# Context to Make You More Aware

Adrienne Andrew, Yaw Anokwa, Karl Koscher, Jonathan Lester, Gaetano Borriello
*Department of Computer Science & Engineering*
*University of Washington, Seattle, WA, USA*
*{aha, yanokwa, supersat, jlester, gaetano}@cs.washington.edu*

## Abstract

*The goal of our work is to help users make more informed choices about what physical activities they undertake. One example is to provide relevant information to help someone choose whether to wait at the closest bus stop, or walk a few minutes to the next stop, without missing the bus. In this paper, we report on our development of a platform which collects relevant context information for five different scenarios, processes this data, and presents relevant information to the user at the right time, in an unobtrusive way. The personal area network we use consists of a sensor platform with wireless capabilities, a Bluetooth-enabled wristwatch, and a mobile phone. We are also able to communicate with the user's PCs and various web services through multiple wireless channels. In future work, we will integrate the scenarios into a customizable set of applications, and evaluate the complete system.*

## 1. Introduction

One billion adults worldwide are overweight, and of these adults, 300 million are clinically obese. These numbers demonstrate what is now a global epidemic – one whose victims suffer from heart disease, stroke, hypertension and diabetes. While the lack of exercise and healthful eating is to blame, it has also been argued that technology has played a role in allowing many adults to maintain a sedentary lifestyle [3].

As researchers, we feel it is important to develop technologies that encourage an active lifestyle. Fortunately, improvements in health can be achieved by simply increasing levels of activity. Clinical studies show that any increase in activity can be beneficial, whether playing sports, going to the gym, or simply walking more [2]. Despite this, most adults do not exercise enough.

We want to focus on the group of sedentary individuals who could greatly benefit from any increase of daily activity, including simply taking more steps each day. To facilitate this increase, we want to build a technology that will help people become aware of potential opportunities to walk more. We want to accomplish this by providing appropriate suggestions, at the right time and place, so that they can choose to change their behavior at that moment.

To ensure these suggestions are on time, accurate, and appropriate, we rely on contextual clues paired with activity recognition. In addition to the physical activity, we use location and data culled from a user's phone, computer, and web services. Finally, we place these suggestions on appropriate devices in a user's personal area network. If a user is working at their computer, the suggestions appear on the screen. If a user is driving a car, suggestions appear on their watch.

In this paper, we first review the work in this area. We then present some target scenarios and describe the system architecture to enable these scenarios. Finally, we conclude with a discussion of our future work.

## 2. Related Work

In his 2001 book and subsequent work, Fogg [5] has described *persuasive technologies* as computer-based tools which persuade people to change their behavior. Some strategies described in the book include self-monitoring, suggestions, and tailoring. Tools to support self-monitoring enable a person to track and review the behaviors they want to change; suggestions provide just-in-time, context-sensitive, appropriate suggestions on how one can change their behavior at particular points in time; tailoring provides customization to the person's situation and preferences to make it easier for them to change their behavior.

Nawyn et al. [12] has also incorporated some of these ideas into a system to help people become more aware of and modify a very specific behavior—television watching. ViTo is an enhanced remote control for a media center that tracks a person's television watching goals. Once the daily goal has been reached, ViTo notifies the watcher and suggests alternative activities to pursue. Thus, they suggest replacing an "undesirable behavior" (watching TV) with a "more desirable behavior" (reading, listening to music, etc), breaking the habitual cycle.

There have been several research groups working on easily accessible displays at IBM, Hewlett-Packard, Microsoft Research, and CMU [11,14,6,7,16,15]. In addition, there have also been several commercial offerings with a wide range of applications and functions. Much of this work focuses on running multiple applications on a device, resolving which application has control of the device for display and input, and providing appropriate processing power. The distinguishing features of our work are the context-aware information display, the choosing of an appropriate display to provide the message, and the impetus of making the wearer more aware of his activity choices.

At CMU, researchers have developed the eWatch which integrates a set of sensors on the watch itself. These sensors are used to determine a user's interruptibility [4] to notifications from applications running on a companion PDA. The eWatch chooses to use LEDs or vibration to notify the user depending on their context.

