Augmenting Everyday Life with Sentient Artefacts

Fahim Kawsar, Kaori Fujinami, Tatsuo Nakajima

Department of Information and Computer Science, Waseda University, Tokyo, Japan
{fahim,fujinami,tatsuo}@dcl.info.waseda.ac.jp

Abstract

The paper introduces sentient artefacts, our everyday life objects augmented with sensors to provide value added services. Such artefacts can be used to capture users context in an intuitive way, as they do not require any explicit interactions. These artefacts enable us to develop context aware application by capturing everyday scenarios effectively. In the paper we present a daily life scenario, and then demonstrate how such scenarios can be implemented effectively using applications that integrate multiple sentient artefacts.

1. Introduction

Ubiquitous computing envisions a future environment that will be aware of its operating context and will be adaptive to ease our interaction. Our approach towards such environment is the environment itself. That means taking the building blocks of the environment and making them smart and context aware by capturing people's implicit interaction. We have been developing such building blocks, namely everyday life objects by augmenting various kinds of sensors. We call them sentient artefacts. Our vision is to utilize these objects for value added services in addition to their primary services. For example, consider a frying pan, its primary use is in the kitchen. However we can utilize the frying pan by augmenting it with some sensors/tags to infer that its owner is in the kitchen or he/she is cooking while the frying pan is being used. Usually these artefacts differ from the explicit sensors in three ways:

1. It requires a small operating software/device driver that captures values from multiple sensors embedded in the artefacts and process these values in a logical way to provide information about its state of use, position or anything the software/driver author wants to provide.
2. Rather than providing an analog/digital sensor value, sentient artefacts provide a "statement" to the interested applications, like "state of use".
3. Finally, a sentient artefact can also be an actuator in some cases.

Some services like scheduler or weather forecast monitor etc. are also considered as virtual sentient artefact. By augmenting sensors, we make these belongings (micro component of the environment) smart. Eventually this process recursively makes our environment smart and context aware in a bottom up approach. In this paper we have presented such a context aware environment scenario, then we have implemented that scenario using sentient artefacts.

In our lab we are constantly drawing real life practical scenarios. We use these scenarios as the design base for deploying the environment components with augmented sensors and for developing integrated applications to implement those scenarios. We believe capturing users context implicitly by their natural interaction with the environment is a key issue for context awareness. Here natural interaction means interacting with natural interfaces like everyday objects. A natural interface activates the cognitive and cybernetic dynamics that people commonly experience in real life, thus persuading them that they are not dealing with abstract, digital media but with physical real objects. This results in a reduction of the cognitive load, thus increasing the amount of attention on content [19]. So our approach is to make the artefact aware but not to make their user aware of this fact by keeping the artefact's primary role and interaction technique intact. Users merely use the daily life objects in the same manner they are used to with. However our infrastructure capture these natural interactions to generate user's context.

In this paper, we have presented three integrated applications implementing a real life scenario. Sentient artefacts are used as the base to infer user's context. These applications are running in the user's washroom, workspace and public dining space respectively. We have tried to demonstrate the ease of context capturing by sentient artefacts and how such artefacts can be used in an integrated manner to implement real life practical scenarios. Our approach is different from others as we concretely focus on natural interactions of users with the environment for capturing the context, freeing the user from the feeling of *using computing technologies*, which we believe satisfies Mark Weiser's vision of invisible computing [15].

The remaining paper is organized as follows: In section 2 we have drawn a hypothetical scenario. Section 3 discusses about the design principles. In section 4 we have presented the capability requirements for the scenario functionalities and the implementation of the scenario using three integrated applications. Section 5 discusses the evaluation of the applications. In section 6 we have cited the related works, finally section 7 concludes the paper.

