A Rapid Prototyping Method for Discovering User-Driven Opportunities for Personal Informatics

A Case Study in a Domestic Environment

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***Abstract*—We propose a rapid prototyping method for discovering user-driven application opportunities for personal informatics. The key idea here is that our discovery is realized by empowering users themselves to figure out and express the meaningful information they want to capture and interpret through the prototypes we provide, in an economical and effective way. From the user study, we could extract the key patterns of information usages for family members: (1) recalling life patterns; (2) self-examination; (3) mutual concern; (4) regulation, which are important insights to be considered in developing new applications for personal informatics.**

Keywords-prototyping; user-driven; discovery; personal informatics

I. Introduction

As the development of ICT (Information and communication technologies) has been increasing and will continue to increase the quantity and the range of information available, it is important to figure out how such information can be utilized in a valuable way that can meet the values and needs of people. Although ubiquitous computing is gradually becoming a reality, our understanding has been more about what is possible in terms of technology than what is valuable and needed in our daily life context [1]. This would be even truer in the case for personal informatics [4]. Sterling introduced a new concept of an artifact, “spime” [9], which archives every data generated anytime anywhere by us and around us. However, it is not clear at all what exactly spime will become as a product and how people will utilize it.

Most of the approaches used in existing research in this domain have focused on the ‘evaluation and testing’ of a particular concept or generating ideas based on the result of the ‘observation’. Testing-driven approaches have mostly focused on the validation of the concepts with working prototypes in the controlled environment. When the concepts are found to be invalid, there is not much learning from the failure in spite of the high cost for developing the prototypes. Even when they were proven to be valid through such processes, it is hard to see other possibilities beyond the boundaries of those particular prototypes. The observation-based approaches have pervaded our investigations to date, but we cannot be sure whether the observed and tested prototypes would work well in a real life environment equipped with ubiquitous computing technologies.

In this paper, we propose a user research method adopting a new rapid prototyping approach to effectively ‘discover’ human-centered opportunities for personal informatics applications in the domestic environment. This approach focuses on two steps: first, how we can effortlessly capture the personal information that is meaningful to users themselves, and second, how to provide effective feedback that can support users in reflecting their lives on their values. We are particularly interested in developing personal life care systems to promote family values as an example domain for exploring the opportunities for personal informatics and its design strategies.

In this paper, we explain in detail how we developed the prototypes and what we discovered through the prototyping approach implemented in the users' daily life environment.

II. Prototyping Method

According to Lim et al. [5], prototypes can be understood in relation to its specific purpose of use, which can be categorized into (1) evaluation and testing; (2) the understanding of user experience, needs, and values; (3) idea generation; and (4) communication among designers. Whereas most of the current research focuses on the evaluation and testing, our new rapid prototyping method has its purpose particularly on the understanding of user experience, needs, and values. The core of our idea lies in realizing that we can discover opportunities for a human-centered application of a personal informatics system in a credible way without implementing a fully-working and high-cost ubiquitous computing environment.

Our idea of enabling such discovery follows two principles: 1) users themselves (not designers, researchers, or developers) actively determine what information should be captured and monitored, and 2) users themselves actively manipulate, integrate, and reflect on the information that was provided to them [6]. These principles follow the idea of discovery-driven prototyping [8] through which we aim purely to discover users’ natural intentions of using artifacts instead of trying to test our hypothetical design ideas. In this process, we try to minimize our own intention or pre-determined ideas, but maximize the

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capability of discovering naturally exposed human-centered values and opportunities of unfamiliar things such as newly emerging technologies. What we pursue here is also that the process of discovery happens through users' experience of utilizing the information itself. This idea sets the role of a user as the subject of discovery apart from the researchers' interventions.

With this intention, we devised our prototyping kit in two major parts. To address the first principle, we devised a portable sensor kit to capture information through a DIY (Do-It-Yourself) approach. To address the second principle, we designed the feedback outputs to be displayed real-time on a display where users can easily recognize the information captured, as well as printed on cards to provide a way for them to rearrange and to reinterpret the information for their own reflection as they would with journaling

The design of the sensor kits is a crucial factor because our method relies heavily on users actively handling the kits themselves. The physical package should be flexible to be used in many different situations in order not to disrupt the users' decision. Similarly, the sensor kits should not appeal a certain purpose of use or a certain situation to be used in, because the purpose of use itself is to be determined by the users. This clearly separates our method from the 'technology probe' [3].