The SPOT Watch [10] is the best example of a commercial general-purpose programmable watch platform, and we use a modified version of this device for our work. The commercial device receives information from MSN's FM-radio transmitters into "channels" on the watch. Channels include weather, sports scores, stock quotes, traffic, news, and calendar data (from desktop applications at the time of the last synchronization).

An increasing number of fitness- and adventure-oriented watches are being produced by companies such as Polar, Garmin, and Timex. These watches incorporate heart rate monitors (with an accompanying chest strap), GPS, altimeters, and pedometer data. Their displays are specialized to a particular application and do not support integration of external data. However, they do enhance a person's ability to self-monitor their daily activity.

## 3. Usage Scenarios

In this section, we provide details about five usage scenarios that have guided the development of our context-awareness platforms described in the next section. They are all related to personal health, specifically, increasing one's base activity level by walking more. Each example illustrates two ideas: (1) collecting precise, relevant information (from a potentially wide-ranging set of sources) and (2) inferring user context. The combination of these two allows us to deliver appropriate information to users at a time when they are most likely to be facing a choice. Our conjecture is that providing this information – already distilled from its raw local and remote sources – at the right time can help make behavioral changes easier. By eliminating tedious steps and mental calculations, we lower the barriers people face when making choices about their health. Providing this information will ensure their choice will not inconvenience them, but rather help inform them about the real tradeoffs in their choice.

All five scenarios presented here are implemented on wearable platforms. While each scenario is implemented individually, more work remains to fully integrate them as a complete, customizable system. In the following examples, the particular devices mentioned are for illustrative purposes only. Our system supports delivery of information to a variety of devices. Deciding which device is optimal in each context is part of the customization that we are working towards, as it is likely to vary per individual based on personal preference and the collection of devices the user carries.

**Scenario A: Should I walk further or catch the bus here?**

John is on his way home, but his activity level has been low for the day and he is far from meeting his step count goal. He has alternate bus routes he could decide from which involve different amounts of walking. As he leaves his building, he glances down at his watch and notices that it is informing him of the time to the next bus at a set of bus stops and how many steps he could add to his total with each choice. He is confident that he'll make the bus at each stop because the system has pre-fetched real-time bus arrival data from the web and pre-computed which choices are practical at this time.


**Figure 1. Bus information showing two choices, their arrival times, and the number of steps to their respective stops**

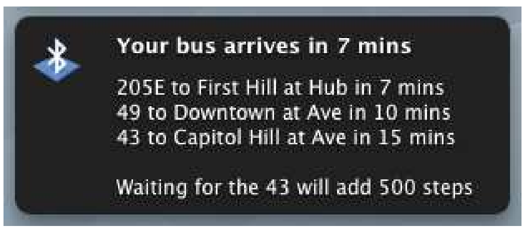


**Figure 2. A similar display to Figure 1, but presented on a PC screen**

**Scenario B: Do I have time to park further away and walk in?**

Traffic was very light on Alice's commute, so she has extra time to park, and get to her first class. She drives towards the campus building and her watch beeps and displays a message – "If you park at Lot E1, it's a 3 min drive and 1500 more steps." Alice smiles as she turns the car toward Lot E1. Her brother had given her the watch a few days ago to help her meet her goals of 10,000 steps a day. The system knew her location, knew she was driving, and pre-computed step counts to her most likely destination from the different parking options available [13].


**Figure 3. Prompt to suggest a parking location and the steps gained by parking there**

**Scenario C: That short drive wasn't worth it**

Peter is getting dinner ready and notices he's missing a key ingredient. The grocery store is only a few blocks away and he does what many of us would do: he jumps in his car for a quick trip to the supermarket. The drive only takes a few minutes and as Peter steps out of the car to enter the grocery store, his watch beeps. "You could have gained 3000 steps and saved $.27 in gas." Peter sighs. He had only saved a couple of minutes, and 3000 steps in each direction would have made a dent in the weight he'd been gaining since the holidays. Peter could have also consulted his phone which would have informed him of the cost of his "quick trip".


