Exploiting Passive Advantages of Sentient Artefacts

Fahim Kawsar, Kaori Fujinami, and Tatsuo Nakajima

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

Abstract. Sentient artefacts are our everyday life objects augmented with various sensors for value added services. We have been exploiting these artefacts for perceiving user context and proving proactive context aware services while keeping their natural appearances and roles intact. From our observations of these artefacts we have identified two passive advantages besides their explicit value added functionalities. The first is a profile-based participation of the artefacts in the application scenarios thus making the artefacts generalized, independent of the applications and reusable in various scenarios. The second one is the role of the static artefacts in identifying the location of the mobile artefacts thus eliminating the requirement of any dedicated location infrastructure for proactive services. In this paper we have discussed these two issues with illustrations of our findings.

1 Introduction

The task of identifying user context is perhaps the central component of ubiquitous computing research. This research put forth several questions regarding understanding, extraction, modeling, management, distribution and representation of context. Our research focus is to answer some of these key issues through an approach that we call Sentient Artefact. Sentient artefacts are everyday life objects like a chair, a mirror, a door, a lamp, etc. augmented with sensors to provide value added services that include identifying human context and providing proactive services. 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. Furthermore, because of these artefacts natural role in our everyday lives, computing becomes invisible, a goal that Weiser envisioned one and a half decades ago [25]. We have been developing various proactive applications using these smart artefacts [14, 15, 8]. However, during our application development we have encountered couple of issues that seek for further focuses.

– 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 generalized

H.Y. Youn, M. Kim, and H. Morikawa (Eds.): UCS 2006, LNCS 4239, pp. 270–285, 2006.

artefacts that can be used in various scenarios and are independent from the applications.
- How sentient artefacts location can be acquired? It is expensive and to some extends impractical to use dedicated sensor infrastructure for location sensing in domestic environment. We confronted the fact that we need some alternative approaches that can provide the location information in an inexpensive and natural way.

Although these two issues are not contradictory with the primary functions of the sentient artefact (perceiving user contexts and providing proactive services), but for the success of our approach the resolutions are very important. Form our observations of the sentient artefacts characteristics; we have come up with the idea of using sentient artefact for the resolutions, which further increases the technical advantages of sentient artefact. These passive advantages were not in our design goals initially but later came into focus from our experiences with sentient artefact based application development. Basically we have identified two specific characteristics:

- Profile based participation of Sentient Artefacts. This is very important for supporting application independent artefact development. Artefacts can implement one or multiple profiles where each profile specifies a role. Profile based approach directly contributes in making artefacts reusable, loosely coupled with proactive applications and in supporting runtime artefact replacement feature.
- A sentient artefact based location system for sentient artefacts. From our observation we have identified there are various artefacts in our environment that are static in nature and designated in static places and we rarely move them, for example a refrigerator, a cooking oven, a room door/window etc. We can exploit this static nature of these artefacts by using them as a reference point for identifying their peer mobile artefacts. We believe this approach is feasible, practical and economical in context aware environment as it eliminates the requirement of any dedicated sensing infrastructure.

In this paper, we have discussed about these two issues and their implementation in a generic context aware middleware. Considering the view points, the contribution of the paper is purely intellectual, as we propose two notions that are very essential in context aware computing domain. However, we have also shown our findings and performance of the applications that exploited these notions.

The rest of the paper is structured as follows: for giving readers a better understanding of our approach we have introduced the sentient artefact in section 2. Section 3 presents the profile-based approach for sentient artefacts. In section 4 we have introduced the second topic of the paper: location system by sentient artefacts. Section 5 discusses in brief the implementation of these two concepts. In section 6 we have presented several applications that we have developed using sentient artefacts and our findings. Section 7 discusses on various aspects of this two issues and a comparison study with related works is presented in section 8. Finally section 9 concludes the paper.

2 Sentient Artefact

Sentient artefact is a mere everyday object without any noticeable features. We augment sensors to it to make it aware of its environment. By doing so we extend its functional advantages as it can provide value added services beyond its primary role. For example, consider a chair, it is primarily used for sitting. We can put a few sensors on it and we can identify when it is used or even who is using it. So from the functional point of view, a mere chair now serves as a source of context information of an entity. But it does not conflict with its primary role of providing support for sitting. This is the basic concept of sentient artefact; keeping its primary role intact as an artefact while allowing it to provide additional services. In the case of the chair it can provide its state of use, and if we know the identity of the person we can infer that the person is sitting (activity) and he/she is at a specific location(chair's location). In Figure 1 we show some of the sentient artefacts that we have developed.

