Ubiquitous Computing Frameworks and Location Sensing Technologies: A Survey

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ABSTRACT

Technological advances in miniaturized devices, sensors and wireless networking have led increasingly to the integration of sensors and devices with users and physical environment, leading to ubiquitous computing systems. Ubiquitous computing (ubicomp) supports a widely networked infrastructure of a multitude of sensing and computing devices. It ensures that information is accessible everywhere and moves the interaction beyond the desktop and into the real world with a special attention to activities of everyday human life. Ubiquitous computing framework provides a structure and set of libraries to design and develop customized ubiquitous computing applications. In this paper a detailed survey of papers related to different approaches of Ubiquitous Computing Frame works and location sensing technologies is done.

General Terms
Sensors, Ubiquitous Computing and Frame Work.

Keywords
Ubiquitous Computing Framework, Location Sensing Technologies, Location Detection.

1. INTRODUCTION

Ubiquitous computing (ubicomp) [Weiser 1988] is a model of human-computer interaction, in which information processing has been thoroughly integrated into everyday objects and activities, and it is the method of enhancing computer use by making any computers available throughout the physical environment but making them effectively invisible to the user.

Mark Wiser in his articles [1,5] related to : “The Computer for the 21st Century” highlighted the future trend of merging of profound technologies into everyday life. Today the ubicomp applications are diverse in nature ranging from small applications that help commuters track train and bus schedules to smart laboratories, smart museums, instrumented classrooms, etc. The ubiquitous computing environment may contain many devices with which user interact. These devices include:

- Laptop Computers
- Smart Phones
- Handheld devices including personal digital assistants (PDAs), mobile phones, pagers and digital cameras.
- Wearable devices such as smart watches, google glass, oculus rift, tile, gps shoes, fin ring, etc.
- Medical wearables such as fitness band, air Louisville, itBra, kardia mobile and kardia band, uv sense, etc.
- Devices embedded in appliances such as washing machines, hi-fi systems, cars and refrigerators.
- Appliances and Devices embedded in Smart Home, Smart Class Room, Smart Road, Smart Shopping Center, Smart Hospital, Smart Vehicles, Smart Agriculture Crop Monitoring System, etc.

Some of the ubiquitous computing applications and projects designed and developed earlier are discussed below:

1. Ubiquitous Health Care [6]: A patient or elderly person is continuously monitored with wearable health sensors placed on the patient’s body. An interface collects data and sends this data to the monitoring system. Due to the seamless connectivity characteristic and context aware behavior of ubiquitous devices the interface remains connected by exploiting the available technologies like RFID, Bluetooth, ZigBee, GPS, etc.

2. Ubiquitous Navigation System [7]: The software provides the information like location, user context (static situation, dynamic situation, static intention and dynamic intention), train operating information, etc. It makes use of technologies like GPS, GPRS, Wireless LAN, Mobile IP, RFID and Bluetooth.

3. E-Class Room: Classroom 2000 [8] is an attempt to study the impact of Ubicomp in teaching and learning activities. The system has feature like: can capture different activities in the class room, can integrate all format of lecture notes in a sequence, can assist teacher for evaluation, can assist for collaborative teaching and learning, etc.

4. Cyber Guide [9]: The project is focused on exploiting the portable computers to assist users making use of physical and cyber spaces. As a subjective study mobile and hand-held technology-based tour guide was developed using GPS positioning systems. It makes use of location information to track the user / suggest establishments and maintains history of places visited, for future.

5. Easy Living [10]: At Microsoft Research, the Ubiquitous Computing Group has created a system called Easy Living that is a prototype of architecture and technologies for ubiquitous computing. The Easy Living system demonstrates many of the capabilities of ubiquitous computing, including mobile, wireless computing with migratory programs; an intelligent environment with context-awareness and location-sensitive computing; and disaggregated computing.
6. **Stanford iroom** [11]: A test bed of smart room with spatial, socially aware, deep physically integrated and coordinated autonomous systems. The room is fixed with multiple large embedded Displays, Laptops and Heterogeneous handheld devices.

7. **Labscape** [12]: Ubiquitous biology Lab with Sensors and PCs. Labscape is a smart environment that was designed to improve the experience of people who work in a cell biology laboratory.

