Creating new business opportunities through Ubiquitous Computing

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We have been liberated from the desktop. As mobile and embedded computing systems increasingly pervade environments, more and more information and content is available throughout our daily surroundings. Sometimes we proactively seek that information – via our laptops or MP3 players or smart phones. Other times, the information is offered automatically, through GPS systems, for example, or sensor-triggered signage.

These pervasive appliances and applications offer new sets of technical and business challenges – along with ubiquitous and fascinating opportunities for innovation, especially in the areas of managing information overload, making computing environments transparent to users, and enabling mobile and ambient devices to serve as intelligent interfaces to our physical surroundings.

Information environments shaped by user intent and context, where content is not “king”

As digital devices and systems proliferate, it is vital to address human needs first and foremost—rather than consider the technology first and then look for a problem that the technology might solve.

These days, people increasingly try to multi-task by juggling the simultaneous use of communications and PDA devices, entertainment gear, home appliances, and even transportation systems. Yet these entities generally do not interact in meaningful ways with each other for the purpose of responding to the user’s tacit needs. The performance of high-tech gear is a specific reaction to the user’s precise input commands, delivering or referencing the content accessible by only that particular device.

However, when we consider the opportunities to equip these systems with sensing capabilities, effortless user interaction, and interconnectivity capabilities, we can envision ways in which they can automatically perform for us within the context of the activities in which we are engaged and the behavior that characterizes our unique personal needs.

By observing the physical environment in which the system is in use, and by recording and analyzing user behavior, intent-aware and context-aware systems can detect people’s intentions without requiring complex, real time, manual interactions. A system that can infer a user’s intention can deliver information in anticipation of the user’s expressed need for that material—able to proactively deliver services and information to transform the ways in which we live, play, and work.

As sensors become less expensive and easier to connect to the Internet, they can give computing technologies “eyes” and “ears” to make sense of the physical world. Orwellian as that may sound, myriad benefits appear possible: from the simple convenience of letting devices handle mundane tasks (media playback, shopping) to the availability of applications that assist mentally and physically challenged people...
that enable more efficient consumption of energy resources … that coordinate safety and rescue efforts… or that provide tighter physical and virtual security.

Intent-aware computing is about developing, evaluating, and improving the user experiences, systems, technologies, protocols, and algorithms, to make these and other applications possible and profitable.

Core issues to address

As digital devices increasingly show up in our daily activities, user interaction models are failing to deliver consistently optimum experiences. Most user interfaces are designed by engineers, not social scientists, cognitive scientists or interaction designers. These exquisitely engineered products boast myriad functions (“feature-itis”) and extensive access to functions. The trade-off is in the user experience. Multi-taskers struggle to operate two or three systems at once, or while accessing data and simultaneously engaging in another activity. Or consider the handheld device user, who doesn’t want to concentrate on the product. Feature-itis demands user attention. Adding insult to injury, the handy devices have limited display size and input capabilities.

Herein we find myriad opportunities for intelligent, adaptive user interfaces and systems that “know” what people want and how to deliver it to them in seamless, effortless ways.

Another issue arises from the emergence of sensing technologies, which are part of the foundation for intent-aware computing. The marketplace is poised to present unprecedented demand for data sources and data exchange. Until mobile information services are truly pervasive, how do we provide the data necessary within a geographical region to deliver vast stores of meaningful information to users based on user behavior and environment? This issue requires addressing media device and system interoperability and data exchange.

When considering the widespread use of sensor networks and devices that track user behavior, we face the challenge of how to simplify operations and ensure security at the same time. Privacy and security concerns can prevent widespread adoption of mobile tools, so they must be addressed in conjunction with the other issues.