The credibility of our method takes root in the engagement of the users into the discovery in their real life environment. As we assume that people are capable of using information for their own benefits with practice, their decisions, activities, and reflections for capturing and utilizing the information in their daily life context can be regarded as the result of their intelligent and independent judgment, and a natural process for the information to figure out and fit into its proper opportunities. Thus, our method can also be distinguished from the 'cultural probe' [2], which regards the users as the source of inspiration, not the direct subject of discovering the opportunities.

III. PROTOTYPE DEVELOPMENT

Before the specification of the prototype system, we conducted a preliminary user study with two families in their home environment to figure out what they truly value to achieve their happiness. We discovered that they mostly care health, safety, convenience, self-development, emotional well-being, communication, and family bonding [7]. The study included the process of analyzing each case of the information needs in particular situations in the domestic environment that they reported, which led us to understand with what sensors they could get the information that they need for achieving those values.

The several examples of the situations in need of information in the domestic environment that the family members reported are as follows. Around the safety issue, they mentioned the concern about falling accidents of their children. They said that it would be better if the environment could know whether their young children were nearby the fence at the balcony or something like warning sound could let them not to be there so that they could take care of their children even when they are not close enough to see them. Around the convenience issue, automatic detection of a particular object or status was frequently mentioned. Specifically, they wanted to be informed whether the flowers that they were growing were in a proper condition (sunlight and water) so that they could know what to do with the flowers. They also wanted to know whether the water taps were left running or leaking when no one was using them, and whether there was a light turned on when nobody was there, to reduce the waste of resource. For those cases, they said those actions were better to be done automatically. For the communication and the family bonding issues, they stated that they wanted to know how they do everyday things and how they feel about everyday things, like the little son's going to an ice-rink or the mother's preparing the breakfast. They knew that they were doing almost the same things everyday in their lives, but they also knew that there were lots of variations in practical details and the emotional status of each other, which were their everyday concern and interest too.

That study convinced us that it is possible to explore the application opportunities for personal informatics by utilizing 'simple sensors' with no need for extremely sophisticated engineering and high budget. It turned out through our analysis that most of the information needs that the families reported can be satisfied with the data which simple sensors such as a photo cell or a noise level detector can detect. That is to say, the information that those sensors provide can be the information that people mostly care. We took notice of the potential of those sensors to be successfully applied for a 'rapid' prototyping method in terms of not only the value of the data but also the economical advantage. Thus, we expected that studying how the information that those sensors provide can be useful and what value those information have in their life could help us to discover the personal informatics applications that are truly needed for the people and the way that those applications should be designed.

For this prototyping, we chose four sensors (light sensor, flex sensor, sound sensor, and RFID reader) which are expected to be the most effective to capture helpful data in the daily life context; those four sensors were turned out to be applicable to daily-life situations with the widest range of diversity in the result of the preliminary study. A light sensor (that a photo cell is used for its light-sensing function) and a sound sensor (which technically functions as a noise level detector) are useful for measuring the status of the environment. A flex sensor can detect the physical contact. A RFID reader can detect the pre-defined information by a user's intentional action of tagging. Regarding such diversity among the sensors and the information that they can detect, besides the effectiveness of individual sensors, a set of those four sensors is expected to provide, in a complementary manner, the possibility to be used in the various situations where the users' information needs lie in.

The prototype developed in this study (Figure 1) consists of eight sensor kits, one main computer with a master node that processes the captured data wirelessly transmitted from the sensor kits, history database storing such data constructed by the main computer, and a display providing visualized pattern feedback of the data to users, and cards that are printed out recording the feedback information.

A. Sensor Kits

We used four kinds of sensors, namely, light sensor (photo cell) for detecting the brightness of the environment, flex sensor for the bend caused by physical contacts, sound sensor, and RFID reader. We wanted to enable the users to capture not only the data of the environment in rather passive ways, but also the data of people themselves in active ways, that is to say, capturing the human activities or emotional status with their own decision and effort. This information could be gathered through more complex and intelligent system including the sensors for detecting physiological condition directly from human bodies and the cameras for sophisticated image processing techniques. Instead of those, RFID reader was regarded suitable for the 'active' data logging, with the advantage of cheap price and the potential to see more diverse ways of utilizing the information and the human interaction around there.

Each sensor kit includes a sensor, a microprocessor (Arduino), a Xbee module, and batteries (six 1.2V AA in series). Eight sensor kits were provided to the users (2 light sensors, 2 flex sensors, 1 sound sensor, and 3 RFID readers with a tag set each). Flex sensors were embedded into cushions with 20~30cm length.