**Figure 4. Prompt for a drive**

**Scenario D: Where should I go for lunch?**

When Bob's phone vibrates around noon, he knows its lunch time. He reaches into his pocket and on the phone is an alert suggesting he try a Thai restaurant a few minutes away. The restaurant recommendation is appropriate because Bob hasn't had Thai for a while and he has been falling behind on his exercise. The walk to and from this restaurant will help him reach his fitness goals, so he hits 5 on the phone to call the restaurant for a reservation, and begins the walk to the restaurant. The phone had consulted an on-line restaurant guide and searched for eateries that matched Bob's tastes and were an appropriate distance away to help him meet today's step count goal.


**Figure 5. Lunch suggestion which will help Bob meet his goal for the day: an appropriate restaurant a reasonable distance away**

**Scenario E: Have I been sitting that long?**

Sarah hits the "Save" button in her word processor and leans back in her chair. Another 45 minutes has passed and the paper she's working on is still a work in progress. Out of the corner of her eye she sees a window fade into the upper left hand corner of the screen. It is an alert which informs her that her friends Bob, Alice and Peter have also been sitting idle for sometime and are likely to be interruptible. Sarah clicks on the alert and it brings up a chat window with Bob. They decide to meet downstairs at the cafe to stretch, walk a bit, and catch up. In this last example, Bob, Alice and Peter chose to share their office context (determined by their wearable sensor and activity level on keyboard/mouse) on a server at work and an application running on their PC checks to see if their work/idle pattern matches that of other users on their buddy list and suggest possible interactions [4].

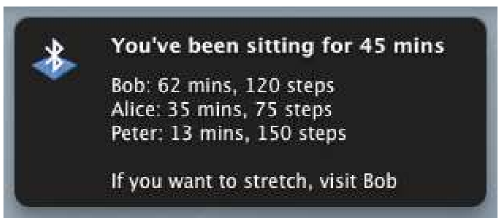


**Figure 6. Prompt on a PC screen when a user is interruptible and has been in the same position for an extended period of time. The suggestion is to interact with a colleague.**

# 4. System Architecture

Our system consists of a small, wearable device that provides sensing capabilities and computational power, web services backend, and a variety of user interface devices. The system implements all the scenarios described in the previous section. Figure 7 shows an overview of our system architecture.

## 4.1. The Multi-Sensor Platform

The Multi-Sensor Platform (MSP) forms the core of our system and is comprised of three main components: an Intel iMote2 (an embedded computer), an MSB (multi-modal sensor board, SD storage, and Bluetooth expansion board), and software running on the iMote2 platform. The iMote2 runs a Linux-based operating system on an 400MHz Intel XScale processor and is capable of Bluetooth (via the MSB) and Wi-Fi (via a USB dongle). The MSP is packaged in a small (3.3" x 2.4" x 0.9") box that can be easily clipped onto a belt, and could be integrated into a phone.

The Bluetooth module enables communication with PCs, smartphones, and Microsoft SPOT watches. Bluetooth connections to PCs and smartphones also provide indirect Internet connectivity via Ethernet, Wi-Fi or GPRS.

Figure 8 shows that at any given time only a subset of devices and network connections are available to the system. We must know what user interfaces are available, and which networks we have access to. One solution may have a separate process for each device or network, periodically scan for the presence of that resource, and connect to it. However, the Bluetooth protocol does not allow for simultaneous connection attempts, or connection attempt and inquiry. To solve this problem, we use a connection manager to synchronize scanning and connection. The connection manager periodically scans for new Bluetooth devices and Wi-Fi networks, and initiates connections as necessary.

Since multiple simultaneous network connections are available, we want to route traffic through the most optimal interface. The measure of optimality may include latency, bandwidth, availability and energy cost. Table 1 lists the tradeoffs between the various communication methods. Our applications do not have large bandwidth or latency requirements, so we prioritize power consumption. Since the connection manager knows which network connections are available, it acts as a network proxy for other applications, routing requests through the most optimal interface.

