Intimate Location Modeling for Context Aware Computing

Mark Burnett, Paul Prekop and Chris Rainsford

Information Technology Division
Defence Science and Technology Organisation
Department of Defence, Fern Hill Park
Canberra ACT 2600
AUSTRALIA
{mark.burnett, paul.prekop, chris.rainsford}@defence.gov.au

Abstract. This paper describes some of the complexity that needs be captured in any location model of an intimate environment. We take the position that a location model for such an environment must be part of a wider framework for handling context that includes knowledge of people, devices and their communication abilities. We present an ontology based on a general object model of people and devices to deal with the complexity of location modeling within an intimate environment and show how temporal events may be represented and reasoned with using standard modeling techniques based on time intervals.

1 Introduction

Smart rooms and workspaces assist in the seamless integration of people with computers within a physical environment. Typically furnished with networked pervasive computing devices and sensors, these rooms are designed to assist people in pursuit of everyday work goals such as finding information, collaboration with colleagues, and so on. Smart rooms are the subject of much research around the world, and a key enabler of smart rooms is the use of context awareness to link pervasive computing devices with users within their physical environment.

Context can be simply defined as *that which surrounds, and gives meaning to something else* [1]. Within a smart room, context is what gives the room its understanding of the user, the user's intention, the user's task, and the physical environment the user is situated within. In most mobile, wearable and ubiquitous computing application, knowing the user's location, absolutely, or relative to other parts of the environment is important for the seamless integration of people with pervasive computing devices within the physical environment [2].

Our interest in location modeling for context aware computing is within the intimate space of a smart room, or smart building. Previous work has attempted to devise location models for intimate environments. The Active Badge system developed at Olivetti research Laboratory [3] used small, active badges, worn by individuals to locate them within a building. The tags periodically emit a unique signal, which is picked up by a network of sensors around the building. This information is then feed into a location model, and used to locate individuals within the space. Xerox Parc's ParcTab [4] system uses a similar approach based on a handheld device called a ParcTab. The ParcTab provides location information as well as to access to networked devices. MIT's Hive project provides similar features for wearable devices, and combines location modeling with automatic integration of wearable devices with the computing devices present within the location [5].

While these applications go some of the way toward location modeling within an intimate environment, most don't capture the full complexity of the intimate environment. Also, for most of these applications, the location model is implicit, and unique to a particular application with limited utility outside of the application for which it was developed.

In this paper, we describe some of the complexity that must be captured in any model of a smart environment. We take the position that a location model within such an environment must be part of a wider framework for handling context that also includes information of people, devices and their communication abilities. We present an ontology based on a general object model of people and devices to deal with the complexity of location modeling in an intimate environment, and discusses how temporal events may be represented and reasoned with using modeling techniques based on time intervals.

2 Issues in Modeling a Smart Environment

Intimate locations are characterized by a very complex and densely populated terrain, which includes people, embedded computing devices, traditional computing devices, as well as furniture, white boards, room partitions and so on. In some cases, the intimate location may span several different rooms, or in extreme cases, several floors of a building. The goal of using a location model for an intimate environment is to determine the optimal way of making information available to a user, or receiving input from a user. For example, given the user current location and orientation in a room, which display device, fixed/mobile, visual/audio, with a particular capability, would be suitable for outputting information? This seemly simple question must take into account a wide variety of other factors. Can the user see the output device? Is there an office partition, or another person in the way? Given the proximity of other people, would an audio output be too disruptive?

The resolution of the location information needed within an intimate environment will need to be very fine, perhaps to the centimeter. Not only would the location need to be captured, but also the user's orientation within the room. Questions like, what display is the user currently looking at? Which input device would offer the user the most privacy? What devices can communicate to each other? Who are the occupants of a room? All need to be answered by the intimate environment location model.

Within the Defence domain, as well as some commercial domains, security of information is important. If information is being displayed on a screen that can be seen by someone not authorized to see it, the screen should be intelligent enough to turn off, or somehow hide the information. This requires the location model to be able to answer question about not only location and orientation, but relative location between classes of object, in this case a person, with a defined viewing range, and a screen within that visual range. In addition person attributes related to security clearances may need to be stored within the model.

