Developing Smart Domestic Applications using a Wizard of Oz Methodology

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Abstract. In this paper we consider how 'smartness' should be designed to enhance the communication in the home. We aim to evoke a rethinking of how smart technologies should be embedded in perspectives of user needs. Through a set of experimental studies, which employ a Wizard of Oz (WoZ) as design and evaluation methodology, we observe and analyse user interactions accordingly with the wizard's simulations. Based on experiment results, our argument is, designing smartness for communication in the home should not heavily rely on invisibly distributed sensors and networks due to interaction design misunderstandings that a large number of sensors and networks can make ambient intelligence with few user understandings. The results also argue that, smartness can be realised by first improving the integration of personal information into the environments, which is closely relevant to social routines.

Keywords. Wizard of oz, smart homes, domestic smartness, communication

Introduction

Since Mark Weiser defined the term 'ubiquitous computing' in 1991, a number of cases have been put forward for devices which interweave into normal domestic routines but exist invisibly [1, 2]. So far research has developed many smart homes, these include Georgia Tech's Aware Home, MIT's Place Lab, Samsung's Smart Home Project and Microsoft's MS Home [3]. Nevertheless, there has not been a great improvement of smartness corresponding to the growth of device number. Technicians may have a profound understanding of technologies they produce [4, 5], however, in terms of user needs, not of the presentation forms in domestic environments since what designers think may not what users need [6]. Abowd et al. doubted that, using wireless to interconnect home stereo components in place of tangible cables could cause confusions due to the metaphor weakness of wireless connectivity from physical objects [7]. In this case, despite the wireless technology has replaced conventional cables, it does not provide a great sense of smartness. Thus, our hypothesis is, building the smartness in the home may not fully rely on component-related considerations rather, on the extent to understanding mechanisms relevant to domestic routines and personal needs [8]. In the regarding of smartness, in this paper, we adopt it as the abilities of sensing contextual information and autonomously communicating with users [9]. To evaluate this hypothesis, we designed system components based on emerging technologies such like speech recognition, and then conducted three practical studies in a simulated domestic environment laboratory. These are done through a Wizard of Oz (WOZ) as design and evaluation methodology.

WoZ is a light-weight methodology which provides simulations for rapid prototype designs and flexible evaluations [10]. The reason of using this methodology is twofold, firstly WoZ enables efficient prototype sketches due to system components can be mimicked by a human wizard with few technical constraints, and secondly it provides the flexibility of evaluation variables.

Furthermore this paper also involves methodological considerations on WoZ. Since the WoZ employs a human wizard to present smartness, it may be severely influenced by the wizard's operations. Particularly, it may generate inconsistent simulations due to the wizard may ignore some activities or take these for granted by instinct. For example, as a human, the wizard can tell a conversation before experiments without taking actions, however, as a computer the wizard should respond the speeches. In order to make the wizard operate consistently, we designed some scripts to align the performances.

In the first section we discuss the research backgrounds, and it is followed by considerations on experimental requirements. In the third section, we describe three iterative studies, and then provide data analysis and discussions in the fourth section. The final section summarises conclusions from the experiment result discussions.

1. Background

1.1. Smartness in households

Progressively, homes have adopted an increasing number of technological appliances such as televisions, radios and washing machines in an attempt to enhance the pleasurable aspects of domesticity while also attempting to reduce the burden and chores of maintenance activities. To date technologies have been identifying new forms of smartness in households [11], since 1999 pioneering researchers called actions to highlight homes and relevant inhabitants for new technology opportunities [12]. Research shows that technologies have achieved preliminary insights into domestic intelligence. For instance, sensors are embedded into home environments and the data is fused for activity recognition thus monitoring inhabitants' behaviours and interactions [13]; In the UK an assisted interactive house has been pioneered for the elderly using augmented controls such as doors and windows [14]; PROSAFE in France attempted to support autonomous living with smart alarms for emergency purposes [15]; in 1991 in Eindhoven the first model smart house was set up and after that several model houses were built in the Netherlands [16].

