User Interface Design of Small-Display Devices for the Rural Developing World

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The development of ICT and wireless network offers a potential solution to bridge the digital divide in the rural developing world. ICT solutions from the developed world have been a poor fit in these areas. Because of user constraints in low literacy levels and little user interface experience as well as environmental limitations in insufficient infrastructure, special consideration must be exercised when designing suitable user interfaces for the domain. This thesis discusses the challenges and UI requirements from different angles, and reviews UI designs of four ICT projects that aimed at rural developing regions. A summary of UI design suggestions of small display devices for the rural developing world is collected and discussed in three aspects: user control, information input and displaying output. This study presents only the initial stage in designing an accessible interface for illiterates in the user-centered design process. An experimental field research should be followed in the future.

Key words and terms: user interface design, rural development, ICT

Contents

1. INTRODUCTION

1.1 Background

The rapid development of information and communication technology (ICT) has been considered as one of the significant factors for improving the quality of life. Nevertheless, the advantages have been brought mainly to industrialized countries, and thus limited to only a part of the people on earth [Brewer et al., 2005]. The term digital divide describes the disparity between people who use modern digital tools or services to access and utilize information technology for their own benefit and those who do not. Since ICT has been gradually integrated into our daily lives in various aspects, the gap between the information haves and have-nots has become large.

The United Nations has acknowledged this problem and been trying to bridge the digital divide by improving the Internet access in developing countries. Bridging the digital divide, however, is not just providing web terminals or hardware. The applications, services and the software user interface (UI) have to be reconsidered to meet the special requirements of the users in the developing world which are different from those of industrialized nations. Yet introducing information communication technology to the rural community is a challenging task. While many problems in basic needs such as sanitation, availability of drinking water and electricity are still waiting to be solved in the developing areas, it is not easy to convince people there that accessing ICT could improve their lives [Huenerfauth, 2002]. Illiteracy and the unfamiliarity of technology are the foremost obstacles for novice users willing to spend time in front of computers [Chand, 2002; Chand and Dey, 2006]. They become the most crucial factors to the design of an accessible user interface and to the success of the computing devices. Furthermore, a basic barrier for rural and pervasive computing also comes from the environmental constraints in power, network connectivity and limited infrastructure. A low-cost ICT device is an essential requirement when deploying technologies in the developing world to achieve the goal of bridging the digital divide.

A number of initiatives and efforts have been taken to combat the growth of digital divide worldwide, especially in the rural developing regions in India, such as information kiosks providing e-governance services and market price information [Singh, 2004]. Nowadays, the increasing wireless communication has reduced its cost for infrastructure which makes it more affordable for rural areas [Brewer et al., 2005]. Researchers could take this advantage to create systems that would support as well as improve rural villagers' lives.

Small-display devices, such as mobile phones or smart phones, PDAs and other portable computing devices are considered to be one possible medium to develop further seamless computing in the rural developing regions in terms of their hand-held size, mobility and low cost compared to conventional PCs. The mobility of hand-held devices allows their use in the rural regions which are difficult to reach in other means. As noted, rural areas in the developing world have special requirements, challenges and limitations, thus the current design and usage of small-display devices from the developed world would not be appropriate or workable for them. Parikh's studies [Parikh, 2005; Parikh et al., 2006; Parikh and Lazowska, 2006] suggested that mobile phones with proper interfaces can act as a suitable means for novice users in delivering essential information services to the rural developing world that currently lacks the required infrastructure and financial resources for PCs. Since recent advances in mobile technologies have made pervasive handheld computing devices available to enhance human activity, it is certainly essential and interesting to study further how user interfaces of mobile devices should be designed for users in the rural developing regions.

1.2 Research Questions

The main objective of this research is to present and summarize from different projects the principles for designing user interfaces of small-display devices for rural developing regions. Having an overview on the experiences of the various projects will help UI designers to be aware of the diversities of the target users, and subsequently design appropriate accessible UI on mobile devices for rural users in the near future.

The core research questions I would like to discuss are defined here as the following:

- How to design user interfaces for small-display devices that will promote the usage of ICT in the rural developing world?
- What are the challenges and computing requirements of rural regions that need to be taken into consideration in the UI design process?

- What UI elements could be applied in designing small-display UIs for the people who have low literacy skills with little or no familiarity with technology?
- What other factors need to be considered when implementing UI designs for rural communities?

Answers to the above questions would help building summary of UI design principles for this target user group. Since low literacy people are usually inadequately understood by technology developers who often erroneously assume the needs of users, this study could be used as a reminder in UI design when working in this domain in the future.

Literature research is used as the research method in this thesis. The core resource comes from surveying previous project work which aimed at developing and utilizing small-screen devices, and projects which were related to user interface design for rural users in developing areas. The discussion and conclusion will be built based on the research outcomes collected and analyzed from these projects.

1.3 Thesis Structure

This thesis starts with a brief description of the UCD approach in Chapter 2 to provide a short theoretical background for the UI design process. Chapter 3 discusses the challenges and limitations of the users and the environment in the rural developing world, including illiteracy in language and technology, affordability for personal devices, poor infrastructure and the diversity of languages. This is followed in Chapter 4 by discussing UI design requirements of ICT devices for the target users. Chapter 5 points out why small devices are considered to be more suitable for rural regions than conventional PCs. In Chapter 6, four ICT projects that aimed at the users in the developing world are brought into discussion: CAM, Simputer, Tamil Market and Negroponte’s hundred-dollar-laptop, OLPC, project. Chapter 7 collects the findings from previous work into an organized summary of the UI design suggestions for the rural users in the developing world. Chapter 8 gives the conclusion of the whole thesis and proposes possible directions in this domain for further studies in the future.

2. USER-CENTERED DESIGN APPROACH

To design an appropriate user interface for a certain user group, the field of Human-Computer Interaction (HCI) advocates applying a user-centered design (UCD) approach. User-centered development involves finding out about users and their tasks and using such information for interaction design. Additionally, users are to be involved and considered throughout the development process [Preece, et al., 2002]. The key principle of user-centered system design is that the characteristics, capabilities of target population, their needs and the environment are the central concern of the whole interaction design process [UsabilityNet, 2006; Smith-Atakan, 2006].

Many HCI researchers have highlighted the significance of the UCD approach in interaction design and clarified the main activities in the design procedure. Preece et al. [2002] specified four basic activities in the process of interaction design: 1) identifying needs and establishing requirements; 2) developing alternative designs that address the requirements; 3) building interactive versions of the designs, which is also acknowledged as prototyping; and 4) evaluating designs of its usability and acceptability. Smith-Atakan [2006] defined six key activities that are similar to those of Preece et al.'s, but more refined, as illustrated in Figure 1.

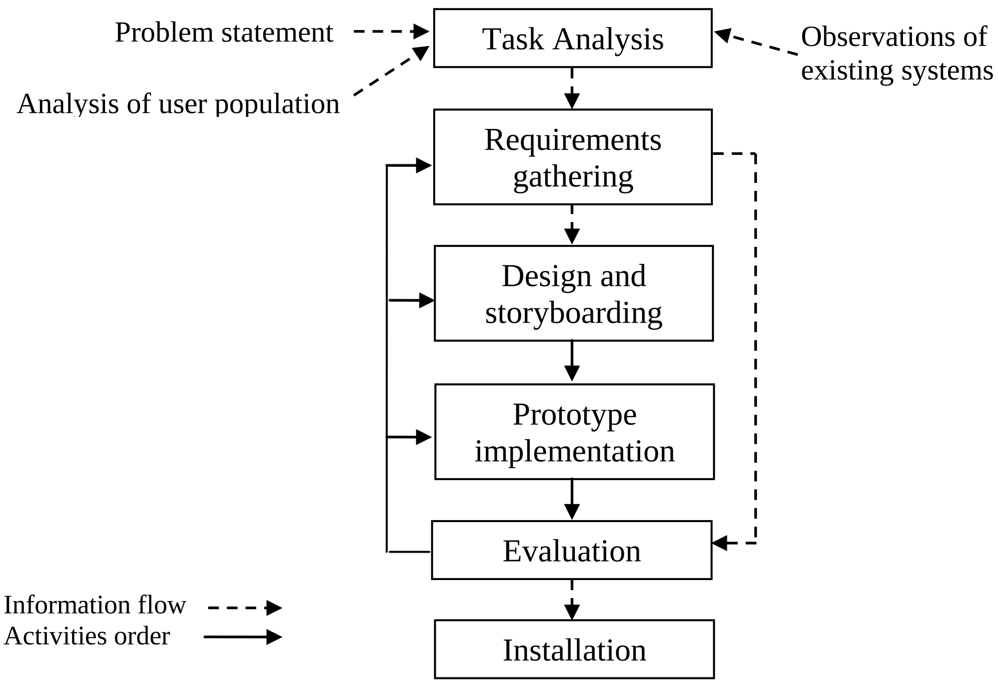

Figure 1: The UCD approach [Smith-Atakan, 2006]