Change in user context causes the actions in ubiquitous computing environment. For example, user entry inside the living room can cause the lights on/off, ac on/off, TV on/off, windows curtains to close/open, etc., depending on the user’s context like mood, activity, time, temperature, etc.

One of the distinguishing features of Ubiquitous Computing is that the computation is a part and parcel of everyday life. The computing services required for user depends on user's social and personal context. Thus the ubiquitous computing systems can provide more meaningful and useful services provided the systems are context aware in nature.

Ubiquitous Systems are a store house of sensors and devices without context aware computing. It is the context aware methodologies which makes ubiquitous systems aware of situations of interest, enhances services to users, automates systems and reduces obtrusiveness, customizes and personalizes applications.

Albrecht Schmidt in his report [13] highlights the importance of context aware computing as: “Context is essential for building usable Ubiquitous Computing systems that respond in a way that is anticipated by the user”. Definitions given by earlier works and standard dictionaries agree on the key idea that contexts describe situations. This definition clearly states that context is always bound to an entity. The entity itself is regarded as something that is relevant to the interaction between a user and an application. The user-application relationship is rooted in the traditional notion of an application, but not limited to it.

Dey and Abowd (2000) have also confirmed this by defining context as: “Any information that can be used to characterize the situation of an entity. An entity is a person, a place, or a physical or computational object that is considered relevant to the interaction between a user and an application, including the user and application themselves.” [14, 15]

The context can be categorized into different types based on the information they carry. Context may be Computing context, network context, user context, device context, sensor context, physical context, time context, etc. User context provides the information related to user like location, name, role, priority, activity, mood and other useful user’s information.

Context aware computing finds its origin as early as 1992 when the, Want et al., introduced the Active Badge Location System which is considered to be one of the first context aware applications. The application used infrared technology to determine the user location. The information was used to forward the phone calls to a telephone close to the user. Based on the location context a couple of location aware tourist guides was developed in the middle of 1990s (Abowd et al., 1997; Sumi et al., 1998; Chevrest et al., 2000). All the context aware applications designed during mid of 1990s were based on location context. In 1994 Schilit and Theimer used the term context aware to describe the context as location, identities of nearby peoples, objects and changes to those objects. In 1997 Rayen et al., used the term context to describe the user’s location, environment, identity and time. A Dey and Abowd (2000) moved a step forward and used the term context as information to describe the overall situation of entities. Zimmerman (2007) et al., described the context in terms of five categories: individually, activity, location, time and relations. Bolchini et al., (2009) defined context as the set of variables that may be of interest for an agent and that influence it actions.

2. LITERATURE SURVEY

The proposed research direction involves in design and development of Ubiquitous computing framework using location sensing technologies. In this direction a survey is made on Ubiquitous Computing Frameworks and Location sensing technologies.

a. Survey Related to Ubiquitous Computing Framework:

A framework provides a structure and common methods to make the life of application developer much easier for building flexible, scalable and maintainable applications. Ubiquitous Computing Framework provides a structure and set of methods/libraries to design and develop ubiquitous computing applications.

<table>
<thead>
<tr>
<th>Framework</th>
<th>Approach</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Service Discovery Framework for Ubiquitous Computing [17]</td>
<td>Using Mapping table of Global Manage Server (GMS) and Local Manage Server (LMS)</td>
<td>Flexible and Scalable Architecture to provide local and remote services.</td>
</tr>
<tr>
<td>A context-aware framework supporting complex ubiquitous scenarios with Augmented Reality enabled [19]</td>
<td>Modeling scenarios as a finite state machine transitions being controlled by context information. The Framework is designed with Augmented Reality architecture to enable augmented interaction in context-aware applications.</td>
<td>• Lightweight and flexible context awareness. • Support for multi-state applications. • Higher interaction and user friendly</td>
</tr>
<tr>
<td>An Energy-Efficient Context</td>
<td>Data reduction approach to lower the</td>
<td>• Energy Efficient</td>
</tr>
</tbody>
</table>
Management Framework (CMF) for Ubiquitous Systems [20] | amount of data sent to CMF over the network, minimizing the energy consumption and the network traffic of sensor-rich CMF | • Maximize lifetime of monitoring platform  
• Improved Availability of context aware services

• Automatically generate the API documentation  
• Creation of the data model on which services act.  
• Communication services using REST and SOAP protocol.

