Semantic Gadgets: Device and Information Interoperability

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1 Introduction

Ubiquitous computing is an emerging paradigm for personal computing and communications [6]. Characteristic of ubiquitous computing – and qualitatively different from current personal computing scenarios – is the proliferation of devices that need to be connected: today's user connects his PC to a handful of other devices (printers, network gateways, etc.) and these connections are fairly static, but we anticipate ubiquitous computing scenarios to involve dozens, if not hundreds of devices (sensors, external input and output devices, remotely controlled appliances, etc.); furthermore, with the advent of mobility and associated proximity networking, the set of connected devices will constantly change as the usage context changes and as devices come into and leave the range of the user's ubiquitous computing device(s).

We present a vision for a class of devices, dubbed "Semantic Gadgets" [4], that will not only be able to function in tomorrow's ubiquitous computing environment, but will combine functions of several devices users have today. In addition, these devices will be able to assist users in ways that elude today's PDAs, mobile phones, and like. Characteristic of Semantic Gadgets is not only their ability to automatically configure themselves in new environments, but also their ability to combine information and functionality from local and remote sources. We will discuss the enabling technologies necessary for realizing Semantic Gadgets.

2 Functionality as Services

A key technology of true ad hoc networks is service discovery. By this we mean functionality by which "services" (i.e., functions offered by various devices on an ad hoc network) can be described, advertised, and discovered by others. Several frameworks and formalisms for service discovery and capability description have already emerged. All of the current service discovery and capability description mechanisms, however, are based on *ad hoc* representation schemes and rely heavily on standardization (i.e., on *a priori* identification of all those things one would want to communicate or discuss).

Semantic Gadgets should be capable of semantic discovery and device coalition formation: the goal should be to accomplish discovery and configuration of new devices without "a human in the loop." In other words, the ultimate objective is the discovery and utilization of services by other automated systems without human guidance or intervention, thus enabling the automatic formation of device coalitions through this

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mechanism. Various Artificial Intelligence technologies, particularly from the area of Knowledge Representation (KR) will be useful and necessary to build "richer" discovery mechanisms. Given that we are dealing with networked devices and distributed software systems, the notion of the *Semantic Web* [2] fits well in this context. Specifically, the emerging DAML-S framework [1] for semantic description of web services will prove useful: virtual and physical functions can be abstracted as web services, providing a uniform view to all different kinds of functionality.

Avoiding *a priori* commitments about how devices are to be connected will improve interoperability and thus will make dynamic, unchoreographed ubiquitous computing scenarios more realistic. The true fulfillment of the vision for ubiquitous computing has a promise of serendipity [3] in it that can hardly be realized without discovery mechanisms that are qualitatively stronger than the current practice.

3 Information Interoperability

The Semantic Web also offers a means of higher degree of interoperability for information: since many ubiquitous computing scenarios involve management of user's personal information (such as PIM information), the ability to flexibly take advantage of discovered information sources will be paramount. Semantic Web techniques, through the introduction of ontological reasoning, are suitable for flexibly discovering abilities in using information that wasn't specifically designed or intended for a particular use case.

4 Multimodal Interfaces

While the goal is for device discovery to take place without a human in the loop, these devices are still there to serve the needs of us humans. As devices include more sensors such as video cameras and microphones; better connectivity through Bluetooth, and other wireless networking (GPRS, WiFi); and improved computing resources including memory and CPU, different user interfaces become more practical.

The ultimate motivation for speech interfaces is that handheld mobile devices are often used in situations where the user is "attention constrained" (e.g., driving a car and unable to take eyes off the road). Mobile phones have had simple voice dialing for years that uses local signal processing to distinguish several "voice tags". Voice commands are now practical to allow hands-free operations for most phone functions. Additionally, text-to-speech (TTS) allows for access to information without looking at the screen.

At Nokia we have also experimented with using a camera to select an object in a room and get information about that object [5]. This real world "point and click" mechanism provides a simple interface to the human user, but relies on the existence of a Semantic Gadget framework for its success. Before an image of an object can be recognized, this object must register a description of its appearance, location, and any other associated information with a registry service. The Semantic Gadget must discover this registry and associated information before such an interface can be successful.

5 Learning Users' Behavior

Entering one's preferences for a variety of topics is time-consuming and provides little value to the user at the time of entry. The effort required exceeds the perceived value. A better approach is to "observe" the users behavior in context, and use machine learning techniques to acquire and/or adjust the information in the user's profile. This may be applied to accessing services, selecting movies, restaurants, shows, etc. The result of learning user's preferences, habits, etc. can also give rise to rich knowledge representation to be shared with other devices, agents, and users.

As Semantic Gadgets are used as remote controls for an increasing variety of devices in the home and office, there is the opportunity to learn sequences of operations that a user performs repeatedly. Such control macros simplify the sequence of steps one must perform. Using a rich and expressive form of knowledge representation such as DAML-S provides the basis for supplying enough context information to support such applications. Combining local control functions (such as controlling one's TV) with remote and virtual services (such as a machine-interpretable version of the TV Guide) can yield useful applications to the user (the spoken command "I would like to watch Sesame Street" should result in the TV tuned directly to the channel broadcasting this program).

6 Conclusions

It is our belief that the idea of Semantic Gadgets represents a useful amalgamation of communication devices with PDAs and home appliances. Critical to the success of this idea is the existence or emergence of certain infrastructures, such as the World Wide Web as a ubiquitous source of information and services, the Semantic Web as a more machine- and automation-friendly form of the Web.

Ultimately the Semantic Gadgets are about device and information interoperability. The serendipity of combining many sources of information, services and functionality will be the ultimate benefit to the user.

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