Besides that user-focus is the core theme, iteration is the other key characteristic of the user-centered design approach. Since users are involved to provide feedback for designers to evaluate the design and refine the requirement, UCD is an iterative process. As a result, the activities of design development, prototyping and the evaluation are interworked, which is also shown in Figure 1 [Preece, Rogers, and Sharp, 2002; Smith-Atakan, 2006].

It is the best practice to apply the UCD approach and involve target users in the UI design development process for rural communities. However, special conditions of rural areas present their own challenges for this approach. A study done by Heukelman [2006] indicated that even though inexperienced computer users in rural areas need not different approaches than those in urban areas in user-involvement, the availability of support, the low level of literacy and lack of user interface experience in rural regions could prove to be obstacles when including users in the development of a user interface.

The above mentioned UCD procedure provides a whole picture of design activities from analyzing the problem and users to prototyping and implementation. In this thesis, I will only focus on the starting stages of the UCD approach: identifying needs and gathering requirements, since they are the most important and relevant information for interface design. Smith-Atakan [2006] stated that “Task analysis is an important stage in UCSD… [It] will tell you about the tasks that the system needs to support. Equally important is an analysis of the abilities, skills and preferences of your users”. The projects that have implemented or are planning to implement ICT in the rural developing world will be discussed to draw out a conclusion of design guidelines for small-display devices.

3. CHALLENGES: USERS AND THE ENVIRONMENT

As stated in the previous chapter, understanding the target user group and the environment is the first step when identifying user needs and requirements. It is a simple idea, but not an easily achieved goal. Often designers assume that they understand the users and their tasks, but this would result in poor interface design, low acceptability by users and even failure of the product. Rural areas have a number of challenges for deploying information technologies. It is fundamental to appreciate the challenges in the rural developing world before designing suitable user interfaces as it provides a significant perspective in realizing the distinguishing characteristics from those of urban areas,. User interface developers need to keep in mind the constraints of users' capabilities and environmental infrastructure. The unique challenges of these regions are divided into two categories: user challenges and environmental challenges. They will be discussed below.

3.1 User Challenges

3.1.1. Language Illiteracy

Illiteracy is used to describe a person's inability to read and write in any language. According to the literacy data collected by UNESCO in April 2006, an estimated 781 million adults, of whom 64% are women, in the world's population do not have basic literacy skills, especially developing countries still hold 770 million illiterates [UNESCO, 2006]. Due to difficulties in economic development, heavy demand of agriculture work and the limited educational resources in the rural developing world, many people, especially women, are forced to sacrifice schooling. Consequently, the illiteracy rates in rural regions are usually much higher than the average. For instance, according to the census of India 2001, the overall illiteracy rate of the country is 35.2%, but it increases to around 45% in rural regions in the northern states. Illiteracy rate of rural women is much higher: more than 50% of the women in those rural states are illiterate [India, 2001].

In many rural developing areas, illiteracy is one of the major obstacles to overcome for ICT deployments. Since a large proportion of the population in rural areas does not have reading and writing abilities, bringing information to them can not rely merely on displaying on PC screens. Besides, they have difficulties in understanding abstractive and symbolic concepts. When illiterate users face a normal internet-connected PC, they can not read text, type in data, or use the keyboard or mouse to control the device without a literate mediator's help [Huenerfauth, 2002]. Even if the user has some literacy, they may still have difficulties in getting access to information as the computing system could be too complicated for them to explore.

Computers and information could be accessible for illiterate and semi-illiterate villagers when an educated, literate village member helps them operate the system and interpret the written text. Although support is provided from volunteers, it is still essential for illiterate users to understand the process of performing the task on the designed system, so to protect their personal data for secured and trusted data transmission [Parikh, 2005]. Speech recognition user interfaces in local languages or dialects are often proposed to be utilized for rural users in many ICT projects. Nevertheless, illiteracy is an obstacle as well in the procedure of recording and collecting linguistic samples for speech interfaces [Brewer et al., 2006].

3.1.2. Unfamiliarity with Technology

In addition to linguistic illiteracy, the unfamiliarity of technology makes people hesitant to use technology. Especially when rural users are not exposed to new technologies, the idea of using a computer or a mobile phone could be frightening for them. Illiterates or semi-illiterates are usually too afraid to ask for help when they do not understand or do not know to proceed [Huenerfauth, 2002]. Another factor which also makes users unwilling to use computing devices is that they "cannot see any direct benefit from it" [Chand and Dey, 2006]. Many rural users who are not familiar with computers often have a wrong idea about them – they expect that computers can solve their problems in daily lives like water, electricity, disease, crop planting, and so forth [Chand, 2002]. Under such circumstances, merely providing training to people would not effectively increase the usage of technology. The technology or the computer must be designed as a handy tool to assist users to solve problems or achieve certain goals. It needs to be easy to use, close to the target users' everyday life in order to serve and facilitate their lives [Heukelman, 2006].

3.1.3. Inability of Affording Personal Devices

Given that the income of most people in rural regions is below the poverty line, an individual is not able to afford a personal computing device which is common in developed countries. The survival and social requirements are the first priorities of rural villagers’ consumption, and they cost already almost all of their income [Parikh and Lazowska, 2006]. In order to have access to information and technology, it is a common situation to share the devices with other family members or villagers in rural communities, such as televisions, pay phones, internet-connected computers and printers in public information kiosks. It is however also costly for villagers who live in other locations and must spend a long time traveling to the information center to utilize ICT. The concept of sharing in the rural world poses a different idea of personalization in the developed world.

3.2 Environmental Challenges

3.2.1. Insufficient Power and Connectivity

The most noticeable environmental challenge in rural developing regions is the availability and quality of electric power. Outages of power are common and unpredictable in the developing world. Even where the electricity is available, the quality of it is often unsatisfactory for ICT, which is more demanding than normal usage for lighting and cooking. Although much effort has been applied to this problem, it still remains as the primary environmental barrier for ICT projects [Brewer et al., 2006]. As a backup solution, strong battery-powered systems are then necessary in any PC-related devices which require constant supply of electricity in these regions. This would increase extra expenses for consumers to bear, which becomes another burden for rural users.

It is expensive to extend the landline to rural villages for internet connections; and even if the information kiosk of a village is connected, the equipment is outdated which lowers the quality of the network [Parikh and Lazowska, 2006]. Internet connections established over phone landlines in developing countries are slow, unstable and often disconnected. Furthermore, connectivity is simply too expensive to be sustained in rural communities. One possible alternative that may provide rural users a better connectivity to have access to technologies would be the wireless network.

3.2.2. Diversity of Languages

Localizing user interfaces and information into local languages is one of the most essential elements in motivating users to approach and employ information technology. Heukelman [2006] stated that “language is an important factor in understanding a user interface" for rural users in particular, since it could encourage them to understand and remember the interface better, and even to transfer the knowledge to other user interfaces. However, the diversity of languages in use over the developing countries may cause challenges to users and the UI design of information devices. For instance, India has 23 official languages, including Hindi and English, and also hundreds of dialects. South Africa has 11 official languages; only 4 of them are spoken as mother tongues by more than ten percent of the population [Pretorius and Bosch, 2003].

