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A SURVEY ON UBIQUITOUS COMPUTING

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Abstract

This work presents a survey of ubiquitous computing research which is the emerging domain that implements communication technologies into day-to-day life activities. This research paper provides a classification of the research areas on the ubiquitous computing paradigm. In this paper, we present common architecture principles of ubiquitous systems and analyze important aspects in context-aware ubiquitous systems. In addition, this research work presents a novel architecture of ubiquitous computing system and a survey of sensors needed for applications in ubiquitous computing. The goals of this research work are three-fold: i) serve as a guideline for researchers who are new to ubiquitous computing and want to contribute to this research area, ii) provide a novel system architecture for ubiquitous computing system, and iii) provides further research directions required into quality-of-service assurance of ubiquitous computing.

Keywords:

Ubiquitous Computing Paradigm, Context-Aware Systems, Pervasive Computing Middlewares

1. INTRODUCTION

The main focus of ubiquitous computing is on the effective and efficient use of smart spaces, invisibility, localized scalability, and context-awareness. The goal of ubiquitous computing research is to refine devices to the point where their use is transparent. For many applications transparent operation requires that the device be context-aware. Unfortunately, the context-aware devices of an individual can be used to infer highly private information. Hence, these devices must be carefully designed; otherwise they may become a ubiquitous surveillance system. Therefore, existing state-of-the-art ubiquitous systems need to be examined from the perspective of attacks which can be reasonably expected against these systems.

1.1 WHAT IS UBIQUITOUS COMPUTING?

Ubiquitous computing is a concept where computing is made to appear everywhere using any device, in any location and in any format [30].

In ubiquitous computing environments computation is embedded. With advancements in computer science and technology the computer applications are seamlessly integrated into our daily lives. The devices worked in networked and standalone environment and capable of communication with the human and with each others. These devices support context-aware application, nomadic users, location aware services, and mobile data access. Ubiquitous systems provide anywhere and anytime access to information and various services while making the presence of the system "invisible" to the user.

1.2 PROPERTIES OF UBIQUITOUS COMPUTING (UBICOM) SYSTEMS

Three main properties for UbiCom Systems were proposed by M. Weiser [28], [29] namely distributed computation, invisibility, and context-awareness. The distributed computation means the computers/systems need to be networked, distributed and transparently accessible. They can interact with humans as well as with each others. The invisibility property means that the computer interaction with humans needs to be more hidden, and finally the third property proposed by weiser is context-awareness that implies that in order to optimize system operation in their physical and human environment it is necessary to make the systems aware of environmental context.

Kang and Pisan [16] argue that the principle goal of ubiquitous computing is to be user-centric that allows users to interact with the system in natural and non-intrusive way. Abowd et al. [3] proposed that ubiquitous computing goal is to assist users in everyday life.

The Fig.1 summarizes five core properties of the ubiquitous computing solutions [21]. It is not required for ubiquitous computing solutions to fully support all five properties. It may not be useful or usable in many cases in practice to support all five core properties.

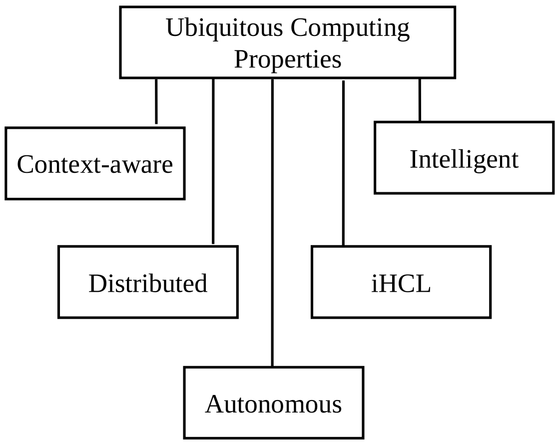

Fig.1. Five Properties of Ubiquitous Computing

1.3 OBSERVATIONS

We observed that the aim of ubiquitous computing to enhance and aid in daily activities of humans. For example, automatically perform certain task that meets the user's intention in a non-disruptive manner, offer new tasks to users by transparently integrating multiple services. To achieve this aim ubiquitous computing systems need to integrate communication devices in non-obtrusive way in human's daily lives, provide services to authenticated users to avoid leakage of user private information. To identify communication devices or sensors mostly used in ubiquitous systems, we performed a study of twenty existing applications. We identified seven general types of sensors are required for ubiquitous systems namely: movement, light, force, temperature, audio, humidity and proximity. In typical ubiquitous applications one or more of these sensors are commonly required to derive context information.