Figure 1. Components of the prototypes: a) flex sensors, b) light sensors, c) RFID reader without the encloser, d) card type RFID tags, e) coin type RFID tags. (Counter-clockwise from the top right)

Three sets of RFID tags, two card type sets and a coin type set, were designed to capture user-driven information that is directly meaningful for themselves. A card type set was for the customized use and consisted of four card tags with different colors on one side. On the other side, a piece of blank paper was attached to allow the users to write a memo for recognizing what it means to log that card. The purpose of coin type set was fixed to capture various emotional statuses of the family members. Printed facial expressions were attached to five tags (each stands for being pleased, touched, surprised, sad, and angry).

Flexibility of installation was an important issue. To enable users to capture the data in a variety of situations that they want to, each sensor kit is packaged in an enclosure and a transparent PVC bag with a strap, so that it can stand alone, and can also be tied to human bodies or other objects in the environment. We also devised it in a way that batteries can easily be replaced by users themselves whenever it is necessary.

B. Feedback

A feedback program provides a real-time monitoring panel and a history viewer corresponding to each sensor. Also, users can print the screenshots on cards to rearrange and reinterpret the information for their own reflection. Following statements are the requirements of this feedback program: 1) The program should be easy to use and control without much technical knowledge. 2) A real-time monitoring panel and a history viewer should graphically represent the characteristics of each sensor data intuitively.

To satisfy the first requirement, the feedback program was implemented on a touch-screen laptop. Users can control all actions by touch. In a normal mode, this program displays real-time data of all sensors in parallel. If a sensor failure occurs for some reason (for example, a battery failure), an alert message is displayed. This will encourage users to check the sensor. Users can get into the history viewer mode by tapping on each sensor section. The history viewer displays the 12-hour history data in one page. A user can navigate the time window by tapping [PREV] and [NEXT] button, or flicking left and right. Also, a screenshot can be printed out by tapping the [PRINT] button. The program goes back to the normal real-time monitoring mode by tapping any place on screen other than those buttons. For the second requirement, we carefully designed the feedback graphics for each sensor to reflect its characteristics.

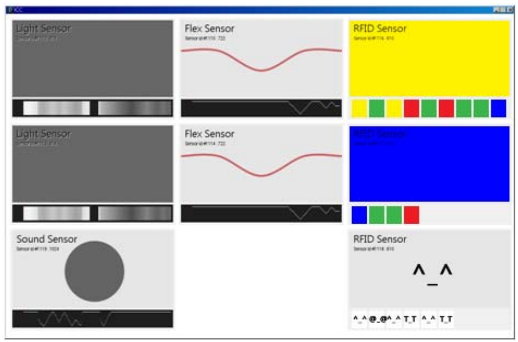

Figure 2. Sensor representations in the real-time feedback

The real-time feedbacks are shown in Figure 2. The data from the light sensors are represented with dark and bright colors to reflect the amount of light. The flex sensor data are represented with the curved string that shows how much flex sensor was bent. The sound sensor represents the level of loudness by the size of a circle. Two RFID sensors directly show the color of each card. Another RFID sensor that we used as an emotion sensor shows the emotion type with text and emoticons. Each feedback panel also shows the brief history of the logged data.

The feedback designs of the history viewer mode are shown in Figure 3. The light sensor representation is not much different from the real-time representation except that the timeline is added. Flex sensor and sound sensor feedbacks filters out data to show only significant changes. The size of the blue circles in the Figure 3-a) signifies how much the flex sensor was bent at that time. In the first row, all horizontal axes are timelines. For the RFID sensor feedback, it displays the sequence of values with the tagged time represented with an analog clock. Emotion sensor feedback is represented with a tag cloud; the font size of each expression is proportional to the frequency that the particular expression was logged.

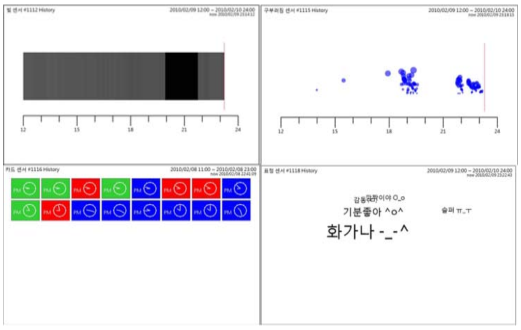

Figure 3. Sensor representations in the history viewer: a) flex sensor, b) RFID reader coin type, c) RFID reader card type, d) light sensor. (Counter-clockwise from the top right)

IV. USER STUDY

The prototype is deployed to a family with 6 members in Korea: two children (both are female elementary school students), their parents in 30s, and grandparents in 60s. While the parents are working during the daytime, the children spend time with their grandparents. We expected that such diversity of the family members across three generations could help us to get interesting results with a wide range of issues. The family used the prototypes for two days.