Fig. 1. Array of Sentient Artefacts

Usually these artefacts differ from the explicit sensors in three ways:

- They require a small operating software/device driver that captures values from the multiple sensors embedded in the artefacts and processes these values in a logical way to provide information about their state of use, position or any contextual information that the designer wants to provide.

– Instead of providing only analog/digital sensor value, sentient artefacts can provide a statement to the interested applications, like state of use. That means the sentient artefact developer can provide the logic for generating abstract context information from low-level sensor data.
– Finally, a sentient artefact can also be an actuator in some cases. For instance, a mirror can be used to display some information. Web services like news provider or weather forecast monitor, etc. can also contribute to identify context and are considered as soft sentient artefact.

Sentient artefacts have some strict and specific design principles that have been mentioned in [9, 10, 14]. We have been developing sentient artefacts based applications for providing various proactive services. From our experiences of application development we have come up with one interesting property of sentient artefact: the role specification. That is how to make these artefacts loosely coupled with the applications. Artefacts must not be developed for specific applications; rather artefacts should have the flexibility to be used in various applications as long as they serve the purpose. Accordingly, as a resolution, we have come up with an idea of using a profile-based approach for artefact development. In the next section this approach is discussed.

3 Profile Based Approach

Sentient artefacts can provide various functionalities according to an artefact designers intuitive understanding. It is not logical to consider that each artefact should have only one functional role beyond its primary role. For instance, consider a mirror, we can use the mirror as an ambient display. Simultaneously, the mirror can provide position information (whether some one is in front of it or not) if we embed proximity sensors into it. Similarly a stand light can provide lighting service or the ambient light level of the environment. The software component that is representing the light or the mirror must handle these multiple functionalities within the same artefact space. That means it must not be tightly coupled with the underlying functionality, like for each function, one soft component. Instead it should provide loose coupling among artefacts functional features while at the same time decoupling the functional spaces for each function within the artefact. For instance, one application may use the display service of the mirror where another application may have interest in the position information that it provides. In such case we must not implement two software components, instead one artefact with two functional features. Similarly two different applications may be interested on a single profile that several artefacts implement. In such case the application can select any artefact that is suitable for the scenario. Considering these, our proposition is to use a profile based approach for artefacts; an artefact can provide multiple functionalities and each functionality is encapsulated into one profile. All the profiles are finally integrated into single software instance that represents the physical artefact in the digital space.

Profile notion is commonly used for defining roles, for example: Bluetooth Profile, J2ME Profile etc. Our profile notion has the same meaning. This is very crucial for ubiquity as sentient artefacts' roles can be manifold. It is feasible to have loose coupling within the artefact's functional space. From a very broad point of view we can say that there are two types of categories for profile: Input profile and Output profile, as sentient artefacts role can be either context source or service actuator. However we cannot confine the profile number, because the sentient artefacts' functionalities are not confined in the first place. Designers are independent to come up with a new functionality by embedding some kind of sensors in a daily life objects to acquire context or actuate service. However in Figure 2 we have given some example profiles that artefact can implement.

Input Profile	Output Profile
- Time (Explicit or Symbolic like Evening etc.) - Location (Symbolic like meeting room or Geometric with longitude, latitude) - Position (Front, Back, Right, Left, In front etc) - Voice - Tag Reader - Authentication - Proximity and Distance - Information (Weather, News, Schedule etc) - State of Use - Emotion - Activity - Environment Attribute (Temperature, Light Level, Humidity etc) - Physical State (Height, Weight, Color, Shape, Size, Temperature, Face Up/Down, Held, etc)	- Sound/Noise - Display - Vibration - Lighting - Movement - Controlling (On, Off, Up, Down, Open, Close etc) - Leveling (Darker, Stronger, Weaker, Lighter etc) - Sending Message (Email/SMS) - GUI Event (Display) etc.

Fig. 2. Example of Profiles

We have adopted this profile-based approach for managing the roles of the artefacts. Usually developers can use any design principle for implementing the profiles. However, we have used the approach mentioned in [9, 10] to implement a profile considering the functional focus and the containment relationship among the underlying sensors. We have developed a middleware component presented in later section that the developer can use for defining the artefact profiles. The component manages distinct spaces for each profile within the artefact thus providing systematic client management at the artefact level. In section 6 we have demonstrated how this profile based approach provides various advantages for the application development.