2. Another Day for Joanna

Joanna is a broker at the New York Stock Exchange. During her daily morning routine in the bathroom, while she is brushing her teeth and putting on her make-up, her mirror provides all the information she needs to start her day. During these activities she can watch her daily schedule. Besides that she also sees what the weather will be like, so she can dress fittingly. Furthermore she finds out if the subway, which she usually takes from her house to the Stock Exchange, is running properly. The subway is often delayed or closed for maintenance, in which case the mirror shows her an alternative route making sure that she does not have to rush to be on time for the morning breakfast meeting with her team.

After arriving at the office she works non-stop for several hours contacting her clients, buying and selling on their accounts. Until her computer reminds her to take a coffee break and tells her not to forget her lunch appointment at 13:00 with one of her biggest clients. She takes a break and later that afternoon she goes to the restaurant to meet her client. While she is waiting for her client, the table she is sitting at shows that tonight there are still tickets left for her favorite musical “Les Miserables” and that her favorite perfume is on sale at Saks and Fifth. Immediately she buys the tickets through her handheld.

After lunch she returns to the office, informs her manager about the resolution of the meeting with her clients. The computer on her desk informs her about some important memos she received during her absence. While she works continuously it is getting darker. Her desk lamp turns on automatically, it dims into a pink shade and her favorite track “For Elise” from Best of Beethoven is being played as she starts responding a client’s email.

3. Design Principle

A context aware scenario like above requires capturing user’s context to provide just in time decision-making information services. The scenario actually introduces three applications to provide the context aware services. A smart mirror installed in the washroom, a workspace assistant and an information service at dining spaces. From design decision point of view the applications should satisfy the following requirements:

1. Natural Interaction: Smart applications/gadget interaction interface should be simple, while we are introducing conventional non computing artefacts as computing gadgets, we must make sure that the end users do not need to learn new interaction techniques to interact with them. Instead our design assumption is that the interaction should be natural and the user will be unaware of the artefact’s participation in computing.
2. Unobtrusive Interaction: Computing fabrication in everyday objects and interaction with them should not go beyond user’s likings or tolerance level. The term “Pleasurably” has already been explored in the literature yet we ought to determine the upper and lower bound of such requirements. Smart gadgets or applications automate many user tasks but we have to make sure that such automation does not bother the target user at any level. Designing such an unobtrusive system is a critical challenge for the smart application developer.
3. Preference Reflection: Another important design requirement is reflecting user’s preference. From our experience, we have found that no matter how useful the application or gadget is, if it does not provide any end user preference management then the end users are reluctant to use the system. Smart applications or gadgets must provide the appropriate interfaces for capturing the end user’s preferences and it should behave accordingly.
4. Privacy Concern: End users are skeptical to use smart gadgets or applications, especially those for home computing. From our user survey of AwareMirror application (presented later), we have found that most of the users are concerned with the system’s security. Home Computing users are not ready to use the application if it has some explicit vision based sensing technology. Similar result has been depicted in Tapia’s work [3]. So while developing a smart application our utmost concern is not to violate user’s privacy and to make it as close as possible.
5. Just in Time: Smart applications are expected to provide just in time service or message to the users to ease their interactions or activities. However not all applications may require just in time automation service or message.
6. Reliability: Accuracy is a major requirement for context aware applications. It is important to combine multiple sensing unit outputs in order to increase the robustness and reliability of the applications [11].

Our design approach towards sentient applications is to satisfy these requirements as much as possible.

4. Scenario Implementation: Applications

In this section we have presented the three applications that are deployed to capture the scenario introduced in section 2. In the following table we have summarized what is required to be sensed for the proper functionalities of these applications and what sentient artifacts we have used to capture them:

Table 1: Functionality mapping from requirements to sentient artefacts

	Scenario Functionality	Required Capability	Augmented Artefact Used
WASHROOM	Display useful information on the mirror	Detecting user’s presence	Mirror augmented with proximity sensors
		Identifying user	Toothbrush as an authenticator of the user
WORKSPACE	Suggesting user for a refreshment and providing just in time message	Detecting user’s presence	Sentient chairs, state of use of chair as users location and activity Desk lamp with motion sensor
		Schedule/music extraction/play	Simple scheduler/media player
	Changing workspace environment	Capturing neighborhood brightness	Desk lamp with photo sensor
DININGSPACE	Display preferred news/information on the table display	Detecting user’s presence	Chairs state of use as users presence
		Detecting user’s orientation	Chairs orientation with respect to the table
		Identifying user’s preference	Table augmented with RFID tag reader

The three applications that implement the scenario are described next. Each application is described from their component and functional point of view.

