CONTEXT AWARE MOBILE COMPUTING AS A CHALLENGE FOR DEVELOPERS AND SOFTWARE ENGINEERS:A REVIEW

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Abstract

The trend of mobile computing has entered the society like rapidly flowing water. Almost every person wherever he is present, is getting benefits from it while working, studying, traveling or even for enjoyment. Due to this great demand of mobile computing there are some challenges such as context-awareness for the developers and the software engineers who are greatly concerned with the satisfaction and ease of their customers. The context aware mobile computing has gained an increasing recognition and is one of the emerging technologies for the mobile devices of next generation. This is a review paper in which we have generally discussed some of the issues of mobile computing with respect to software engineering and specifically we have reviewed some issues and problems of context aware mobile computing for developers as well as software engineers.

Keywords: Mobile computing, Context aware, Software engineering

Introduction

Mobile computing is gaining wide acceptance because of the fast improvement in wireless communication technologies. This has led to an increase in the requirement for mobile information access (Mandi Gobindgarh & Abhishek Kumar Gupta 2008).Mobile computing means that the users can access information and collaborate with others by using portable (mobile) computing devices. These devices may include tabs, Laptops, PDA's, smart phones and other handheld devices. Mobile computing environment is distributive,where we have mobile hardwares (mobile devices) as clients having mobile softwares in them and information systems (e.g; satellites, internet etc) as servers. Mobile computing devices use wireless technologies such as Wi-Fi, LAN,MAN and GPRS etc (K. Asha &Vallikkanna 2008).

One challange in mobile distributive computing is to make use of changing environment with a new group of applications that are concious of context in which they run.The context aware system adapt itself according to the collection of people around, accessible devices and changes to these things over time.So a context aware system provide suitable service or content to users by making use of contextual information without too much user interaction(Sangkeun Lee, Sungchan Park, & Sang-goo Lee 2009).Different authors have identified different issues related to mobile computing such as creating user interfaces accessible to differently-abled users, Handling the complication of providing applications across many mobile platforms, designing context-aware aware applications and specifying requirements ambiguity(Josh Dehlinger & Jeremy Dixon 2011). Some authors have focused on context awareness issues like Architecture Style of context aware systems, its performance, Historical Context Data & User Behavior, Privacy Protection were identified. Some imaginary scenarios were also proposed which should be considered as a future of context aware mobile computing (Sangkeun Lee, Sungchan Park, & Sang-goo Lee

2009). In the area of mobile computing, the goal of applying context is to make the device capable to offer better services to people by providing the context information that is available (Li Han, Salomaa Jyri, Jian Ma & Kuifei Yu, 2008). Issues related to main components of context aware systems such as Context Acquisition, Context Representation etc were discussed by different authors(Nazir Malik, Umar Mahmud & Younas Javed 2007).According to some authors context-awareness framework can be appealing as in mobile environments context changes gradually over time and space(Yaser Mowafi & Dongsong Zhang 2007).

In this paper we have generally discussed some of the issues of mobile computing with respect to software engineering and specifically we have reviewed some issues and problems of context aware mobile computing for developers and software engineers.The remainder of this paper is organized in literature review,analysis,results and discussions and finally conclusion and the future work.

Literature Review

The growth of computing platform has outpaced the software engineering work adapted to mobile application development (Josh Dehlinger & Jeremy Dixon 2011). Mobile device user interfaces (UI) provide a new paradigm for new human-computer interaction sequences that have not been previously explored in research and there were no established UI guidelines present and different mobile platforms (Android, Windows 7, etc.), differing hardware manufacturers for platforms (e.g., Android versions on HTC, Google, Samsung) and cellular phone and tablet platforms (e.g., Apple’s iPhone and iPad) have necessitated developers to make a chain of the same application modified for each type of device. These features discussed above found in mobile devices are leading towards four main challenges to mobile application software engineering such as creating user interfaces accessible to different users, handling the complication of providing applications across many mobile platforms, designing context-aware aware applications and specifying requirements ambiguity.