Transforming the approach

Previous commercial attempts at adaptive user interfaces have informed the current marketplace and technological approaches. Today it is relatively easy to identify, for example, the reasons for the poor business performance of Microsoft’s 1995 “Microsoft Bob,” positioned as a one-size-fits-all, user-friendly interface for Microsoft Windows. In a retrospective assessment 11 years later, PC World editor in chief Harry McCracken critiqued, “It seems to be aimed at a six-year-old.” Microsoft Bob was introduced when the World Wide Web started gaining global acceptance, yet Bob offered no web-related functionality.
Part of the problem inherent in this and other attempts at developing adaptive interfaces, both past and current, is that the developers address the problem—and the marketplace—from a technology perspective (“what is possible to achieve?”). A more effective method to initiate innovation involves asking the question:

“What do people want to be able to do?”

Then, the responses are best evaluated within the context of the market, the technology, and the network infrastructure.

And naturally, today, unlike in Microsoft Bob’s day, Internet technologies figure prominently in efforts to integrate computing systems within intent-aware and context-aware market opportunities—such as information retrieval, interactive advertising, and emerging electronic communication and social media techniques.

**Sweet spots for commercialization**

With a unique, industry-savvy social science perspective and computational science legacy, PARC is exploring ways for users to more easily understand, configure, and control complex environments composed of devices and services designed without the intention of interoperating. This requires bridging between physical and digital domains.

Our ultimate goal is to enable seamless interaction with pervasive systems that deliver seamless performance. Beneficial things would just “happen” for people, thanks to the sensing, computing technologies on us, near us, or surrounding us.

Toward this end, PARC takes a unique multidisciplinary approach to identifying game-changing challenges in the industry that we can solve today. We have identified ways to apply emerging and converging technologies, designing novel techniques for uses ranging from task management to location-based services. Our ubiquitous computing work involves four broad, interdependent innovation areas:

1. **Anticipation of human needs: Behavior, Activity, & Intent-Aware Systems**

   To deliver information based on inferring particular user activity, our research shows the effectiveness of modeling user behavior by employing and aggregating a range of electronic data sources such as keyboard use, calendar items, email, and web use, physical data sources, including location, date, time, sound, motion, vision, previous behavior, and historical data sources (diary entries describing activities).

   Intent-aware computing adds value only when used to infer the user’s *ultimate* goal. One implementation of this approach is in a retail setting where signage displays dynamic animation – driven in part by sensor technology enabling it to respond to a shopper’s eye gaze to infer and present relevant content.
Presently, most advanced sensor devices are deployed for industrial control, environmental monitoring, and security applications. PARC has developed a system that enables wireless sensors to interoperate using optimal processing and messaging formats that conserve the sensor’s limited battery power. This approach forms the foundation for intent-aware computing, a new area that integrates research from several disciplines: ubiquitous computing, artificial intelligence, human-computer interaction, psychology, anthropology, and specialized subfields of these areas.

Intent-aware technologies have broad implications for the future of how businesses relate to consumers. How do people behave and use a company’s products? What are the best ways for making recommendations or prompting a person to take action? Having that class of information has great power for any organization—and acting on it could fundamentally alter the customer-vendor relationship, as well as an organization’s operations.

Once sensors automatically infer a consumer’s activities, and transmit this information to the consumer’s social network, vendors and providers (and their competitors) must be ready and open to change and adapt to new markets for information, new capabilities and applications, and previously unimagined enhancements to existing technologies.

Companies that hold intellectual property in this area will be rewarded significantly.

(2) **Reduction of barriers: Data & Device Infrastructure**

In today’s marketplace, open standards define the media formats and encodings used across manufacturers, and are necessary to provide consumers with the freedom to choose among compatible devices. However, standards such as Bluetooth, ZigBee, Universal Plug and Play (UPnP), and the Digital Living Network Alliance, all require time-consuming negotiation. They also fail to accommodate unforeseen technical advances.

PARC is able to address the need for universal interconnectivity by building upon the Objé™ Interoperability Framework: a radical new way to design devices and services to easily interoperate and provide coherent user-interaction experiences. We built our wireless sensor network, for example, on Objé, which combines mobile code and “meta-interfaces” in an open solution for development.

