Report of the Activity

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If current trends in mobile phone technologies, personal digital assistants, and wireless networking are indicative of the way people will interact between them in the future, then our everyday activities is likely to be based upon an abundance of devices and applications providing the computational resources of a complex ubiquitous computing environment [10]. Although the potential of combining these numerous applications and devices is very promising, many different current applications leave the environments functionalities unexplored and only a small fraction of the environments potential is utilised.

Of particular relevance to the intelligent environment area is the healthcare problem. As cures for life threatening conditions are being discovered, life expectancy increases significantly. A direct consequence of this situation is the fact that the cost for the healthcare as actually conceived will grow significantly due to the rise of the number of people that have permanent or chronic health conditions. The current situation represents already a big challenge for governments that have the necessity to tackle the growing healthcare expenditures. Policies such as cost containment measures may slow down the spending in certain healthcare areas, but they could cause resentment amongst those patients affected by such restrictions.

In this context an interest is growing towards the so called *smartcare* area [7]. Smartcare is concerned with the continuous, automatic and remote monitoring of real time emergencies and lifestyle changes over time. The challenge is to manage the risks associated with independent living of people that have chronic or permanent health conditions such as diabetes, hepatitis or dementia.

The main issues of smartcare are about defining infrastructures to connect to hospitals and doctors related to the final user of the system, but also to define standards to deal with the different devices used to monitor the different conditions.

In order to meet the challenges of complex distributed systems posed by the smartcare area, the notion of *agency* is an appropriate development metaphor. A software agent is a computer system that is capable of flexible autonomous action in dynamic and, possibly, unpredictable or open environments [12]. The characteristics of dynamic and open environments suggest that improvements on traditional computing models and paradigms are required. Thus, the need for some degree of autonomy, to enable agents to respond dynamically to changing circumstances while trying to achieve their goals, is seen as fundamental. Many observers therefore believe that agents represent the most important new paradigm for software development since object oriented programming [8].

Of particular importance for distributed applications such as the one of the smartcare, is the concept of *agent environment*. The agent environment works as a powerful coordination medium to handle the interaction but also to modularise and split the responsabilities in the system between heterogeneous agents. As specified in [11], modelling the concept of agent environment in MASs results in more manageable solutions when dealing with distributed and ubiquitous entities. Also, an agent environment allows to model the perception dimension as the situated agents can observe the state of the entities sharing the same portion of the agent environment.

The GOLEM agent platform [2, 3, 9, 4, 5] models the concept of agent environment as a first class abstraction that the agents can observe and manipulate in a distributed setting. In particular GOLEM defines the agent environment as a distributed event based system (DEBS), where agents publish events directed to other entities of the environment in the distributed settings.

In the context of this activity, we proposed to use and extend the concept of agent environment, as intended by the GOLEM agent platform to tackle the issue of continuous monitoring of chronic conditions such as diabetes, an illness that is the fourth leading cause of death in most developed countries [1]. In particular, our motivating scenario is the case of Gestational Diabetes Mellitus (GDM), which occurs during pregnancy due to increased resistance to insulin.

The case of GDM is of particular interest as the precise mechanisms underlying it remain unknown and about 4% of pregnant women incur in this sort of complication. The current approach includes a planned diet, exercise and self-blood glucose monitoring tests that can be administered at home. In several cases the doctor requires that the patient visits the dietician once per week. However, often one check per week is not enough: as if the hyperglycemia last for more than one day, this may cause macrosomia (excessive growth of the fetus). Thus, in this cases it is important to act as fast as possible to prevent any serious complication to the mother and the baby, by normalising the blood pressure and glucose levels with appropriate and quick treatments.

The care of diabetes and especially GDM would be qualitatively improved with:

- automatic alerts to patients inviting them to visit sooner their medical doctor if hyperglycemia appears;
- constant monitoring and recording of glucose and blood pressure values, in order to give dieticians and medical doctors the view on the history of the patient, and thus to ease treatment adjustment. Actually, treatment adjustment is the key issue in diabetes treatment, especially for GDM.