These ongoing projects employ various sensors such as webcams, ultra sonic and thermograph sensors, and they are integrated with monitoring technologies. However, the smartness which is dependent on monitoring and sensing can not behave autonomously unless an event triggers the system. Meanwhile this smartness can neither satisfy social and cultural requirements due to the limitation of passive reactions. Thereby alternatively providing domestic applications with 'information-push [17, 18]' smartness, instead of 'demon-pull [17, 18]' smartness, may cause less user dissatisfaction. In terms of user needs, home applications with smartness should not only assist householders with physical functions but also with social relationships which require some personal information.

Domestic smartness should be able to model and represent entities in the home, and to plan decisions and communicate with users [9]. Currently the lack of studies in user needs is one barrier to implement smartness in households. This situation is reflected by the fact that industrial projects tend to embed sensors to gain information rather than to understand sensors' social impacts on users [19]. Accordingly, combining user information and sensor and networks may strike a balance between technology distributions and the smartness.

1.2. Wizard of Oz methodology

Wizard of Oz is a method which intercepts communications between users and systems, and returns simulations which mimic smart interactive functionalities with unconstrained technologies. In other words, WoZ sketches pseudo-like systems and presents simulated components such as a listening type writer [20]. The type writer employed a person to mimic a novel computer thus it was able to recognise speeches and output texts. WoZ allows researchers to explore applications with imaginary technologies in cost-justifying means. It was deemed a highly effective method [21], both in designing prototypes and evaluating interactive systems. For instance, in Hudson's study [21] researchers used environmental sensors to assess human intractability, and they changed and replaced sensors without pre-programming.

Without consuming long period of design-evaluation-redesign, WoZ can fit in many study phases. Simulated performances can be categorised into three groups: controller, supervisor and moderator, accordingly by different levels of interference [22]. Simulators have two channels to interact with subjects via observations and simulations. This method is powerful at convincing users believing that they are interacting with a smart system. Although any minor awareness of the simulation may destroy the experiment foundations [10, 23]. Several criteria are used to measure simulations through dimensions of the usability, flexibility and the interpretation. The former two criteria are reflected by user experiences, and the third is measured by data quality.

WoZ has been adopted in many studies of natural language interfaces as well as multi-modal systems [24, 25]. Thus in terms of natural interactions –like speech and gesture recognition-based applications – WoZ is highly configurable in terms of experiment variables.

2. Requirements

2.1. Experiment environments

To evaluate the smartness our studies should be conducted within domestic environments or simulated home spaces. These can provide a range of domestic infrastructures for smart applications. Thereby we set up laboratory scenarios with sofas, a coffee table (see Figure 2) and multiple projectors thus displaying information around the space (on the wall, floor and coffee table). A webcam is mounted on the projector over the coffee table, so it can provide real-time surveillance for the wizard (see Figure 1).

Figure 1. Projectors and webcams **Figure 2**. Experiment environments

The space is designed to simulate domestic scenes where subjects can carry out mundane tasks. Other devices such like the microphone are located unnoticeably. And we make the projector and webcam as components of the domestic space. Sitting in sofas in front of the coffee table, the projector make displays as if these are generated by the coffee table. Taking together these infrastructures and devices, the scenario provides an ambient and natural means of interaction for information-based systems.

2.2. Applications

Smart applications should integrate with mundane routines to gain resourceful actions, as suggested by researchers [26]. These applications need to have close relationships with some rhythms in the home. Applications should also adopt natural interaction methods such as speech and body gestures. We developed a domestic calendar which used speech recognition as an input means. Users could manipulate daily appointments through the application via speech commands. Application interfaces were displayed on the coffee table, so the user needed to speak to the table as if it was a communication agent.

2.3. Subjects and instructors

As a participant in our WoZ experiments, the user should have little knowledge about the system but be willing to experience novel interaction styles. The user is given tasks designed by the experimenter (the wizard). Also, an instructor is presented to support user interactions, whose tasks are to assist the user. All studies employ only one user, but each of these generates different user understandings according to system evolvements. Therefore experiment results can be compared amongst different experiments rather than different users. One reason of doing this is that we can observe intuitive evolvements of smartness sensed by the user.

Ethical issues are concerned due to some minor ‘deception’ may be involved in our studies. Since the user will not be told the system truth in studies, she is convinced to believe that she is interacting with a genuine smart system. User consents should be gained before experiment data collections such like video recording and interviews. In the last experiment, the truth will be revealed to the user, and any further data analysis is under user permissions.