The Objé framework also provides mechanisms to deliver the right interfaces to the user at the right time to enable control of many types of devices. For example, Objé can dynamically send content from a media source (TV, cable box, media server, etc.) to a player (display, speakers, printer). The framework provides a flexible security mechanism for safe interconnection of trusted and untrusted devices and services, all under the user’s direct control.

By enabling fast time-to-market for new media formats and encodings, Objé offers a way to transform the market for digital devices. Consumers can remain confident that
their current and future electronic products will work together. Manufacturers can more freely introduce innovative devices and networking options. Reliable interoperability allows consumers to make unexpected connections between devices, creating a network effect as more and more interoperating devices create new value for the user.

(3) Greater individual control of environments: Lightweight, Fluid & Dynamic User Interaction Techniques

The quest for easy user interaction is being addressed by focusing on end-user control of information environments. Our fundamental goal is to seamlessly interact with many public and shared devices, delivering Internet and location-based data and services, with ease and immediacy. Users must be able to quickly and effortlessly make the connections needed to receive the desired services and information.

Emphasizing mobile and wearable interaction techniques, PARC invents systems and techniques to improve users’ ability to seamlessly interact with digital information while engaging in other activities. We are interested in diverse approaches and devices to solve these problems; recently we have investigated several techniques.

In one approach, PARC developed the OSCAR user interface, and designed and built a handheld- and tablet-based prototype (simultaneously demonstrating the ease of composing and configuring devices using the Objé platform). Analogous to a universal remote controller for media devices, OSCAR is a universal connector, allowing people to easily define connections between devices and services in our increasingly wirelessly networked homes. We have conducted iterative user studies to improve and refine OSCAR, and to ensure that non-technical users can use OSCAR to compose and control various devices for managing a wide range of tasks.

Two other, recent PARC innovations in user interaction design are the Paradiddle text-entry technique and the Wrist Top UI form factor for wearable computing.

The “Paradiddle” technique lets users enter text on virtually any surface—such as touch-sensitive surfaces embedded in devices, clothing, furniture, vehicles, or buildings. It is device-independent, extremely flexible and adaptable; you make sequential finger taps to enter text. This approach builds upon our understanding that certain wearable technologies will make it possible to create quick text entries via any sufficiently solid surface.

PARC built a prototype of the wrist-mounted “Wrist Top” display that provides easy access to information; it is outfitted with sensors that allow users to interact with information and applications by moving and rotating their arms.

(4) Ubiquitous personal SECURITY and PRIVACY

Businesses interested in deploying context- or intent-aware technologies usually understand the potential for some customers to perceive activity detection as
invasive. Not everyone expresses enthusiasm for “smart” devices that learn and adapt to one’s personal preferences. Consumers will demand control over the process of notification regarding their personal lives.

PARC’s computer scientists, cryptographers, and sociologists are determining ways to inform users about how the information about them is being applied, and techniques for users to directly and transparently manage their exposure. Our approach, for example, equips systems to automatically detect privacy risks to prevent identity fraud. Our researchers emphasize in-network data processing, simplified and scaleable programming, and practical yet robust approaches to security and privacy.

There are four tiers of “smart” ubiquitous systems. At each level, different classes of applications are possible to automatically serve the user’s goals and desires.

Context-aware systems detect the location, time, nearby people and other aspects of a person’s physical environment. Context-aware systems enable applications that are triggered by context, regardless of individual behavior patterns. Examples:

- Motion-sensing light switch
- Storage of data indexed by context
- Location-based services
- Selecting nearest printer
- Sharing situation awareness with others

Behavior-aware systems model the patterns of a person’s actions in different contexts. “Behavior” can be conscious or unconscious, overt or covert, and voluntary or involuntary such as typing, walking, standing, holding, turning, clicking, etc. Behavior-aware systems enable applications that infer, and potentially respond to, present behavior without necessarily understanding the user’s conscious activity or intent. Examples:

- Consumer observation
- Security monitoring
- “Contextual” reminders
- Contextual learning

Activity-aware systems model the person’s activity from observations of context and behavior patterns. In contrast to “behavior” where a person’s actions are not necessarily consciously made, “Activity” is a conscious, voluntary pursuit, such as “shopping for clothes,” “writing a report,” “searching for an answer,” “explaining a solution,” etc.