Agent oriented software engineering can be used for mobile application software engineering which can improve the design of context-aware applications but different authors find that many service scenarios assume too ideal situation (e.g. an agent knows everything about every user).RELAX is a medium of expressing environmental and behavioral ambiguity for the behavior of dynamically adaptive systems(Josh Dehlinger & Jeremy Dixon 2011). In RELAX requirements are partitioned to those that are invariant (i.e., requirements that must always be satisfied) and variant (i.e., requirements that may be partially satisfied) .For each variant requirement, the RELAX process documents what environmental changes can affect the requirement and how the requirement can be partially satisfied. This approach extends the traditional shall requirement to document the uncertainty and how the application can adapt in the face of uncertainty to still deliver some functionality. When combined with an agile approach, it would provide better requirements structure and improve analysis and satisfaction of non-functional requirements in mobile applications when the environment/context changes.History of context awareness has described technical issues of context aware systems. Review was performed by different authors in which they find that many service scenarios assume too ideal situation (e.g. an agent knows everything about every user).By keeping these things in mind seven realistic service based scenarios were proposed (Sangkeun Lee, Sungchan Park, & Sang-goo Lee 2009).

A. Historical background of context aware systems

Context aware systems history is from 1994 to 2008.

- Evolution of Context: Context definition was location only first time then it refined to location, time, identity and environment. In 1998 emotional status also become the part of context elements. In 2000 context was further refined to be called an information that can be used to describe the situation of entities that are considered appropriate to the communication between a user and an application, which includes the user and the application themselves.

- Context Aware Systems And Applications: These applications can be general and specific. Context aware system represents context data, gather and manage context data and do service matching. It includes:

➢ Location aware systems and domain specific applications: In 90's first location based service system was developed and that was the time when there was limited types of context data supported by context aware systems such as tour-guide, shopping assistant etc.

➢ Context aware frameworks: In 2001, Context Toolkit was developed that can be used as reusable software components for accessing and interpreting context data. Then in 2002 hydrogen framework was developed. Both these frameworks had peer to peer architecture.

OWL (Web Ontology Language) was also designed for the Semantic Web, but many context-aware systems used OWL as the context-model. It had performance problems.CoBrA was agent based context aware system which has centralized context broker which maintains and manages the shared context data. Using it users can define privacy policy for their identity protection. Another architecture called context fabric also provide privacy protection facility to users while getting context information.SOCAM (Service-Oriented Context-Aware Middleware) was similar to CoBrA, because it also aims to build a middleware for context-aware services and uses OWL to model its context. SOCAM had upper ontology and domain-specific ontologies.CocA was another framework that uses ontology approach and database approach to manage context data. These two approaches ,loading only relevant data according to heuristics and good performance made it acceptable to many context aware systems.Different research issues such as architecture style, performance, historical context data & user behavior, and privacy protection of context aware systems were identified.Architectural styles were peer to peer and centralized server architecture(Sangkeun Lee, Sungchan Park, & Sang-goo Lee 2009). Context can be divided into social, physical and internal context (Li Han, Salomaa Jyri, Jian Ma & Kuifei Yu, 2008).

- Physical context is the real world around user; it includes the physical things like building, computer etc.
- Internal context describes the abstract things related to people like thought, action, feeling, task, interest etc.
- Social context describes the s social surrounding of users i.e. social relationship. It includes people related to user. Every kind of context information can belong to either past, current or future context.

Context information can be proposed by user as when registering for a website. Context information can be provided by mobile handheld device like mobile phones, or by sensor devices which are installed on specific location. In the area of context, location is most important information which belongs to physical context. The most widely used location-sensing system GPS(Global Positioning System).GPS does not work well indoors because signal strength is often too low to penetrate in buildings. RADAR system can localize a laptop in building within 2-3 meter location using finger prints from four 802.11 access points. There are many other indoor location systems which use ultrasonic and infrared technology, but extra hardware infrastructure installation is required for them(Li Han, Salomaa Jyri, Jian Ma & Kuifei Yu, 2008).

B. Service scenarios of Context aware Systems

Author also proposed seven context aware service scenarios. so that these aspects should be focused while making practical context aware systems(Sangkeun Lee, Sungchan Park, & Sang-goo Lee 2009).

