Designing a Context-aware System to Detect Dangerous Situations in School Routes for Kids Outdoor Safety Care

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Abstract. Ubiquitous computing is targeted at services and applications of computer and communication technologies in the real world. This research, as a part of UbicKids Project, is focused on designing a context-aware system that dynamically detects the possible dangerous situations in the routes where kids go to and return from schools, and provides prompt advices to kids who may encounter some dangerous situations. Based on analyses of typical dangerous situations in school routes, the paper then shows the system architecture and discusses about danger-related context information processing including context description, representation and presentation. Security and privacy issues and possible solutions are also explained. A preliminary system prototype has been implemented and some GUIs are explained. Related work is discussed with comparisons to other research work.

1 Introduction

Since Weiser's pioneering work, it has been recognized that communications between small embedded sensors and related data processing devices are an integral facility in many ubiquitous computing scenarios. It is common that context-aware services [1-3] are involved in a huge amount of spatial and other contextual information to be sensed, exchanged and processed among a number of pervasive devices. Such ubiquitous computing and communication have being opened a great many of opportunities to provide novel solutions to various issues in the real human life.

Caring children is one kind of common human activities, and consumes a lot of time/energy to many parents. It is a fact that parents cannot always watch their kids and give them prompt supervisions/helps in 24/7, but they do expect their kids to be well taken care of with their preferred means in every place at all times. Therefore, we started the Project UbicKids [4], a smart hyperspace environment of ubiquitous care for kids, from early 2004. There are lots of kids caring activities to be supported, which can be basically divided into three categories: kids awareness, kids assistance and kids advice, i.e., 3As. Among these, a ubiquitous service strongly desired by parents is to have some system that can help them to take care of kids safety, especially when the kids are out of home and at somewhere outside. One popular case is when primary school kids are on the way to school/home by themselves.

Thus, this research is focusing on designing a ubiquitous kids safety care system to dynamically detect possible dangerous situations in school routes and promptly give advices to kids and/or their parents in order to avoid or prevent from some possible dangers. To detect the dangerous situations, it is essential to get enough contexts of real environments in kids surroundings. This is based on two basic assumptions: (1) a big number of sensors, RFIDs, tags and other information acquisition devices are pervasively distributed somewhere in and near school routes, and (2) a kids should carry or wear some devices that can get surrounding context data from the above pervasive devices. The data amount received by the kids devices are often enormous and dynamically changed during their walks on the roads. One of core issues is how to effectively process the enormous and varied context information for the system to automatically and correctly recognize what and where dangers will be encountered by the kids so as to take the further actions to avoid them by advising the kids. Such complex context processing is currently impossible to fully complete with only using devices carried by kids since their computing performance is relatively low. One solution is that the kids devices only make simple processing on the sensed contexts and then send them to some powerful host to have further processing. Due to some problems including security [5, 6], the host, called safety server, should be at a kid's own home. The safety server will not only process contexts but also analyze changed situations, find possible dangers, advise kids, etc. It also plays a role of mediators to communicate between kids, parents and other public information services. This paper presents our preliminary research on such a safety care system, which seems the first in the world.

In the rest of the paper we first describe computing scenarios of the kids safety care services in the next section, and discuss our system architecture including context descriptions and processing flows in Section 3. Next, Section 4 explains our considerations about possible solutions to the security and privacy issue. Section 5 shows how the advice information is presented on some prototype GUIs to kids and parents. Related work is given in section 6, and conclusions are addressed in the last section.

2 Computing Scenarios of Kids Safety Care in School Routes

Figure 1 shows a system overview of computing scenarios to support kids safety care in their school routes. The whole system can be described with five basic entities: school kid, kids surrounding, remote parent, information provider, and safety server. A school child should carry some devices that dynamically collect context data from his or her surrounding. The surrounding context data is sent to and processed by a corresponding safety server located at the kid's home. The safety sever may need to get the further necessary surrounding information from some related information provider. When needed, the safety server will send situational information around a kid to his/her parent, and act as a mediator between the kid and the parent.