A Context Realization Framework for Ubiquitous Applications with Runtime Support [22] | Dynamic Run Time Context based Service Recommendation | • Developers can specify their context requirements at design time and automatically realize them at runtime in a soft integration fashion.

Mobile Agent based Framework for Mobile Ubiquitous Application Development [23] | An event-based communication paradigm designed specifically for ad-hoc wireless environments is incorporated, which supports loose coupling between sensors, actuators and application components | The framework allows developers to fuse data from disparate sensors, represent application context, and reason efficiently about context, without the need to write complex code.

Context-aware ubiquitous framework services using JADE-OSGI integration framework [24] | This paper presents a context aware ubiquitous approach based on lightweight coupling between multi-agent JADE system and OSGi framework | Dynamically configurable and extensible due to the heterogeneity and the mobility of smart appliances and users.

A Distributed Location Based Service Framework of Ubiquitous Computing [25] | The framework uses an extensible web crawler to get the necessary information from the Internet and are turned to location-aware information by connecting them with their locations which are extracted from themselves | • The service framework provides information based on users search requests and location of infotainment and user at any time.  
• Provides the traditional navigation service and runs on real data.

**b. Survey Related to Location Sensing Technologies:**

The three technologies areas that are required in order to realize the design and development of Ubiquitous Computing frameworks are 1. Sensing technology (particularly location sensing) 2. Context Aware Computing and 3. Network Technology. Sensing technologies are essential to capture the user context like activity, mood, time, location, etc. Location sensing and capturing is one the important sensing technology that is essential for designing Ubicomp Frameworks. Most of the user required services depends on his /her location. Authors Jeffrey Hightower and Gaetano Borriello [26] in their research paper presented a detailed study of location sensing methods and technologies that can be used in Ubiquitous computing framework as illustrated in Table 2 and Table 3.

| **Table 2: Types of Location Sensing Methods and Examples** [26] |
|---|---|---|
| **Type** | **Sub Categories** | **Approaches** | **Examples** |
| Triangulation: Uses the geometric properties of triangles to compute object location. | Lateration: Measures distance from reference points | Direct: Direct measurement of distance uses a physical action or movement. | Robotic Movement |
| | | Time-of-Flight: Measuring the time it takes to travel between the object and point P at a known velocity | GPS, Active Bat, Cricket, Bluesoft and PulsON. |
| | | Attenuation: Measuring the intensity of an emitted signal. Calculate based on send and receive strength, attenuation varies based on environment | SpotON |
| Angulation: Measuring Angles form reference position. | Angles are used for determining the position of an object. | VHF Omnidirectional Ranging (VOR) aircraft navigation system |
Scene Analysis: Uses features of a scene observed from a particular point.

Compared scenes to reference scenes
- Images
- Electromagnetic readings

Microsoft Research RADAR location system

Proximity: The object’s presence is sensed using a physical phenomenon with limited range (nearby).

Detecting physical contact
Using pressure sensors, touch sensors, and capacitive field detectors

Touch Mouse

Monitoring wireless cellular access points.
Monitoring when a mobile device is in range of one or more access points in a wireless cellular network is another implementation of the proximity location technique

Active Badge Location System, Xerox ParcTAB System.

Observing automatic ID systems.
If the device scanning the label, interrogating the tag, or monitoring the transaction has a known location, the location of the mobile object can be inferred.

Uses automatic identification systems such as credit card point-of-sale terminals, computer login histories, land-line telephone records, electronic card lock logs, and identification tags such as electronic highway E-Toll systems, UPC product codes, and injectable livestock identification capsules