- Collaboration among devices: PDA rings and asked the user whether to prepare ice coffee or not. On saying yes the coffee pot in room starts to make iced coffee. The U-home terminal notified the user that the iced coffee is ready. It is concluded that there is a functional collaboration between multiple devices. A context-aware system should consider device substitution for services (If user has cell phone instead of a PDA, participating devices could be changed for the same service).
- System should use information form external sources: U-home management terminal rings and gives weather forecasting information from the website that it will rain today. So it is concluded that the system should be able to use information from the external sources e.g; web sites, web services, etc.
- Recommendation based on User's Schedule: User puts reminder about event on the calendar application on PDA. System should remind the user and give him suggestions for travelling e.g; about trains, buses so that he can reach at the event place safely and timely.
- System should catch the changing information: Context information such as location of bus keeps changing rapidly so context-aware systems should be able to catch up the rapidity of changing information.
- Automatic Environment Setting and feedback: System should maintain e.g; suitable temperature for sleeping and plays a calm music. The system should ask different questions from user like "Did you sleep well? Yes / No" and use these answers as a feedback for later services.
- Cooperation among devices: For example at the conference room the brightness of room should be adjusted by the system automatically for the presentation and Listeners can automatically see the slides through their PDA or other portable devices automatically. The system should support devices to make an ad-hoc network without a centralized server to achieve availability of the system.
- Using legacy database information: Context aware system should use legacy system's database as context-data and give this information to the user by physically sensing his presence on the system. e.g; User sits on the system to apply for graduation. The system recognizes him and show him the application deadline by getting information from the university database and suggest him to visit department office.

The existing context-awareness applications can be of three types (Li Han, Salomaa Jyri, Jian Ma & Kuifei Yu, 2008).

- Intelligent space that presents an ideal vision of future life where the device would be disappearing but service would be ubiquitous.
- Providing information based on context represents intelligence of service that will change the way of using Internet from people looking for information to information looking for people .e.g. Tourist guide is one of the example.
- Mobile context sharing application that make the communication between people easy.

Many services of internet can get better through context aware mobile computing by improving intelligent features e.g. Q&A service. In current websites of Q&A as Ask Yahoo!, people look for questions which they can answer(Nazir Malik, Umar Mahmud & Younas Javed 2007). Depending on the knowledge people can answer only a part of questions. Much time and energy can be saved if questions can look for people who can answer the question instead of people looking for questions. Following are some differences that this concept has from the work done previously (Li Han, Salomaa Jyri, Jian Ma & Kuifei Yu, 2008):

- Context of all the questions will be fully considered
- To know the user well all the related context information of every user including question and answer will be analyzed and stored.

- People closely related to the question will be actively looked by the service thinking that they can answer the question according to their history.

So the context-aware Q&A will provide the answers quickly to the people who ask question and also increase the efficiency of people answering the question by making use of context information.There are five main components of context aware systems such as Context Acquisition, Context Representation, Context Storage, Context Interpretation and Context Adaptation(Nazir Malik, Umar Mahmud & Younas Javed 2007)**.**Context acquisition deals with sensing the contextual data through sensors built into the mobile devices and present in the environment and gathering the contextual data by the acquisition modules of the context-aware systems.The acquired raw data is then represented in a standard format for sharing the data. The issues in context representation are :

- Representation Schemes should use standard schemes and if are they not used then there must be some context transformation mechanisms to translate contextual data between the standard formats.
- Identities of the context-aware systems involved in inter-communication require to be authenticated earlier than starting exchange of data.
- Exchange of data should be secure from the malicious objects requiring confidentiality. Communication can be established using public or private cryptosystems.

The context data is then stored into the context aware device which allows the system to keep a history of context that is used to identify preferences of the entities(users, smart phone network companies).Issues of Context data storage are that:

- It requires a plenty of memory and fast retrieval mechanisms to achieve memory related efficiency.
- The old context data must be removed but its effect should be maintained (Little information must be present). Preferences should be maintained in quantitative format.
- History must be there to predict the context data in the absence of sensor data.
- Contextual data should be stored in encrypted form at storage areas to keep away from exposure to unauthorized entities. Encrypted data is shared among the participants in areas of high risk.