Under such a linguistically diverse environment, localizing computing devices into all of them would be impractical. Even though users are literate in their mother tongue, they may not be able to control the computing device if the UI or information is in a different language. The user still needs to take the advantage of illiterate accessibility features of the device [Huenerfauth, 2002]. It is a challenge yet a requirement to design user interfaces for a multi-language user population in the rural developing world.

4. UI DESIGN REQUIREMENTS FOR RURAL USERS

By better understanding the constraints of rural communities, designers would be able to identify better the needs of users and how they could interact with the ICT devices. Likewise, by establishing a set of requirements of the target population, designers can move forward to the design stage. After discussing the capabilities of target users and the environment in the previous chapter, requirements of information devices for rural users will be clarified in this chapter.

4.1 Interfaces for Novice Users

An important attribute of the target user population is that they have a low level of computer and user interface experience. They, also defined as novice users, become a serious consideration for UI designers. Users are often anxious about using computing devices, and worry about accidentally doing something undesirable or breaking the computer, which restrains learning of the system. The first user requirement is to reduce novice users' anxiety towards computers; moreover, to encourage them to learn how to manipulate the interface to perform particular tasks. It has been suggested to apply step-by-step prompts or instructions that constrain and guide users to proceed with appropriate actions to enhance the learning procedure [Preece et al., 2002]. Other useful design principles for novice users are using user-familiar or constantly used terms on the UI and providing informative feedback of successful completion as well as precise, constructive error messages. Limiting the number of required actions to complete a simple task also helps enhance users' confidence and reduce their nervousness [Shneiderman, 1998].

Another essential aspect of UI design is to minimize the memory load when using the system, especially for novice users. If an interface requires users to remember a lot of information with complicated procedures to carrying out tasks, it will be definitely difficult for novice users to operate. A poorly designed UI does not present enough information on the interface but forces users to recall the procedure how to use it to perform specific tasks. One of the well-known findings in memory research is that we can recognize objects much more easily than recall them from memory. For this reason, interface elements like menus, icons, and consistent objects can act as clues to promote users' recognition instead of recall of a command [Preece et al., 2002].

Besides, to keep the current system status visible to users eases users' anxiety and the memory load of remembering where they are in the sequential procedure of the interaction. Particularly when target users are often insecure, the interface should be able to indicate users that their interaction with the UI is progressing correctly. This helps them continue without difficulty especially when they are distracted in the middle of the operation. Accordingly, it is unreasonable to expect users in rural regions who are unfamiliar with information technology to remember complicated interaction procedures. Designing interfaces for such novice users needs to take the above aspects into account to construct a suitable interaction.

4.2 Suitable Input and Output Channels for Illiterates

Considering the high illiteracy rate of the target user group, text is not the best means of carrying information and services to the rural population. With their little experience in user interfaces, they also encounter difficulties in interacting with the menus, buttons, and browsing options on a common WIMP user interface. Moreover, it is unrealistic to expect users to enter data successfully to the interface by the common input device, keyboard. Not only does the illiteracy hamper the use of keyboard, but also keyboard mapping of local languages is difficult. While many languages or dialects spoken in the developing countries have different scripts that are not included in the standard Unicode set, rendering those scripts requires support from the operating system which complicates the design [Parikh and Lazowska, 2006]. Apart from keyboard input, using a mouse as the main interaction mechanism for pointing and clicking on the desired objects on the interface appears to be difficult for users who have little experiences on computing devices, particularly for the older and less educated [Parikh et al., 2006]. Controlling the pointer in the focused area and the timing of clicks are complicated as well as unfamiliar concepts for rural users to discover [Chand, 2002].

4.2.1. Speech Interaction with Audio Feedback

Due to the difficulties in normal interactive ways described above, other interaction techniques on ICT devices are required for rural communities. To employ speech-based interaction and audio feedback as means of communication on computing interfaces for low literacy users is considered desirable for its naturalness. The most widely used communication method to exchange information within rural villages is by word of mouth. Applying this ordinary interactive ways on ICT devices to mimic the interactions between humans is regarded as a suitable solution for illiterate users [Brewer et al., 2005; Huenerfauth, 2002; Plauché et al., 2006]. They can learn to operate the system with only little training by speech interaction.

An interface with speech interaction, however, could be user-unfriendly. Besides the complexity and difficulty of speech generation and recognition which have been discussed over studies related to speech techniques in HCI (e.g. [Shneiderman, 1998, Chapter 9.4]), speech interaction could be frustrating in some other ways for users. For example, inexperienced users may feel uncomfortable and not be able to distinguish the meaning of the silence during the interaction. The silence could indicate that the system is waiting for input from users, or it is processing. It would be helpful for illiterate users to have other hints from the UI suggesting what they should react to in the interface. Audio output is a good option to be combined with speech interaction to guide attention. Through various non-linguistic auditory feedbacks in addition to speech output, like beeps or error sounds for warnings or alarm purposes, the interface could bring more information to illiterates in rural villages.

4.2.2. Visual Display and Speech Interaction

Visual display on screens is the most common output format for guiding users' attention to relevant information on interfaces. The visual channel can be used to communicate information by means of non-literate illustrations such as icons and graphs for illiterate users. One of the main reasons for the popularity of icons is that they can reduce the complexity of the system, and make it easier to learn and use [Preece et al., 1994]. Icons and other types of graphical representation should enable users to distinguish their meaning easily from others and be simple to recognize [Preece et al., 2002]. Undoubtedly, a meaningful and communicative visual representation should derive from real users' life experience in which it is deployed; otherwise it becomes a poor, confusing and useless design.

It is noticeable that such visual display is a culturally sensitive challenge: non-western users in developing areas may interpret a graphical image in a different way than the ones in western developed regions. Concrete objects are easier to represent, whereas abstract concepts are difficult to be designed and symbolized, especially for less educated rural users [Parikh and Lazowska, 2006; Preece et al., 1994]. Therefore, selecting and employing a proper image is not an easy task. Mullet and Sano [1995] and Shneiderman [1998] described in detail more basic icon-specific design principles, common errors, practical techniques and considerations in order to promote the visual conciseness, also enhance the usability of the product.

Given that graphics can transfer meanings, Goetze and Strothotte [2001] conducted a web-browser with graphical reading aids for functionally illiterates in industrialized countries. It was a pen-based interface that allowed users to point at a word to display the pictorial image explaining its meaning. However, it is not likely to select understandable and intuitive pictures for each word and misinterpretation could happen. Apple has developed a graphical user interface for a mobile device to be used by rural healthcare workers in India [Grisedale et al., 1997]. Icons were carefully designed according to the cultural conventions and used to represent various states of the patient and household for healthcare workers to record. Although the workers relied more on text than on icons, positive feedback has been received when using icons as the main record navigation means. Applying icons with text explanation is feasible for people who have little or no UI experience.

Visual feedback could support significantly the speech-based interaction. One considerable contribution of visual feedback on screens is to inform users of the current status in the interaction process for feeling in control. Preece et al. [1994] discussed what a system should do to provide current responses to keep users informed. Well-illustrated graphical elements on the UI along with speech interaction may help reduce users' memory load when operating the interface, and also indicate illiterate users the interaction status. Nevertheless, relying too heavily on non-linguistic graphics on the interface to convey messages might result in that people need to memorize the meaning and the shape of the icons, so as to make the interaction faster. Thus, attention is required to how to balance the usage of visual images and speech interaction on the UI of the device.

4.3 Shared and Inexpensive Devices

Almost all electronic devices in rural villages are always shared within family or the community. On one hand, the concept of privacy and personal property is not valued as high as in the developed countries. Instead, information and product sharing as well as group communication are more common for rural user groups [Lindholm et al., 2003]. On the other hand, as discussed in the previous chapter, rural users have economical difficulties in affording personal devices. Creating a more affordable, inexpensive device than a conventional PC could help in deploying ICT increasingly in the rural world.

An alternative for accessing information for rural villagers, apart from going to public information kiosks, is to rely on agents with handheld devices travel to rural communities to collect or deliver information [Grisedale et al., 1997]. The cost of handheld computing devices is lower than a PC for a community to afford, which is more viable in such context. Therefore, designing a multiuser interface for sharing purposes on low-cost ICT devices is an essential UI design requirement.