- Interruptibility modeling
- Pro-active information delivery
- Mobile information recommendation
- Health monitoring
- Elder care
- Activity-targeted Advertising

Intent-aware systems have insight into the user’s current state of mind, possibly inferred from context, behavior and activity models. Intent-aware systems sufficiently predict future behavior to have value in the present. Examples include planning systems (travel routes, task plans, etc.).
Creating opportunities with emerging technologies

How might an individual's activities establish a context for targeted, responsive, promotional messages? PARC is exploring responsive media technologies as a platform for modeling sequential interactions and behaviors between buyers and sellers. Responsive media use computer-initiated interactions with retail shoppers to attract, detect, and maintain customer engagement with products or messages. Content segments play at specific points in the standard cycle of interactions between buyers and sellers; the system infers and predicts the shopper's intentions.

To explore opportunities for responsive media in the buying and selling of clothes, and also to explore potential responsive media design requirements in the “bricks and mortar” retail setting, PARC recently designed and built a complete prototype installation, the Responsive Mirror, an interactive, fashion recommendation system.

The Responsive Mirror is an implicitly controlled video technology for clothes fitting rooms. Watching his reflection in an apparently conventional mirror, a shopper may directly compare a garment he’s trying on adjacent to an image display of photos of himself wearing the garments he previously tried on. In both his live reflection and the photographs of his previous outfits, his physical poses match. The system also allows live, side-by-side comparison to fashions popular with friends in the shopper’s social network. PARC’s user study elicited a number of design challenges and tradeoffs that designers of such technologies must consider regarding privacy, adoption, benefits to shoppers and merchants and user behaviors in fitting rooms.

When a person interacts with a fitting room mirror, he provides implicit cues about the information he seeks. When he turns his body, he is observing how the clothes look from a different angle. Sensors can be used to detect this implicit information-seeking behavior, and supplemental information can be provided. Shoppers need not be taught how to use the system – they behave naturally.

Kyoko is a 22-year-old woman shopping for blouses in a small clothing store. She browses the rack of recent arrivals for tops in her size, takes a selection into the changing room, and puts them on, one at a time. Each time, she exits the changing room and stands in front of the mirror, turning to view the blouse from multiple angles.

Kyoko notices the two, large, flat-screen displays, one on either side of the mirror (although she doesn’t immediately notice the small video camera mounted atop the mirror, aimed directly at her). One screen shows Kyoko wearing each previously worn blouse. As Kyoko turns to view her blouse from multiple angles, the changing images of her in the previous blouse match her poses as she moves around to compare the fit and style from each angle of view: front, left, right, and back.
The results of this research contribute to our understanding of the potential impact of ubiquitous computing technology in the domain of physical shopping.

In another project, inspired by the popularity of online advertising based on the context of users typing keywords into a search engine, our scientists have noted that targeting mechanisms for ubiquitous computing environments lack analogous approaches. Moreover, none of the current, interactive electronic advertising systems explicitly models a consumer’s abstract activity.

In this study, PARC has applied activity detection to targeted advertising. To research data collection issues, behavior pattern-capture, product requirements, and potential market value, we developed the Proactive Experience Sampling Tool. We deployed mobile phones to monitor subjects engaged in certain activities to enable the presentation of messages at the time they would make maximum impact. We defined and evaluated a proposed architecture and its implementation, using two mechanisms to link activity descriptions with ad content: direct keyword matching using an online advertising service, and “human computation” matching, which enhances keyword matching with help from online workers. Early research findings show that people consider advertisements related to certain types of current activity to be more relevant and more useful than non-targeted advertisements.

In the near future, activity detection will achieve sufficient accuracy rates to enable many new applications, including highly targeted advertising. Combined with location-based service delivery, PARC envisions a rapidly growing market with many avenues of opportunity.