Context data is then interpreted and implications are reasoned which provides instructions for adaptation process and applications. The interpreted contexts provides information about ‘What’, ‘Who’, ‘Where’ and ‘When’ contexts e.g; to identify the best service available it must be according to the preference of the user, to identify the best route, the context of the intermediate environments on the route should be interpreted. Research issues in interpretation process are :

- The interpretation should consider the user mood and preferences (predicted through history) before adaptation.
- The context-aware systems should interpret the context on the basis of their scope e.g; a context-aware laboratory should gather contexts of all people working on different experiments.
- Interpreted context should be reasoned to deduce implications e.g; if the context of a scholar engaged in research activities is busy for the past two hours then it may deduce that the scholar desires a break. Reasoning is the basis for the discovery and adaption of services.

Context adaptation uses decision making techniques to help the users in his daily tasks. It discovers the Service for the user on the basis of load and cost as element of their context preference. The selected service is then delivered to the user through the mobile devices. The delivery process selects an interface that is well-matched with the participating devices. The contextual data is used to adapt the service behavior and the device behavior. Context adaptation can be event-based or event-less. Event-based adaptation is carried out when an external event occurs. Eventless adaptation is carried out in the absence of external event when internal reasoning recommends adaptation of services.More focus has been made on extracting and acquiring context from the surrounding environment and less effort have been made on finding out how to develop context-awareness within mobile computing globe.One of the approach to build a conceptual framework for context-awareness in mobile computing is the user-centered approach.The misinterpretation or ambiguity in the set of collected context data that is captured by context-aware systems has been brought in notice by many researchers. An alternative approach addresses those concerns as following(Yaser Mowafi & Dongsong Zhang 2007):

- The integration need implicitly means that which context-aware systems will proactively provide the users with awareness behaviors and explicitly means the direct input through end users'. We argue that traditional dependency on the sensor-based context acquirement is reduced with such integration .
- Context-awareness should be interpreted from the user's perspective to enable a context-aware system to capture some of the contextual information that is already abstracted by the user themselves instead of completely relying on the system to gather the user's actual context.

Integration of user context with physical context is the need that is emphasized by the relevancy of context to user's interaction with the mobile devices. User centered context-awareness approach would reduce the erroneous inference of users' relevant context. It is composed of user context profile, context information manager, dialog manager and context-awareness service manager.

Analysis

Research methodology we have adopted includes the review of some research work done by different researchers in mobile computing and context awareness. The review of related work reveals that the context aware UI design is difficult and mobile application developers must foresee the targeted device e.g; Apple devices are restricted to two sizes based on the size of the iPhone and the iPad while Windows 7, Android, and Blackberry offer screens of varying sizes and screen resolutions. Developers should consider Shneiderman's guidelines that can be easily translated to mobile devices such as enabling regular users to use shortcuts, designing dialogs to yield closure, offering informative feedback and supporting internal locus of control. Developers should use software product line engineering approach for mobile applications to save development time and cost. This approach may be appropriate to mobile application software engineering in that it would give confidence to developers to proactively focus on what the common requirements, design, resources, etc. to the development of a mobile application across different OS platforms (e.g., iOS, Android, etc.) or hardware platforms (e.g., HTC, Samsung, Google, etc. for the Android OS). Researchers should look to how SPLE can be specifically modified for mobile application software engineering to avoid duplicating early software engineering work and assets (K. Asha & Vallikkanna2008).

Developers should consider context-awareness as a first-priority feature in mobile application software engineering to design better context-aware applications. Agent oriented software engineering can be used for mobile application software engineering which can improve the design of context-aware applications but different authors find that many service scenarios assume too ideal situation. (e.g. an agent knows everything about every user)(Josh Dehlinger & Jeremy Dixon 2011).The dynamic, contextual nature of mobile application content (e.g., location-based applications) allows for cases in which the application's behavior may not be able to completely convince the specified functional and non-functional requirements so in this case it is better to provide old content (i.e., content based on a previous location) instead of displaying an error message (e.g; due to low battery, GPS sensor disabled, etc.) or no response from the application.As mobile applications become more context-aware, self-adaptive requirements should be integrated into agile development so that developers more thoroughly consider the behavior of an application when its full requirements cannot be fulfilled dynamically and how it may self-adapt to partly satisfy the requirements. All the context information cannot be obtained easily, particularly the internal context information such as context information of people emotion. Context information that is obtained is not always fully utilized. As for mobile application, the knowledge in the mind of people is important but it is impossible to let that be expressed explicitly. Previous and current context information can be used to gather such context information(Li Han, Salomaa Jyri, Jian Ma & Kuifei Yu, 2008).

