges remain to be addressed:

- to manage communications and information flow among patients and caregivers effectively;
- to offer flexible scheduling capability;
- to monitor patients' health status and care delivery continuously.

Here we propose the addition of an agent-based approach to address these specific challenges and enhance the capability of the CfMS framework to support collaborative, patient/-family centred care delivery.

III. An Agent-based Architecture

An agent-based architecture can support patient-centred palliative care delivery in the following ways.

- Agents facilitate communication and collaboration among patients and caregivers. When a care team is formed for a patient, the information flow among the team members can be managed by the agents that are assisting them. For example, when there is new lab test data available, a care coordinator agent may obtain the data report on behalf of a human coordinator and send it to the appropriate caregivers' agents according to the information flow defined; the caregivers' agents then notify the caregivers. The information flow can be dynamically changed as new members (e.g., specialists for an newly diagnosed issue) are brought into the team.
- Agents facilitate monitoring and scheduling in reactive or proactive manners. Reactive behaviours occur when an agent observes and acts accordingly. Proactive behaviours occur when an agent initiates actions on its own. For example, a monitoring agent may generate a reminder when it senses an abnormal change in a patient's health status data; a scheduling agent may suggest a 'better' time slot for a patient to meet a physician, when it spots an empty time slot due to changes in the physician's time table and it 'considers' the time preferences of the patient.
- Agents facilitate personalized workflow execution. As care is delivered by individual caregivers, agents make personalized workflow tasks for these individuals and remind them in a timely manner.
- Agents enhance data and privacy protection. In patient-centred care, patients can decide which information (e.g., family contacts, medical history, and preferences) can be accessed by whom. The access policy can be managed by the agents according to patients' decisions.
- Agents increase availability of services. For example, it is possible for agents to migrate to mobile devices to provide services when the caregivers are in remote areas where the network is not immediately accessible.

Our agent-based architecture is illustrated in Figure 2. There are two layers: the first layer is the CfMS (refer to [7]); the second layer consists of multiple interacting agents. We divide agents into two categories: agents that interact with humans directly–the so called assistant agents–as, for example the patient agent or the coordinator agent, and agents that only interact with other agents–the so called system agents–as, for example the monitoring agent or the scheduling agent. Communications between users and their assistant agents are indicated by dotted lines; users can access them via a web interface or specialized software client in mobile devices such as cellphones, netbooks etc. Communications among agents are indicated by single lines; arrows indicate directions of information flow.

We now describe what different types of agents do and how they facilitate collaboration in patient-centred palliative care.

Patient Agents

Upon a patient's intake to the palliative care program, an agent is created for this patient. The patient agent provides the following services: (1) maintain all the relevant information related to this patient including the personal and health status information, and patient/family's specific preferences and priorities; (2) communicate and collaborate with other agents, e.g., to set up appointments with caregiver agents via a scheduling agent, or to send health status information to a

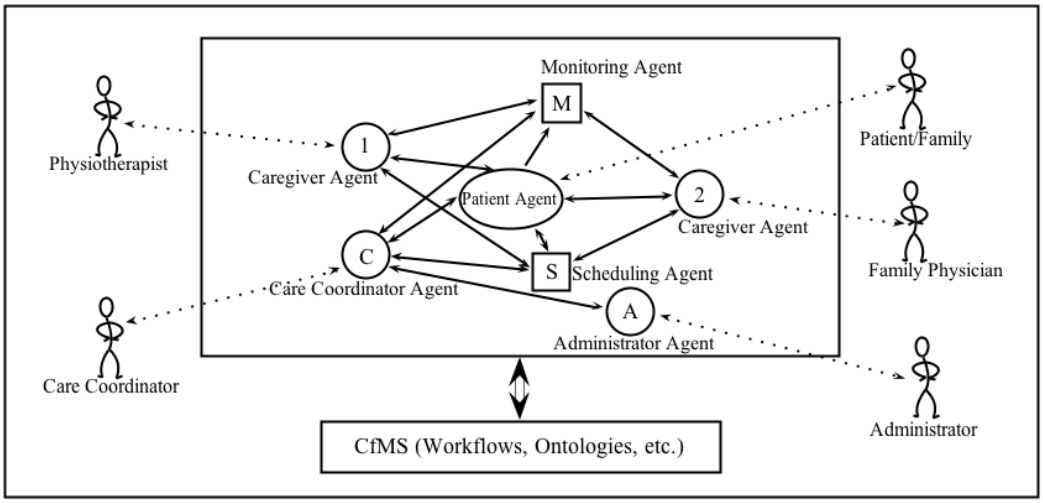

Figure 2. An Agent-based Architecture for Patient-centred Palliative Care

monitoring agent; (3) send reminders to the patient regarding scheduled appointments, medications, etc.