In the next section we will focus on the second issue of this paper: sentient artefact based location system for sentient artefacts.

4 Spreha: Sentient Artefact Based Location System

Sentient artefact based application often requires the location information of the underlying artefacts. However, one of the design principles of sentient artefact based computing is to avoid dedicated sensing infrastructure. To satisfy this issue, we have developed a simple lightweight location system Spreha, where the artefact itself acts as a reference point for location information. The basic concept here is that: there are several artefacts in our environment that are static in nature and we rarely move them; for example Refrigerator, Cooking Oven, Room Door/Window etc. These artefacts can act as a reference point for identifying their mobile peers like chair, lamp, coffee mug etc. Spreha exploits this particular nature of the artefacts. Also from our experience with the application development we have observed that the "centimeter level" accuracy is not needed for the development of contextual services, actually identifying proximity even within few meters is enough for utilizing the sentient artefacts in domestic environments. So, instead of accuracy our essential design principles are flexibility and simplicity.

4.1 Design Decisions

While designing Spreha we have considered several important characteristics that are essential for pervasive environments. Following are enumerations of the guidelines that we have considered in Spreha:

- *Transparency:* The location provider should gather location information in a transparent way without any interference from the applications. Application will only be notified for location change event and must not be responsible for any network management related to location identification.
- *Abstraction:* Heterogeneity is a common characteristic of pervasive environment. The location providers should cope with this heterogeneity issue of the underlying artefacts and should provide the location information in a unified way.
- *Availability:* The location information should be available to the applications all the time regardless of the operating status of one or more location providers.
- *Privacy:* The location information should be protected from malicious client applications.

Based on these principles, we have designed Spreha that composes of some logical components that we have presented in the next subsection. Spreha uses Bluetooth as underlying technology for sensing the artefacts. A 48 Bit Bluetooth device address is used as the location identifier in Spreha, however a higher-level friendly name can also be used. The static location of the artefact is always a higher-level name such as Meeting Room, Fahims Workspace etc. This static location is the identifier of the artefacts location. For resolving the conflict (when two or more hosts see the same artefact in their territory) currently Time of Flight (TOF) is used, however Radio Signal Strength Indicator (RSSI) can also be activated where available.In Spreha there is a predefined trust policy, which contains two attributes: public policy and private policy. Public policy means location information of the artefacts can be published publicly, whereas private policy means the opposite. Artefacts can provide their preferred policy during deployment time.

4.2 Logical Components

As shown in Figure 3 few logical components participate in Spreha; their roles are discussed in the following:

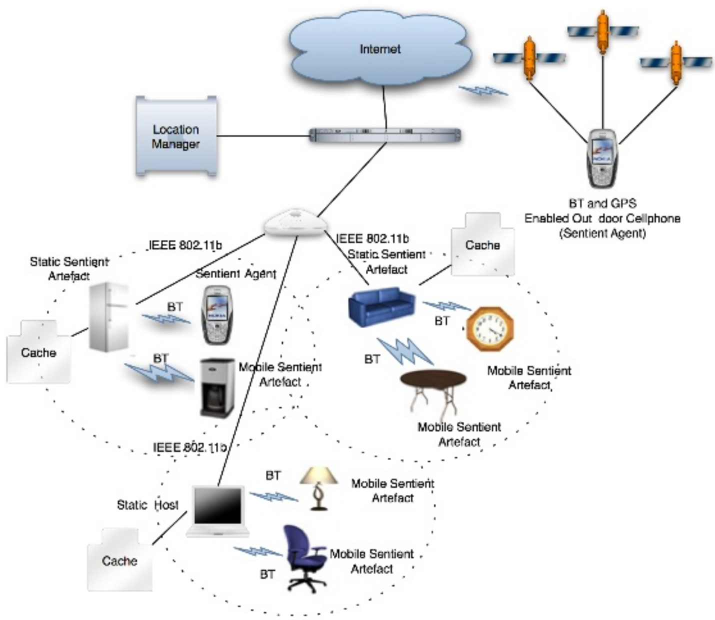

Fig. 3. Logical Architecture of Spreha

Location Manager: This is the central component that manages the location information of the artefacts. (Also each static host and static artefact manages location information locally) During deployment each artefacts register themselves to the manager. Each static artefact and static hosts periodically notify the manager about the artefacts information available to them. Application can query location manager for location information or can register for notification. On receiving new location information, it notifies the interested applications. Location manager resolves conflict when two or more hosts see the same artefact in their pico net by simply considering the minimum TOF and/or maximum RSSI for deducing artefacts location. However in case of out door sentient agents it communicates directly to receive the GPS information.