5. THE SUITABILITY OF SMALL DEVICES FOR RURAL REGIONS

Although conventional computers could not bring information technology pervasively to the rural communities due to the environmental constraints, recent development of wireless network and mobile computing technology encourages researchers to seek other opportunities. Mobile phones and other small-screen devices are likely to provide a potential solution that addresses the constraints of rural communities. In this chapter, the characteristics of mobile computing devices and the reasons why they suit this target population are discussed in order to provide another foundation for further discussion about UI design principles for rural communities.

5.1 Mobility

Given the poor quality of roads and long traveling distance in rural regions, accessing computing and information resources in certain towns from the wide rural area is costly and time-consuming. The growth of wireless connectivity makes it possible to reach more areas where mail or telephones could not do. About 97% of the population in South Africa has access to the cellular network [Jones and Marsden, 2006], which is a good illustration that wireless networking could be a more appropriate technology in the rural developing world. Advances in wireless communication technology and the mobility of handheld devices enables bringing the information and services out to rural villages where it is needed the most.

In addition to Apple's early experiment of utilizing handheld devices in rural India [Grisedale et al., 1997], also projects that have implemented mobile handsets in microfinance [CGAP, 2003] and healthcare services in Africa [SATELLIFE, 2006] have received encouraging feedback. They have well demonstrated the viability of mobile technology in the developing world. Information and knowledge can be carried and transmitted via handheld devices by field workers or users in rural regions, without being limited by unstable and insufficient infrastructure. The deployment of handheld devices could increase the accessibility of information and field data. Furthermore, it would improve the efficiency, productivity and accuracy in data collection for microfinance or healthcare activities, which saves a lot of time and labor from paper work as well as transportation, and then enable focusing more on providing required services to rural users.

5.2 Small Screen Size

Mobile computing devices must be small to be easily carried in hands or pockets. In order to ensure portability, the physical interface of the device is compact. One of the popular discussion topics about mobile devices concerns their limited display space. The small screen space of handheld devices, so called baby faces, limits the amount of information that can be presented to users at a given time. During the 1980s and early 1990s, a number of studies were done focusing on the impact of screen size on usability and user comprehension (e.g. [Jones and Marsden, 2006, Chapter 9]).

Since most rural users are novice users of ICT devices and are not capable of reading large amounts of information, displaying all information on a large screen at once may not address their need, but simple and easily-learned interfaces are more adequate for them. As noted above, ICT novice users require simple interfaces to carry out tasks that facilitate their lives and meanwhile build their confidence towards information technology. Sequential presentation of data or a task has been recognized to be suitable for small screen devices which have the compact design for the purpose of mobility [Lindholm et al., 2003]. More importantly, it also appears to be easily accepted and learned by rural users when deploying ICT. Parikh et al. [2003] found that an interface with discrete and small task spaces, which minimize the tasks to users at one time, was easier for users to comprehend. Sequentially displaying information or tasks on small-screen devices would reduce possible confusion and improve the accessibility for rural novice users.

5.3 Natural Interaction

Since mobile devices are small in size and portable, few of them provide a full QWERTY keyboard. Usually a few functional keys are provided, or a 12-key numeric keypad like in mobile phones. Input hardware as keyboards or mice would be difficult to use with such handheld devices. As discussed in Section 4.2, rural users would have difficulties to use keyboard as an input device due to the lack of literacy.

In order to overcome the challenge of illiteracy with input channels, the key concept lies in utilizing the mechanism that target users are familiar with, or implementing their natural interactive ways on ICT devices. A keypad, for example, is a more viable option than a keyboard. The 12 numeric keys on mobile phones are familiar to ICT novice users, since landline phones and calculators have the same keypad design, thus not much training is required. Parikh et al. [2003] found out that rural users are more numerically literate than textually, the interaction design built on the basis of the numeric keypad on mobile phone was easily accepted and learned by rural users.

Voice-based interaction on computing devices mimics the human-human communication, so it is natural to all users. Microphones and speakers are easily integrated into mobile devices, therefore the use of speech as an interaction modality provides an appropriate alternative to the rural population on handheld devices where the physical size of the hardware limits the input and output capabilities. Moreover, audio feedback plays an important role in enhancing the usability of mobile devices that have small functional buttons and in increasing users' satisfaction of the system [Brewster, 2002; Parikh, 2005].

6. CASE STUDIES: ICT PROJECTS IN THE RURAL DEVELOPING WORLD

Various ICT projects aimed at the rural developing world have been planned or implemented for providing more services. Two of them utilized small-screen devices as the medium to interact with users: CAM and Simputer. Both of them are described in this chapter. Additionally, some other projects that were not particularly implemented on hand-held devices but had the same target users are also discussed here: the spoken-dialogue system of Tamil Market and Negroponte's Hundred Dollar Laptop. They also provide valuable experiences and design principles for accessible UI to illiterates. The goal is not merely to discuss their effort made to the rural communities, but to focus on their UI design considerations to bring out common features for designing small-display devices.

6.1 CAM: Utilizing Camera-Equipped Mobile Phone

Parikh and his colleagues [Parikh, Ghosh and Chavan, 2003; Parikh, 2005; Parikh et al., 2006; Parikh and Lazowska, 2006] in the University of Washington has conducted a series of studies on constructing a paper-based architecture operated on mobile phones for deploying mobile applications to deliver remote information services to the rural developing world. The smart phone is selected as the information appliance for this system because of its strong communication facilities, and the strength of low-cost and low-power requirement. This framework uses a camera-equipped smart phone to interact with paper documents which contain barcodes. It is named CAM since the digital camera on the phone plays a significant role in the interaction.

The first application developed for the CAM platform was to collect microfinance data (transactions about payments, loans, withdraws, deposits, etc.) from rural self-help groups in India, where data was only collected and recorded manually on paper formats [Parikh et al., 2003]. It was claimed that “CAM is designed to link inefficient, paper-intensive process to online information systems” [Parikh et al., 2006]. After receiving positive feedback from users about the performance of microfinance data collection, some applications based on the CAM platform are currently under design and development to support other economy related activities or agricultural and health care services in rural villages [Parikh and Lazowska, 2006; Parikh, 2007].

6.1.1. CAMBrowser and CAMForm

There are two major elements in CAM that users need to interact with: CAMBrowser and CAMForms (see Figure 2). CAMBrowser is a mobile phone application which operates with the CAM architecture. It has been implemented for several phone models based on Nokia's Series 60 platform. A smart phone's physical interface is limited to a small display area, a keypad of 12 buttons and a joystick with some soft-keys. Users first enter data on CAMForms (see Figure 3), which are paper documents containing two-dimensional visual codes and complementary numbers. The major interactions of CAM are simplified to two actions: click the joystick over the visual code, or scan the code with the viewfinder. Users then enter or edit data in numeric form in the pop-up query. All of the data is transcribed, processed and uploaded via CAMBrower to a web server when the phone has a network connection.

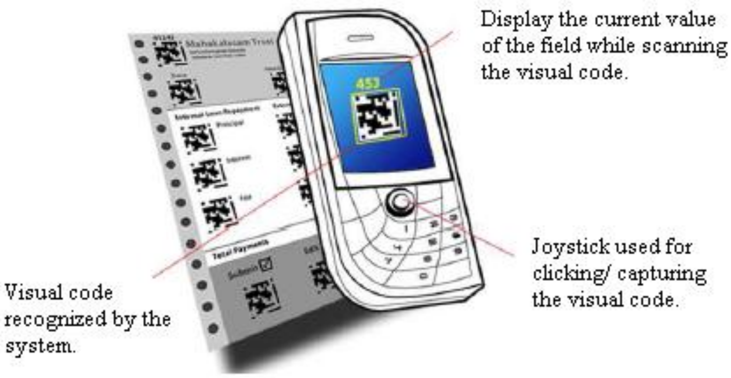

Figure 2: The CAMBrowser and CAMForm [Parikh et al., 2006]

6.1.2. Input: Numeric UI and Paper Document

To overcome the illiteracy challenge in rural India, Parikh and the research team leveraged the commonness of rural population's numeric literacy - the ability to remember, enter and manipulate numbers - to design the numeric interface of CAM. Most illiterate or less educated users had difficulties in reading texts but they could understand well data in numeric form such as time and dates, phone numbers, and sums. Because numeric data was understood more widely by users, the researchers decided to utilize such advantage on the interface and apply it in the CAM platform. Furthermore, Parikh found that rural users were more used to deal with information on paper documents. The representation of information on paper with tabular data entry was frequently used and accepted; low-literacy users could even learn to identify data from the tabular form [Parikh et al., 2003]. The concept of combining paper document with information services via numeric interfaces established the key frame of CAM design.