4.1 AwareMirror

AwareMirror [14] is a smart mirror installed in the washroom as shown in figure 1. In addition to its primary task of reflecting someone's image it can also provide some useful information about the person who is using the mirror. Before deploying this application we have carried out two potential users surveys. About 50 people aging 20-50 participated in the surveys. The first survey was to find out the information categories that are preferred by the user to be displayed and second survey was to figure out the best sensing technologies. Based on the survey result, we have selected three categories of information to be presented to the users; these are i) Schedule ii) Transportation Information, iii) Weather Forecasting. The sensing technology preferred by the participants is implicit sensing via everyday objects rather than any vision based explicit sensing.

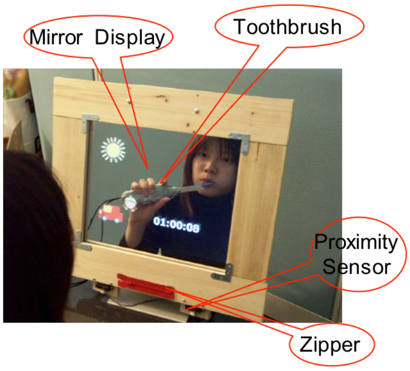

Figure 1: AwareMirror, in operation.

4.1.1. Component View

The following sentient artefacts and sensors have been used in the AwareMirror application:

1. AwareMirror: The mirror is constructed using an acrylic magic mirror board and ordinary computer monitor. The acrylic board is attached in front of the monitor, and only bright colors from the display can penetrate the board. The mirror is fabricated with a slider sensor that is used to navigate through the abstract and detail mode of the information display. Two proximity sensors have also been embedded into the mirrors. These are used to infer users distance/position from the mirror.

2. Toothbrush: A Toothbrush is augmented with two-axis accelerometer and connected to Phidget Interface Kit [17]. It can detect start and end of brushing. This is achieved by monitoring zero crossing through the differentiation between two latest measurements, i.e. from plus to minus and vice versa. In addition a RFID tag is fabricated into it, which can be used to detect the toothbrush in a specific location or the presence of it's owner in a specific location. As a toothbrush is a highly personal belonging that is rarely shared with others, we can infer that only it's owner will use it. This fact we have utilized to infer the identification of a person (owner) by the toothbrush's state of usage. The toothbrush actually acts as the initiator for rendering information to the mirror.

3. **Web Services:** For three category of information we have used 3 distinct web services. Yahoo Japan has been used for the weather forecasting. iCal based scheduler service is used for tracking the user schedule. We have used a dummy web service for the transportation information.

4.1.2. Functional View

The application's control flow can be stated as follows:

1. During the system initialization all the components are enumerated accordingly.
2. The user initializes the system by providing necessary information.
3. If the user uses the toothbrush in the morning, while the system is running, the user is identified by the system and his/her preference information is loaded.
4. Accordingly the web services are contacted to collect the information.
5. The system then renders the information to the Mirror.
6. The display has two modes, initially the mirror displays very abstract information in appropriate positions within the mirror making sure that information does not cover the main portion of the mirror.
7. The slider can be used to change the mode of the display. By using the slider user can navigate to the detail mode that shows detailed information. In this case the mirror actually turns into a mere display.
8. During the system initialization, the user can provide his/her preference regarding information category, timing of the display and mode of the display.