Static Sentient Artefact: This component acts as both a reference point and a location provider. Any sentient artefact that is considered to be stable in its location like a mirror, a cabinet, a couch, etc. can be considered as static artefact. These artefacts are augmented with bluetooth tag reader. It contributes to location sensing system by maintaining a cache of nearby sentient peers that is periodically updated by running the discovery service embedded in it. The discovery service discovers the nearby peers within its pico net. The cache also contains the RSSI and/or TOF. Whenever the cache state is changed it notifies the location manager and to the applications subscribed to them. During the deployment of the artefact it specifies its name, role as a location provider, static location and security policy to resource manager.

Mobile Sentient Artefact: This component is the ordinary sentient artefact that is mobile in nature like a chair, a watch, etc. A bluetooth tag is embedded in it. Static artefacts and/or the static hosts identify these tags and notify the location manager. During deployment these artefacts specifies their mobile role, name and security policy.

Static Host: This component is an ordinary location provider embedded with a bluetooth tag reader and runs the discovery service periodically and maintains a cache of seen artefacts. Whenever cache state is changed, location manager and the subscribed client applications are notified. During deployment it specifies its role as static host and its static location.

Sentient Agent: This is a special component that assumes to be run in a handheld device owned by a person. Spreha assumes that a person will carry this device. During initial deployment the agent should register its name, IP address, and security policy. Hosts identify this agent when it is in their designated pico net and notifies location manager. However if the agents location information is missing when queried by applications, then location manager communicates directly with the agent running in the handheld, and agent uses the GPS to retrieve its location information and notifies the manager. Thus locating nomadic people is supported in Spreha.

5 Implementation

The two concepts presented in the previous two sections have been implemented as modules of a generic middleware for context aware computing titled Prottoy [16, 13]. For clarity here we are introducing the middleware components in a summarized way.

- *Resource Manager:* Responsible for resource discovery, managing location information and reconfiguration of the underlying environment.
- *Artefact Wrapper:* Responsible for encapsulating artefacts and offering artefact service and context information to applications.

– *Virtual Artefact:* Responsible for providing unified interface to applications for interacting with the underlying layers.

The artefact wrapper component provides all the support to implement the concepts presented in this paper. The location manager component of Spreha is a module of the Resource Manager of Prottoy that notifies location information to clients and responses to the applications' query.

An artefact can implement one or more profiles based on the roles and functionalities it can provide. Developers use the artefact wrapper component to encapsulate the profiles of artefacts. The developers should implement a profile handler using the interfaces of artefact wrapper for each profile that the developer wants the artefact to support. However, they only need to provide the data acquisition and service provision logic, other functionalities like communication, data management, storage, representation, deployment, etc. are handled by the artefact wrapper internally. We have assumed that developers are responsible for providing the quality of service of each profile. Artefact wrappers have interfaces through which developers can specify the quality of service information. However, we do not prescribe any guideline for defining the quality of service. This quality of service can later be exploited by the application to select the best artefact with similar profile.

While participating in the Spreha, a static artefact can implement the location profile, in addition to its other profiles. For participating in the location system, application developers only need to manipulate the deployment tool to provide artefacts bluetooth information and willingness to participate in the location system. Developers do not need to write any code for this, as it is already implemented in the artefact wrapper components. The artefacts (static artefact, static host, mobile artefacts and sentient agents) are deployed in the environment using the artefact wrapper internal deployment tool. For detail of the artefact wrapper and Prottoy implementation please check the references [16, 13].

6 Experiences with Sample Applications

We have developed several context aware applications integrating multiple sentient artefacts on top of Prottoy middleware. In this section we will mention about four applications. Furthermore, our observations and experiences regarding the two focal issues of this paper are discussed.