<table>
<thead>
<tr>
<th>Technology Name</th>
<th>Technique</th>
<th>Properties</th>
<th>Accuracy and Precision</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>Radio time of lateration</td>
<td>Physical, Absolute and LLC</td>
<td>1-5 meters (95-99%)</td>
<td>Not indoors</td>
</tr>
<tr>
<td>Active Badges</td>
<td>Diffuse infrared cellular proximity</td>
<td>Symbolic, Absolute and Recognition</td>
<td>Room size</td>
<td>Sunlight &amp; fluorescent interference with infrared</td>
</tr>
<tr>
<td>Active Bats</td>
<td>Ultrasonic Time of flight lateration</td>
<td>Physical Absolute and Recognition</td>
<td>9cm (95%)</td>
<td>Required ceiling sensor grids</td>
</tr>
<tr>
<td>VHE Omni Directional Ranging</td>
<td>Angulation</td>
<td>Physical, Absolute and LLC</td>
<td>1° radial (~100%)</td>
<td>30-140 nautical miles line of sight</td>
</tr>
<tr>
<td>Motion Star</td>
<td>Scene Analysis, Lateration</td>
<td>Physical, Absolute and Recognition</td>
<td>1mm, 1ms, 0.1° (nearly 100%)</td>
<td>Control unit tether, precise installation</td>
</tr>
<tr>
<td>Cricket</td>
<td>Proximity, Lateration</td>
<td>Symbolic, Absolute, Relative and LLC</td>
<td>4x4 ft. regions (~100%)</td>
<td>No central management, receiver computation</td>
</tr>
<tr>
<td>MSR RADAR</td>
<td>802.11 RF scene analysis &amp; triangulation</td>
<td>Physical, Absolute and LLC</td>
<td>3-4.3m (50%)</td>
<td>Wireless NICs required</td>
</tr>
<tr>
<td>PinPoint 3D-iD</td>
<td>RF Lateration</td>
<td>Physical, Absolute and Recognition</td>
<td>1-3m</td>
<td>Proprietary, 802.11 interference</td>
</tr>
<tr>
<td>Avalanche Transceivers</td>
<td>Radio signal strength proximity</td>
<td>Physical and Relative</td>
<td>Variable, 60-80m range</td>
<td>Short radio range, unwanted signal attenuation</td>
</tr>
<tr>
<td>Easy Living</td>
<td>Vision, triangulation</td>
<td>Symbolic, Absolute and Recognition</td>
<td>Variable</td>
<td>Ubiquitous public cameras</td>
</tr>
<tr>
<td>Smart Floor</td>
<td>Physical contact proximity</td>
<td>Physical Absolute and Recognition</td>
<td>Spacing of pressure sensors (100%)</td>
<td>Recognition may not scale to large populations</td>
</tr>
<tr>
<td>Automatic ID Systems</td>
<td>Proximity</td>
<td>Symbolic, Absolute, Relative and Recognition</td>
<td>Range of sensing phenomenon (RFID typically ~1m)</td>
<td>Must known sensor locations</td>
</tr>
<tr>
<td>Wireless Andrew</td>
<td>802.11 cellular</td>
<td>Symbolic, Absolute and</td>
<td>802.11 cell size</td>
<td>Wireless NICs required, RF cell</td>
</tr>
</tbody>
</table>
### 3. CONCLUSIONS

The proposed research work is to design and development of Ubiquitous Computing Framework using Location sensing technology. In this perspective a literature survey was made to understand the different approaches followed by the researchers and different sensing technologies available. The proposed framework shall be designed such that it will provide a structure and set of methods/libraries which can be used to write a user centric program for the following:

1. To capture the live data (location, time, day, network, user id, user activity, light intensity, temperature, weather conditions, etc.)
2. To recognize the user context dynamically through integrating live data semantically
3. To provide the services suitable to user context using suitable machine learning algorithms.

As a subjective study one of the following case study shall be considered for developing the prototype of the frame work:

1. Navigation Systems
2. Tourist Guide System
3. Smart Room

Following steps will be adapted sequentially for implementing the proposed framework.

2. To identify Machine Learning Techniques required to recognize the dynamic context and action recommendation.
3. Design and Full Stack Implementation of the proposed Framework and its Components
   a. User Interface
   b. Middle Ware (User context sensitive recommendation System using ML)
   c. Back End (User service repository for training, testing and validation)
4. Developing Ubiquitous Computing Applications (Smart Living System / Tourist Guide, etc.) using the developed Framework.

### 4. REFERENCES


[8] https://www.cc.gatech.edu/fce/c2000/overview/