2.4. The wizard

The wizard is also the experimenter who is familiar with the control system. In our studies the wizard designed the smart application as well as control panels (Figure 3). The reason of having the wizard as the designer and evaluator is that, extra trainings to manipulate the system are not required, and the wizard is eligible to deal with system errors.

In terms of measuring wizard's performances, we refer to user responses which include system acceptance, usability and experiences. These measurements are from observations, interviews and video analysis. The video analysis processes user responses and system reactions thus it can provide quantitative data such like operation durations.

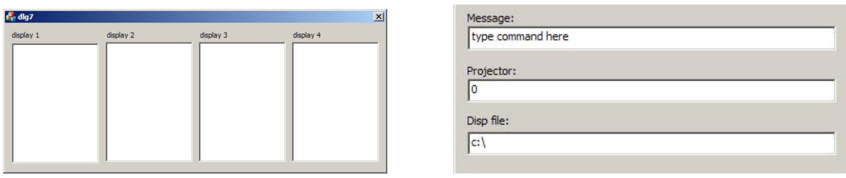

Figure 3. Left: multiple-displays control panel, Right: message control panel

3. Experiments

3.1. The pilot study

The pilot study was proposed to test the environment configurations, as it attempted to explore whether multiple displays were suitable for smart applications. We began the pilot study by designing a multi-display control panel which controlled four displays around the space (the wall, floor, coffee table and a pen-control white board) (Figure 3 left). Dragging files to these slots can show contents in specific displays. Meanwhile, to make the wizard be able to communicate with the user, we designed a text-based dialogue system (Figure 4). Through the dialogue, the wizard can send texts in human-like tones. When the wizard cannot recognise user speeches, she can output a message like 'Whoops, I cannot recognise your speeches, can you repeat it slowly?', for example.

Figure 4. The message dialogue which displays information for the user

The experiment started by asking the subject to talk to the system which was projected on the coffee table. For instance, the subject said 'show me a book on the wall'. The wizard then randomly dragged an e-book file to the control panel and displayed contents on the wall. In the case of using incorrect commands such like 'can I listen to music', the dialogue would display an alert. Throughout this study, various types of content such like web pages, pictures and PDF files were picked by the user. And some unexpected commands were also encountered.

The procedures were recorded by a video camera set beside. Meanwhile, the study was also observed by the instructor, and the wizard could monitor activities via a webcam. Videos were turned into transcripts manually with statistics such like the number of mistakes and operation durations. The video analysis reflected some clues about how a multi-display environment related to smart applications. We observed that, only one display gained main attentions in all operations at a time. This was also supported evidently by the subject's post-experiment interviews. Too many displays with equal importance might cause serious distractions. In this position, following studies were designed with one display for main interactions, and another for information display.

3.2. Study 2

This study aimed to evaluate how the user sensed the smartness of a speech-based calendar. The domestic calendar accepted specific speeches as commands, and then displayed graphical interfaces on the coffee table. The wizard hid behind and responded to user speeches, and the instructor provided necessary explanations. A task list was given to the user by the instructor, and tasks were listed on the sheet. These were required to complete. Speech formats were demonstrated with tasks and these were in specific grammars – see Table 1.

The user needed to learn speech commands before carrying out tasks, however, she was not limited to do these tasks in a specific order. When the user was ready then she could start to do tasks. The user sat in a sofa in front of the coffee table speaking commands. Below are two examples of task conduction.

- Viewing and adding an event

Subject: meeting
System: please pick a date (this message was generated by the wizard in text format)
Subject: today
System: inputting the appointment 'meeting' in calendar (processed by the wizard)
Subject: waiting for system response
System: confirm? (wizard tried to remind the subject to confirm the input)
Subject: confirm.
System: inserting the event into database and refreshing the event list

- Deleting an event.

Subject: delete appointment
System: getting ready to delete today's appointment
System: delete the event?
Subject: cancel
System: performing the delete operation

To check an event, the user first needed to say a date such like 'Friday'. The wizard recognised the speech and then picked the date. At the beginning of experiment, there was no appointment in the calendar. After some adding operations such like 'have a meeting at 10:30' and 'go swimming', the subject became more comfortable to organise these events. The user asked the instructor some questions about the system occasionally, such like 'can I change the event'. Below is a scene with user response details.