6.1 SoLite

This is a simple application that employs only two mobile artefacts namely a stand light, a chair and a static artefact: a desk as shown in Figure 4(a). If the chair and the stand lights are in the desks location, the light is automatically turned on/off based on the ambient light sensitivity of the surrounding and the presence of the user sensed by the state of use of the chair (sitting/not sitting).

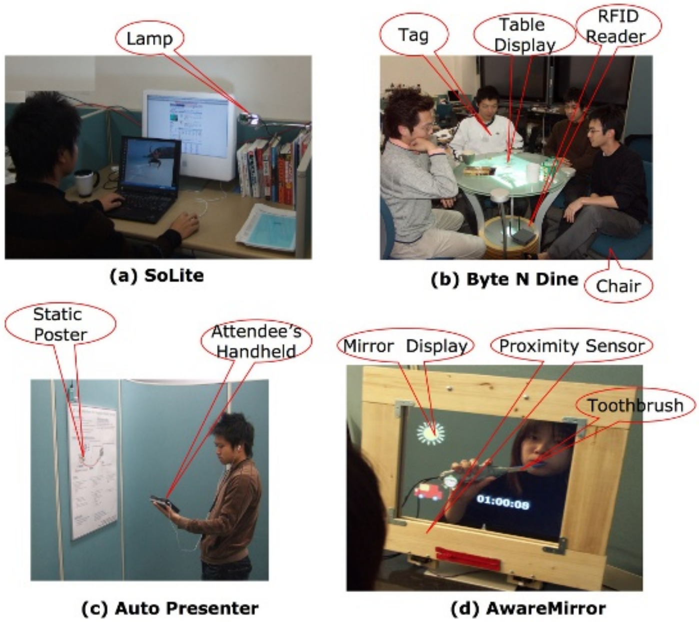

Fig. 4. Sample Applications

The desk implements location profile; the chair implements state of use profile and the lamp implements lighting profile.

6.2 Byte N Dine

This application as shown in figure Figure 4(b) , runs in a public/private dining space where the dining table acts as an ambient display. The table displays information/news about topics based on users preference. We have assumed that the user will carry a RFID tag that reflects his/her preferred topic. This application uses chairs to identify users presence by chairs state of use, and the table, which is embedded with a touch screen display and augmented with RFID Tag reader and proximity sensors (used to measure the proximity of the table and chair). The chair implements state of use profile and the table implements display, location, proximity and tag reader profile.

6.3 Auto Presenter

This application is designed for assisting conference attendees in the poster sessions at conferences as shown in Figure 4(c). The basic idea is to provide the attendees with a handheld device, which can run a small video clip about the nearby poster content. Since the posters are usually static in nature, we have used it as a static artefact with location profile. The attendees handheld implements a display profile. The handheld is augmented with bluetooth tag that is identified by the poster and accordingly the video is rendered.

6.4 Aware Mirror

AwareMirror, (the initial version was presented in [8]) is a smart mirror installed in a washroom as shown in Figure 4(d). In addition to its primary task of reflecting some ones image it can also show some information related to the user like schedule, weather forecasting, transportation information etc. based on the presence of a user. The mirror is constructed using acrylic magic mirror board through which only bright color can penetrate. A toothbrush (embedded with a 2D accelerometer) is used as an authenticator and also as an indicator of the users presence when co-located with mirror. Also proximity sensors embedded in the mirror are used to measure the users distance from the mirror. The mirror implements location, proximity and display profiles. The toothbrush implements the authentication profile. The mirrors static location is used to identify the presence of a person who is carrying the toothbrush.

6.5 Findings and Observations

Considering the two focus issues we will mention the findings into two parts, first we will mention about the profile based approach and then the location system.

Profile Based Approach: Our basic concern was to monitor the performance of three features through the profile based approach.

- *Reusability:* Since in profile-based approach, each artefact implements one or multiple profiles rather than an applications requirement, artefacts become reusable. For example: we have used the same chair in Byte N Dine and in SoLite applications. Similarly the profile itself can be reusable. That means once a profile is implemented it can be used in different artefacts that have similar properties. For example: the display profile is used in the mirror and in the table in AwareMirror and Byte N Dine applications respectively.
- *Replacement:* Our next concern is the artefact replacement functionality. Because of the profile-based approach, we have found that artefacts can be replaced anytime with another similar artefacts as long as they implement the same profile. For example: in AwareMirror, we have found that if we use a comb instead of a toothbrush, that implements authentication profile, the application runs smoothly. Similarly in Byte N Dine we have seen that if we use coffee mugs that implement the state of use profile, the application has no functional effect. We have tried using different artefacts at different runs also, and found the applications to be stable.This finding supports the fact that application has no effect on the replacement of similar profiled artefacts.
- *Loose Coupling and Independence:* This feature is the conjugal effect of the previous two advantages of profile-based approach. Because of the reusable and replacement facilities, the artefacts are completely independent of the application/scenario requirement. We have found in all four applications that applications are interested in the context information or service provision (in profile in our approach) but not on the artefact itself. So artefacts have been developed in an adhoc manner considering the design issues of sentient

