A Survey on Context Awareness

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Abstract—we have reviewed the research of context awareness of recent years in this paper. First of all, we describe the definitions of context and context awareness which are made by different scholars in different fields，and propose our own definition. In addition, different classifications of context and context awareness are analyzed. We focus on context acquisition and sensing, context modeling and representation, context filtering and fusion, context storage and retrieval in context awareness computing. Finally, the context awareness application of domestic and foreign are discussed, and the development of the context awareness is prospected.

Keywords-pervasive computing; context; context aware; context aware computing; context aware system

I. INTRODUCTION

With the rapid development of mobile communication technology and user interface technology, many mobile internet devices such as PDA, laptop, notebook, smart phone, etc, have been remarkably concerned by modern society. Ubiquitous computing is becoming a reality which emphasizes the integration between the information space and the physical space. With the help of it, people can receive and process information anytime and anywhere through a device which can connect any internet. As a result of this, it can reduce the complexity of using device and make people's lives easier and more efficient. The environment of user in ubiquitous computing such as the location, or terminal equipment, etc. is constantly changing, which is called context. As one of the core areas of ubiquitous computing, context-aware computing has become more and more popular among people.

Since the advent of context awareness, none of the studies gets a strict definition of context. The aim of this paper is to survey the most relevant literature in this area. Section 2 reviews various definitions of context and context awareness, and some ways of classification. In section 3, we analyze context acquisition and sensing, context modeling and representation, context filtering and fusion, context storage and retrieval in context awareness system. The last section presents some current application in this area and gives a final prospect and summary in this survey.

II. CONTEXT AWARENESS

A. Definitions of Context

With the development of technology and changes of social life, researchers at different stages and fields may have different understandings of the context, so far, there is no clear definition. Now most scholars define context through enumerating examples, which is first from 1994. Schilit, Adams, et al. [1] introduce the concept of context which is related to the location, nearby person，hosts or objects, as well as changes of them over time. Brown, Bovey, et al. tailor the information such as location, time, season, temperature and so forth into several aspects of user's context in [2]. Context information includes the capabilities of the mobile devices, the characteristics of the network connectivity and user specific information [4]. In addition, emotional state, attention focus, orientation, date and time of day, objects and people in the user's environment can be view as the aspects of context [19]. Furthermore, some scholars also use synonyms such as the environment，state, surroundings or situation to explain the meaning of context. However，there is not an agreement that whether to use user's environment, the application environment, or the other areas. In addition, Snowdon and Grasso [3] consider context as a multi-layered set, which contains personal, project, group and organization. It consists of people and their expertise, information sources, informational documents and the evaluation of their relevance, and relevant pragmatic documents.

Comparing to the above three definition methods, enumerating examples is applied in practice more easily. In [1], authors believe that three important aspects of context are: where you are, whom you are with, and what resources are nearby. Because of this, they divide context into three parts:

- Computing context: available processors, devices accessible for user input and display, nearby resources such as printers, displays, and workstations, network capacity, connectivity, costs of computing and communication, and bandwidth.

- User context: user's location, collection of nearby people, user profiles and social situation.

- Physical context: lighting, temperature, noise and humidity level, traffic conditions.

In order to achieve a better understanding of the concept across a time span, Chen and Kotz [5] add time context such as time of a day, week, month, season of the year ,and time zone into above viewpoint. Through this method, they also obtain some time information such as a context history, which could also be useful for certain applications.

Gu [6] defines a context spectrum from the view of user center: computing context, user context, physical context, time context, and social context.

Ubiquitous computing pays attention to the context of people-centered and puts computer invisible existence into our living space. In the case user ignore the computer, thus reducing the user's intervention provide users with maximum ease and efficient service. From the people-centered perspective, we define the context as following:

- User context: it refers to any information related to user, including user dynamic information(user current and historical location, user current and historical activity, user current emotion, relationships or contact with colleagues or friends and so on)and user static information(social situation, user personal information, user habit, user preference and so on)

- Physical context: it contains environment physical information(lighting ,noise, temperature, and humidity level, traffic conditions and so on) and device physical information(device battery, memory, the size and type of screen, terminal's OS, input and output method , nearby resources such as printers, and so on)

- Network context: network capacity, connectivity, costs of computing and communication, bandwidth and so on.