Subject: today [Speaking without hesitation and starting to wait for system responses]
System: showing today's events
Subject: add appointment. [Looking at the table and giving the speech when saw today's events]
System: popping up a input window for event contents
Subject: event for tomorrow and 2 o'clock [speaking naturally, still looking at the table and waiting for next response]
[a short pause due to the user forgot to use the 'confirm' to finish the input]
System: popping up a message 'Confirm?'
Subject: ye, confirm [suddenly realising the system would not respond without 'confirm' , then giving the right command and waiting for system responses]

After all tasks the instructor encouraged the user to tell her feelings and thoughts. This semi-formal interview focused on interaction engagement, user experiences and sense of smartness. As a part of experiment data collection this procedure was also video recorded.

The truth was not revealed in this study since the user had not been aware of the wizard. The interviews aimed to find out some deep thoughts such like smartness expectations and system acceptance.

Table 1. The task sheet with speech command instructions

Show an appointment: DATE
e.g. today, tomorrow, the day after tomorrow, yesterday, the day before yesterday, July 20th 2010, next Monday,
Add an appointment: DATE + ADD APPOINTMENT + APPOINTMENT DETAILS + CONFIRM
e.g. tomorrow, add appointment, go to swim tonight, confirm/ abort July 10th 2010, add appointment, go to play tennis, confirm/abort
Delete an appointment: DATE + DELETE APPOINTMENT + NO. + CONFIRM
e.g. the day after tomorrow, delete appointment, second appointment, confirm/abort
Your tasks: 1. to check today's appointment 2. to add some appointments on tomorrow, next Friday 3. to delete an appointment which has been canceled

3.3. Study 3

This study was planned to evaluate whether the sense of smartness was improved when the calendar contained more personal information. To investigate this, we added some weekly appointments in advance, as well as events which were generated in last study.

In this regarding, we could compare the user's attitude changes towards system smartness. This study invited the same subject.

In last study we observed the user adopted some natural languages such like 'confirms' and 'create an event', thereby, in this study, we allowed some natural commands instead of formatted speeches. Meanwhile the user was encouraged to think aloud to express thoughts. Tasks were the same as in last study.

Below are two typical scenes demonstrating user interactions.

- Viewing events

Subject: show new appointments
System: please specify a date (text dialogue)
Subject: today
System: you have two appointments today

- Adding a new event

Subject: add an appointment
Subject: today, go swimming
System: displaying 'speech analysis in progress' in the dialogue, typing event contents as the subject could see typing procedures)
Subject: confirm it

By the end of the study the instructor interviewed the user. This interview focused on the improvements of smartness and acceptance. The simulation system was revealed after interviews in this study. The user compared the smartness between two studies and discussed this with the instructor.

Several user responses changed in this study. Firstly, the user became more patient with slow system reactions. When the system was out of response, the user tended to have a second try. Secondly, the user was active to add more specific events which were close to personal lives such like 'go shopping tomorrow afternoon'. Thirdly the user deleted less but added more events, and finally the user tended to look for command vocabularies as if she did not know what exactly the system capabilities while using natural languages.

3.4. Experiment data analysis

Several phenomenons were observed throughout studies. Firstly, the user became active to manipulate events. The number of manipulations in a single task cycle is listed below in Table 2, which demonstrates the increase of manipulations. Meanwhile, durations of each operation slightly decrease (see Table 3). The third study was designed with more personal events. This improved system acceptance in contrast to previous studies.

In the second study the application contained few appointments. In the third study many appointments had been added thus the wizard was able to provide more personalised prompts to enhance interaction engagements. This also presented the user a personalised application. User's comments on system usability firmly supported this hypothesis. During the interviews the user indicated that active prompts gave clearer guidance. This provided understandings towards command vocabularies which might make the application smarter.

Secondly, natural language-based application increased the sense of smartness. In the second study we required the subject to use commands in specific formats, or the system would not respond. Through specific commands the subject sensed little 'smartness' since current technologies already have a similar interaction style. We shortly adjusted the experiment strategy to encourage natural languages.