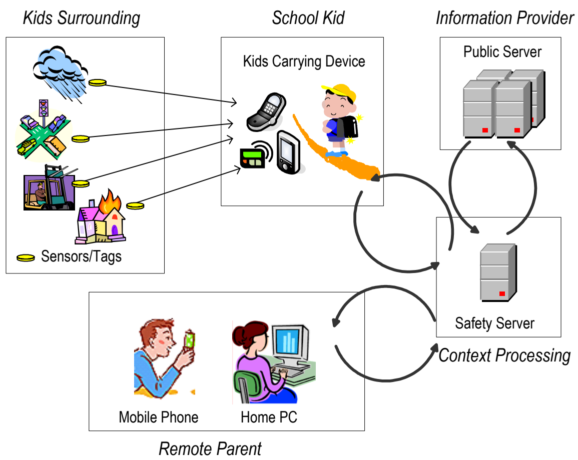

Fig. 1. System use scenarios and process relationships among the machines and devices in outdoor, home, information provider and the users.

Theoretically, a kid's device fully satisfying the safety care should have the following general features: (1) realtime acquiring the necessary kids surrounding context from the sensing and tagged devices distributed on the real world, (2) always knowing its current position information, (3) fast communicating with the safety server, (4) necessary multimedia interface for presenting easily noticeable advices, (5) reasonable continuous working period or low power consumption, and (6) compact, light, reliable, etc. Such a device is greatly useful not only for kids safety care but also other care functions, and even in many other ubiquitous applications. It does not exist yet at the present and would be available in near future. However, it is possible to use current available devices, such PDA, cell phone, compact game machine and some wearable devices, as some substitutes to build some prototype system at the current stage. Although it takes time to really deploy a number of the sensing and tagged devices to the real physical environments, many types of these devices are available, such as GPS, RFID, tiny microphone/camera, various sensors, etc. They can be used in making prototype systems and conducting related experiments. The devices used by parents may be PC, PDA, cell phone, or some handhelds.

The safety server can run on an ordinary PC. A tag like RFID may not include enough information about a physical state but can indicate where to get its more information. The detailed information about a dangerous site, such as a road cross, traffic accident, fire event, or others, may be put some public server. For security considerations, the kid devices will not directly access the public server, and the safety server, after getting the information address, e.g., URL/URI, accesses the public server to get further necessary information. Generally speaking, the safety server should not only continually track a kid's movements and acquire its surrounding contexts, but also know the situated contexts about parents and their surrounding so as to actively or proactively send the kid related urgent information to the parents in right place, suitable time and proper manner.

3 System Requirements and Architecture

The main objective in designing this system is to meet the following requirements:

- *Context data collection*. The system should have a data collection service of spatial information related to a kid and his/her surroundings. This service provides the space related information to the safety server.
- *Dangerous situation detection*. The system should facilitate detecting possible dangers with using the space information and other contexts. The detection service must be based on some semantic model of dangerous situations and general data processing schemas.
- *Device dependent presentation.* The information should be properly presented with adapting to various devices. The most commonly, kid's devices (such as PDA, mobile phone and other similar handheld devices) may have less function of presentation since the dust devices have limited presentation power. On the other hand a PC used by parent is often with rich representation power.

In designing the safety care system, these fundamental requirements are essential to build rational and feasible system architecture. In order to detect a possible danger somewhere around a kid, and inform the kid and his/her parents of it, the architecture should interconnect four main roles: kid, parent, safety server and data store. When a kid is on the way to school, a kid's device scans various data such as whether, building, traffic and so on. The surrounding data may contain sufficient information related to the state of a physical event, or partial information only with a state ID code/string, such as a URL, from which the safety server can get more detailed information about the state via accessing a corresponding database or data store offered by an associated information provider. With using all available information, the safety server analyzes possible hidden dangers, and, when necessary, sends some alerts to a kid and/or parents.

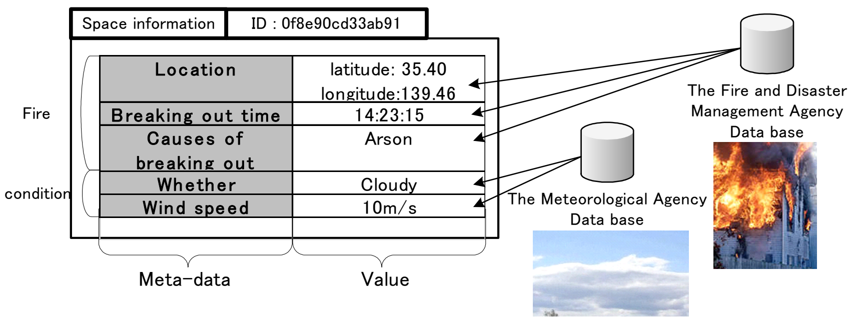

Fig. 2. Fire context information (top of table) and conditions (bottom of table) contained in space information are presented metadata (left of table) and value (left of table).

