An Explorative Review Into Uses and Pitfalls of Context Aware Mobile Systems

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With computing devices and applications being so integrated into our lives, the drive towards ubiquitous computing is constantly accelerating. Making applications smarter through context awareness is a method of removing user input. This allows the device itself to predict the users' intentions and is a major way of increasing ubiquity and driving technology towards transparency. Mobile devices are key to this development due to the ever-present nature of such devices and the level of hardware and sensing tools available on most platforms. This paper will first introduce context awareness and the major challenges faced by such systems. Following this introduction, it will develop into an exploratory review of various uses and applications of context aware systems in mobile devices, as well as current issues and pitfalls that face these applications.

Introduction

Context specific information can be an exceptionally valuable tool for developers. Dey describes context as "any information that can be used to characterize the situation of an entity" [1], this can be regarded as the standard overarching definition of contextual information in computer science. Contextual information can take many forms but can broadly be classified as location specific, time specific, person specific and action specific data. Taking advantage of this information in systems requires the system to first acquire the relevant information and to subsequently interpret the context and provide a useful response to the identified context [2]. This functionality is known as context awareness.

Clearly, the ability of systems to optimise tasks and user experience can be greatly enhanced by context aware functionality. This paper will firstly further the definition of context awareness, specifically with its uses in mobile systems, and how it can be used to adapt both systems and user behaviors. Uses and advantages of context aware mobile systems will be discussed as well as potential issues and pitfalls that arise from the ubiquitous integration of these systems into daily life.

Context Aware Systems

Defining Context Awareness

The applications of context aware systems are broad and varied but are classified by Dey into three main areas: [1]

- present information
- execution of a task automatically
- tagging of an identified context to information.

Context awareness in mobile devices is enormously popular due to the ubiquitous use of mobile computing devices in daily life and ever-increasing sophistication of mobile hardware. Often the integration of context awareness with mobile devices is enabled by the device itself via onboard sensors, such as location and light sensors, providing the context for the various tasks and data carried out by the device. Due to

users becoming increasingly dependent on "always on" network connectivity, vast amounts of data is always accessible to connected mobile devices. Fusing the data provided by these services such as calendars, emails, social media, online marketplaces, photos and music with the sensing capacities of mobile devices provides countless possibilities for context aware systems to optimise user workflows and user experience.

The key challenge faced by context aware systems is not just to deliver information based on sensor-based triggers but to provide context-specific information at an appropriate time and location and to present the information in a way that is optimised for the individual user [3]. In location based systems this is regularly done by using a narrow definition of context and using specific predefined location data as a trigger [4]. In systems that focus on recommending various services or products to individuals, the contextual information can be less restricted, using data from users' past activities as well as sensory based information [5]. An example of combining data such as this could be a system that identifies that the user is outside and warning the user of potential changes in weather by suggesting nearby amenities and activities that fit the users' preferences as an alternative to the outdoor activity. In ambient intelligence systems, environmental data can be acquired from many local embedded devices that acquire contextual data and use the data to customize the system.

Context aware mobile systems have many interesting and varied applications. User preferences are an obvious example and can be applied to entertainment applications such as music players [6], which can be used to provide a context aware recommender service to offer new recommended music. Other novel uses include medical applications such as fall detection devices for use in care homes [7]. A selection of applications of context aware mobile systems will follow with a discussion of their functionality and potential pitfalls and possible solutions to identified issues.

Discussion of Potential Uses and Pitfalls of Context Aware Mobile Systems

The increasing power of mobile devices provides a wide array of interesting applications for context awareness, one such example of this is mobile augmented reality systems. With 4G network connectivity and public clouds widely available alongside powerful commercialized AR systems, such as Google Glass, makes truly mobile AR a reality. Manweiler discusses this possibility using public clouds as an answer to limited mobile computing by using powerful back-end systems as a cloud service for providing contextual information based on the users' activities [8]. However, problems with this method are identified, a major issue being latency on a public network. In a system such as AR where continuous, strong, computer vision is required the system is extremely latency-sensitive thus highly dependent on network speed.

Maier et. al. propose an alternative approach to computer vision driven context aware mobile systems based on a concept known as "Context-Proximity Awareness" [9]. Rather than using public networks for identifying context and backend processing, an algorithm is proposed that uses the visual input from multiple local users devices (such as Google Glass) and performs traditional feature matching techniques to identify users proximity to each other. Using this similarity value it is proposed that the users can be effectively identified as being part of the same social group and services can be provided accordingly to this context alongside other contextual information.