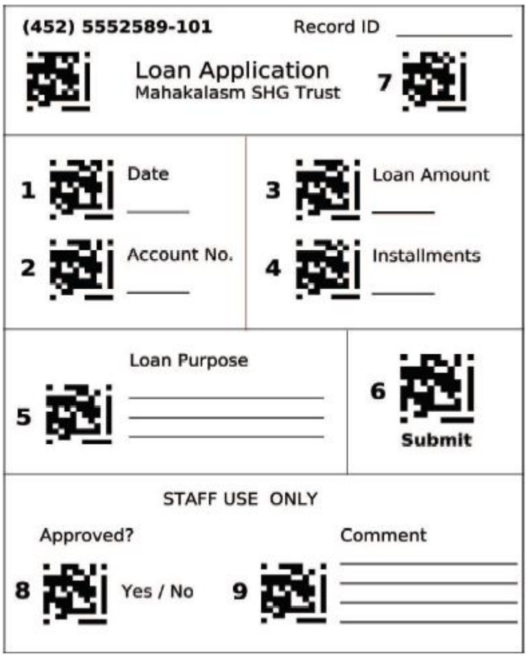

Figure 3: An example of CAMForm with visual codes: a microfinance loan application. [Parikh and Lazowska, 2006]

The most significant characteristic of CAM is its input approach. Since it is operated on Nokia’s Series 60 smart phone, the core input channels of CAM platform are the built-in camera and the keypad of 12 numeric keys which illiterate users are also familiar with. Applications and their functions are indexed into numeric format and encoded as visual codes or as numeric strings, which could be printed out as a CAMForm like in Figure 3. For accessing CAM applications and functions, users can either click the joystick button on the mobile phone to capture the associated visual code on CAMForm via the embedded camera, or enter the corresponding numeric strings via the keypad. The required input data from users is also transformed into numeric formats, such as using member ID or account number for identification, to avoid textual input from illiterate end-users. Finally, the CAMForm can act as a local record of the action for the user.

Such interactive approach simplifies the procedure in navigation compared to the commonly used menu-based system, which was complicated for inexperienced users to learn in the first place. The paper document analogs the tabular information format that the rural population is accustomed to; meanwhile, it is linked to the digital world of information services by CAM interactions.

Besides numeric input, speech is also utilized as another input alternative when the data can not be formed into digits. In cases such as “Loan purpose” in the CAMForm in Figure 3, an audio clip is captured by voice recorder instead. The audio clip will be submitted with other numeric data as a complete loan application from a rural user. With this approach of combining audio and numeric input, CAM platform tries to address the difficulties of textual input for various local languages.

6.1.3. Output: Sequential Display with Audio Feedback

CAMForms can be distributed to users before using CAM applications. They fill the required data on the paper form with the help of a literate person if they not able to read and write. When starting, the application ID code on the form is captured firstly to activate the appropriate CAM application. To transcribe a new loan application, users can capture the top-right code on the form which activates a function that presents a series of prompts in sequence. Guided by the prompts and audio feedback, users can enter the values on the form sequentially. Sequential display of tasks on interfaces, like wizards in configuring software applications, reduces rural users’ anxiety towards the computing system; the step-by-step process eliminates novices’ confusion about what and how to do next.

The prompt has text displayed in local Indian languages as an image, because the mobile phone system might not support the special scripts of the numerous target languages in the developing countries. Displaying texts as an image for local people is one temporary solution for the languages that are not yet supported in the operating system. Besides the visual display of texts, CAM utilizes audio in its output channel, which brought significantly positive feedback from users in their usability testing. Each prompt is associated with an audio feedback that is brought up to the interface at the same time to notify users of the name of the currently displayed field. Illiterate users could follow the process without difficulties by listening to the voice feedback. The audio output enhances the interactive process with users; it analogs the human-human conversation which makes the procedure on CAM applications more vivid.

After data has been entered, users can verify if all the entries were correct before submitting the digital form to the web server. They can focus the camera (the view-finder) on the visual code (Scan-mode) of the required field, and the current value of the field is displayed beside the visual code on the screen, as illustrated in Figure 2. If the value is incorrect, they can capture the visual code (Click-mode) by clicking the joystick, and a prompt is displayed with data-entry field for users to edit. Associated voice feedback is played as well to help users during the whole procedure.

Parikh and his research team performed several usability evaluations with real end users in the field. They found that the CAM system was easily accepted and learned by rural users and agents because of its simplicity. CAM presented a unique and viable platform for rural communities by taking the advantages of the embedded multimedia features on mobile phones as the core means of input and output. Combining users' experience and the constraints as well as the opportunities of mobile devices to avoid textual elements in the interaction enhanced CAM to step forward to the less-educated population in the rural world.

6.2 Simputer: Computer for the Masses

The Simputer, short for Simple Inexpensive Multilingual Computer, is a PDA-type computing device developed by a group of scientists and researchers from the Indian Institute of Science and engineering professionals from Encore Software in Bangalore, India. Their goal was to create a device that could provide universal access to the masses. The Simputer was initially designed and intended for low-literacy and low-income rural populations in India. Thus it was meant to be a simpler pocket computer than a conventional PC, having easy usability and user interfaces based on sight, touch and audio [Simputer Trust, 2000]. In order to bring the Internet and the benefit of IT to the common man in India, especially to the rural world, Simputer was aimed to be an affordable, inexpensive and shared device for a local community of users. It was intended to address the specific requirements of the rural environment which were discussed in Chapter 4.

A concept paper identified the areas where to focus on to create a practical and universal access device to the common man [Manohar, 1998]. The organization of Simputer Trust was then built to promote it "as a platform for social change" [Simputer Trust, 2000]. Two companies, Encore Technologies and PicoPeta Simputers, have been issued the licenses for the production by the Trust and carrying on the sales of the Simputer. Their focus and products looked different; Encore has focused more on enterprise sales only, whereas PicoPeta has been looking into retail sales with the Amida Simputer model for low-attainment users [Fonseca and Pal, 2004; Ganapati, 2003].

Figure 4: The early design of Simputer [Simputer Trust, 2000]

6.2.1. Simple Touch UI Supporting Indian Languages

Powered by an Intel StrongARM processor, the Simputer is equipped with 32 MB memory and a 320*240 LCD display panel. The Simputer operates on a Linux operating system and uses Information Markup Language (IML), which is a standardized and simplified interface language developed for the Simputer. Simplicity is the key principle in designing the Simputer interface, offering a user-friendly environment and an easy learning curve even for the illiterate population.

The touch panels overlaid on the LCD screen work with a stylus as the primary and direct input; users can activate functions by pointing at the graphical icons on the screen with a plastic stylus. Icon-based interactions require no text-entry from users for most of the applications. Handwriting recognition is supported in the Simputer as an input alternative for the literates; users are able to write notes by hand on the Simputer using a stylus and send as email to specific recipients.

Undoubtedly, it is important to have Indian language interfaces for deploying the Simputer to local users. The Simputer interface supports several Indian languages not only in displaying but also typing in Indian languages. Full-featured on-screen Indian language keyboards are available for Hindi and Kannada in the current design of Amida, and it is planned to apply more Indian and foreign languages [Amida Simputer, 2004]. PicoPeta has conducted various test projects in different regions, which drew on the simplicity and the diversity of Indian language UI of the Simputer, for E-governance, education, micro-finance and so forth [PicoPeta Simputers, 2004].