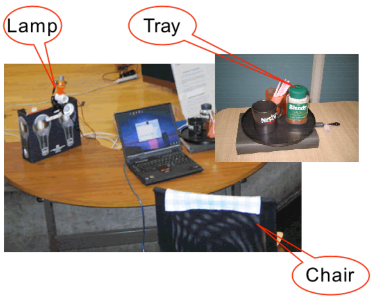

Figure 2: Smart Assistant application in workshop demonstration

4.2. Smart Assistant

This application (figure 2) is designed for a workspace running on the user's desktop. It is a simple media level context aware application that can track user's activities by the usage of artefacts populated in the workspace. To be specific the application uses a chair, a desk lamp, a tray and a few mugs and jars for sensing user's contexts. Based on the state of these artefacts the application can track if a user is in the workspace and whether he/she is working for a long time. If so the application suggests the user to take a refreshment and can provide the user with some predefined schedule notification. Also the application can control workspace lighting based on the user's presence and surrounding environment's brightness. It can also play music using system's media player. The system uses an animated chatting agent to interact with its users. The user can additionally chat with this agent during leisure time. Though the chatting agent is not very smart, it can entertain the user for a while.

4.2.1. Component View

The following sentient artefacts and sensors have been used in Smart Assistant application:

1. Sentient Chair: An ordinary chair, which is augmented with multiple sensors. To be exact we have embedded five force sensors, four on its seat, one in its back and one photo sensor at the joint of the seat and the back. These sensors are connected to Phidget Interface Kit [17]. Sensor values are processed accordingly to generate the abstract contextual information like "The chair is being used".
2. Sentient tray: The sentient tray is augmented with a RFID tag reader, so it can track the objects put on top of it and can also keep records of these objects' history. (Like when the coffee mug was taken, for how long the coffee mug was used etc.)
3. Sentient Mugs, Jars: Mugs and jars are fabricated with RFID tags that represent both its owner and itself. These mugs and jars are used to infer their owners' probable activities (drinking coffee etc.) in conjunction with the owners' location.
4. Sentient Lamp: It's a traditional desk lamp that is augmented with a motion sensor and a photo sensor. The lamp is connected to the power line using X10 module. Using the motion sensor, the lamp can infer whether the user is in front of the desk. This information, in conjunction with the chair's state has been used to infer user's activity. The photo sensor is used to track the environment's light level.
5. Scheduler: A simple scheduler that keeps track of user's schedules.

4.2.2. Functional View

The application's control flow can be stated as follows:

1. During the system initialization all the components are enumerated accordingly.
2. The user initializes the system by providing initialization and preference information.
3. The system uses the chair and the motion sensor (fabricated on the lamp) to infer that the user is in his/her desk and working.
4. When the system identifies that the user is working for a long time, the chatting agent appears and suggests that the user should take refreshment while servicing him/her with some important schedule information.
5. When the user eventually takes a break, it is identified by the analysis of the state of the tray, mugs and jars and user's location (tracked via chair, motion sensor). Then when the user returns to his/her workspace, the agent appears again, asking the user about the refreshment while providing important event (received email/memo) happened during the mean time.
6. When the environment gets darker, the application initiates to turn on the lamp with appropriate dimming based on the sensed information from the photo sensor and user's preference. The application only initiates this process if the user is in his/her workspace.
7. Additionally, the system can turn on the media player based on user's preference. The user can also chat for a while with the chatting agent.

4.3. Byte N Dine

This application, as shown in figure 3 is designed for a public/private dining space scenario. The goal of the application is to provide the latest news to the user while dining. A lot of people prefer to read newspaper, magazine, books in a café or a restaurant. We tried to capture this practice by providing information on the dining table, which means the table acts as an ambient display. We have assumed that people will carry a tag/token that will represent his/her preferred topic. Accordingly the system provides that topic's latest news to the user in an unobtrusive manner. User can browse through the news and look for detailed information or can simply close the display.