User Authentication and standard context aware representation is an important issue. In addition to this Context aware information must be provided to the user according to his preference and must be according to the scope, not outside the scope.Context aware architectural style must be according to the requirement of the system such as Peer to peer and central server. Different devices support heterogeneous data that was also the main issue of context aware systems(Mandi Gobindgarh & Abhishek Kumar Gupta 2008).Software engineers and developers must address Performance issues which arise If there are many users to approach for the same context data. The increased number of sensors also effect the system performance so these issues must be kept in mind while designing the context aware system(Josh Dehlinger & Jeremy Dixon 2011). By analyzing user behavior log, the system should automatically suggest a new service to service provider.System should be able to protect user's private information from the illegal accesses (e.g. "my mailing address and current location should not be accessible to other users"). In context-aware mobile computing one of the important problems is to balance the relationship between acquiring context and protecting privacy(Yaser Mowafi & Dongsong Zhang 2007).

Results and Discussions

From the above analysis done by reviewing some of research work done by different researchers in mobile computing and context awareness we have highlighted some of the issues faced in the area of mobile computing and context awareness. The section also presents some guidelines for software engineers and developers in the area of context aware mobile computing. The results are presented in table 1.1 as given below.

Table 1.1 Challenges in context aware mobile computing and guidelines for developer and software engineers

Issues /Challenges in context aware mobile computing	**Guidelines for developers and software engineers**
Inferring context information.	Context information can be inferred from complete location information so researchers must do research on location information mining
Difficult to sense internal context.	Use methods that allow users submit internal context such as nicknames used by users.
Time and accessibility.	Information should be delivered to the most accessible device of user's context and timely delivery of data is also the important aspects which the context aware system should have.
Improvement and efficiency in service.	Internet services can get better through context aware mobile computing by improving intelligent features
Lack of automatic means of inferring information.	Computers should be improved to gather context and deduce it, the increases in richness of communication in human-compute interaction results in a more powerful and more useful computational environment.
Complexity in context acquisition due to gradual change of context over time and space in mobile environments.	Developing a context-aware system based on the framework can decrease the complexity related to the traditional context acquisition approach that is mainly based on the sensor-based structure, by influencing users' natural dialogue with value-added services of mobile computing that are currently available on most mobile devices e.g. GPS or messaging services. For the successful design, development, evaluation and deployment of context-aware artifacts such simplification is very important.
Insecurity of users regarding context aware applications.	User's privacy, authentication, his required data preference and scope of the required data should be kept on the top priority while developing and designing the context aware software.
Reusability and development process of context aware software.	Context aware software's must be developed through mature SDLC having reusability as its core and reusability must be done carefully and it must save development time and effort.

Conclusion and Future Work

Mobile computing is gaining wide acceptance because of the fast improvement in wireless communication technologies.The aim of context-aware computing is to make the mobile devices smarter by enabling them to recognize and understand the surrounding environment and also react intelligently. But still the design, development and deployment of the artifacts of context-aware mobile computing are in its initial stages as the existing research in this area has not gone beyond restricted research laboratories or are in proof-of-concept stage. Due to the great demand of mobile computing there are some challenges such as issues related to context-awareness for the developers and the software engineers who are greatly concerned with the satisfaction and ease of their customer.This is a review paper in which we have generally discussed some of the issues of mobile computing with respect to software engineering and specifically we have reviewed some issues and problems of context aware mobile computing and suggested some guildlines for developers as well as software engineers.

Future context aware computing environment could consider realistic scenarios such as collaboration among devices and it may give recommendation to user based on user's schedule, provides information to user by using legacy database information and automatically sets the environment according to user requirement and use his feedback to improve its services. The issues in context representation and context data storage should be considered and research should be done on the interpretation process of context aware systems.

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