A CONTEXT-AWARE HOME FOR CHILD-MINDING

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Abstract. This paper introduces the concept of *context awareness* to the application of designing an *interactive home* with emphasis on *child-minding*. We set up the functional requirements of a *context-aware home* and seek the technology to provide safety monitor and real-time guidance for kid who is temporarily alone at home. The approaches presented are: (1) *Survey and Research Scope* (2) *User Life Pattern Observations* (3) *Activity Zones and Scenarios* (3) *Context Database and Context Manager* (4) *Media and Interface* (5) *Evaluation*. The process and result will lead our following applications of context awareness in future *interactive home* study.

1. Introduction

This paper introduces the concept of *context awareness* to the application of designing an *interactive home* with emphasis on *child-minding*. The busy life-styles of double-income families aroused our interests to consider embedding some new technology in dwelling space to increase our care to the children. This study focuses on developing an information-enhanced smart system in dwelling space, which is connected to intranet and internet, and which is responsive and attentive to the child-minding needs setup in our scenarios. Through our survey, it is revealed that the context-aware system is the base for developing future smart space, especially for those who expect information to be provided intuitively, naturally and with low-learning gap, e.g. kids in this study, Rodden and Bendford, 2002).

For the above concerns, we chose child-minding as our subject and elementary school children's after-school activities at home as our scenarios. we suggest that the context-aware child-minding system should include the following criteria:

(i) automatically detect related context: these can be agreed in advance by family members to reduce unwilling surveillance; (ii) trigger corresponding interactions; and (iii) transmit messages to the parents if elsewhere. Therefore, for a kid who is temporarily alone at home, the system then is enabled to provide him/her: (i) safety monitor, (ii) real-time guidance, (iii) reminders for homework exercise, and (iv) interactive support to become self-disciplined.

1.1. UNDERSTANDING OF EXISTING PARENT-CHILD AFTER-SCHOOL COMMUNICATION

Elementary school children in Taiwan need to go to after-school care centres for homework supervision and personal safety. Some children would rather go back to their sweet home to enjoy a better nap, snack, self-arranged work and entertainment. Phone-based communication is the existing way for parents to make sure the child is fine. Phone-based communication in the form of either conversation synchronously or messages asynchronously become the routine pattern for parent–child communication in the 2–3 hours of arriving home period between after-school children and off-work parents. Sometimes either parent or child may miss the communication by accident, e.g. the parents are busy in a meeting; the child has not arrived home yet; the mobile phone is out of power, etc. No matter whether communicated through conversation or message, automatically in-time two-way parent–child communications for routine safety check is one of our requirement in this study.

A mobile phone with a small display, though portable, is not an efficient tool for better knowing the child's after-school context at home, e.g. home arriving / homework doing situation. Multiple web cameras installed in dwelling space may provide another solution via internet for obtaining implicit real-time audio-video information for knowing the context at home. Yet this solution may cause some other discussion issues: e.g. who will keep monitoring the space? How to protect personal privacy for child, especially for parents with working monitor resided in public office space? The one-way communication without mutual interaction is not a good way of expressing parental care to the child. The developing of context-aware smart space for home is our suggestion to amend the above weaknesses of the existing phone-based and webcam-based communications. The scope of study is illustrated in Figure 1. The scope of this research has two areas to explore: (i) how to abstract event sensor data into meaningful context, and (ii) what we should consider for context-aware interactive space design.

1.2. CONTEXT AWARENESS

"Context is any information that can be used to characterize the situation of an entity, where an entity can be a person, place, or physical or computational object,

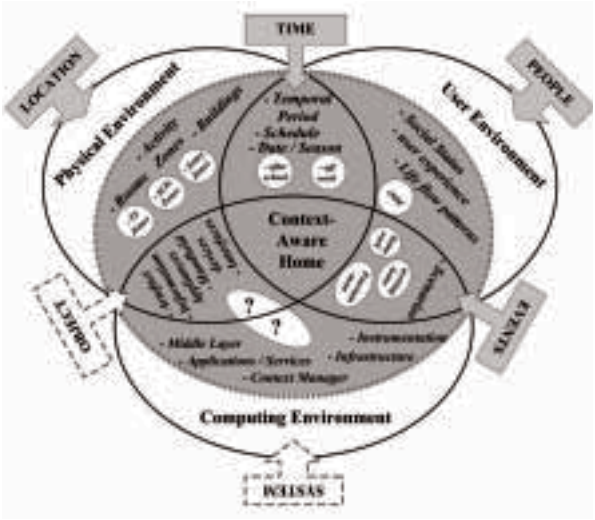

Figure 1. The Research Scope of this study.

that is considered relevant to the interaction between a user and an application, including the user and the application themselves." (Dey et al., 1999) Hence, the computational consideration for context should include: user's location, identity of people nearby and related environmental resources. With a constantly changing circumstance, context exists in three environments as described in Figure 1, (Adams & Want, 1994; Dey et al., 1999; Pascoe, 1998): (*i*) *Computing environment*: processors, user input/output devices and computer networks, (*ii*) *User environment:* location and social situation, (*iii*) *Physical environment:* spatial characters and physical situations.