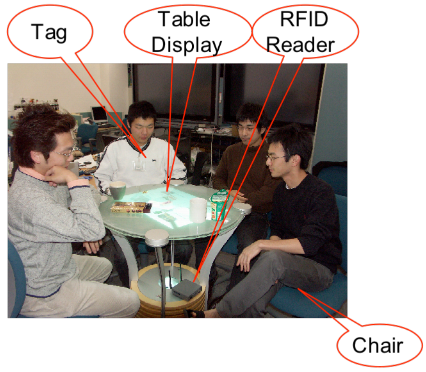

Figure 3: Byte N Dine, being used by our lab members

4.3.1. Component View

The following sentient artefacts and sensors have been used in the Byte N Dine application.

1. Sentient Chair/Couch: This is the same chair that we have presented in Smart Assistant application. In Byte N Dine we have used four sentient chairs that inform the application about their state of usage (sit by someone or empty).
2. Sentient Table: Byte N Dine uses a table that acts as an ambient display. The table is embedded with a touch screen display. The application renders the information to this display with very simple interface for browsing.
3. Spider RFID Tag Reader: We have attached a RFID Tag reader to the table. The reader reads the tags carried by the people that represent their preference regarding news topic.
4. Proximity Sensor: We have embedded proximity sensors to the table to infer that the table and chairs are used in conjunction and the user's orientation is toward the table.

4.3.2. Functional View

The application's flow can be summarized as:

1. During the system initialization all the artefacts are enumerated and the application requests for event notification.
2. When the chairs are used, the application initiates a query to proximity sensors.
3. If the proximity sensors' response is affirmative regarding chairs orientation and distance from the table, the application requests spider reader to read the preference tag.
4. Once the tags are read, respective news is collected from the news resource center and rendered to the table display.

5. Initially the application displays very abstract information like a picture or a caption, if the users are interested to know more they touch the corresponding caption or image to get detailed information.
6. When the user leaves the table the display is automatically closed.

5. Discussion

The three applications presented in the last section implement the hypothetical scenario that we have introduced in the beginning of the paper. Our goal has been to deploy these applications with a natural way for interaction. All three applications attempt to capture the user's context implicitly by manipulating the everyday artefacts augmented with various sensors. In this section we will provide the applications' evaluation from two points:

From the design point of view: One of our design goals has been to use sensor augmented daily life objects to capture user's context. By doing so, we have satisfied the natural interaction requirement. We have utilized the *state of use* context of various artefacts to infer the user's position, location or activity to some extent. For example, if the chair is being used, we can infer that its owner is sitting, or its owner is in the location of the chair etc. However none of the applications actually concretely depend on single context information to actuate any service to meet the reliability requirement to some degree. For example in AwareMirror application, to identify user's presence in addition to the toothbrush's state of use, we have also utilized proximity sensors; where both cross check each other. We believe it is important to combine multiple sensor outputs in order to increase the robustness and the reliability of the sensor infrastructure. All three applications provide the service or information in a *"just in time"* manner, for example in AwareMirror we have presented decision making information in the morning, which justify the category of the information presented. However in Byte N Dine, the information provision is much lighter considering the time and scenario.

During the application design we were very careful regarding privacy issues. We have omitted the use of any vision based sensing, considering the sensitive locations like washroom. Also during information category selection we were careful and we filtered out the survey result accordingly to conform that none of the applications output or actuation violates its user's privacy. Byte N Dine application usually runs in a public space, however as the users themselves are carrying the preference tags knowingly, they are aware of the information exposure, which does not violate any privacy issues. However carrying explicitly such tag conflicts with our design goal of natural interaction. If we consider the intentional spectrum introduced in [1], we find that carrying tag can be considered as an expected interaction technique that sits between incidental and intentional interactions in the continuum of intentionality. So we are not claiming that this specific action is completely natural. All three applications provide interfaces to the end users to reflect their preference. Although none of these applications is capable of self-learning, we have provided GUI based preference manager for the AwareMirror and Smart Assistant. Using which users can provide their preference regarding application services. In byte N Dine the user him/her self carries the preference tag. So explicitly we have not provided any preference manager.

