Chapter 15
An Ontology-Based Context-Aware Infrastructure for Smart Homes

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ABSTRACT
A general infrastructure that can facilitate the development of context-aware applications in smart homes is proposed. Unlike previous systems, our system builds on semantic web technologies, and it particularly concerns the contexts from human-artifact interaction. A multi-levels’ design of our ontology (called SS-ONT) makes it possible to realize context sharing and end-user-oriented customization. Using this infrastructure as a basis, we address some of the principles involved in performing context querying and context reasoning. The performance of our system is evaluated through a series of experiments.

INTRODUCTION
Computing is moving from traditional computers towards everyday artifacts (e.g., appliances, furniture, cups) to make them “smart” and “intelligent”. By making use of the perceived contexts, smart artifacts can support a variety of human-centric applications. This paper proposes a general infrastructure which can ease the developers’ efforts in building context-aware systems.

Designing and developing context-aware applications in smart environments have been drawing much attention from researchers in the recent years. However, context-aware services
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have never been widely available to home users. Recent research results show that building and maintaining context-aware systems is still a complex and time-consuming task due to the lack of an adequate infrastructure support. We believe that such an infrastructure requires the following supports:

• A formal context model that can facilitate context sharing and reuse among different smart environments and context-aware services. Raw context data obtained from various sources comes in heterogeneous formats, and applications that do not have prior knowledge of the context representation cannot use the data directly. Therefore, a single method for explicitly representing context semantics is crucial for sharing common understandings among independently developed context-aware systems. A unified knowledge-representation scheme also makes it easy to implement knowledge-reuse operations, such as extending or merging existing context definitions. Without such a common context model, most context-aware systems have to be written from scratch at a high cost.

• It can easily integrate with generic reasoning and querying engines. Context reasoning is a key aspect of context-aware systems because high-level contexts (e.g., is there anyone near the book? what is the person doing?) cannot be directly provided by low-level sensor contexts (e.g., the lighting level of a room, the 3D coordinate data of a book). On the contrary, they have to be derived by reasoning. A context querying engine is also important for context-aware systems, which allows applications to selectively access the contexts they concern by writing expressive queries.

• It can be easily customized by users from different families. As a platform that is intended to work for users from different families, the knowledge infrastructure should be “sharable” and “easily-customizable”, because different families usually have different domestic settings, daily routines, and user considerations.

To facilitate rapid prototyping of context-aware applications, we proposed a new system infrastructure called Sixth-Sense. Unlike similar studies that mainly use ad-hoc data structures to represent contexts, Sixth-Sense explores the Semantic Web (Berners-Lee, Hendler, & Lassila, 2001) technology to define a common ontology that can assist the development of context-aware systems. The Sixth-Sense Ontology (SS-ONT), expressed by the Semantic Web language OWL (Web Ontology Language) (Smith, Welty, & McGuinness, 2003), reflects portion of contexts that typically exist in smart home environments, such as sensors, locations, smart objects, humans, as well as interactions between humans and objects.

Benefiting from the hierarchical definition structure and semantic sharing natures of the ontology, SS-ONT enables home-knowledge sharing and customization among different families. By exploring this formal context modeling method, Sixth-Sense also integrates several standardized approaches and tools that support expressive querying and reasoning of defined facts and contexts. In a word, the Sixth-Sense infrastructure builds a good foundation to support the development of a wide variety of context-aware applications in smart home environments. A series of experiments have been conducted to evaluate the performance as well as the effectiveness of our knowledge infrastructure.

In the following sections, we will firstly give a brief survey on existing context modeling methods, and then describe how to explicitly represent contexts by using the Semantic Web language – OWL. Readers can also learn about the methods on ontology-based context querying and reasoning from this chapter. Samples demonstrating how to use this infrastructure to quickly create context-aware applications are also presented.