Context-aware system enables the space to become smart by capturing low-level context data from sensors and process them into high-level information for applications. Context-awareness represents a generalized model of input, including both implicit and explicit input, allowing almost any application to be considered, (Dey et al., 2001; Dourish, 2004). The purposes for designing a context-aware system are: (i) It performs as a proactive system to anticipate users' needs and reflects the complicated task requirements of information-processing in real life; (ii) It enables the computational system to abstract different granularities of information according to context needs; (iii) It requires low user affordance by reducing explicit data input. Applications of context-aware systems are mainly focused in two directions: (a) context-awareness of handheld devices for mobile environment (b) context-awareness of user events for stationary smart space. In this study, we will focus on the context-awareness in smart dwelling space with the abstraction of data captured from child's after-school activity patterns.

1.2.1 Basic Components of the Context-Aware system
According to the related researches (Meyer and Rakotonirainy, 2003; Dey et al., 2001; Winograd, 2001), context-aware system architectures should include the following basic components: (i) *Instrumentation*: smart sensors, wireless networks, (tangible) user interfaces, (ii) *Middleware*: the infrastructure to gather information, process it and derive meaningful (re)actions from it, it includes: *the hardware abstraction layer*; *the context-manager,* (iii) *Applications*: to execute the actions, the gathered contextual knowledge infers what the user expects, provide models for use and update models in change, (iv) *User Experience*: provides persistent storage for context models produced and shared by other components (e.g. task-specific vocabularies, personal preferences, speech and handwriting characteristics, *Privacy: a privacy manager* suggested, (Meyer and Rakotonirainy, 2003).

1.3. CONTEXT-AWARE HOME

From the survey of research on context-aware homes (Meyer and Rakotonirainy, 2003), many Recent Researches for Context-Aware Home Scenarios are presented. The characters of home activities are: informal, not necessarily structured and more focused on becoming safe, supportive, convenient, pleasant, enjoyable, entertaining and relaxing. The related work by Nagel et al. (2001) describes the intra-home human-human communication styles by traditional intercom system. And it introduces the ubiquitous technology to the design of a context-mediated intercom prototype system to support a lightweight, spontaneous, hands-free communications between residents in different parts of home. The context widgets represent abstractions over sensors are *Location* and Speech *Recognition.* The prototyping process and system components provide valuable reference for our works.

2. The Framework for Context-Aware Home

2.1. THE USER ENVIRONMENT

2.1.1. Observations
For defining the meaningful context, we did the qualitative observations and analysis on two young examinees in one family in advance. We analyzed their life patterns by videotaping and annotating their activities during at the period after school and before dinner on weekdays. We interviewed their parents and summarized their most common worries for their children after school. The issues to be involved include: not or late arriving home/ getting hungry/ feeling alone/ addicted to watching TV and playing video games.

Figure 2. Video Annotation Tool and After-school activity flows for examinees .

2.1.2. Scenarios

To better portray the after-school activity pattern of children and the communication pattern between parent and child, we describe the scenarios in detail below: (i) Senario 1- *Arriving Home*: On weekdays, normally the daughter comes home a little earlier than her parent. After she open the door by the keys, at the entry lobby, she puts her keychain back to the storage box. With the personal e-tag attached to her keys, on the e-door of the box, it displays some real-time messages from parents and friends, (e.g. memos, greetings, new mails, things to eat in food storage, etc.). These messages may come from mobile phones or email. Then the Context-Manager connects to the parents' phones to make sure that their daughter has safely arrived home. (ii) Senario 2- *Doing Homework:* After eating some snacks, she starts to do her homework. She put her pencil-case on the desktop and opens it up. The e-tag attached to her pencil-case, actuates the desktop surface display and automatically gets link to her homework website and restores to her the current working page that she needs to finish on the desktop. The homework to-do list also pops up beside her current working page to remind her else things to do. The homework can be done by pen-based mimio or live board. After she finishes all of the homework, she can send a message to her parents to ask them to sign the communication book on the web, if they are not home yet. (iii) Senario 3- *TV Entertainment:* Whenever she wants to relax, lying on the smart sofa with her slippers on the smart carpet, the LCD TV screen presents the choices of (a) TV programs (b) friends on-line (c) family current snapshot (d) reminders for her own schedule planning, e.g. practise violin, etc. And for protecting her from myopia, the *Context-Manager* will track the time she continuously sits or tres on the sofa, automatically suggests her to turn off the TV and do some other activities.