Caregiver Agents

As there are many types of caregivers (see Figure 1), we need different types of caregiver agents as well. Some of the common services provided by caregiver agents include: (1) obtain tasks from the care coordinator agents (given below); (2) schedule appointments with patient agents, and meetings with other caregiver agents via the scheduling agent; (3) receive information from patient agents and the monitoring agent; (4) send reminders to caregivers regarding scheduled appointments, meetings, and workflow tasks. A caregiver agent can be configured to fit a specific caregiver. For instance, an oncologist may only need information related to the patient's cancer status, so its agent helps to filter out irrelevant information to prevent information overload.

Care Coordinator Agents

This agent is a special type of caregiver agent: in addition to the common services described in the caregiver agent, it provides two essential services to assist the human care coordinator.

First, it automatically manages the agents for a care team. For instance, a patient may need a physiotherapist during the course of care. The care coordinator decides to bring a physiotherapist into the patient/family's care team. Correspondingly the care coordinator agent automatically establishes links between the physiotherapist's agent and the agents for other caregivers already on the team, thereby giving the physiotherapist access to information and enabling communication with other team members.

Second, it assigns requests for work to caregivers via their agents based on the workflows in the CfMS. *A workflow*

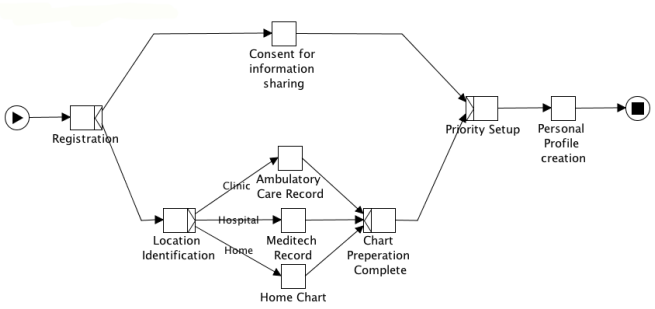

Figure 3. The *Intake* Workflow

is the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules. Figure 3 gives a simple workflow created using a workflow language and tool named YAWL [12]. The circles represent the start and end of a workflow, the boxes represent tasks, and the arrows indicate the order of tasks to be completed. A workflow can be instantiated as a result of an event. For example, when a patient is referred to a palliative care program, a caregiver coordinator creates a case for this patient in the CfMS; if this patient should be accepted by the palliative care program, an *Intake* workflow (Figure 3) is then instantiated. There are 14 workflows for palliative care in our CfMS system, such as *assessment, information sharing, care planning, care delivery, confirmation*, etc. Refer to [2] for details.

With the help of an assistant agent, the care coordinator must assign the instances of workflow tasks to appropriate caregivers. There are numerous requirements to consider including:

- the type of caregiver capable of doing the work related to the identified patient/family issues; e.g., *home safety assessment* should be performed by a physiotherapist;
- the caregivers' current workloads;
- the temporal dependency specified in the workflow; e.g., *care planning* must be performed before *care delivery*;
- the priority levels; e.g., 'urgent' means "responding in 1 working day", 'normal' means "responding in 3 working days"; thus, if a new patient is referred for urgent assessment and treatment, he or she should be seen by a palliative care nurse or physician within one working day;
- the location of this work to be performed; in palliative care, patients often move across a variety of settings during their illness, e.g., hospital, hospice unit, home, long-term care, etc.

The care coordinator agent can deliberate on these requirements, communicate with caregiver agents to obtain relevant information (e.g., caregivers' current workloads) and make recommendations to the care coordinator. There are general rules that can be applied to the selection process: the caregivers' workloads should be balanced; concurrent work items can be used to improve the efficiency by contacting the most appropriate caregiver for the work to be done; travel of caregivers, particularly in a rural area, should be minimized.

Administrator Agent

This agent supervises the overall performance of the system, and communicates only with care coordinator agents. For instance, the administrator agent gathers statistical information from the care coordinator agents to assist budgeting and strategic planning for the organization.

Scheduling Agent

A scheduling agent helps other agents schedule work items, such as, lab tests, appointments, meetings, etc. Each agent has its own calendar, which can be accessed by the scheduling agent. The goal of the scheduling agent is to meet numerous requirements (such as temporal dependency and priority among the work items) as well as to improve the overall efficiency of care delivery.