Figure 4. The touch-screen laptop and the photo printer installed in the living room of the users' house

A. Procedure and Settings

On the first day, the researchers visited their house to install the touch screen and the photo printer (Figure 4). Detailed and clear explanation was also essential to make them understand the purpose of this study as well as the function of each sensor. To be successful in the implementation, the users were encouraged to be active and creative in using the prototypes. They should not be trapped in the conventional ideas of using things. They also need to be free from the mood of "being tested" or "being pressured to find the right answer". They were instructed to decide the purpose of use by themselves, and print out the cards twice a day for each sensor.

After the two days, the researchers visited again for debriefing. Following questions were asked about each sensor : 1) Place : Where were the sensor used?, 2) User : Who used it?, 3) Purpose : What was the purpose of use?, 4) Reflection value : What kind of changes came up on your thoughts or behaviors?.

B. Results

This section is the summary of what we have discovered through the users. Following statements are the brief description of their experiences of each sensor kit and its feedback, in terms of where and who used it for what purpose.

The light sensors were fixed in the living room, kitchen, and bedroom, or worn on the body. Mother and father were the main users and they did not define the purpose of its usage before they use it. They experimentally put them in many different places and saw what can be captured. What was interesting from these sensors was that the users discovered the value of the information captured from the sensors after they reviewed the feedback even though they from the first place did not know what these sensors could be good for.

Different from the light sensors, the flex sensors had clear intention of usage beforehand. They were used as a wrist cushion when they use a keyboard or write with a pen, and also used as a neck pillow when they were sitting on a sofa, mostly in the evening. Father and the children used them, sometimes just for fun. In case of the flex sensors, the affordance seemed to strongly influence the users. They did not try to use the sensors for other purposes than how the cushions are used conventionally.

The sound sensor was fixed in front of the TV, in the living room. All family members used it to detect the noise of children when they shout or run inside the house. What was interesting about this sensor was that the family members tended to be quieter than usually only with the existence of this sensor. Apart from the graphical feedback that we intended to provide, they said their behaviors were influenced by their awareness of the sensor itself.

The card type RFID tags (for customization) were used for well-regulated life of kids (watching TV, eating snacks) and health care for the grandfather (drug or urination check). The kids carried the reader when they move to do the activities that were decided to record, from the table in the kitchen to the sofa in the living room. The reader for the grandfather was put on the table in the kitchen, where his drugs were placed nearby.

The coin type RFID tags (for expressing emotion) were used by all family members to get to know the emotional status of family members collectively. The reader was usually placed in front of the TV, but they moved or carried it occasionally for their convenience. All of the family members shared the same tags. Since both parents were not staying home in the daytime for their work, the children were the main users.

Through this research, we could extract the key patterns of information usages for family members, which must be carefully considered in developing new applications for personal informatics and lifecare information systems for domestic environments and activities.

1) Recalling Life Patterns

Parents recalled their life patterns from the feedback. The parents and children used flex sensors (embedded in the cushion) for their physical comfort when they studied or worked. Figure 5 shows the record of one flex sensor that the father used; the family members recalled that the father used a computer for work for a long time after he got home. They could easily recognize the time spent on those activities.

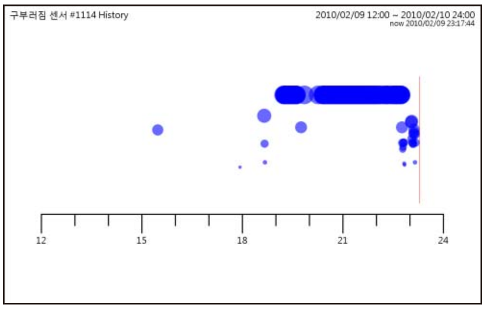

Figure 5. History view of the flex sensor

They mentioned that they could have a chance to 'see' how much time and when they spent on, especially the kids spent on such activities. We suspect that recalling life patterns from the visualized information has a certain value on their life, in terms that being aware of the information became the starting point of thinking about other family members or themselves.

2) Self-Examination

As we mentioned with the sound sensor, sometimes the captured data or the existence of the sensor itself provided chances to reflect on their behaviors. The sound sensor installed in front of TV in the living room happened to effectively detect whether the TV was turned on or not; Figure 6 shows that the noise level was high at the night time when the sensor was turned on. The father said that he tended to watch TV less being aware of the sensor; watching TV too much was shameful thing for them to do.