Ubiquitous computing can be localized within a context and available to users when it is required instead of making the computing services accessible everywhere for all devices. Automatic interactions and decisions are needed to reduce the bottleneck of human interactions; therefore, explicit human interactions are not necessary in all devices and could be less practical with micro-sized devices.

1.4 CONTRIBUTIONS

In summary, this research paper makes the following contributions:

- Classifies state-of-the-art research performed in ubiquitous computing.
- Provides analysis of important aspects in context-aware ubiquitous systems.
- Presents novel system architecture, a distributed frame-work designed to support ubiquitous computing applications.
- Presents a survey of sensors that are required for ubiquitous systems.
- Provides guidelines and further research directions required in the ubiquitous computing area.

The rest of this research paper is organized as follows: Section 2 describes our motivation. Section 3 discusses the literature survey. Section 4 provides user survey and analysis. Section 5 presents system architecture for ubiquitous applications. Section 6 suggest open research question in ubiquitous computing, and we conclude the paper in Section 7.

2. MOTIVATION

We were motivated to perform this survey in order to enumerate and compare state-of-the-art research that proposed techniques in the ubiquitous computing domain. This study paper provides analysis and summarizes architecture principles of ubiquitous computing. This research work presents a novel system architecture, a distributed framework designed to support ubiquitous computing applications. This paper can become the starting point for anyone trying to understand, evaluate and develop techniques for ubiquitous computing.

3. LITERATURE SURVEY

3.1 SERVICE COMPOSITION MECHANISMS

The idea of ubiquitous (pervasive) computing is to provide new services to users by combining the existing services. Researchers have extensively studied and explore a feature of the ubiquitous computing that allows transparently compose the services from various devices in a more or less ad-hoc manner.

In Amigo [12], the focus of the service composition mechanism used was to build a “global” automaton system. Using OWL-S [5] services are reported as semantic Web services in the Amigo service composition mechanism [4]. In that, the atomic processes have the QoS attributes with values obtained from runtime measurements.

ICrafter [24] is an example that allows users to combine services from different devices and have an aggregated user interface generated. With UbiDev [23] an application developer provides user interfaces, ontology, and classifiers for services included in an application. The classifiers are used to map resources on devices into concepts in the ontology.

We observed that in service composition three characteristics are needed namely, usability, adaptability and efficiency. The usability is a concern about how easy for users to accomplish a desired task using the system. The adaptability is the capability of the system to adapt to different environment and context. The efficiency is the property of the system to provide appropriate response and performance to the user requests or actions within a stipulated time. The three characteristics we have outlined in this paper are not explored in earlier service compositions mechanisms. Therefore, there is a need and opportunity of research available in the service composition mechanisms.

3.2 CONTEXT-AWARE SYSTEMS AND DESIGN PRINCIPLES

Location information based context-aware systems are widely used by users in their daily activities and demand for them is also growing due to increase in popularity of mobile devices. For example, various tourist guide projects [6], [10], [13], [19] that provide information (such as hotels, restaurants, museums, concerts halls, etc) to the users based on their current locations. To collect location information various sensors and modules are available such as GPS satellites, mobile phone towers, proximity detector sensors, cameras, barcode and magnetic card readers. These proximity sensors or devices are commonly used in the systems to identify the location of the user and provide services to the user based on the detected location.

In context-aware system project majority of them used and focused only on the location awareness however context-awareness can be improved by using different context aware sensors such as noise detectors, movement detector, light and smoke detectors. Integrating these elements and utilizing the information gathered from one or more of these sensors can allow to design and develop more useful, adaptive, efficient and usable systems. Munoz et al. [2] presented a context-aware systems infrastructure that adds context awareness to support information management in hospitals by using instant messaging paradigm. Devaraju et al. [1] proposed a framework for a context gathering that uses the sensor data model, messaging system, communication protocols and application programming interfaces (API). He also analyzes approaches for sensory data acquisition for sensory data acquisition.

The principles of the context-aware system designing include methods of context data acquisition and context management models. Chen et al. [7] presented three different methods of context data acquisitions: Direct Sensor Access, Middleware Infrastructure and Context Server. Winograd [31] described three different context management models: Widgets, Networked services and Blackboard model.