The complexity of scheduling lies in the dynamic (and frequently unpredictable) nature of the healthcare processes, and in numerous temporal and resource constraints. With the availability of rich information (e.g., calendar data, healthcare delivery records, preferences), and the automatic and reactive nature of agents, this complexity can be well addressed.

After a work item related to a patient/family issue has been assigned, a scheduling agent gets relevant information such as *caregivers associated with this work item, temporal dependency with other work items, priority level, and location*. In addition, preferences of patients and caregivers can be considered by the scheduling agent. For example, the patient can not come for appointments on certain days, when family members are unavailable to drive him to the appointment.

Monitoring Agent

A monitoring agent processes information from all patient and caregiver agents to automatically generate and send reminders and alerts (=alarms) to relevant agents. Two kinds of information are concerned:

1) *A patient's health status.* For example, the Edmonton Symptom Assessment System (ESAS) is used as a tool to assist in the assessment of nine symptoms common in patients experiencing serious illness: pain, tiredness, nausea, depression, anxiety, drowsiness, appetite, wellbeing and shortness of breath. Patients often need to have regular assessments, including ESAS, by caregivers. The assessment data should be monitored continuously and be sent to relevant caregivers, such as the patient's family physician and any nurses, or other care providers who are regularly involved in the care. When abnormal health status occurs, such as a sharp increase in pain, the monitoring agent generates and sends alerts to the agents of appropriate care providers, so that the severe pain or other noxious symptom can be promptly addressed. The conditions of alerts can be pre-determined by the patient/family and/or the care providers.
2) *Care delivery information.* Caregivers' work is guided by certain requirements to ensure safe, quality care and prevention of errors. In Canada, palliative care is guided by national principles and norms of practice [3]. Fo example, one norm states: "The patient's decision-making capacity is assessed regularly". As this care delivery information can be recorded by the caregiver agents, the monitoring agent can check whether the actual healthcare practice meets the norms of practice and remind the healthcare provider(s) when necessary.

We plan to use the logic-based framework that we proposed in [10] to monitor above-mentioned information. The ideas are, in brief, (1) to build linear-time models of the health status and care delivery information, then (2) to express the specifications to be monitored in the logical language we proposed, called **FO-LTL-K**, which is a combination of a first-order linear temporal language and a description logic language, (3) to use the monitoring agent to check whether the specifications hold in the models; the results of the checking are then used to generate reminders and alerts.

The **FO-LTL-K** is specifically designed:

- to represent and quantify over the data contents in a health record;

- to specify real-time requirements in different intervals, e.g., an assessment must be made within 3 hours (or 3 days);
- to specify temporal changes of data, e.g., in one assessment, the pain level is 8, but in the next assessment, it is 4;
- to specify healthcare knowledge expressions, e.g., medication 1 is not compatible with medication 2.

The monitoring agent takes an **FO-LTL-K** formula, e.g., $Medication(Med1)\,\mathbf{U}\,\exists x.(Pain(x) \wedge x < 3)$ (which represents a monitoring property "Use medication Med1 until pain level is less than 3"), and then checks it with the pain assessment and medication records continuously. If there is a violation of this property, the agent shall send an alarm to appropriate caregivers.

In [8], the authors described how an Agent-based alarm management was designed for a Palliative Care Unit to address monitoring of health status information. We can specify more sophisticated alarms in the monitoring agent since our data model and language are more expressive for supporting complex temporal and knowledge-based reasoning.

IV. Conclusion and Further Work

We conclude that an agent-based architecture can be a useful tool for supporting collaborative, patient-centred palliative care delivery. An early pilot is currently in place in the Guysborough, Antigonish, Strait Health Authority (GASHA) of Nova Scotia to develop electronic documentation and communication tools for this purpose. Ongoing close working relationships with palliative care clinicians and managers at GASHA and information from this early pilot will inform a second pilot where we implement a fully functional CfMS with the agent-based features described here. Among the challenges of further work are:

- to integrate agents with CfMS using an agent development framework. The JBees [11] and the WADE (Workflows and Agents Development Environment) [1] are promising candidates.
- to implement the core function of monitoring agent. We have studied the model checking complexity and algorithm in [10].
- to realize agent-based scheduling. Recent work [5] presented an agent-based patient admission scheduling in hospitals, which gives some hints on how we should realize our scheduling agent.

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