In the third study the user kept using previous commands with minor changes. As the application in the third study presented understandings of personal information and natural, the sense of smartness was highlighted. The shorter duration taken by each operation showed that the subject used the application with higher effectiveness (see Table 3).

Thirdly, the wizard could not provide real-time simulations, particularly when she met unrecognisable speeches. Though some messages were preset, these were still insufficient to address various interactions. Besides, when the user asked the instructor questions, the wizard did not respond to speech commands in the conversation. This caused inconsistent operations since the wizard should have acted as a computer taking all recognisable commands equally. However the user had not been aware of this.

Finally, the command formats used in last two studies were actually similar. For instance the specific commands were like 'confirm' and 'show an appointment today', but in the third study the commands were like 'show the appointment' and 'ye, confirms'. This type of differences existed in subtle perspectives. Two reasons may cause these, one is the subject had adopted this type of formatted command, and the other is that natural interactions made personal information presentation adoptive, particularly with a system which had human-like cognitive abilities.

Table 2. The number of event manipulations

	Viewing events	**Adding events**	**Deleting events**
2nd study	4	1	2
3rd study	7	4	1

Table 3. Average time taken by operations in 2nd experiment and 3rd experiment

	Operations	**Total durations**	**Average time**
2nd experiment	8 operations	70 seconds	8.75 seconds
3rd experiment	15 operations	75 seconds	5.00 seconds

3.5. Implications for experiments

In the second study, the user thought the system was smart. But the smartness was limited in technical aspects that a novel coffee table could organise appointments through speech controls. In the third study, the system had more personal appointments, and thus the wizard presented more interferes correspondingly. This enhanced the interactions in terms of usability and acceptance.

The most improvements of smartness between studies are the number of appointments and prompts. The reason of the improvements is twofold. One is the user felt more engaged due to appointments were with high relevance, and the other is the use of natural language which presented a sense of user understanding. Our experiment results show that the user can sense such improvements immediately. The use of natural language also helps to increase the smartness in terms of speech understanding. In the third study the user gave few natural commands. Most commands were like those in the second study, and only some simple words were used such like 'ye', 'can I …' and 'show me …'. Throughout interviews after the third study, the user explained the feelings of smartness improvement, since this made her use some utterances which were used with humans and this also made the user feel she was understood well by the system.

Current speech recognition technology has not been widely integrated into everyday artefacts [23], the WoZ simulation filled this gap. In our experiments the wizard simulated as a speech recognisor thus generating smartness. In terms of emotion understandings, behaviour anticipations and other high-level communication, the wizard can export intelligence and make the application as smart as humans. However there are some issues of WoZ methodology. The wizard is familiar with the system, but her responses were still slow. This can be improved by adding automation components in the future. Wizard's operations were inconsistent to mimic a computer strictly due to humans have some instinctive responses. The inconsistence does not refer to making same reactions to specific interactions throughout simulations rather, it regards to mimicking a smart computer system in strict means of smart systems.

4. Conclusions

Drawing on these evidences, the sense of smartness can be enhanced by integrating personal information, and such improvements can happen naturally when these are embedded with everyday rhythms. Both the information integration and natural commands contribute to the enhancements.

Some implications are provided by these understandings. Designers of novel domestic applications need to consider the adoption of 'smart' technologies carefully in terms of how sensing devices are integrated with user needs. In the home what sensors can do may not equate to what householders might want to do [4]. If designers are going to push smart technologies in the home, they should be aware of how such devices need to map onto regular and mundane rhythms with personal information.

In terms of WoZ methodology, it provides great flexibility in interaction evaluations by presenting novel technology simulations. Together with other evaluation methodologies such like think-aloud and interviews, the WoZ provides insights into futuristic technology use in the home. However, WoZ needs further investigations in terms of operation consistence and effectiveness. Currently few studies have examined these aspects. These will be investigated in our future studies in designing smart technologies on communication purposes.

The main objective of this paper is to identify what forms of interaction styles might be most suitable for domestic smartness, particularly in terms of domestic communications. There are still obstacles and restrictions hindering the progress of smart technologies, our early studies have looked into domestic application smartness and suggested that, smart technologies can be integrated into domestic environment through mundane routine considerations, and integrating personal information –with a necessity of anticipations and user understandings- may fit in future smart domestic application developments properly.

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