At the time of this writing, there is still no standard way of defining the term of context. As far, most researchers even accept a more general definition made by Dey [7] that context is "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves."

B. Context Categorization

Context categorization can discover the possible context easily，simplify the context manipulation and can be helpful in providing quality context information.

Two possible broad categorization viewpoints are [8]:

- Conceptual viewpoint –it descripts contextual space in terms of the actors, the actions and the relationships between them.

- Measurement viewpoint – it contains continuous context, enumerative context, state context, and descriptive context, physical and virtual context.

In addition, contexts could be classified as static or dynamic context. Another similar meaning is continuous and discrete context. Some researchers do the categorization from the following points of view: internal context or external context, material context or social context, physical or virtual context [15], real-time context or unreal-time context, natural context, technology context or social context.

Although the context information is varied, some types are more important than others, such as location, identity, time and activity [9] .These types not only answer the problem of 5ws--who, what, when , where, and why, which is the minimum necessary set of context information in the ubiquitous computing environment , but also can be a source of other context information[10].

C. Definitions of Context Awareness

The first introduction of context awareness can be traced back to Active Badge research project of Olivetti Research Ltd in 1992[11]. Since then, definitions about context awareness were discussed by many researchers. Context awareness is the ability of a program or computing device to detect, sense, interpret, act and respond to aspects of the environment, such as location, time, temperature or user identity [12], or from the perspective of adapting application to context , it is the ability of applications to examine the computing environment and react to the dynamical changes such as the location of user ,the collection of nearby people, hosts, and accessible devices, and adapt their behavior based on the context of the application and the environment[1]. Schmidt al.et[13] state context awareness is the knowledge which was related to the user's and IT device's state, such as surroundings, situation, and location, and use a three-dimensional space composed with environment, self, and activity to understand the context. Razzaque, Dobson et al.[14] believe the notion of context awareness coming from computer science in order to describe the information devices with circumstances and this device operate and react according to the circumstance. Salber, Dey et al. [20] define context aware to be the ability to automate a software system, to modify an interface, and provide maximum flexibility of a computational service based on using context information.

Dey [7] compares and summarizes the previous definitions in his doctoral thesis paper, and provides a more general and easier definition to implement ： "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task."

We believe that in the traditional computing, the user provide detailed information with the device using input device, such as a keyboard, mouse, keypad, touch screen, etc. Meanwhile, the user must give a reasonable explanation to the device which can be understood by the computer. While context awareness in pervasive computing aim to provide the computing devices which hides context information by the new human-computer interaction methods or a wide range of sensors available , and computing devices make the appropriate response to the right place at the right time through inferring the user's intention. Throughout the process, even if the user does not even input any information, he can get the correct and reasonable feedback.

D. Context Awareness Categorization

According to the influence of system behavior，context awareness can be divided into active and passive context awareness[5].

- Active context awareness: an application automatically adapts to discover context through changing the application's behavior.

- Passive context awareness: an application presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later.

Context awareness also can be broadly classified into the following areas: self-contained and infrastructure based context awareness. If considering from information acquisition tools, it also consists of hard context awareness which can be obtained by hardware sensors measuring context awareness, and soft context awareness which knowledge inference based on the information repository of the context awareness [17].

III. CONTEXT AWARENESS SYSTEM

A context awareness system comprises three main components which we are concerned. To begin with, the system gathers context information available from user interface, pre-specified data or sensor and adds it to a repository. Furthermore, the system converts the gathered raw context information into a meaningful context which can be used. Finally, the system uses context and gives a reaction, and reveals the appropriate context to the user.

A. Context Acquisition and Sensing

Context acquisition is the most basic level of context awareness. In general, there are three ways to acquire context in the following [18].

- Sensed context: Environment information and user physical information can be acquired by physical or software sensors. And the user interaction habit, and interactive historical record are gained mostly by logical sensor from the host.

- Derived context: This kind of contextual information can be computed on the fly.

- Context explicitly provided: For example, user's preferences can be obtained when they are explicitly communicated to the requesting application.