We observed that the existing solutions and research efforts mainly focused and used physical sensors for context awareness. However, we believed that logical and virtual sensors are also useful and capable of providing more contextual in-formation. Virtual and logical sensors need to be incorporated in ongoing research solutions and systems.

3.3 PERVASIVE COMPUTING MIDDLEWARES

The aim of pervasive computing is to create a smart environment using embedded sensors and networked computing devices that provide users transparent access of services. Examples of existing pervasive computing middleware systems are Aura [11], [25], Gaia [8], [22], CORTEX [26], Scenes [15] and Universal Intelligent Objects (UIO) [27]. Abhijeet [17] provides a comprehensive survey of mobile healthcare problems and need of could assist pervasive devices.

We observed that pervasive computing middlewares helps developers to design the application in multiple ways. It's most important feature is, it provides system abstraction to developers that help them to focus only on the application logic instead of worrying about low-level implementation details. Another feature of pervasive middleware systems is to provide management of system resources such as ser-vice management, context management and data management of context using ontology allows the application of various measures of semantic similarity based on the structure of the ontology.

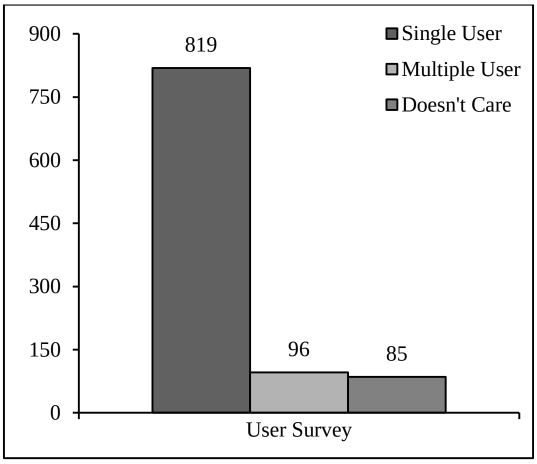

Fig.2. Survey result of single user operated vs. multiple user operated

4. USER SURVEY

To identify user requirements for user interface design and features of ubiquitous devices we conducted a user survey of 1000 engineering students. Even though the number of people participated in the survey are very small in numbers and far from providing conclusion but it provides an indicative figures of user preferences [20]. The survey included following seven questions. To each user same set of questions and choices were given.

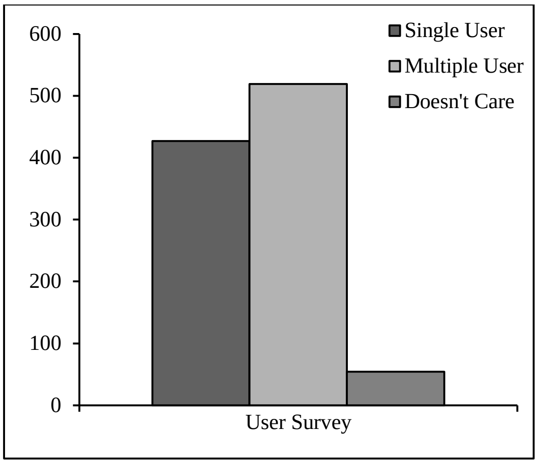

Fig.3. Survey result of single task vs. multitask

Would you prefer a typical smart device to be single user operated or multiple users operated? The Fig.2 shows the result of the survey. Total 819 users preferred a smart device single user operated, ninety six users preferred multiple user operated and eighty five users simply don't care.

Would you prefer a typical smart device to be specific for a single task or should support multiple tasks? The Fig.3 shows the result of the survey. Total 427 users preferred a smart device should be single task specific, 519 users preferred multi-task operations and fifty four users simply don't care.

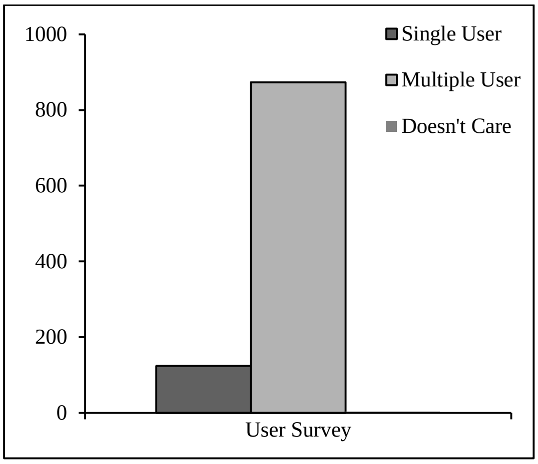

Fig.4. Survey result of stand-alone vs. networked

A ubiquitous device should be stand-alone or networked? The Fig.4 shows the result of the survey. Total 124 users preferred a smart device should be stand-alone, 873 users preferred network operated device and three users simply don't care.