Figure 5: Encore's Simputer [Encore, 2002]

Figure 6: Amida Simputer by PicoPeta Simputers [Amida Simputers, 2004]

The multi-lingual text-to-speech (TTS) capabilities in English and several major Indian languages, such as Hindi, Kannada, Telugu and Tamil in Amida Simputer, are used as the major output channel in enabling low-attainment users to manage the Simputer applications. Additionally, consistent design of the interface across applications in Indian languages makes it easier for low-literate users to operate the Simputer. UI consistency assists end users to learn and remember the style of the Simputer effortlessly.

6.2.2. Sharing Scheme: Smart Card System

The Simputer has various applications like other general-purpose PDA and handheld devices do: image viewer, calendar, calculator, Internet browser, notepad, spreadsheet, Email, and MP3 player. An important feature to distinguish the Simputer from other PDA products is its embedded smart card reader/writer, which builds the shared model of the Simputer. With the usage of smart card, a large group of users are able to share and personalize one device that is possibly owned communally. Users should own their smart card that stores their individual profile and information offline. After inserting the smart card into the Simputer, it can read the profile from the card to identify the user and then access or update the information like micro-finance transactions, for example, during the current usage of Simputer.

Smart cards not only enhance the security of managing personal information when sharing the Simputer within a village, but also simplify the routine user-identification process, in other words, the procedure of typing user names and passwords for login. Since rural users are not likely to remember long and unfamiliar combinations of numbers and letters, the function of smart card identification reduces users' memory load in memorizing specific data for user identification when using the Simputer.

6.2.3. Low Cost Device

Besides simplicity, the other core consideration of the Simputer design was low cost. It was meant to be a low price device and be able to perform with limited electricity availability to address the needs of a whole community [Fonseca and Pal, 2004]. The original envision of the price for the Simputer was about $100 (Rs. 5000). With such price most of the communities or households could afford buying a Simputer [Manohar, 1998]. Nevertheless, the current prices for various models of the Simputer range from $240 - $440 (Rs. 12,000-22,000) [Ganapati, 2003] which are not competitive enough when comparing with desktop PCs or other handheld devices. As discussed in previous chapters, low cost is one of the significant features of the device to be deployed in the rural community. Thus Simputer is not yet widely available for the common man.

The palm-sized Simputer is a more complex and powerful handheld device than a normal PDA; it consists of a number of different applications although not many of them are required for its initially planned users. Rural users would use one or only a few applications for specific purposes. In other words, the Simputer probably provides far more services than the actual needs of the rural users. Nevertheless, it attracts more urban, rich mobile-professionals for its various functionalities which become common features for them on a handheld device [Fonseca and Pal, 2004]. Simputer did not receive an overwhelming acceptance from the target user group. Despite that this landmark project did not gain commercial success, it offers a valuable lesson for designing IT solutions for the rural world which are still under development.

6.3 Tamil Market: A Spoken Dialog System

ICSI (International Computer Science Institute) researchers and the TIER project (Technology and Infrastructure for Emerging Regions) in the University of California at Berkeley have been working on developing speech recognition technologies for emerging regions. As part of the efforts, they have created a speech recognizer, Tamil Market, for the Tamil language which is spoken by over 60 million people in India [OCLC, 2007]. Tamil Market is a simple spoken dialog system operated by voice over the phone, providing farmers and other rural villagers with information on local weather, market prices for 10 agricultural crops and rainwater collection techniques [Plauché and Prabaker, 2006]. The system was developed to investigate how the speech recognition technology can be utilized, and how it can be integrated into useful applications for developing areas.

6.3.1. Speech UI

It is very challenging to design a speech interface that could support different dialects and accents. The initial design of Tamil Market was merely a speech interface running over a phone line. Tamil, like most languages, refers to several dialects which vary by geographical location, social and educational status, and register (spoken and written). Therefore, the system was designed to be powered by a limited speech recognition resource. It has a vocabulary set which were only thirty Tamil words, such as crop names, digits and some command words – application independent command vocabularies. The system is primarily driven by the words “Yes” and “No” in Tamil, since their functions and meanings would not be affected under different situations and dialects. Besides, such binary distinction of yes and no could enable easily the usability and reduce the complexity of speech recognition, given the huge linguistic variation in Tamil language.

To enable users to learn the interaction quickly with little or no training, explicit prompts are used in the spoken dialogs. The dialog starts by asking a user what information they would like to obtain with a yes-no question. The user just needs to say “yes” or “no” to the proper questions. When the user would like to know the prices of a particular crop, he/she is prompted by the name of the crop. It requires the user to say the zip code when accessing the local weather forecast, although it was suggested in user assessments to use the district names instead. Here is one example of a dialog with Tamil Market, translated from Tamil to English [Plauché et al., 2006]:

TM: *Welcome to Tamil Market. I can tell you about crop prices, weather, and rainwater collection.*
Would you like to hear about crop prices?
Please say "Yes" or "No."

User: *Yes.*

TM: *Please say the name of the crop you would like today's price for.*

User: *Lise. (Rice)*

TM: *I'm sorry. I didn't understand what you said.*
I will tell you the price of all crops in rupees per kilo. Wheat, 9; Rice, 10; Corn, 8…

6.3.2. Revised to Multi-modal Input

Tamil Market's spoken dialog system was designed to be set up in village knowledge centers in rural communities of Tamil Nadu, India; it was suggested to have a kiosk version that could combine additional interaction techniques with speech. Additional output channels of displaying graphics or local text as well as input interactions with a keyboard and touch interface could provide further and multiple clues for inexperienced and mainly illiterate users to perform better with the system.

The research team constructed a kiosk prototype of flex button system by using locally available recycled materials: a PC screen to display graphics and texts and a keyboard. The prototype was made to support speech input as well as touch. As shown in Figure 7, each flex button is placed next to a graphical picture or command word in Tamil displayed on the screen. The same structure of dialogs is still used in the multi-modal kiosk version as the main interactive approach, while the visual displays with flex buttons provide meaningful information when the users' input could not be recognized. A detailed user study and analysis of the kiosk version of Tamil Market is however not yet available for further discussion.

Figure 7: Tamil Market kiosk prototype [Plauché et al., 2006]

Unlike previous projects introduced in this chapter, Tamil Market is not limited to be applied on small-display devices. The speech interface was designed to operate over a phone line, and it was further adapted to a kiosk version which allowed additional input and output channels. As learned from the user study, it had a low user error rate with high recovery rate from system errors. Tamil Market revealed the potential of a speech-based interface in local language in encouraging rural users to IT access as well as in enhancing the accuracy of the information and the time of interaction [Plauché and Prabaker, 2006]. Tamil Market presented an inexpensive spoken dialog system that could be deployed with a simple and limited-resource recognizer for limited tasks in a single rural village. The flexible interface could be developed and modified further to result in more deployable solutions to adapt to new languages and applications in the rural regions.

6.4 OLPC XO: Hundred Dollar Laptop

Professor Nicholas Negroponte, from the MIT Media Lab, announced in 2005 their new initiative of developing a low-cost laptop at the price of $100 explicitly for the children around the world, especially for those in rural villages of developing countries. To construct and oversee the development of the "$100 laptop" project, a non-profit organization, OLPC (One Laptop per Child), was founded by Nicholas Negroponte and MIT Media Lab members with a number of sponsor organizations. Their goal and mission is to provide children with opportunities to explore, experiment and access knowledge [OLPC, 2007]. The current model of an inexpensive laptop developed by OLPC is called XO (Figure 8), and it is planned to be in mass production and in the market in 2007-2008.

Figure 8: Photo of the green model of OLPC XO laptop [OLPC.com, 2007]

6.4.1. Sugar: A Special Icon-Driven GUI

Even though XO is a laptop, its 7.5 inch monitor is actually smaller than a conventional laptop's to enhance its mobility in developing regions. Since XO is a learning tool intended for children of varying ages and nationalities who have little or no computer experiences, OLPC has put special emphasizes on simplicity, discoverability and usability as their key design principles [OPLC wiki, 2007]. A special UI, Sugar, has been carefully created to be simple and intuitive as the core of the XO interface for children to explore and express themselves.