Though a lot of context information is in the system, we pay attention to identity, location, activity and time than others.There are two different ways of approach to sense the location information. The first approach is client based , just like Global Positioning System ,which is the most widely used and accurate method, Infrared and Radio Signals, RFID,WiFi, Bluetooth, and the indoor GPS signal generator. The other one receives the location information from the network of a certain area.Some identity information can be given to the context awareness system explicitly, such as a user's sex. Time information is easy to obtain from the built-in clock of the computer. In addition, high-level context information such as the user's "current activity" is a big challenge. One approach to acquire is machine vision, which is based on camera technology and image processing. Another possible approach is to consult the user's calendar directly to find out what the user is supposed to do at certain time. A third method is to use artificial intelligence techniques to recognize complex context by combining several simple low-level sensors.

B. Context Modeling and Representation

In order to depict the user surroundings and situation, the system uses context modeling and representation in the context awareness computing. Context modeling must be formulated to provide a resource for applications to avail of. There is almost not a problem for all kinds of context modeling independently, but it is a challenger to handle all kinds of context in a unified and general context modeling in today's technology conditions. According to the current situation, the unified context modeling can be divided into two levels: Different context use the same data structure to express mode, such as Key-Value Models, Markup Scheme Models, etc. It also can support the semantic unity, such as ontology Based Models, Graphical Models, etc.

C. Context Filtering and Fusion

Raw data after sensing is single, unstable and inaccurate, and it is necessary to effectively use the context by filter and match conditions. The one aim to filter is extracting simple semantic information from the sensor data, and shielding off the information which system does not care. The other one is filtering specific context information because of privacy.

In order to form valuable and clear semantic context, you need to develop the internal relation between context elements, and make a fusion according to the specific application. The system can obtain the context information from a variety of ways, including physical sensor and logical sensor and so on, but the information from the different variety of sources probably is abhorrent, sometimes even contradictory. Therefore, context fusion is the request of maximum gain from the inconsistent information in the application based on certain knowledge and rules in order to avoid improper decisions by the system. Context elements after semantic relations fusion have more directly influence and effect for higher application and convert into higher level usable by applications, which is the ultimate context information.

D. Context Storage and Retrieval

Raw context data as well as filtered and fused context information can be stored into some places for further retrieval. Just as passive context awareness is defined [5] which an application presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later. Context should be well organized into various data structures, such as table, object, tree, graphic, etc. Moreover, context storage is necessary to get history records in order to make processed context information out. The architecture for context storage can be either centralized or distributed [16].

The effective and reliable storage of context information related to many problems, such as instantaneity, relevance between context and objects, context retrieval requiring with range rather than single conditions, etc. In addition, it associates with the context modeling and representation.

E. Context Application：

How to effectively use context is an important issue. In [1], applications can be roughly broken down into the following categories:

- Proximate selection

- Automatic contextual reconfiguration

- Contextual information and commands

- Context-triggered actions

There are two more applications in [15]：

- Metadata tagging: Context information, along with existing pieces of information, gives us more implicit information.

- Terminal adaptivity: Because of small and cluttered user interface in mobile devices, context information can help to increase usability presenting the user with only relevant information.

In [7], Dey summarizes and revises the above view of category and proposes three categories which may be supported by context aware applications:

- Presentation of information and services to a user;

- Automatic execution of a service;

- Tagging of context to information for later retrieval.

IV. CONCLUSION

As a hot topic of researching pervasive computing, since appearance, context has got a wide concern from the academic and corporate field. From the perspective of using context information, context application generally can be divided into two kinds. For one thing, it focuses on physical context information, and the most common example is location based server. The leader application in foreign field is Foursquare, while location based server in domestic is actively following the steps, such as jiepang, play4f, etc. In addition, Apple Computer also applies for a patent of adaptive interface application. Finally, when the equipment perceives the state of motion, it finally will automatically adjust to the appropriate screen size which will be able to adapt to the present in the movement of equipment and users. For the other thing, it can use the user context to the server, such as in the mobile computing the system can get the user preference and the user behavior information to provide with personalized recommendation, personalized retrieval information and so on. Of course, there is a kind of application connecting the physical context and user context information, such as intelligent advertisement service, life-log platform and so on.

