Chapter 31
Resolving and Mediating Ambiguous Contexts in Pervasive Environments

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ABSTRACT

Pervasive computing applications envision sensor rich computing and networking environments that can capture various types of contexts of inhabitants of the environment, such as their locations, activities, vital signs, and environmental measures. Such context information is useful in a variety of applications, for example to manage health information to promote independent living in "aging-in-place" scenarios. In reality, both sensed and interpreted contexts are often ambiguous, leading to potentially dangerous decisions if not properly handled. Thus, a significant challenge facing the development of realistic and deployable context-aware services for pervasive computing applications is the ability to deal with these ambiguous contexts. In this chapter, the authors discuss a resource optimized quality assured ontology-driven context mediation framework for resource constrained sensor networks based on efficient context-aware data fusion and information theoretic sensor parameter selection for optimal state estimation. It has the ability to represent contexts according to the applications' ontology and easily composable ontological rules to mediate ambiguous contexts.

INTRODUCTION

Recent research in smart environments offers promising solutions to the increasing needs of pervasive computing applications; our work has demonstrated the use of such environments to support the elderly in home based healthcare applications (Roy, Julien, & Das, 2009; Roy, N., Roy, A., & Das, 2006). Essential to such applications is human-centric computing and communication, where computers and devices adapt to users' needs and preferences.

We focus on the computational aspect of user-centric data to provide context-aware services; we demonstrate this through an application for intelligent independent living. Given the expected availability of multiple sensors of different types, we view context determination as an estimation problem over multiple sensor data streams. Though sensing is becoming increasingly cost-effective and ubiquitous, the interpretation of sensed data as context is still imperfect and ambiguous. Therefore, a critical challenge facing the development of realistic and deployable context-aware services is the ability to handle ambiguous contexts. The conversion of raw data into high-level context information requires processing data collected from heterogeneous distributed sensors through filtering, transformation, and even aggregation, with a goal to minimize the ambiguity of the derived contexts. This context processing could involve simple filtering based on a value match, or sophisticated data correlation, data fusion or information theoretic reasoning techniques. Only with reasonably accurate context(s) can applications be confident to make high quality adaptive decisions. Contexts may also include various aspects of relevant information; they may be instantaneous or durative, ambiguous or unambiguous. Thus, the mapping from sensory output to the context information is non-trivial. We believe context-aware mediation plays a critical role in improving the accuracy of the derived contexts by reducing their ambiguity, although the exact fusion or reasoning technique to use is application and domain specific.

RELATED WORK

Pervasive computing applications, such as the Aware Home (Orr & Abowd, 2000), Intelligent Room (Coen, 1999) and House_n (Intille, 2006), do not provide explicit reusable support for users to manage uncertainty in the sensed data and its interpretation and thereby assume that sensed contexts are unambiguous. Toolkits enable the integration of context into applications (Dey, Salber & Abowd, 2001), however, they do not provide mechanisms for sensor fusion or reasoning about contexts' ambiguity. Although other work has proposed mechanisms for reasoning about contexts (Vurgun, Philpose & Pavel, 2007), it does not provide well-defined context-aware data fusion models nor address the challenges associated with context ambiguity. Distributed mediation of ambiguous contexts in aware environments (Dey, Mankoff, Abowd & Carter, 2002) has, however, been used to allow the user to correct ambiguity in the sensed input.

Middleware has also effectively supported context-aware applications in the presence of resource constraints (e.g., sensor networks), considering requirements for sensory data or information fusion (Alex, Kumar & Shirazi, 2005). DFuse (Kumar, Wolenetz, Agarwalla, Shin, Hutto, Paul & Ramachandran et al., 2003) facilitates dynamic transfer of application level information into the network to save power by dynamically determining the cost of using the network. In adaptive middleware for context-aware applications in smart homes (Huebscher & McCann, 2004), the application's quality of context (QoC) requirements are matched with the QoC attributes of the sensors through a utility function. Similarly, in MiLAN (Heinzelman, Murphy, Carvalho & Perillo, 2004), applications' quality of service (QoS) requirements are matched with the QoS provided by the sensor network. However, the QoS requirements of the applications and available from the sensors are assumed to be predetermined and known in advance. In pervasive computing environments, the nature (number, types and cost

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