The Sugar interface on XO is an entirely graphical, icon-driven and colorful user interface. More differently, there is no concept of "application" in the Sugar UI but only "activity", since the latter is more meaningful and close to children's way of understanding. XO contains only a few activities that aim at promoting learning and collaboration abilities for the target audience and reduces unnecessary applications.

The icons on Sugar UI representing different activities, buddies, places and objects are simple graphics to be understood by children easily. Icons of activities are placed on the lower border; different viewing modes are on the upper frame. Activities and toolbars are launched by clicking the appropriate icon on the black frame (like in Figures 9 and 10). However, children in the third-world who have never had access to technology might not be able to recognize at once the meaning of the Web application icon until they try it; the painting icon could be confusing too if they are not familiar with the painting tools as shown in the icon. Children would need to try or be instructed about the different dots in the upper frame which are meant for different views. Since these icons are distinguishable and used uniquely, users would be able to learn the meanings and their functions after familiarizing themselves with the system.

Color, which is meant for personal identification in Sugar, is heavily used compared to previous projects. The icons of buddies and objects on the right and left frame of the UI are identified by different colors for different users. Such color-identification system would work well when there are not too many icons with various colors listed. When there are many buddies with distinct colors, it would become a burden for users to memorize and recognize all. Nevertheless, a reminding short text for names when the indicator is moving over a buddy icon helps.

6.4.2. Four Different Views on the Sugar UI

The Sugar UI is very different from the normal desktop environment of the traditional GUI as it hosts 4 discrete views: Home, Groups, Neighborhood and Activity. There is no “desktop” or “workplace” on Sugar, only a task-manager-like Home view that indicates directly to users what activities are currently open on the system.

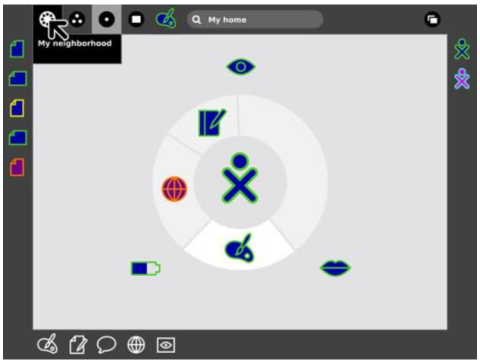

Figure 9: Home view [OLPC, 2007].

Figure 9 illustrates the Home view of the Sugar UI on XO. It contains a stick-figure icon in the center that represents the user and his laptop surrounded by a white ring displaying icons of concurrently running activities (applications) – at the moment 3 activities are open. Users can switch between running activities back and forth from the ring. The size of ring division that an icon occupies tells the memory usage of that activity. When the ring is full, it means that there is no free space or memory left to launch a new activity [OPLC wiki, 2007]. The Home view is presented as a simple pie menu that clearly illustrates the status of the system to be understood effortlessly by users.

The Group and the Neighborhood views are intended to show the user graphically in different scales what activities are being shared between users and what the status of other people is on the same network. Figure 10 is an instance of the Neighborhood view which shows all users and the ongoing activities. Three activities are shared by large groups of users while few people work alone. Each distinct color represents an individual user. To share a currently running activity, a user can send invitations to others to join and cooperate. A pop-up menu shows up for accepting or rejecting the invitation. With these two views, the Sugar UI provides a collaborative environment and introduces the conception of community for children.

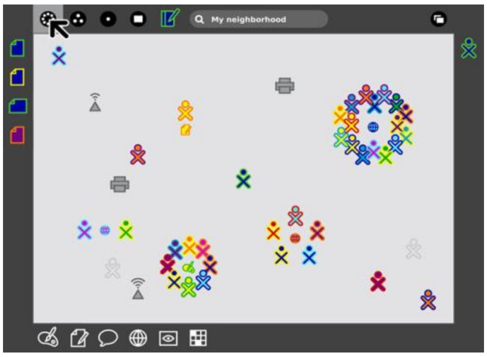

Figure 10: Neighborhood view [OLPC, 2007].

To maximize the usage of the limited available screen space, there is no static menu list on the UI across all views. When the user starts an activity, it takes the whole screen and uses the full-screen mode. Moving the pointer around the screen edge or corners brings up the black border of the Sugar UI which contains all the menus, icons and UI elements consistently. When the cursor moves away from the edge area, the black frame disappears that allows the current ongoing view or activity to make use of the entire screen for viewing or editing. This feature and idea, however, would not be intuitive to children to learn at once. Besides instructing users about this feature, it is important to make the interaction natural but not annoying. Thus one consideration of this function is to allow unintentional quick movements over the edge without actual reaction from the UI, as users would not be able to control precisely the timing and action of the cursor.

6.4.3. Interacting with the Sugar UI

The keyboard and the touchpad underneath serve as the primary input devices for the Sugar UI. The keyboard is unique for having around 70 keys; its layout looks mostly normal, but with some special keys, indicated with simple icons, which are designed according to OLPC XO functionalities. Users are able to type, edit, control the Sugar UI with the basic embedded hardware (microphone and speaker) and switch to different modes of view by using the keyboard. Given that English is not the first language of the majority of the developing nations, it is planned to have localized keyboards, such as Arabic, Thai, Nigerian, Spanish and Portuguese [OLPC, 2007].

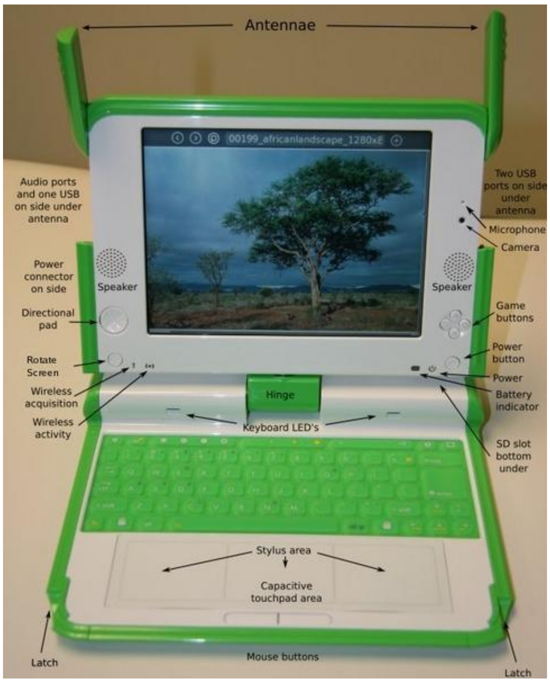

Figure 11: OLPC XO laptop with labels [OLPC wiki, 2007].

The touchpad is dual mode that supports both finger (capacitive mode) and stylus (resistive mode) stimuli. As shown in Figure 11, the whole touchpad area responses to a stylus, while only the central part of it accepts finger movements. No special stylus is required but any blunt stick-like tool works on the touchpad. Using a finger on the touchpad for pointing on the Sugar UI plays the role of a mouse, because external mice may be limited or unavailable for school children in target regions. One of important design considerations on the Sugar UI is to avoid extremely precise movements for interaction.

Microphones and speakers are embedded in OLPC laptop. It is able to integrate audio functionalities into activities such as voice recording or voice communication. They are used as supplementary means of interaction for certain designed activities. Text-to-speech (TTS) synthesis will be supported in the XO, thus it raises as well the complexity in localizing into various languages and dialects.

The XO laptop from OLPC introduces the possibility and the role that information technology can take in education for developing areas. Its target audience has been specified as the children mainly from the rural regions. By leveraging the ICT capabilities, the XO laptop could become a learning tool for kids who lack proper resources for studying. The functionalities of XO have more educational purposes than those of previous projects discussed in this chapter. Even though the Sugar UI is icon-oriented, as intuitive as possible with only a limited amount of text, localizing XO in all aspects to fit into each developing region is still essential. The existing beta systems are still in English, and the progress of localization is still underway. A number of usability tests should be held in different countries to evaluate the usability and adaptability of the Sugar UI along with users' acceptance of the system since XO has been approaching to the last stage of development. However, there is no feedback yet from the target end users in the developing countries to evaluate the system further from their points of view.