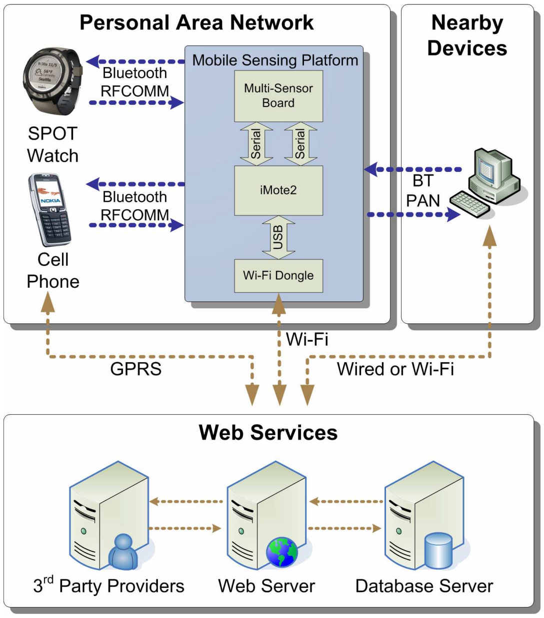


**Figure 7. System Architecture**

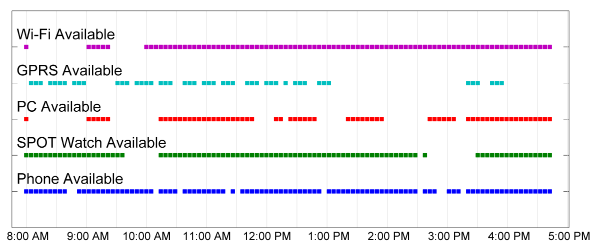


**Figure 8. Availability graph for a typical user in our department. Our building has poor cellular reception in many areas, but pervasive Wi-Fi.**

**Table 1. Tradeoffs between available radios**

| | Latency | Bandwidth | Availability | Energy Cost |
|---|---|---|---|---|
| GPRS | High | Low | High | Medium |
| Wi-Fi | Low | High | Medium | High |
| Bluetooth | Medium | Medium | Low | Low |

**Figure 9. MSP, SPOT Watch, and Nokia E70 Phone used in our system**

Location information is primarily gathered through Wi-Fi localization. Our applications only require relatively coarse location information outdoors. Since we are already scanning Wi-Fi access points to search for a usable connection, we utilize this information to determine our location without consuming more power than a GPS receiver. In addition, when indoors Wi-Fi location is often available whereas GPS is not. A list of access points and associated signal strengths can either be sent to a server for processing, or compared with a local database to perform the Wi-Fi localization [9].

In addition to location, we also have some indication of what activities the user is engaged in through real time activity inference from sensors on the MSP. Using a sensor like the accelerometer, it is possible to determine when a person is still, and for how long, or when a person is walking or driving. These inference results are combined with location and other information to determine the appropriate prompts to give the user.

## 4.2. Web Services

We utilize a central web server for many of our applications. This web server acts as an interface to our database, and provides information such as restaurants in your vicinity, and how long your friends have been idle. Data can both be queried and inserted. The web server also gathers information from the Internet (using SOAP, XML-RPC, or screen-scraping), and formats it in a form readily usable by the user interfaces. The server is implemented using CGI scripts, with Apache. Communication with the web server is via HTTP POST and GET requests.

## 4.3. User Interfaces

We use a Microsoft SPOT watch as it provides a glanceable interface device for notifying the wearer. The device is a 27Mhz ARM7 Suunto N3i running and is equipped with 4MB of FLASH, 384KB of SRAM and a 96x120 pixel monochrome screen. Unlike other SPOT devices, our N3i has been modified to include a fully integrated Promi-ESD02 Bluetooth module, allowing it to connect wirelessly to the iMote2. The watch runs a scaled down version of Microsoft's Common Language Runtime known as TinyCLR and supports applications built in C#. Our particular N3i was the result of collaboration between Intel and Microsoft.

Our watch implementation waits for an iMote2 to connect over Bluetooth, and upon connection, waits for a variety of alerts. The SPOT watch is primarily an end-point display and leaves the actuation the MSP. Example alerts are shown in Figures 1 and 3.

We also use a Nokia E70 as a component in our system. This smartphone is equipped with GPRS/UMTS, Bluetooth, and Wi-Fi. It has a larger (352x416 pixels) color screen than the SPOT watch, and allows for input into the system using predictive text or a full keyboard. Data on the web can be accessed via the phone's GPRS or Wi-Fi connection and sent back to the MSP via Bluetooth. This transaction is initiated silently by the MSP without any user input. We also plan on using smartphone contextual information (use of phone, calendar information) to inform the system.