For typical networked smart devices would you prefer wired connectivity or wireless connectivity? The Fig.5 shows the result of the survey. Total 967 users preferred a smart device should have wireless, 24 users preferred wired connectivity and nine user simply don't care.

What type of haptic input should be supported by a typical smart device? [One-handed, two-handed, hands free]. The Fig.6 shows the result of the survey. Total 356 users preferred one-handed input method, 46 users preferred two-handed and 598 preferred hand-free input method.

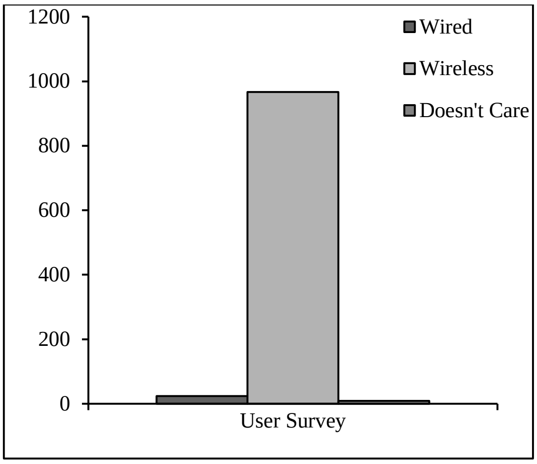

Fig.5. Survey result of wired connectivity vs. wireless connectivity

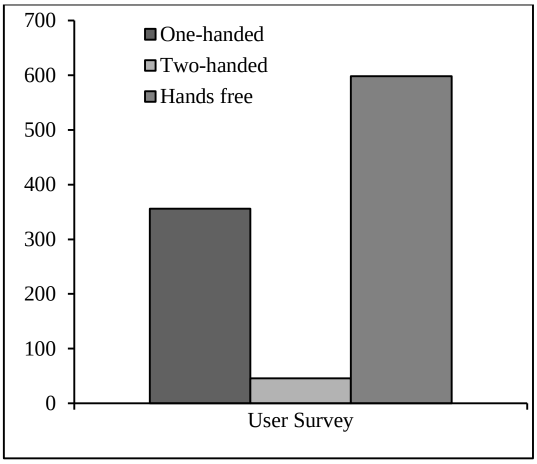

Fig.6. Survey result of haptic input methods

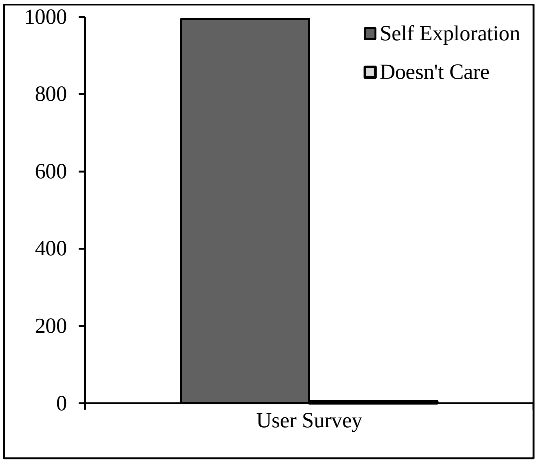

Fig.7. Survey result of safe exploration

Should a typical smart device provide a safe exploration that can allow user to undo operations or try different things? The Fig.7 shows the result of the survey. Total 995 users preferred a safe exploration, five users don't care.

Does a smart device should support instant feedback that can allow users to see immediate effect of an action they perform? The Fig.8 shows the result of the survey. Total 964 users preferred instant feedback, 34 users preferred cumulative feedback and two users don't care.