artefacts and the best alternatives are selected for the applications based on requirements and availability. Our findings validate the fact that profile based approach provides the generalization for managing sentient artefacts.

Spreha Location System: Exploiting the static sentient artefacts for locating the mobile sentient artefact is the primary goal of Spreha. From this point of view we have found from the developed applications that Sprehas logical components can contribute to the location sensing tasks successfully. However, from the performance point of view, a few issues have been identified. In a real environment we have found that bluetooth performance was not always satisfactory. Especially if the static hosts and static sentient artefacts are located in congested manner than it is very difficult to infer the actual location of the mobile artefacts. For example, in Auto Presenter since the posters are closely arranged differed by 2 3 meters, it is very difficult to identify the location of the attendee (in front of which poster the user is). Furthermore, if two static hosts/artefacts are located nearby (6-8 meters) it is difficult to select the proper one by only calculating the TOF, because sometimes it leads to wrong prediction. However, in other applications where the static hosts are arranged in disperse manner (artefacts' locations are differed by more that 12 meters), Sprehas performance is satisfactory. Since in other applications we have used only one static artefact, the identification was correct.

From this observation, it can be said that it is necessary to arrange the static hosts and static artefacts in a disperse manner for proper location sensing. However, this is not a shortcoming of the proposed concept because we can distribute the artefacts in a way that they do not conflict with each other and it is logical. For instance: consider a kitchen, we can have several sentient artefacts that are static in nature like a cooker, a refrigerator, a cabinet, etc. that are closely arranged. However, we can use only one of them as a reference point in the kitchen for location discovery. The same is true for other locations like a TV in the living room, a bed in the bed room etc (Even there may be multiple static artefacts in these locations, but we can implement location profile in one of them only). This approach is practical and economical. So the only constrain to use Spreha is that we need a prior design and layout of the environment for deciding the artefacts that can play the role of static host or static sentient artefact. So in a larger environment that includes several spatial location, Spreha can easily be used for location identification as long as the static artefacts are arranged in a disperse manner.

7 Discussion

In this section, we will focus on some specific issues of the two concepts presented in the paper.

7.1 Focus of Profile-Based Approach

We believe the Profile-Based approach for artefact development is one step towards realizing sentient artefacts as a successful context information provider for proactive services. We have shown that sentient artefacts roles can be manifold and all these roles are reusable. So it is feasible to consider the implementation of different artefact independently. This approach leads to high reusability and cost effectiveness, since one artefact can participate in multiple applications. We can generate a profile and use the profile in various artefacts that can support that profile. Similarly we can develop an artefact with specific profiles and can use the artefact in various applications. This leads to the loose coupling between artefacts and applications. This is very important for sentient artefact based application development, and in general in context aware computing. Several research groups have used several augmented artefacts for identifying context [22, 5, 1, 2]. Unfortunately, most of those artefacts are tightly coupled with the scenario in hand so can not be reused in other applications. This fact is further validated in the related work section. One interesting extension of this profile-based approach may be a wizard for artefact developers to generate artefact wrapper on the fly. If we follow the context pattern proposed in [21], the profile type and numbers, we can come up with an assistive tool that can recommend the artefact developer about the wrappers possible implementation.

7.2 Focus on the Spreha Location System

From design principle point of view Spreha satisfies the transparency and abstraction requirement by using the artefact wrapper component of Prottoy [16, 13]. In Spreha location information is stored centrally in location manager and each static host and static sentient artefact also host their own location information. From this point of view Sprehas approach is a hybrid one between centralized and distributed data storage. Because of this hybrid organization in Spreha the location information is always available either from location manager or from static location providers. Spreha does not exploit any dedicated sensing infrastructure for location sensing. We use sentient artefacts with augmented services for location sensing in an adhoc manner. From this point of view: readers may be confused about what we mean by dedicated. Our proposition here is that each artefact has its primary role in our everyday life. We are keeping that role intact while using it for location sensing. So the underlying infrastructure is the sentient artefacts not any sensor nodes deployed only for location sensing like active bat, ubiSense or cricket [24, 3, 18]. The strength of Spreha is not the sensing technology but the idea of using sentient artefacts as a location reference point.