While rendering output or actuating services our attempt was to make it unobtrusive. However in the case of Smart Assistant, we felt from the users comment that the animated character actually makes it's user annoyed. Both in the AwareMirror and Byte N Dine, the display is provided in two modes, the initial mode is the abstract mode where we have presented some images or captions to highlight the major points to get users attention. The other mode is the detail mode where we have provided more detailed information regarding the topic. In either case the user can actually turn off the display if they want to do so. We believe such flexibilities meet the unobtrusive requirement of our design goal.

From the usability point of view: All three applications have been evaluated by a large number of people. The same people, who participated in the initial requirement survey, have evaluated AwareMirror. Additionally a four members family has used AwareMirror for two days for real time experience feedback. The expressions that we have received are pretty satisfactory. Most of the users liked it and commented constructively. For example, some commented that at first glance the displayed abstract information was not comprehendible, slider is confusing etc. Our lab members and several researchers from industry and other universities have evaluated Smart Assistant during our in house workshop. Most of the user liked the natural interaction and just in time service actuation. However a few people did not like the chatting agent. They commented that first few times the appearance of the animated character may be fascinating but soon it becomes annoying. Also some users suggested that the system should automatically learn user's behavior and should reflect them accordingly. Our lab members also evaluated the Byte N Dine application. They liked the application and many of them wanted it to be available commercially immediately. However they pointed out that the orientation of the display is an issue, which needs improvement. They commented that the touch screen table display can also be used for displaying the menu with pictures and ordering the food accordingly.

The three applications that we mentioned are built using a context aware framework "Prottoy" [5,6] which attempts to provide a generic interface for the underlying physical space. It removes all access issues thus application development becomes very simple and rapid.

We believe capturing user's context for providing them with just in time value added services is one of the major feature of future smart environment. Our approach towards that smartness is to deploy the conventional furniture/artefacts with computing ability exploiting their natural interface. The significance of our approach is the natural interaction. Users are not using any computing device or any new technology. To them, they are using their very commonly known artefacts as usually. However our sensor infrastructure is utilizing those mere artefacts to perceive user's context and operational context and thus automating just in time service actuation. All three applications are dedicated to capture real life scenarios that we face every day or practice everyday. These applications' novelty is that they are providing intuitive, effective, decision-making and unobtrusive services to augment additional value to our daily life activities using mere everyday artefacts while conforming to the design requirements. Additionally the response time of all three applications is pretty rapid. The background processing for sensor fusion or context analysis consumes negligible amount of time.

The key to achieve natural interaction is the synthesis of number of aspects, like non-obtrusive, sensing, response time, and cognitive load [19]. All three applications essentially satisfy these aspects. From the application development experience, we have figured out that for deploying context aware applications drawing the practical scenario plays the key role, developing sentient artefacts eventually helps us to capture that scenario in one or more integrated applications. However one major question that is yet to be answered is how to determine the sentient artefacts participation in context aware applications in a generic way? We must not develop application or scenario dependent sentient artefacts, rather we have to come up with proper guidelines that will allow us to develop independent artefacts that can be used with various scenarios. We are working specifically on this issue and hope to come up with some interesting results soon.