As well as being populated by people, the intimate environment will also include different kinds of mobile devices, wearable devices, fix and semi-fixed interaction devices, displays, input devices, and so on. The characteristics, and the movement of these devices would also need to be captured by the location model. Over time, intimate environments change. Furniture is moved; interaction devices are added, moved or removed. The location model should be able to track these movements, and keep its representations current.

In the next section, we describe a location model of an intimate environment that is able to address many of these issues.

3 Location Model for an Intimate Environment

We argue that a simple position based location model isn't enough to capture the wide range of other location relevant information needed to provide location awareness within an intimate environment. Any location model for an intimate environment will need to include a considerable amount of other information directly related to the person's or the object's location. For example, this might include the visible range of a display device, or the distance over which audio output can be heard, or the range of a bluetooth connection needed for a mobile display and so on.

Rather than a location model, what is needed is a comprehensive *object* model that captures properties that describe the object within the context of the space in which it exists. For a smart room, these properties may include:

- Unique Identifier;
- Type Class;
- Current Location -- Position within the space;
- Means of Communication -- Visual, audio, bluetooth, touch, and so on, and
- Range of Communication -- Maximum effective range of device's input or output.

3.1 An Object Model for Location and Context Awareness

The information needed for the location model of a intimate environment could be captured in a class hierarchy, with each object in the environment -- people, fixed devices, mobile devices and so on -- simply being a specialization of some generic object. This is shown in Fig 1.

The attraction of this kind of structure is that additional levels of contextual information can be added as required (say to the *Person* entity). Composite objects that contain other objects -- such as rooms -- are accommodated within the model as a distinct object type.

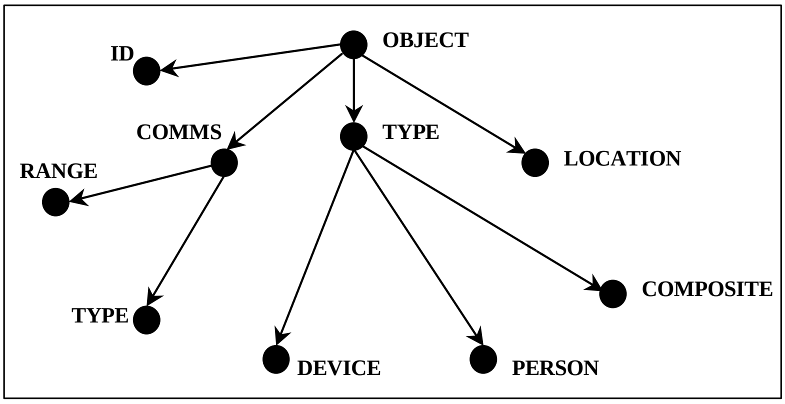

Fig 1. A simple object model for location awareness

Given the structure and additional information captured by the object model it becomes possible to address many of the complexities of the intimate space described in the previous section. These include:

- Proximity of objects within the space;
- Person-person proximity;
- Person-computer proximity, and
- Connective and communicative ability of objects -- which objects within the space can be connected to what other objects, given their current proximity.

It is quite likely that the environment may permit only partial knowledge of any particular object, so that the object model will at times not be fully populated or will contain out of date information. Hence it is important to choose a knowledge representation implementation technology that allows useful inferencing despite the uncertain and fluctuating nature of the environment.

3.2 Applications, Knowledge Representation and the Object Model

The approach taken in this paper concentrates on the development of an ontology for location and context awareness within an intimate environment. This contrasts with other approaches, such Dey et al [6], which adopt a *software infrastructure* for context-awareness approach. As discussed by Davis et al [7] commitment to an ontology forms the first step toward implementing this model within a knowledge representation technology. Our goal is to implement the ontology in a knowledge representation technology that allows for intelligent reasoning and that provides a medium for efficient computation of the location model. A semantic web representation, based on of Resource Description Framework (RDF)-encoded Uniform Resource Identifiers (URI), would provide a very general framework for making assertions and statements about data, and potentially allows re-use of the data by other programs and agents [8].