2.2. THE PHYSICAL ENVIRONMENT

2.2.1. Activity Zones Derived by Scenarios

Activity Zones and Scenarios are defined as spatial and temporal modules to filter and group related context cues in the rules of database query. In Figure 3, each zone, required sensors and information display devices are installed for front-end data input and output.

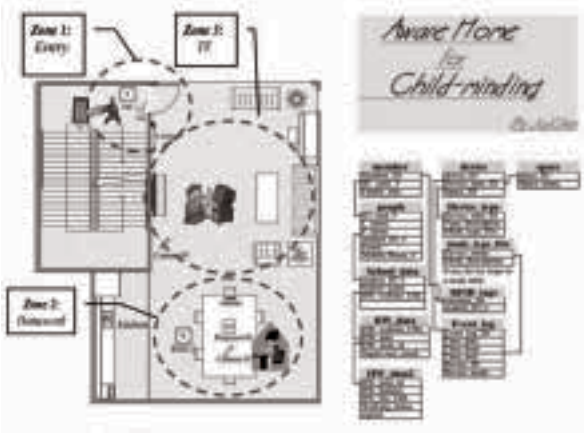

Figure 3. Activity Zones specified for Child's after-school Activities.

2.2.2. Embedded Devices in the Interactive Space

(i) Scenario 1: a networked key storage box with RFID readers and mid-size LCD display on the door; (ii) Scenario 2: a desk/table with large surface display and pen-based input accessibility is needed. The RFID reader embedded in the desk senses the identity of the user and connects to the right links. (iii) Scenario 3: a smart sofa with sensors to detect if the sofa is occupied and RFID reader embedded in the smart carpet around the sofa to detect the identity of the slipper's owner.

2.3. THE COMPUTING ENVIRONMENT

2.3.1. Context Sensing and Abstractions

Based on the application goals with predefined profiles for user and physical environment in a context-aware home, we try to do the mapping between context meanings and sensor data as in the *Arriving Home* scenario. The following context cues abstracted from previous observation on the child's behaviour pattern can be an example to describe the meaning of events happened in the Entry Zone: (i) *If (the door of key storage box is open) ∩ (personal e-tag in keychain is read) is True;*

Then (e-board on the door shows her personal message) and (forward arrive-home message to parent) (ii) In the *Homework* scenario,the pencil-case provides context cues to actuate the projector, and link to the homework website and opens up a work sphere. The meaning can be abstracted as sensors detected: *If (the pencil-case is open)* $\cap$ *(pencil-case e-tag on desk is read) is True; Then (projector over the desk turn on) and (the homework web pages open on the desk)* (iii) In the TV scenario, the child sits on the sofa with the slippers off on the carpet. The first objective here we want to provide is a person-aware TV/game program to the user on sofa according to the personal slippers: *If (the slipper id is Kathy)* $\cap$ *(pressure sensor is on) is True; Then (TV LCD turn on) and (show Kathy's TV/game program menu page)* The previous examples simply explain our concepts. For real life context abstractions, many complex circumstances will happen and the inference for different levels of granularity will be considered in system implementation.

2.3.2. Context-Aware Interaction Design

We built an experimental *context-aware home* in examinees' place. Three *activity zones* embedded with instruments for context-aware interaction designs and inherited from user's life styles are: (A) in *the Entry Zone*: (i) portable keychain with e-tag for identity attached, (ii) key storage box with display on the door and RFID reader inside the box to sense whose key is in, door state sensors to power on the devices and automatically message-sending ability to connect to parent's mobile phones. The interaction design concept here is to inherent original traditions, e.g. keys to open the door, for the purpose of liability and let the users feel in control of everything inculding viewing his/her own message. (B) *Homework Zone*: (i) pencil-case with open/close state sensor and e-tag to arouse the personal work sphere, includes homework web page, projector, interactive pen-based desk surface, etc. Here the child uses the pencil-case to start the homework and take control (ii) web-based communication book allowed to be verified on handheld devices. (C) *TV Zone*: (i) sofa with pressure pads (ii) carpet with RFID reader (iii) personal slippers with e-tag embedded (iv) person-aware TV/Game System.