6. Related Work

Most of the context aware projects use artefacts that are either traditional general purpose computing platforms ranging from small handheld to large sized high end computers like ParcTabs, or dedicated artefacts designed for providing specific contextual information like Active Badge infrared sensor. However our work is different from these two approaches as we concretely focus on everyday objects for context capturing without compromising their primary role. Digital Décor [10] project augments traditional drawer and coffee pots to use as a smart storage and a media for informal communication respectively. However users are responsible for explicitly using these artefacts for their services. Also they only provide some services (searching, communicating with people etc.) rather than any contextual information. Tangible Bits [7] project attempts to bridge the physical world and virtual world by providing interactive surface, graspable objects and ambient media. However such explicit dedicated interfaces violates the design principle of natural interaction and natural augmentation of conventional everyday objects. Recently one Internet service [18] provides similar notion as ours by providing activity information of remote elderly by capturing the state of coffee pot. Although they have augmented everyday object the consumer of this information is not the person who uses the system. It is a kind of monitoring system, which does not provide any contextual information. Like AwareMirror, Philips recently has done a prototype of TV mounted mirror that can also provide some information regarding user's health care [20]. However to our best knowledge it is not clear what underlying architecture and sensor framework are exploited. Another system that targets the washroom is the bathroom activity monitoring based on sound [13]. However using microphone for context recognition is a serious threat to privacy and suffers from poor acceptability. Also their application is mainly on health care to support dementia patients. Our focus is more general and by using multiple sensors embedded in the sentient artefacts we approach a more reliable and unobtrusive context recognition than single environment sensor like microphone. Paradiso's work [12] in wearable computing arena matches our vision as he has exploited sensor-augmented footwear to obtain contextual information. TEA [8] project attempts to embed various sensors to augment handheld devices to provide contextual information. However they only focus on handhelds. MediaCup [15] projects and its succeeding SmartIts [9] provide insight into the augmentation of artefacts with sensing and processing. Our work is greatly influenced by them and exploits the Aware Artefact model introduced in [8]. However our sentient artefacts do not require any explicit interaction as MediaCup or SmartIts based artefact requires. Our approach is to make artifact aware but not their user aware of this fact. Sentient artefacts are mere everyday artefacts without any noticeable feature. Users manipulate them in the natural way they are used to with. They don't need to do something explicitly to make something happen. This natural feature distinguishes our work from other projects.

7. Conclusions

In this paper we have presented the notion of sentient artefacts and how these artefacts are utilized in integrated context aware applications to implement our daily life scenarios. We envision such micro building unit of our environment can provide us with the realistic base for deploying true context aware application because of their natural features. The paper also provides an implicit guideline for implementing a real life scenario from visualization into realization.

References

[1] A. Dix et al. *Human Computer Interaction*, Third Edition, Prentice Hall,

[2] A. Schmidt et al. *How to build smart appliances,* IEEE Personal Communications, 2001

[3] E. Munguia Tapia et al. *Activity recognition in the home setting using simple and ubiquitous sensors,* Pervasive 2004,

[5] F. Kawsar et al. *Design and Implementation of a Software Infrastructure for Integrating Sentient Artefacts,* Mobiquitous 2005

[6] F. Kawsar et al. *Prottoy: A Middleware for Sentient Environment*, EUC 2005 [To appear]

[7] H. Ishii et al. *Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms.* CHI 1997

[8] H.W. Gallersen et al. *Adding Some Smartness to Devices and Everyday Things,* WMCSA 2000

[9] H.W Gallersen et al. *Physical Prototyping with Smart-its*, IEEE Pervasive Computing Magazine, Vol. 3, 2004

[10] Itiro Siio et al. *Digital Decor: Augmented Everyday Things.* Graphics Interface 2003

[11] J. Andreoli et al. *Augmenting Offices with Ubiquitous Sensing*, Smart Object Conference 2003

[12] J. A. Paradiso et al. *A. Interfacing the Foot: Apparatus and Applications.* CHI 2000 Extended Abstracts

[13] J. Chen et al. *Bathroom Activity Monitoring Based on Sound.* Pervasive 2005.

[14] K. Fujinami et al. *AwareMirror: A Personalized Display using a Mirror*, Pervasive 2005

[15] M. Beigl et al. *Media Cups: Experience with design and use of Computer Augmented Everyday Objects.* Computer Networks, special Issue on Pervasive Computing, Mar '2001

[16] M. Weiser. *The Computer for the 21st Century.* Scientific American, Vol. 265, No.3 1991

[17] S. Greenberg et al. *Phidgets: Easy Development of Physical Interfaces through Physical Widgets,* UIST 2001

[18] www.mimamori.net

[19] www.naturalinteraction.org

[20] www.research.philips.com