Context aware advertising is a more traditional application of context aware mobile systems. Having billboards or other digital media reacting to nearby consumers mobile devices which share information on the consumers shopping habits is the obvious solution, however, this introduces an obvious privacy risk. Shabib et. al. provide an approach to context aware advertising based on identifying products the consumer has on their person [10]. It is suggested that RFID tags could be integrated into clothing and the digital media could detect

this resulting in advertising similar styles and brands. As there is no inherent connection between the consumers' identity and the product information there is no risk of a privacy issue.

Privacy is a key concern with most context aware systems, this is more so the case with mobile devices where public networking and data sharing is crucial to identifying relevant contextual information. A wide range of privacy protection methods have been proposed for mobile devices, such as sticky policies [11] which attach usage conditions to shared data and resources. However, in context aware systems the problem of privacy is more of a concern due to users' perceptions of privacy concerns regardless of whether the concern is a real threat as the data involved is highly personalized by definition. This perception may discourage users from adopting context based systems. The general solution to sharing personalized data is via an independent trusted mediator known as an anonymiser, however, systems such as this are vulnerable to a single point of failure. Rahman et. al. discuss the issues of traditional privacy protection in context aware systems and introduce a methodology designed for context based applications in mobile and pervasive environments that use a collaborative model between requester and service provider to remove the need for the anonymiser [12].

Context awareness has also been applied to privacy and security systems, context aware security frameworks for users contextual information within mobile applications have been proposed [13], [14]. The framework allows or blocks data and network access based on the context of the user at the time of the security request. For example, the context aspects could include location, time of day, movement speed and network location, these aspects could be used to identify the users' activity and provide security accesses accordingly. If the mobile application in question is a fitness app used for tracking runs it will require access to location data and the device accelerometer, the framework would block access to this information unless the user has been identified as being in a public place moving at a jogging pace and on a cellular network. This could be used to reduce the risk of the users daily personal activities being inferred from the data passively collected by the application when the user is not running.

Location based services are some of the most common context aware systems in mobile devices due to the easily accessible location data from the mobile hardware. Applying additional context to location data, however, can be challenging. Viktoratos et.al. discuss a procedure called Geo SPLIS which collects data from external sources such as point of interest websites and APIs combining it with demographic based profiles and rules to model user preferences and evaluate data to deliver points of interest matching the users' needs [15].

The system described by Viktoratos is an example of a location based recommender system, context aware recommender systems are a common usage of context aware systems. Emerging as a novel type of recommender system that uses contextual information to adapt user preferences, the fundamental argument for use of a such a system relies on assumption that a users current requirement will be dependent on the context of the situation [16]. An example of this is the choice of restaurant may be dependent on if the user is with children or not. Context identification is usually achieved via user profiles such as age and gender, item features such as films or music, and action attributes such as time or location. Due to the complexity of contextual data in recommender systems they are often failure prone, this failure rate is a significant pitfall of many context aware systems. Unger proposes a potential solution by extracting "Latent" contexts from hidden patterns in contextual data [17]. These patterns are identified by treating contextual data as numeric vectors and using deep learning techniques. These deep neural networks discover underlying latent contextual data making the final contextual identification more reliable. Despite the accuracy of prediction and context identification, context aware systems are still dependent on users trust in the system's behaviour.

Making context aware systems intelligible so users can understand how contextual deci-

sions are made, and better place their trust in such a system is a solution to lack of user trust. In context aware systems this is a complex process due to the non-triviality of the data involved and the applications decision-making process. Lim and Dey present a toolkit for developing intelligible context aware applications in which they breakdown explanations into types, these types include inputs, outputs, what, what if, why and why not explanations of procedures of the system [18]. This categorisation of explanation types can be used to rapidly generate explanation structures for complex context aware systems. This can then be used to help users understand the application and improve their trust in the system.

Conclusions

The main failings and pitfalls in context aware systems previously identified are focused on two issues, firstly, privacy and user trust in the system, secondly, correctly identifying the relevant context. Issues with privacy and security have been addressed with collaborative models removing the need for third-party anonymisers and applying context awareness to the security framework itself. Although security frameworks, on the whole, are robust, a key sticking point is encouraging users to trust the behavior of the system and trust how the system handles personal data.

Identifying context via various means is a focal point of many of the papers discussed, ranging from location based systems to more complex systems that compound large amounts of contextual data and employ deep learning methods to spot underlying contextual patterns. Access to contextual information is not an issue in many systems due to the sophistication of hardware and the seamless integration of sensing technology, this has only been identified as an issue in high powered applications such as AR where alternate computing processes have been investigated such as cloud computing. Reliability of context identification and building user trust in context aware systems is an area of constant development, increasing intelligibility or making context aware systems more ubiquitous are key mechanisms for achieving this.

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