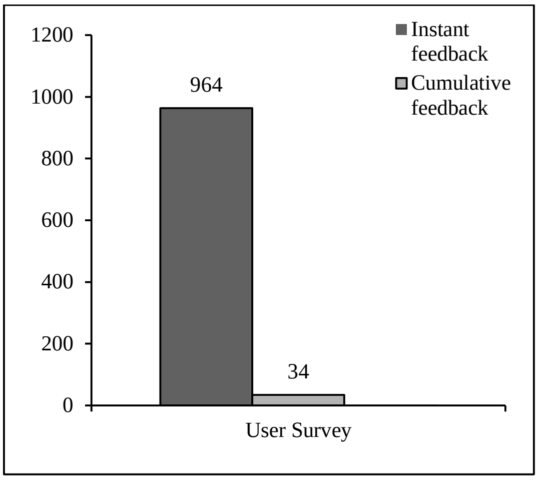

Fig.8. Survey result of instant feedback vs. cumulative feedback

5. SYSTEM ARCHITECTURE

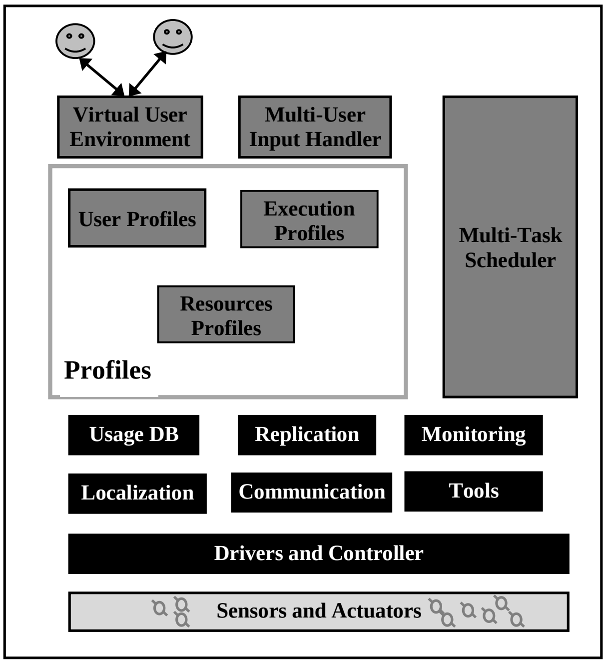

Fig.9. A novel system architecture for ubiquitous computing

5.1 APPLICATIONS

This section presents a novel system architecture designed to support ubiquitous computing applications. Ubiquitous computing is categorized by the interaction of various heterogeneous devices, ranging from high-end servers to tiny mobile sensors. Devices can be connected to each other using wireless communication technologies like Bluetooth, IrDA or Wi-Fi (IEEE 802.11).

The Fig.9 shows the principal components of the proposed architecture. It includes various types of sensors and actuators and drivers and controllers to handle them, it also includes various profiles such as resource profiles to handle resources optimally, user profiles to manage user settings and preferences, execution profiles to control execution of processes. The multi-task scheduler module is used to handle multiple tasks efficiently and support multi-task environment in the application. The multi-user input handler and virtual user environment modules provides support to multi-user as well as context and user design management. The User DB module helps to authenticate users. The other modules such as tools, monitoring, replication, communication, localization supports various features in the ubiquitous computing applications.

6. RESEARCH QUESTIONS

To solve research problems in ubiquitous computing needs to address the research challenges in human computer interaction, artificial intelligence, and context management. The need to ubiquitous computing solutions generates a number of important research questions:

What methods can researchers use as they explore a design context?

- To provide implicit Human Computer Interaction (iHCI) property, how can user tasks be modeled and analyzed automatically by the system? For example, Timetrees, which is a branching-time structure to Model the state and activities in HCI.
- How user intent is determined correctly? Does it implicitly determine by the system or system needs explicit user interactions.
- How to represent user intent into the system?
- How to present context in the system and how it could be used to decide application state.
- How often context information is needed to be updated and how frequently system needs to consult to the context information database.
- How to identify minimum number of services required for the system.
- Research in ubiquitous computing is crucial because it is a fusion of a research in many disjoint areas.

7. CONCLUSION

This research work presented a survey of a survey of ubiquitous computing research. We provided a classification of the research areas on the ubiquitous computing paradigm and presented common architecture principles of ubiquitous systems and analyze important aspects in context-aware ubiquitous systems. This works also presented novel system architecture, a distributed framework designed to support ubiquitous computing applications. This research paper serves as a guideline for researchers who are new to ubiquitous computing and want to contribute to this research area.

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