3. Implementation

3.1. SYSTEM INFRASTRUCTURE

We suggest a system which is able to observe the real-world situation by sensors, (e.g. RFID readers and web cameras), and to abstract the data through the process of the insulating layer, *the Context-Manager*. The reasoning results, operated with the underlying context database server system, then distribute context to multiple applications in a ubiquitous fashion: for instance, it triggers the related interfaces and display to the children the interactive media embedded on wall, furniture, TV,

etc. according to the current context. Media and interface which adapt to the habits of home living culture are considered for children. Referring to the context-aware system components suggested in *Section 1.2.1*, the components in this study are described as follows:

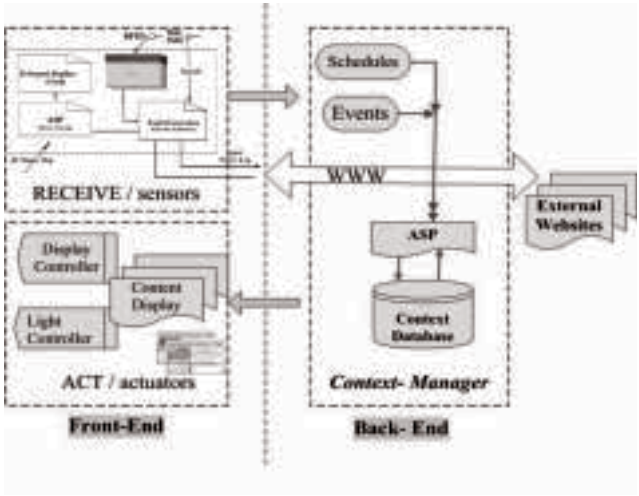

Figure 4. System Requirements for Context-Aware Home.

3.2. INSTRUMENTATION : CONTEXT DATA ENCODING

As illustrated in Figure 4, the upper left part are for sensing data processing. For achieving context awareness, we develop a system which enables the interpretation of context data from low-level explicit technical signals into high-level implicit social meanings. In the paper, we sum up all the possible meaningful combinations of sensor modes and event-logs and present rules and triggers for scenario facts to detect current home context and actuate related devices, e.g. e-board display, auto-controller, etc.

3.3. MIDDLEWEAR: CONTEXT DATABASE AND CONTEXT MANAGER

The logic generated from the original qualitative analysis plus subsequent context cue records enables the system to actuate (or control) the corresponding output devices and feedback to the context database for next interaction. Those event-log data are in XML data formats with structured hierarchy, i.e. Event-log, Interactive-zone, Device, Member and Time.

3.4. APPLICATIONS: MEDIA AND INTERFACES

The media and interface for context-aware interactive space in our project are: (a) the Entry Area—the interactive interface embedded in the door of key storage box for system response and exterior link, e.g. mobile-phone message; to identify the person arrived home by e-tag reader; (b) the TV Area—the menu displayed for TV programs and video games; controller and reader embedded in sofa and carpet with internet and phone access (c) the Homework Area—touch sensitive work bench with internet homework webpage access for current user.

3.5. USER EXPERIENCE: EMPIRICAL STUDY AND EVALUATION

The evalutation is based on observations on the after-school activities with and without the system by the video annotation tool used in *Sec. 2.1.1.*. We also interviewed their parents and examinees for post-use empirical study. We came up with a daily evaluation worksheet to record the level of children's self-accomplishment as a reference for further improving our system. We are also aiming at applying qualitative post-use empirical study to evaluate our *context-aware home* for *child-minding*.

4. Conclusion and Future Study

We have presented the design and implementation of a child-and-parent communication system. With the process for designing a context-aware system to interact with typical child-minding scenarios at home, this system has been designed to support: (i) a better communication system between child and parent than normal phone-based systems (ii) the use of context sensed from the environment and child's action to mediate the initiation, management and termination of child-parent one- and two-way communication; (iii) the research prototype that can endure further development in technology and mediation strategies resulted from future evaluations; (iv) a demonstration of how ubiquitous computing technology can be targeted toward a more invisible interface supporting an everyday activity.

This study, in view of social concerns, suggests a context-aware smart environment for enhancing family connections. It suggests qualitative approaches and technical solutions in developing a context-aware environment. The process and result of this study will lead our following versatile applications of context awareness in dwelling space. For future directions in designing applications in smart home study, we expect to include more social considerations for reflecting local home living styles and adapt more likely patterns of user needs.

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