Design and Evaluation of a Ubiquitous Computing Application for Law Enforcement †

Andrew L. Kun[1], W. Thomas Miller, III[1], Peter A. Heeman[2]

[1] Electrical and Computer Engineering Department, University of New Hampshire
[2] Center for Spoken Language Understanding, Oregon Health & Science University
[1] {andrew.kun, tom.miller}@unh.edu [2] heeman@cslu.ogi.edu

Abstract. We present approaches we have taken in designing a ubiquitous computing application. We propose several metrics that can be used to evaluate this application and other existing and potential applications.

Integrating devices in police cruisers

In his article "The computer for the 21st century", Mark Weiser describes a world where ubiquitous computers blend into the background [1]. Humans rely on information streaming between these computers and they interact with them effortlessly. Our world of course is very different from the world of Weiser's vision – our computers often cannot share data and we often need extensive training to be able to interact with them. Work at the University of New Hampshire has made the inside of a police cruiser look more like the world in Weiser's article [2]. We designed a system (called Project54) that integrates in-car devices into a single, voice-controlled system where all devices can talk to each other, as well as to remote computers, to share data. The system also provides an elegant speech user interface that is easy to learn and easy to use in the hands-busy, eyes-busy environment of the police cruiser. The system is deployed in about 300 police cruisers in the US.

Approaches taken and metrics for assessing results

In creating and deploying the Project54 system, we solved some (and identified other) device interfacing problems and speech user interface problems. We also created a system that serves as an example of how useful ubiquitous computing can be.

Device interfacing

We have integrated electronic devices using the CAN 2B standard for hardware interconnections and the Microsoft COM standard for software modules (these control individual devices). We feel that adopting open standards is what makes affordable

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ubiquitous computing possible. Without open standards, ubiquitous computing would rely on proprietary solutions or on intelligent software and hardware that learns how to communicate with other devices. While the latter may become a long term solution, it is not practical or cost effective today. Proprietary solutions limit access to know-how to certain organizations and geographic regions and thus preclude the development of ubiquitous computing systems that span multiple domains and locations.

What standards should one adopt? Standards change and the system may use more than one standard for a certain type of activity. To prepare for modifying or adding standards, the system software and hardware should be modular. The Project54 system is modular. For example, it has a module for communicating with handheld devices that uses the 802.11b standard and another module for communicating with remote servers using the Project 25 digital radio standard.

Four measures of the success of device interfacing efforts are:

- **Do the hardware and software of the system follow open standards?** We adopted and extended existing standards. Our extensions are freely available.
- **How many domains do the interfaced devices cover?** The domain of our system is law enforcement. However, we are working on interfacing devices for home automation, which would add another domain.
- **How many activities within a domain do the interfaced devices cover?** The types of devices (each type covering an activity) we integrated within cruisers are: lights and sirens, radios, radars, GPS devices, barcode scanners, video systems and database software.
- **How many different devices have been enabled for integration into the system?** We enabled over 30 devices for integration into the Project54 system.

Speech user interface

The in-car environment is an eyes-busy, hands-busy environment. While driving, officers often use our system's speech user interface (SUI). A GUI is also available, as well as the original user interfaces of the devices. The SUI uses a press-to-talk button, a directional microphone, a commercial recognizer and text-to-speech engine and a set of grammar files. Grammar files prescribe the form of valid user utterances.

The next generation of SUIs should support multi-threaded dialogues in order to allow concurrent interaction with multiple devices or programs in ubiquitous computing applications. The SUI will need to support interruptions and resumptions of individual spoken interactions. To discover what conventions are natural for people to use, we are running experiments in which pairs of subjects need to complete multiple tasks at the same time, and where the tasks require the two subjects to converse [3]. These studies are inspiring our approaches to developing the new SUI.

Four measures of the success of a SUI implementation are:

- **Is the SUI being used?** We completed a field study of the Project54 SUI and found that officers in the field do use it for certain tasks.
- **What is the SUI recognition rate?** Our field study showed that the average SUI recognition rate is 85%.
- **How much training does using the SUI require?** Officers are trained to use the Project54 system, including our SUI, during one 2-3 hour training session.
- **Does the SUI allow natural speech?** Officers learn set phrases for each application.

The effect of a successful example

For the hundreds of people who use our system, ubiquitous computing is an everyday reality. This success created a pool of sophisticated users who expect electronic devices to perform in a ubiquitous computing environment. In the public safety domain, this has created pressures on industry to adopt standards that will promote ubiquitous computing applications. It also created interest for similar efforts in other domains. For example, our work on police cruisers sparked the interest of firefighters, freight train engine operators and one major US auto manufacturer.

Three measures of how an application can be expected to promote ubiquitous computing research, development and deployment are:

- **How many related domains are there for the application?** Our application domain is law enforcement. Related domains are, in general, domains in which humans interact with multiple devices in hands-busy, eyes-busy environments (e.g. other emergency response applications, human extra-vehicular activities in space, some home automation applications).
- **How many industrial partners are involved in creating the applications?** The Project54 effort has about ten major industrial partners. None of these support the effort financially but collaborate on development and deployment.
- **How many people use the application?** The Project54 system is used by over 500 officers in the field (many of the over 300 deployed cruisers are used by more than one officer) and is being adopted by police agencies throughout the US.

Selecting applications for ubiquitous computing research

We expect that successful ubiquitous computing applications will use open standards and modular software and hardware. If the user is involved in eyes-busy, hands-busy tasks, speech user interfaces will play an important role. Industry participation in the development process is important because of the promise of explosive deployment. Industry participation is more likely if there is existing interest from potential customers and if the application has multiple related domains of use. Starting with these ideas we propose metrics for evaluating the Project54 system. These metrics can be used to evaluate and compare existing ubiquitous computing applications. They can also be used to systematically evaluate potential applications. We can assess the ranges in which we expect the answers to be, once an application is complete, and use these assessments to evaluate the prospects for success of the application.

References

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