To achieve this, we studied the deployment of a pervasive healthcare infrastructure, that we called MONDAINE[1] to collect data, monitor and alert GDM patients and inform their caretakers with historical values. To setup this infrastructure, we modelled a pervasive and ubiquitous multi-agent system deployed in the environment and accessible to users by means of smart phone devices.

On one hand from the stand point of distributed agent environments the application is interesting from multiple perspectives. First of all the application we modelled is a highly distributed event based system where events have to be interpreted to diagnose possibly critical conditions and alert a healthcare professional. This means that possibly many events have to be handled at the same time in an efficient way.

Secondly the distributed agent environment we modelled has to be capable to adapt to changes in the lifestyle of the patient and consequently the current assumption that the topology of the distributed agent environment is fixed is going to be broken by the requirements of the application.

Thirdly, the cognitive model deployed for the agents has to deal with cognitive tasks such as finding a diagnosis for the current situation of the patient, which implied applying, extending and adapting current abduction logic programming techniques [6] to deal with the diagnosis of the illnesses as well as creating a cognitive model that is capable to interact with a highly distributed and possibly changing agent environment.

On the other hand, from the medical perspective the significance of this study resides in the possibility of applying continuous monitoring outside the boundaries of the hospital care. Firstly, the patients are allowed to keep their habits, while safely monitored by the distributed agent environment. Secondly, continuous monitoring provides data that can uncover the unknown mechanisms of GDM. Thirdly the infrastructure may help to curb the percentage of critical situations resulting from untreated or poorly treated GDM, allowing the healthcare professionals to keep in touch with their patients.

References

[1] The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. The Diabetes Control and Complications Trial Research Group. *N. Engl. J. Med.*, 329:977–986, Sep 1993.

[2] S. Bromuri and K. Stathis. Situating Cognitive Agents in GOLEM. In *Engineering Environment-Mediated Multiagent Systems (EEMMAS'07).* Springer, Oct 2007.

[3] S. Bromuri, V. Urovi, P. Contreras, and K. Stathis. Virtual e-retailing environment in golem. In *Intelligent Environments (IE'08).* IET, Jul 2008.

[4] Stefano Bromuri and Kostas Stathis. Distributed Agent Environments in the Ambient Event Calculus. In *DEBS '09: Proceedings of the third international conference on Distributed event-based systems*, New York, NY, USA, 2009. ACM.

[1]MONDAINE stands for Artificially Intelligent Networked Environments for Diabetes Monitoring

[5] Stefano Bromuri, Visara Urovi, and Kostas Stathis. Game-based E-retailing in Golem Agent Environments. *Journal of Pervasive and Mobile Computing*, 5(4), 2009. In press.

[6] A. C. Kakas, R. A. Kowalski, and F. Toni. The role of abduction in logic programming. In D. M. Gabbay, C. J. Hogger, and J. A. Robinson, editors, *Handbook of Logic in Artificial Intelligence and Logic Programming*, volume 5, pages 235–324. Oxford University Press, 1998.

[7] Ying Liu, Jean Bacon, and Roger Wilson-Hinds. On smart-care services: Studies of visually impaired users in living contexts. In *ICDS '07: Proceedings of the First International Conference on the Digital Society*, page 32, Washington, DC, USA, 2007. IEEE Computer Society.

[8] O. Shehory M. Luck, P. McBurney and S. Willmott. Agent Technology: Computing as Interaction (A Roadmap for Agent Based Computing). In *AgentLink*, 2005.

[9] Kostas Stathis, Stella Kafetzoglou, Symeon Papavasilliou, and Stefano Bromuri. Sensor Network Grids: Agent Environments combined with QoS in Wireless SensorNetworks. In *The Third International Conference on Autonomic and Autonomous Systems (ICAS07)*, Jun 2007.

[10] Mark Weiser. The computer for the 21st century. *SIGMOBILE Mob. Comput. Commun. Rev.*, 3(3):3–11, 1999.

[11] Danny Weyns, Andrea Omicini, and James Odell. Environment as a first class abstraction in multiagent systems. *Autonomous Agents and Multi-Agent Systems*, 14(1):5–30, 2007.

[12] M. Wooldridge and N. R. Jennings. Intelligent Agents: Theory and Practice. *The Knowledge Engineering Review*, 10(2):115–152, 1995.