Semantically Enabled Contextually Aware Pervasive Computing Environments

Ian Millard, David DeRoure, Nigel Shadbolt
Intelligence, Agents Multimedia group
School of Electronics and Computer Science
University of Southampton, SO17 1BJ, UK
{icm02r, dder, nrs}@ecs.soton.ac.uk

Abstract

This paper outlines work in progress related to the construction of a system which is able to deliver information in a contextually sensitive manner within a pervasive computing environment, through the use of semantic and knowledge technologies.

1 Introduction

During the course of the last decade, our lives have become increasingly dependent on the availability and exchange of information. In today's world, knowledge can be equated to people, money, flexibility, power, and competitive advantage. Knowledge is more relevant to sustained business than capital, labour or land, yet in most organisations it remains the most neglected asset. For large businesses and organisations, being able to access the right information at the right time is key to success.

Another notable trend in recent times is the increasing level and availability of hi-tech devices within the workplace, including a wide range of portable and/or personal computing and communications devices, laptops, desktop machines, plasma screens, and projection displays. Often these devices are powerful, offer significant storage capacity, and feature wired or wireless networking technologies; yet a lack of interoperability prevents the seamless transfer of information. Instead, we are presented with the chores of having to remember where information is stored, and manually transferring data between devices – a far cry from the integrated, all-knowing solutions promised to us in visions of the future.

The contextually aware environment aims to harness the abundance of technological resources to aid workers in every-day situations, by presenting the right information to the right users, at the right time and in the right place. In order to achieve this, a system must have a thorough understanding of its environment, the people and devices that exist within it, their interests and capabilities, and the tasks and activities that are being undertaken.

This paper outlines the approach taken to semantically model the required information, details a number of software components which have been developed, and presents an overview of our prototype system.

2 Ontological Modelling

It is clear that for any form of contextually aware system, a wealth of knowledge is required to describe the environment in which the system is situated.

Experience drawn from the Advanced Knowledge Technologies (AKT) interdisciplinary research collaboration gives us confidence in taking a semantically-orientated approach to these modelling tasks, using the robustness of formal knowledge representations, the descriptiveness of ontologies, and the power of inference which they offer. Given such a rich representation of a particular domain, a wealth of knowledge or agent-based services may be envisaged, utilising the data acquired to provide useful and proactive assistance to the users of that environment.

2.1 Location modelling

In order to achieve the goals of proactively assisting users within an environment, a contextually aware system must have a thorough understanding of where people are, and the resources which are available to them. We take the view that it is more important to comprehend semantic information regarding locations, such as the type and/or purpose of different areas or spaces, rather than their spatial coordinates, and have created a location ontology [3] which permits these kinds of relationships to be described. Furthermore, this ontology can be used to describe the layout of an environment and serve as a basis for combining location data from a wide range of different sensors in a single repository and inferring additional facts about the environment [1].

2.2 User modelling

While it may be reasonable to assume that the location ontology may be repurposed across deployments and in different domains, a generic model of user context would most likely not be able to offer the level of detail and/or expressiveness required. Across different domains in which a system may be deployed, the important concepts, activities, interests, and the relationships between people in that environment will be diverse; hence we believe use of detailed domain-specific ontologies is most appropriate for representing this knowledge.

In addition, it can be argued that the activities carried out by people can usually be described in a task-oriented fashion. For example, most working days can be conceptualised as a sequence of different tasks, such as a project meeting, document review, teleconference, patient consultation, or student supervision. This task based model has been used in our prototype system, with users' current activity forming a key contextual indicator.

2.3 Device modelling

To enable the contextually aware environment to assist users as they go about their everyday tasks, the system must also have an understanding of the devices available within that environment, their location, capabilities and usage characteristics.

To achieve this, a device ontology [2] has been created which permits a particular set of features relating to a computer interface to be described. These focus mainly on the input/output and user-interaction capabilities of the device, rather than the typical system hierarchy approach of describing processor, disk, and memory specifications, although the ontology could easily be extended (or others incorporated) if these details were thought necessary at a later date.

3 System components

We have described the core modelling requirements of the contextually aware environment, yet for a working system this information must be stored, kept up-to-date and made easily accessible to other service components.

We have developed a combined RDF repository and OWL inference engine, 'OwlSrv', which is capable of executing custom inference rules and handling near real-time updates. This plays a central role in our prototype work by providing core services of data storage, query and inferential capabilities required to form the 'intelligence hub' of the contextually aware environment.

Built using the Jena libraries, OwlSrv uses a MySQL database to store persistent data, and a custom reasoner to provide OWL and domain-specific inference. An integral web server permits the data to be browsed, and RDQL queries are accepted through the HTTP POST method. Data in the model can be updated by asserting or retracting RDF models, again through the HTTP interface, and additionally triple assertion and retraction may be performed through an interface to the Elvin distributed messaging system, permitting easy integration with a range of existing location sensing components and services.

Many pieces of information within the data repository can be used to build up the contextual picture for a given domain. To assist in this task a generic analyser has been created which permits domain specific queries to be executed, with each result contributing to a metric or weighting for a number of different concepts relating two entities. For example, this tool can be used to give a value indicating whether two individuals are of a personal or professional acquaintance, or to give a notion of superiority based on line management or academic status. Given appropriate understanding of the domain in which a contextual message delivery system is deployed, suitable queries should be definable to identify the important factors which make up the contextual picture of that particular domain.

As an external service, the generic analyser(s) are called by the reasoner as and when required to perform specific analyses. This decoupled arrangement not only offers flexibility but permits complex and/or intensive processes to be performed which are not appropriate for general execution in the reasoner.

4 Prototype

A prototype system is nearing completion, which aims to deliver messages to users within an academic environment in a contextually-sensitive manner.

A wide range of data is collated in an OwlSrv repository, including background domain information, detailed data on staff and students, input from location sensors, and scheduling information from calendar applications.

Messages are injected via email and a generic analyser determines a number of metrics between the sender and recipient(s), if not already known. Another analyser assesses the current 'interruptability' of each recipient, based on their current task, and determines if the importance of the message/sender is sufficient to warrant delivery in the current context. A third analyser then attempts to identify suitable devices within the environment on which to deliver the message, based on user location, the message format, and sensitivity/nature of the message, before issuing the relevant instructions to action delivery of the message.

5 Conclusions

We have briefly outlined our work in the area of contextually aware pervasive computing environments, detailing our use of semantic technologies in our modelling approach.

The architecture and software components developed have been built with generality in mind, and should permit the system to be repurposed in domains other than that of the prototype system by swapping in appropriate ontologies and analysis/inference rules.

Acknowledgments

Part of this work has been supported under the Advanced Knowledge Technologies (AKT) Interdisciplinary Research Collaboration (IRC), which is sponsored by the UK Engineering and Physical Sciences Research Council under grant number GR/N15764/01. http://www.aktors.org/

References

[1] Millard, I.C., DeRoure, D.C., Shadbolt, N.R. "*The use of ontologies in contextually aware environments*". 1st International Workshop on Advanced Context Modelling, Reasoning and Management, Ubicomp 2004.

[2] http://signage.ecs.soton.ac.uk/ontologies/device

[3] http://signage.ecs.soton.ac.uk/ontologies/location