Usually, a large amount of surrounding data in raw data types is dynamically acquired during a kid's way to home/school. To smoothly perform efficient operations, the data must be semantically represented with some metadata [7-9] and the data amount has to be greatly reduced by abstracting only needful information to describe meaningful dangerous events. Figure 2 shows an example of a fire related context representation.

The core of the safety server is to effectively process the context data in real time, and precisely adapt to various situations in kids safety care. It, as shown in Fig. 3, consists of three basic functions: Situation-Analysis-and-Decision (SAD), Context-Actuation-and-Representation (CAR) and Response-Action-and-Presentation (RAP). And Fig. 4 gives the whole system architecture.

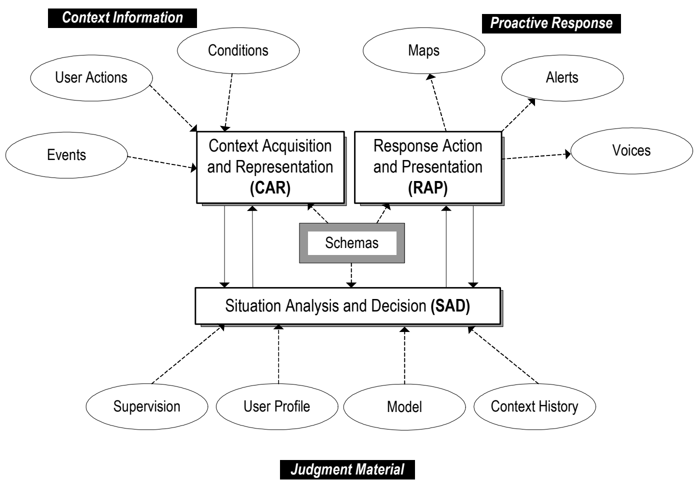

Fig. 3. Context processing functions and flows. Context processing in all modules is based on schemas since context information may be in various representations or regulations.

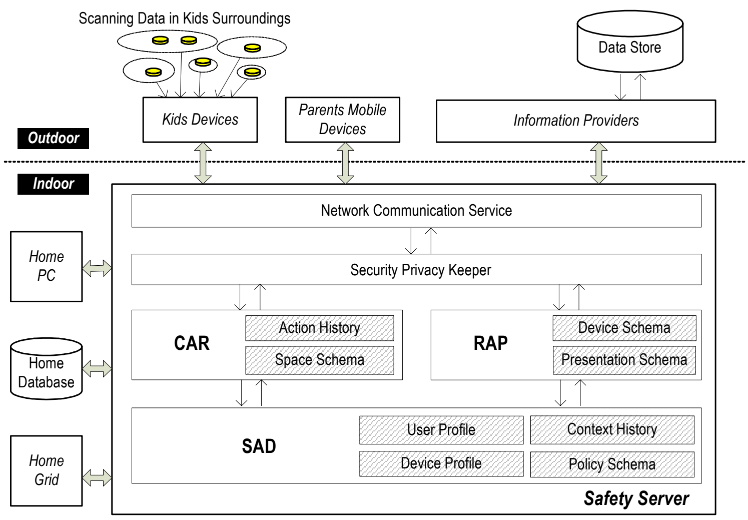

Fig. 4. System architecture consists of internal processing flows of main functions and external communications via networks.

CAR is to fulfill two main tasks, one is to acquire the context data from the kid's devices and other sources, and the other is to represent the context data with meaningful metadata and extract the useful data so as to reduce data amount. SAD plays a central role in this architecture since it is to analyze a situation using semantic context information provided by CAR, make a judgment if the situation is or to become dangerous, and decide what action(s) should be taken to avoid the danger. When an action is decided by SAD, corresponding instructions and associated data will be given to RAP that completes the action via presenting some information to some devices used by a kid and/or parent with adapting to their available device types and other surrounding states. Besides the above three basic functions the architecture also includes other important functions: *network communication services* to mange communications between devices/machines inside and outside homes, *security privacy keeper* to guarantee security of data and communication, and *home database/grid* to further enhance data storage and processing abilities.