The main concern that pushed this family to keep self-examined was the etiquette to their neighbors. The noise-between-floors (this family was living in an apartment) was an especially sensitive issue to them. They seemed to recognize that it is their job to keep their children from jumping, running, and screaming in the house, not to make noise to their neighbors. The mother said it would be better if the feedback shows a threshold for the noise that they should not reach concerning the neighbors. They even suggested an idea for sensing the noise of the children running by the vibration detectors installed under the floor.

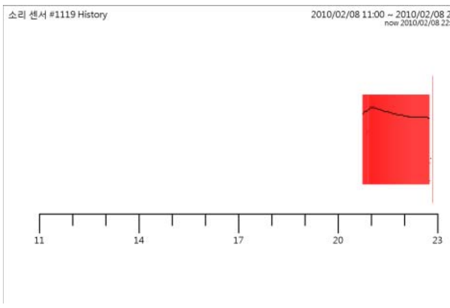

Figure 6. History view of the sound sensor

In case of the light sensor, even though they did not pre-define the purpose of use and just installed it in the living room, they pull out the value of its information when recalling the specific activities that they did like sleeping in the early evening and eating at night time, referring to the brightness change recorded. For example, the father said, when he was looking at the printed card of the light sensor representation of the history review, the dark part of it, which means that the sensor was lying in a dark environment, reminded him that he slept for a while in the early evening and got up at night to eat some foods. He also said that he could have a chance of self-reflection on his day from that record because what he was reminded that he was doing was what he was trying not to do for his health.

3) Mutual Concern

The feedback of emotion tags (RFID coin type) promoted the family members to be concerned about what happened to other family members. The father said that he became to be curious in his workplace about what kinds of emotion tags his children used. He also mentioned that, when he got home and had a look at the history view, he asked them what happened during the daytime and why they used those emotion tags. The mother had a similar experience with that. For example, if the word 'angry -_-^' was the biggest, as shown in the Figure 7, she asked them what made them so angry.

Figure 7. History view of the RFID emotion tags

Though it seemed that the emotion tags promoted them to pay more attention to one another, and consequently triggered conversations, there was a gap between the parents' view on the role of the emotion tags. The mother said that they could start conversation with their children by asking them what happened or what made them to log that emotion. She mentioned that the kids in her children's generation are keeping their privacy strongly, comparing to when she was at their age, so they do not like to share their diaries, and even what happened in the school. In case of the 'angry -_-^' tags above, she found out that her children were not seriously angry but they just did logging for kidding each other. It was not the most important issue that whether the emotion tags could represent the record of the users' emotional status by their literal meaning or not. For her, the emotion tags could be a way of overcoming the 'lost conversation'. The father had a little different opinion. His concern was that using the emotion tags or other technologies could take the conversations away which might have been there among the family members without those technologies. Nevertheless, he was the one who tried to talk about what happened behind the history view of the emotion tags with the children.

4) Regulation

The card type RFID tags were customized to check whether their rules were kept properly. One set was used for well-regulated life of children. The activities that they decided to record include 'eating snacks' and 'watching TV'. The other set was for health care of the grandfather such as urination check or drug-taking check.

The users logged the data by themselves but they said they did not feel uncomfortable about recording. The parents did not want their children to watch TV too much and the children knew about that. It might not have been possible if the parents had been severely strict about this issue, but we cannot exclude the possibility that an influence of the voluntary recording activity itself might exist. It is clearer with the example of the 'snack card'. The children were not allowed to eat snacks more than a certain number of times by the rule that the mother made. They willingly logged the 'snack card' when they were given snacks too.

The mother told that the RFID helped the children not only to keep the rule by themselves but also to persuade each other to keep the rule as it provided solid records of what they did. She said that they used to nag her to get some more snacks when it was not the time for snack, but when they saw the records they tended to agree on following the rules without nagging anymore.

V. CONCLUSION

We propose this method for discovering user-driven application opportunities for personal informatics in the domestic environment. The key idea here is that our discovery is realized by empowering users themselves to figure out and express the meaningful information they want to capture and interpret through the prototypes we provide, in an economical and effective way. The key patterns of information usages extracted from the user study, recalling life patterns, self-examination, mutual concern, and regulation, are valuable insights to be considered in developing new applications for personal informatics. We see the value of this approach not only in terms of efficiency and effectiveness, but also in the point that this line of idea is also supported by what is expected for future where users themselves will define their own artifacts to use with the pervasively archived information.

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