We consider dedicated infrastructures are not applicable in a domestic environment. Our claim is further justified by the recent proliferation of Place Lab approach [20] of using existing networks for location detection.

Cost of Location Node is minimal in Spreha as no external sensing system is necessary. The value added services of sentient artefact nullifies the location system cost as the location system components (bluetooth tag and reader) are parts of the sentient artefacts. If the artefacts are not bluetooth enabled, then the cost of the system is the summation of the Bluetooth configuration cost for each mobile and static artefact.

Another important issue is that Spreha does not implement any location model on top its sensing system. Any suitable location model can be used on top of Spreha to represent the physical world, for instance: we have mentioned in section 6 that it is necessary to do a prior layout design before deploying Spreha, if each static host and static artefacts static location is organized in a predefined hierarchical manner we can easily represent any virtual model of the physical world.

8 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 Using sensor augments artefact for contextual service provision is common practice in context aware literature. Unfortunately, till now no work has been tried to generalize the roles of these artefacts so that they can be used in multiple application scenarios. For example, consider the Digital Dcor [22] project where augmented traditional drawer and coffee pots are used as a smart storage and a media for informal communication respectively. Since the profile notion is missing in their artefacts, these artefacts can not be used in any other applications, or these artefacts functionality can not be ported in other artefacts. Same is true for Phillips Home Labs initiatives [2], where they have been developing various smart artefact similar to ours like Smart Mirror, Smart Shaver etc. But due to the tight coupling with the end applications these artefacts are not reusable in other application scenarios. MediaCup [5] project is perhaps the first work that presented the augmented artefact notion, but it did not specify anything about the specific roles that the similar artefacts can implement. Some other works on augmented artefacts are, Tangible Bits [12] , Paradisos work [17] or MIT Media Labs commercial initiatives Ambient Devices [1] But all these works lack from the generalization feature that we have tried to achieve through the profile based approach in this work.

Considering Sprehas proposition, comparing Spreha with other location sensing system may seem ambiguous. The reason is Spreha introduces sentient artefact in location provider dimension but it is using bluetooth as underlying sensing technique. And using bluetooth for indoor location sensing is not a new observation as it has already been explored in [4, 11]. So from this point of view we cannot actually compare Spreha with other indoor sensing. Sprehas contribution is in introducing the novel notion of sentient artefact as reference point. On the other hand Spreha does not implement any location model as proposed in numerous literature [7, 19, 23, 24, 6]. The distinction of Spreha with other indoor location system is an intellectual one because of the utilization of sentient artefact instead of dedicated infrastructure. For example there are numerous indoor location system that make use of ultrasonic [18, 23], infrared [24], ultra-wideband radio [3]. All these systems require a hardware infrastructure be installed in the environment. Most importantly these systems are generally expensive, costing thousands to tens of thousands of US dollars for a 1000 square meter installation. These systems primarily focus on optimizing accuracy rather than wide-scale deployment. We consider these systems are not suitable for sentient artefact based computing because of such inherent dependency on infrastructure. Place Lab proposes using RF/WiFi base stations as reference points [20]. Basically we can think, Spreha augment their idea by embedding the base station in the sentient artefacts that are static in nature. Though using RF access points as reference is inherited from Place Lab, Spreha introduces few features that are missing in Place Lab, like artefact end security policy, distribution of location information in static hosts and artefacts, role of location manager and the notion of sentient agent for seamless change between bluetooth to GPS usage.

9 Conclusion

In this paper we have presented two passive advantages of using sentient artefact based approach for developing context aware applications. we have provided a illustrative explanation of our approach by providing its direct implications in the developed applications. We believe the proposed notions are very important for realizing the ubiquitous computing environment. Profile based approach is specially essential for exploiting the physical computing feature of ubiquitous computing. Also the light weight location system poses interesting findings that may be helpful for the community to further investigate the issue for better resolutions.