4 System Security and Privacy

The system is designed based on a fundamental principle that a kid device is able to directly communicate with the safety server at home but can only passively received information from surrounding devices in the outside without actively communications with other machines not at home. This will greatly reduce the possible security holes and move the major security management work to the home safety sever that takes a full responsibility to control all authentications in accessing the system. We adopt the S/KEY authentication scheme [10, 11] that protects user passwords against passive attacks. It can be easily and quickly added to almost any UNIX system, without requiring any additional hardware and the system to store information that would be more sensitive than the encrypted passwords already stored. Figure 5 shows how the S/KEY authentication scheme works.

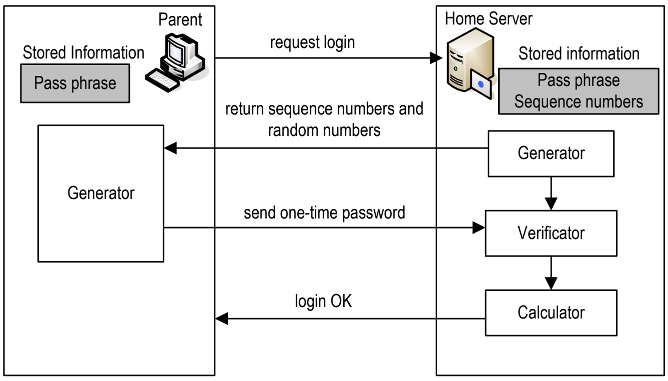

Fig. 5. The S/KEY proposal authentication includes some security modules.

First, when a client make a request to login to a home safety server, the sever generator produces a random number and sends it to the client. Next, the client generator creates a one-time password with using the random number, a sequence number and a hash function, and sends its one-time password [11] to the server. Then, the generator in the server also generates a one-time password and the verification compares with the two one-time passwords. If they match, a permission is sent to the client. Finally, the calculator subtracts one from the sequence number for preparation of a next connection. In the authentication with password, the key of security intensity is how to maintain a secret of the password completely. Even if we configure sophisticated password, once a malicious user knows it, he can do unauthorized access easily. But the S/KEY authentication scheme that, whenever one logs into, uses a different password, eliminates almost all of the risk from that. Additionally, the S/KEY authentication system doesn't have to send and receive a password itself, so we need not to worry about eavesdroppers. The information flowed to the network is only seeds generated by random numbers and sequence numbers subtracted one-by-one every time we correspond, and one-time password based on them.

All users are unwilling to cope with a complex security system. There are some weaknesses in this S/KEY authentication system, but S/KEY authentication system is simple and easy to use. For this reason, it is thought that this scheme serves its purpose. Except the access authentications, communications between a safety server, kid's devices, parent's devices and data store should be also secure. Such communications can be encrypted by SSL protocol (Secure Socket Layer). In the future, constructing better security schemes and related systems will be a major challenge in solving security and privacy problems.

5 Prototype GUIs

The GUI shown in Fig. 6 is for a parent to get current kid's information. A parent runs this application on a PC, PDA or a cell phone at home or some other place whenever he/she wants to know a kid's information.

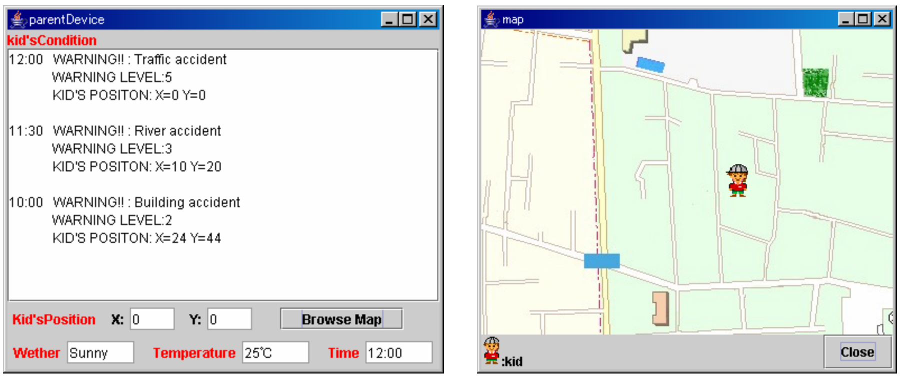

Fig. 6. Left figure is the interface on a parent's device which displays kid's dangerous information and right figure is a map showing the current location of a kid.