Context information can be used for application more humanization and more convenient. Especially in the pervasive computing field, due to the users' demand and the rapidly changing environment, using context information is more value. But context awareness computing relays on many technology developments. One of them is multimodal user interface technology. In order to improve the man-machine interactive naturalness and high-efficiency, it uses multiple interactive channels which are based on the vision tracking, speech recognition, gestures input, feeling feedback and some other new interactive technologies, in parallel and accurate way to interact with the computer system. With the improvement of interactive technology, more and more context can be caught, and context information fusion based on the multichannel will become a big problem. The other challenge is cognitive psychology. Context awareness computing needs to deal with environmental context just like the way of human does, which requires seriously studies of human cognition method, process and proposes suitable cognition model for computer using. Cognitive model can help to context deeply on perception, processing and reasonable use. But the research is still in its infancy. Moreover, when the user is in multiple tasks, how to distinguish the user cognitive model at present and switch timely is also a problem.

As mobile equipment updating technology in pervasive computing, such as computing capacity upgrade, the screen size increases, the frequency of people using mobile devices also becomes noticeable, and it will involve in every facets of our life. Of course, it will have more opportunities and challenges in the future.

REFERENCES

[1] B.N.Schilit, N.Adams, and R. Want, "Context-Aware Computing Applications," IEEE Workshop on Mobile Computing Systems and Applications, December 8-9 1994

[2] P.J.Brown, J.D.Bovey, andX.CHEN, "Context-Awareness Applications: From the Laboratory to the Marketplace," IEEE Personal Communications,October 1997,pp.58-64.

[3] D. Snowdon , A.Grasso, "Providing context awareness via a large screen display,"

[4] A.Held, S.Buchholz and A.Schill, "Modeling of Context Information for Pervasive Computing Applications,"

[5] G.L.Chen, D. Kotz "A Survey of Context-Aware Mobile Computing Research,"

[6] G.Z.GU, "Context Aware Computing," Journa l o f East Ch ina Norma lUn iversity (Na tura l Science) ,N o. 5, Sept 2009

[7] A. K. Dey, "Providing Architectural Support for Building Context-Aware Applications,"

[8] M.A. Razzaque, S. Dobson and P. Nixon, "Categorization and Modelling of Quality in Context Information,"

[9] A. K. Dey, G. D. Abowd, "Towards a Better Understanding of Context and Context-Awareness,"

[10] G. D. Abrown, E.D. Mymatt, "Charting Past, Present, and Future Research in Ubiquitous Computing," ACM Transactions on Computer-Human Interaction, Vol. 7, No. 1, March 2000, pp 29–58

[11] R.Want, A.Hopper, V.Falcao and J.Gibbons "The Active Badge Location System,"

[12] B.N.Schilit , M.M. Theimer, "Disseminating Active Map Information to Mobile Hosts," IEEE Network Septembed/October 1994, pp.22-32.

[13] A. Schmidt, K. A .Aidoo, A.Takaluoma, U.Tuomela, K. V. Laerhoven, and W.V. Velde, "Advanced Interaction in Context",

[14] M.A. Razzaque, S.Dobson and P. Nixon, "Categorization and Modelling of Quality in Context Information"

[15] K. Barrett, "State of the Art: Context Management，" State of Art Surveys: Release 2: May 2003，pp69-87

[16] J.Z.Sun , J.Sauvola, "Towards a Conceptual Model for Context-Aware Adaptive Services"

[17] E. Tuulari, "Context Aware Hand-held Devices." Espoo, VTT Electronics, 2000. VTT Publications

[18] G. K. Mostifaoui, "Context-Aware Computing: A Guide for the Pervasive Computing Community," 2004IEEE,pp39-48

[19] A.K.Dey, "Context Awareness Computing:The CyberDesk Project," In the Proceedings of the AAAI 1998 Spring Symposium on Intelligent Environments (AAAI Technical Report SS-98-02), pp. 51-54, Palo Alto, CA, AAAI Press. March 23-25, 1998

[20] D. Salber, A. K. Dey and G. D. Abowd, "The Context Toolkit: Aiding the development of context-enabled applications," In Proceedings of CHI'99, Pittsburgh, PA, May 15-20, 1999, pp:434-440