References

1. Website of AmbientDevice. http://www.AmbientDevics.com.
2. Website of Philips Home Lab Reserach. http://www.research.philips.com.
3. Website of UbiSense. http://www.ubisense.net.
4. G. Anastasi, R. Bandelloni, M. Conti, F. Delmastro, E. Gregori, and G. Mainetto. Experimenting an Indoor Bluetooth-Based Positioning Service. In *23rd International Conference on Distributed Computing Systems Workshops (ICDCSW'03)*, 2003.
5. M. Beigl, H. W. Gellersen, and A. Schmidt. Media Cups: Experience with design and use of Computer Augmented Everyday Objects. *Computer Networks, special Issue on Pervasive Computing*, 35-4, 2001.
6. M. Beigl, T. Zimmer, and C. Decker. A location model for communicating and processing of context. *Personal and Ubiquitous Computing*, 6(56), 2002.
7. M. Burnett, P. Prekop, and C. Rainsford. Intimate location modeling for context aware computing. In *Workshop on Location Modeling for Ubiquitous Computing, in UbiComp2001*, 2001.
8. K. Fujinami, F. Kawsar, and T. Nakajima. AwareMirror: A Personalized Display using a Mirror. In *3rd International Conference on Pervasive Computing*, 2005.
9. K. Fujinami and T. Nakajima. Augmentation of Everyday Artefacts for Context-Aware Applications' Building Blocks. In *Workshop on Smart Object Systems (sobs05) in conjunction with Ubicomp 2005*, 2005.

10. K. Fujinami and T. Nakajima. Sentient Artefacts: Acquiring User's Context through Daily Objects. In *The 2nd International Workshop on Ubiquitous Intelligence and Smart Worlds (UISW2005)*, 2005.
11. J. Hallberg, M. Nilsson, and K. Synnes. Positioning with Bluetooth. In *10th International Conference on Telecommunications (ICT 2003).*, 2003.
12. H. Ishii and B. Ullmer. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In *CHI 1997*, 1997.
13. F. Kawsar. An architecture for sentient artefact based computing. Master Thesis, Computer Science Department, Waseda University, Japan, 2006.
14. F. Kawsar, K. Fujinami, and T. Nakajima. Augmenting Everyday Life with Augmented Artefacts. In *Smart Object and Ambient Intelligence Conference*, 2005.
15. F. Kawsar, K. Fujinami, and T. Nakajima. Experiences with Developing Context-Aware Applications with Augmented Artefacts. In *1st International Workshop on Personalized Context Modeling and Management for UbiComp Applications, A Workshop in conjunction with UbiComp2005, the 7th International Conference on Ubiquitous Computing*, 2005.
16. F. Kawsar, K. Fujinami, and T. Nakajima. Prottoy: A Middleware for Sentient Environment. In *The 2005 IFIP International Conference on Embedded And Ubiquitous Computing*, 2005.
17. J. A. Paradiso. A. Interfacing the Foot: Apparatus and Applications. In *CHI 2000 Extended Abstracts*, 2000.
18. N. B. Priyantha, A. Chakaraborty, and H. Balakrishnan. The Cricket Location-Support System. In *MOBICOM 2000*, 2000.
19. I. Satoh. A Location Model for Pervasive Computing Environment. In *Third Annual IEEE International Conference on Pervasive Computing and Communications (PerCom 2005)*, 2005.
20. B. Schilit, A. LaMarca, G. Borrirllo, W. Griswol, E. L. D. Mcdonald, E. Balachandran, and J. A. Hong. V. Challenge: Ubiquitous Location-Aware Computing and the Place Lab Initiative. In *First ACM International Workshop on Wireless Mobile Applications and Services on WLAN (WMASH)*, 2003.
21. A. Schmidt. *Ubiquitous Computing-Computing in Context.* PhD thesis, Computer Science Department, Lancaster University, 2002.
22. I. Siio. Digital Decor: Augmented Everyday Things. In *Graphics Interface 2003*, 2003.
23. R. Want, A. Hopper, V. Falcao, and J. Gibbons. The Active Badge Location System. *ACM Transactions on Information Systems*, 91-102, 1992.
24. A. Ward, A. Jones, and A. Hopper. New Location Technique for the Active Office. *IEEE Personal Communications*, 42-47, 1997.
25. M. Weiser. The Computer for the 21st Century. *Scientific American*, 265, 1991.