3.3 Temporal modeling

In handling a dynamic environment we need the model to support inferences on how objects have changed over time and predictions on how they may change in the future. In our object model many of the attributes will not change with time, while others may change rapidly. For example, a printer is unlikely to change location very often and its other attributes would be expected to be similarly static for long periods. In contrast a person walking through a building will have a dynamic location and his proximity to, and connectivity with, other objects will change rapidly with time.

Our approach to modeling time is based on two ideas: (i) Adopt a model of time that supports both intervals and instantaneous points, where points are modeled as a special case of a zero duration interval. This approach allows complex reasoning about temporal interval relationships and is consistent with the TSQL2 standard [9] (ii) Use an implementation of the object model in which time is stored as the key external contextualization of the underlying model, and that allows tractable computation over the model with respect to time.

Object models are stored with their associated valid temporal intervals in a database of the form shown in Table 1. These temporal periods define the time for which the object description was observed to be true. When the state of an object changes, say at time T_3, a new entry is made in the table showing the completion of the time interval bounded by T_2 where $T_2 < T_3$ and the difference between the two time points is one chronon (the smallest measurable unit of time within the system). T_3 then becomes the start time for a new interval. Each object is tracked over time in this way to permit the system to be interrogated for proximity and connectivity information.

Table 1. A database description of an object as it changes over time

Valid Time Interval	Object Model
$T_1 - T_2$	$O\ (T_1, T_2)$
$T_2 - T_3$	$O\ (T_2, T_3)$
$T_4 - \infty$	$O\ (T_4, \infty)$

Allen describes thirteen basic temporal relationships between two intervals [10]. Freksa [11] extended these relationships to describes semi-interval relationships where some endpoints are unknown. Semi-interval relationships allow reasoning with incomplete knowledge and also to generalize across a number of Allen's basic relationships. By recording the temporal intervals associated with each Object's properties we can use the taxonomies provided by Allen and Freksa as a basis for describing and reasoning about temporal behavior.

4 Conclusions

In this paper we have begun to outline some of the problems and requirements for modeling location in closed, densely populated, intimate environments. We argue that to capture many of the complexities of the intimate environment, a location model for objects must capture more than just location. It must deal with properties and temporal events that describe the context of the object and it's surroundings.

References

1. A. Schmidt, M. Beigl, and H. Gellersen, "There is More to Context than Location," *Computer & Graphics*, Vol. 23. (1999) 893-901
2. T. Selker and W. Burleson, "Context-aware Design and interaction in Computer Systems," *IBM Systems Journal*, Vol. 39. (2000) 880-891
3. Roy Want, Andy Hopper, Veronica Falcao & Jon Gibbons, "The active badge location system", *ACM Transactions on Office Information Systems (TOIS)* Vol. 10. No. 1. (1992) 91-102
4. R. Want, B. Schilit, N. Adams, R. Gold, D. Goldberg, K. Petersen, J. Ellis, and M. Weiser, "An overview of the PARCTAB ubiquitous computing experiment", *IEEE Personal Communications*, Vol. 2. No. 6. (1995) 28-43
5. B. J. Rhodes, N. Minar, and J. Weaver, "Wearable Computing Meets Ubiquitous Computing," In the *Proceedings of the Third International Symposium on Wearable Computers*, San Francisco, CA. (1999)
6. Dey, Anind K., Daniel Salber and Gregory D. Abowd. "A Context-based Infrastructure for Smart Environments". In the *Proceedings of the First International Workshop on Managing Interactions in Smart Environments (MANSE '99*), Dublin, Ireland. (1999) 114-128
7. Davis, R., Shrobe, H., and P. Szolovits "What is a Knowledge Representation?" *AI Magazine*. (1993) 17-33
8. T. Berners_lee, J. Hendler and O. Lassila, "The Semantic Web", *Scientific American*, May 2001.
9. Dyreson, C.E., Soo, M.D., and Snodgrass, R.T. "The TSQL2 Data Model for Time", In *TSQL2: A Design Approach*, Ed. Snodgrass, R.T. (1994)
10. J.F. Allen, "Maintaining knowledge about temporal intervals". In *Communications of the ACM*. Vol. 26, No. 11. (1983)
11. C. Freksa "Temporal reasoning based on semi-intervals". In *Artificial Intelligence* Vol. 54. (1992)