Table 1. The information related kids space conditions in the lower pane.

Kind	Form	Receive Frequency
Warning	String	When danger approaches the kids.
Warning level	Int	When danger approaches the kids.
Kid's position (x, y)	Double	Always
Weather	String	When weather change.
Temperature	Int	Always

The GUI window contains a message pane. When a parent checks a kid's situation, it will be reloaded immediately, and the related message will be shown on the message pane. In the lower part, some items are showing current kids surroundings. When warning information is coming from the safety server as a result of analysis for kids surroundings, the GUI displays the following information: the time displaying when the warning message is received, the kind of warning briefly showing what a danger event it is, the warning level illustrating a judgment of a degree of the current danger to be prevented (For the same kind of warnings, their warning levels may be different), and the kid's position where a danger event occurs, as shown both in Fig. 6 and in Table. 1.

A kid's application informs a dangerous situation to the kid immediately with a GUI shown in Fig. 7. This application can be seen as a simplified one as compared with the parent's one. This is because a kid's device may have relatively poor processing performance. Apparently noticeable information, such as short words using speech, is necessary and may be better to remind a kid a possible danger. The kid's application runs before a kid leaves home. An alarm will be given to a kid when his/her carrying device receives a warning message from the safety server. The warning level will be higher if the situation becomes more dangerous. We use the alarm sounds that are more comprehensible than displaying warning texts for effective kids notice.

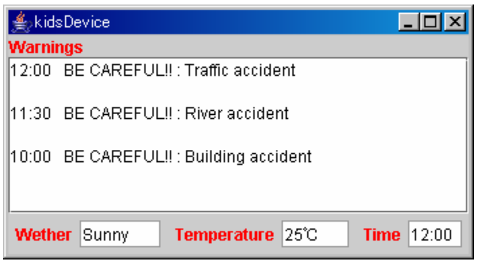

Fig. 7. Interface on a kid's device which calls a kid's attention to a dangerous situation using the alarm sounds and the warning messages.

6 Related Work and Discussion

In the past, a number of systems have been developed to support context-ware computing. These systems have made progresses in various aspects of context-aware computing but are weak in processing huge amount of context information for effectively detecting dangerous situations specifically for outdoor kids safety care. The context collecting service in our architecture can reduce the context data amount with using meta-context representations for dangerous events. MoGATU [12] is a project explicitly designed to deal with data management in the ubiquitous computing environment. A profile as well as context information is used to guide the interactions among different devices. MoGATU considers each of the devices individually to serve their users' information accesses. Their results can be used to complement our system.

Filho, et al. gives a detailed description of the design of the event notification system. There has been research in using event notifications in context-aware systems and how to notify users in a context aware manner [13]. Huang provides a good overview of the network architecture design challengers to publish or subscribe in mobile environments [14]. The technique we used in the judgment of dangerous situation is related to the decision tree algorithm. Van's work [15] under the framework of decision trees has benefited our design described in this paper.

7 Conclusion and Future Work

In this paper, we present the design of a context-aware system that dynamically detects the possible dangers in the routes where kids go to and return from schools, which is a part of our UbicKids Project [4] started from early 2004. The system architecture has been discussed in detail in terms of danger-related context information processing. Security and privacy issues and possible solutions are also explained. The semantic representation of danger-related contexts is essential topic for realizing the context-aware system. Our short-term objective is to implement the prototype system for the trial of providing kid's care and to enhance a context usage related to both users and activities by including temporal and spatial relations in ubiquitous computing environment. At present the design of the SAD and related models/methods are still in the early stage of research. Our preliminary research in the SoM based system [16] shows the space oriented diagnosis engine in our previous work. The hypothetic method based SoM looks adequate to define space information for supporting context reasoning and knowledge sharing. This method should be integrated into this architecture in near future. Of course, it is very necessary to develop a completed system prototype able to work and test so that we can find more practical problems, which can guide us to build a really useful kids safety care system. This work seems the first research aimed at building a ubiquitous system to assist the outdoor safety care of the schools kids in the real world.

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