For alerts, a background application scans for a known MSP, connects, and watches for alerts. The application automatically reconnects when disconnected and jumps to the foreground when an event occurs. Such an alert is shown in Figure 5.

Another component of our system is computer integration. Many users spend their working day in front of a computer. It has a much larger display than a phone, is network connected, and has some of the contextual information of the phone. We implemented computer alerts using Growl, a network-enabled notification system on Mac OS X..Notifications can be sent directly over the web or through Bluetooth. In our implementation we send alerts through our server to a user's known IP address. An example of these alerts can be seen in Figures 4 and 5.

## 5. Conclusion and Future Work

People make many choices throughout their day that affect their health and fitness. We have developed a wearable platform that gathers and processes information automatically so that users can make more informed choices at the right time without incurring the overhead of attention and time. The five scenarios we have implemented demonstrate the capabilities we want to further develop. Our future work will consist of integrating these suggestions into a coherent framework that will appropriately arbitrate information that is likely to be the most useful at any moment. We will also evaluate tradeoffs in choosing the most power-efficient communication method available and the most appropriate display modalities based on user customization and learned preferences. Evaluation of our work, from both the system performance and user interface perspectives, is ongoing. Many aspects of suggestion tactics are not yet understood, as we enumerate in [1], and this work provides an opportunity to explore this space.

## 6. References


[1] A. Andrew, G. Borriello, J. Fogarty. "Toward a Systematic Understanding of Suggestion Tactics in Persuasive Technologies," International Conference on Persuasive Technology for Human Well-Being, (PERSUASIVE 2007), Stanford, CA, April 2007.

[2] Centers for Disease Control and Prevention, U.S. Dept of Health & Human Svcs, "Preventing Obesity and Chronic Diseases Through Good Nutrition and Physical Activity," Preventing Chronic Diseases: Investing Wisely in Health, (Jul 2003).

[3] S. Consolvo, K. Everitt, I. Smith, J.A. Landay, "Design Requirements for Technologies that Encourage Physical Activity", SIGCHI Conference on Human Factors in Computing Systems (CHI), Montreal, Canada, April, 2006.

[4] Fogarty, J., et al., 2005. Predicting human interruptibility with sensors. *ACM Trans. Comput.-Hum. Interact.* 12, 1 (Mar. 2005), 119-146.

[5] Fogg, B. J. (2003), *Persuasive Technology: Using Computers to Change What We Think and Do*, Morgan Kaufmann Publishers.

[6] P. Hutterer, et al.,, "Lightweight User Interfaces for Watch Based Displays", 6th Australasian User Interface Conference, Newcastle, Australia, February 2005.

[7] P. Hutterer, et al., "A Lightweight UI Software Infrastructure for Wrist-Based Displays", 3rd International Conference on Information Technology and Appications, Sidney, Australia, July 2005.

[8] Intel iMote 2: http://platformx.sourceforge.net/

[9] A. LaMarca, et al., "Place Lab: Device Positioning Using Radio Beacons in the Wild", International Conference on Pervasive Computing, Munich, Germany, May 2005.

[10] Microsoft SPOT Watch: http://direct.msn.com/.

[11] C. Narayanaswami, M.T. Raghunath "Application design for a smart watch with a high resolution display", 4th International Symposium on Wearable Computers, Atlanta, GA, October 2000, pp 7-14.

[12] J. Nawyn, S. Intille and K. Larson, "Embedding Behavior Modification Strategies into a Consumer Electronic Device: A Case Study", 8th International Conference on Ubiquitous Computing, Orange County, USA, September 2006.

[13] D. Patterson, et al., "Opportunity Knocks: a System to Provide Cognitive Assistance with Transportation Services", Ubicomp, 3205 (2004)

[14] M. Raghunath, C. Narayanaswami, C., "User Interfaces for Applications on a Wrist Watch", *Personal Ubiquitous Computing*, Vol. 6, No. 1, February 2002, pp 17-30.

[15] A. Smailagic, D.P. Siewiorek, U. Maurer, A. Rowe, K.P. Tang, "eWatch: context sensitive system design case study", IEEE Computer Society Annual Symposium on VLSI, Tampa, FL, May 2005, pp 98 – 103.