**Tailoring client services to business models & market analysis**

Many research institutions are investigating these areas, focusing on component discovery. PARC’s approach, though, is to apply foundational scientific understanding to the implementation of new techniques within entire systems, while maintaining laser-sharp focus on leveraging our clients’ business models and strategic strengths.

For example, Fujitsu, Ltd., has embraced the need to develop and deliver solutions for the “ubiquitous network society.” Fujitsu turned to PARC to help define a new, long-range business plan, and to conceptualize and create opportunities for mobile information and communications technologies.

As part of this open innovation endeavor, several PARC researchers work on site at Fujitsu’s Tokyo headquarters, collaborating with internal research, development, and product organizations. The Fujitsu-PARC collaboration centers on three broad themes:

1) “Near Zero Administration” for networks: Fujitsu uses PARC’s Public Key Infrastructure technology to improve usability, automate installation and
setup, strengthen ID and password functions, and support VPN application maintenance.

2) “Recombinant Computing” enables Fujitsu to connect different system devices through peer-to-peer services, allowing both to take advantage of previously unseen networked resources—and to interoperate fluidly.

3) Large-Scale Sensor Networks (to be deployed in large public places) optimize interactions among different types of sensors to reduce and optimize network bandwidth and battery consumption.

PARC innovations are now being implemented within Fujitsu product lines to enhance Fujitsu’s offerings in home, retail, and health care.

Creating new business for DNP: Location-based, Mobile Recommender Services

PARC’s activity detection technologies have been integrated within a mobile recommender system codenamed “Magitti,” in collaboration with Japan-based Dai Nippon Printing Company, Ltd. DNP is one of the world’s largest business service and commercial printing companies. A team of PARC social scientists, computer scientists, cognitive scientists, and linguistic scientists joined forces with DNP to collaborate in the identification of a new market and the invention of new media applications for handheld phones equipped with GPS and touch-screens.

Our work with DNP focused on developing mobile techniques and systems to find and filter leisure activities based on the device owner’s personal interest and preferences, geographical location, and relevance of data about vendors and their offerings, hours, and pricing.

PARC conducted initial analysis and subsequent development and in situ evaluation of a conceptual prototype in Japan. Feedback from prospective users has enabled PARC to further develop the Magitti prototype into a unique technology concept with an exceptionally easy-to-use, one-handed interface. The compelling platform portends a promising future for contextual service delivery.
The PARC Difference

The user-centric approaches explained here are much investigated in the academic milieu. At PARC, we have moved well beyond investigation to:

• Identification of technologies with the greatest commercial value;
• Design of infrastructures and prototypes that simplify construction of “aware” systems;
• Development of techniques to comprehend and use contextually collected data;
• Invention of methods for representing and reasoning about contextual information.

Our approach naturally leverages PARC’s renowned, historical contributions to computing science and the field of human-computer interfaces and intelligent systems, honoring the global precedent set by the late, venerated PARC scientist Mark Weiser. Under Weiser’s leadership, PARC pioneered the vision of ubiquitous computing, where technology exists all around us in the form of mobile, sensing, and embedded technologies. Drawing upon this and other landmark contributions to the field of computational science, PARC’s current work is distinguished by a focus on user-centric applications. This includes long-term analysis of tradeoffs between invasiveness vs. utility in the use of sensor technologies.

At PARC, our work centers on people, not technology. Taking a holistic view of the capabilities of technology and users to create transformative systems that fit seamlessly into users’ lives, we can increase the adoption rate of such technologies and enable higher consumer impact, truly transforming the ways in which we all live and work . . . liberated from the desktop.

For a demo and to explore how PARC can discover ways for your organization to build new businesses, please contact Jennifer Ernst, Director of Business Development: phone 650-812-4916 or email ernst@parc.com.

PARC invented the concept of ubiquitous computing in the early 1990s, embracing many context-aware computing concepts and techniques. Today, experts in the field regard ubiquitous or “pervasive” computing as the hardware infrastructure to enable context-aware computing. PARC has developed systems that blend context-aware computing with seamless interoperability, simplifying the development of distributed, heterogeneous, context- and intent-aware applications.