7. DISCUSSION: SUMMARY OF UI DESIGN SUGGESTIONS FOR THE RURAL WORLD

After reviewing previous research projects for the developing world, a summary of design suggestions is drawn here based on the comparison of the projects with earlier chapters which discussed environmental challenges and limitations to user requirements and how mobile devices suit better to the rural environment than conventional PCs. This chapter consists of three major parts, as they are the core dimensions of an interface: user control, information input and displaying output. Since this research applied a non-experimental approach by literature survey and analysis, the summary provides an initial user-centered study for the user interface design before eventual experimental fieldwork takes place.

7.1 User Control

Given that the target is to design mobile devices for illiterate novice users who use them infrequently, the system should be supportive, and assisting users to make decisions without fear. The UI needs to provide clear command options instead of abstract descriptions to be controlled easily by rural users [Parikh and Lazowska, 2006]. Here are some key considerations in terms of user control to contribute to the UI design.

Simple start. The opening screen of the device should be simple and clear for novice and illiterate users to start from. One solution could be presenting all available applications of the device at once on the UI for users to select from. For instance, OLPC XO laptop lists all available activities on the lower border of the black frame, and meanwhile shows the tool bar as well on the upper screen. The speech interface of Tamil Market also starts the dialogue by telling users what information the system can provide. Showing the services at the beginning helps users anticipate what they can do with the device.

Dedicated functionality. It is less complicated for users to have only few specific applications or functions on one device. It could help reduce users’ anxiety and also make a simple start in the UI design. CAM, for instance, is currently applied to micro-finance, some agricultural and economic related activities; therefore, users utilize smart phones specifically for submitting related data. CAM application can be initiated easily by capturing the starting visual code with the camera from the main view of a Series 60 mobile phone.

Visible status. Keeping the current status visible to users with visual display encourages them to understand the interaction. XO laptop implements a pie menu to show children what applications (or activities) the system is working on. Besides, users should be able to return to the previous step or the starting stage easily by tapping on the consistently designed icon or command option at any time during the interaction.

Consistent design. The common command options should be distinguishable non-textually and consistently displayed on the UI. Consistent design of the commands as well as interactions across functionalities shortens users' learning curve; it helps inexperienced users being able to learn and control the device in a shorter time, as one of the Simputer's main design principles.

Voice feedback. Voice feedback in local languages provides valuable support for both illiterate and literate users [Parikh et al., 2006]. Although text is not the most essential element on the UI for the rural target users, it is still encouraging for end users to include the localized text. It is beneficial to them that each option is read by a speech synthesis system while the option is highlighted on the UI. Therefore users can recognize which option the audio is referring to, and they are encouraged to learn the text via the UI, especially for illiterate and semi-literate people.

Table 1 shows how the four projects apply their UI design for the above five suggested aspects in user control.

User Control	CAM	Simputer	Tamil Market	OLPC XO
Simple Start	Initiated by camera	Touch screen	System-initiated dialogue	All options available
Dedicated Functionality	Specific functionalities	Various applications	3 main functionalities	Few educational applications
Visible Status	By voice feedback		Lead by speech dialogue	Pie menu in home screen
Consistent Design	Prompts in texts with audio feedback	Yes, across applications	Explicit questions	Same icons and locations
Voice Feedback	In local language	TTS in major Indian languages	Speech UI in Tamil	TTS will be supported

Table 1: Design considerations of user control in 4 example projects.

7.2 Information Input from Users

Users need to input the required information to the devices in order to initiate the interactions and to receive services. Instructing rural users to enter easily and to correct their input on small display devices is one of the main goals in the UI design. Some suggestions about users entering information are collected in this section.

Explicit speech instructions. While text input in local languages is not realistic to illiterates or semi-literates, speech interfaces are proper alternative input means for the target users because of the naturalness in their interaction styles. Not only are explicit questions required in speech interfaces, but also the list of options to multiple choice questions should be kept short. The system can read the short list of options to the user and allow him or her to choose the desired one by speech input.

Supportive touch input. Since speech recognition could be very challenging due to various dialects in different rural villages or the numerous disturbances in local environments, touch screens should be utilized as another direct input technology besides speech. The Tamil Market spoken-dialogue system tries to combine both speech and touch interfaces by being operated by limited voice commands, and meanwhile having flex buttons as a touch interface which should improve the accuracy of the interaction with users.

Distinct commands. It could be helpful for users to have some simple command options, such as “Yes/No”, “Back” or “Exit”, being displayed consistently in distinguishable and meaningful colors or shapes on touch screens. The speech interface can instruct users to enter their selection by touch input to eliminate the possible speech recognition errors and reduce the anxiety and frustration from users.

Sequential interactions. Form- or wizard-based interactions are considered to be an appropriate design approach for inexperienced users, as discussed earlier in Chapter 4. Especially when performing the task on a limited display device, guiding users through the task by step-by-step prompts with terms that are familiar and relevant to their everyday language use enhances their understanding of the interaction. Paper forms are commonly used in the rural societies in recording activities like financial transactions and healthcare checks. Therefore, adopting and combining the similar paper forms into the UI design, such as CAM, could be accepted and learned by users in a short time. Moreover, when semi-literate users are more used to the system, they would learn the way the forms are structured and interact with them within a shorter time.

Automated identity. An identification system like the Smart Card scheme in Simputer could simplify the process of entering personal information for rural users. The system would be able to automatically retrieve the required personal data from the card to fill in some fields in the form without questioning the user. Automating the input for the predefined and fixed information assists reducing the complexity of the required interactions with end users.

Media support. Media enhancements, like microphones, recorders or cameras, also facilitate the interaction. For speech-based-interfaces, microphones and recorders are helpful for free text input if the information can not be structured into simple multiple-choice questions. Camera was not widely used in rural ICT projects, except in the CAM. Using cameras in the interactions mostly requires more precise movements or actions which would be difficult for rural users to control. Therefore, supportive designs should be provided for instance to fix the focus or avoid hand-shaking to increase users' confidence of controlling when taking the camera into interaction [Parikh et al., 2006].

Numeric input format. Numeric input could be considered as one alternative in addition to the above suggestions. Rural users may have a better literacy in numbers than texts; however, designers should not take it as granted. Depending on the attributes of the provided services, numeric entries may be applicable for finance related services. Inputs of long combination of numbers should be avoided as it increases the difficulties of accurate input.

Table 2 presents the common and different UI designs regarding information input in the four different projects.

Information Input	CAM	Simputer	Tamil Market	OLPC XO
Explicit Speech Instructions	Speech support from visual codes		Yes	
Supportive touch Input	Input from keypad	Touch UI	Use of flex buttons	Touch pad
Distinct Commands	Visual codes on paper		Keywords in speech	Icon-driven commands
Sequential Interactions	Prompts in sequence		Explicit questions in sequence	
Automated Identity	Numeric data	Smart-card system		Color and icon for identification
Media Support	Capture by camera and voice recorder	Microphone and speaker	Microphone and speaker	Microphone and speaker
Numeric Input Format	Yes, from the phone keypad			

Table 2: Design considerations of information input in 4 example applications.

7.3 Displaying Output to Users

Presenting commands to users to start interactions and displaying the results after users entering the required information are all related to the design of output. The format of displaying information to rural users plays a vital role in the UI as it determines if users can understand the system and furthermore receive the provided services. Some design considerations about output are collected here.

Representational icons. Icons or graphics are often selected as the first choices to substitute for texts on a conventional user interface. However, it is not a simple solution to apply to overcome all the obstacles of illiterates. Realistic and meaningful icons need to be employed to communicate the correct concepts. A realistic and meaningful icon should be distinct, concrete and memorable that derives from the local culture, users' life experiences and their common understanding of the concept in question. For example, the icons for incorrect actions and undo were not well recognized by users who had low user interface experience in Heukelman's research [Heukelman, 2006]. The icons for this kind of ideas were not recognized well since the designed action was not closely linked to end users' life experience.

Proper size of icon. Especially on small display devices, icons as well as images showed on touch screens for selection should not be too small to recognize. It is suggested from the above projects to avoid precise interaction with rural users.

Accurate input with stylus or fingers is not a common idea for the rural population to perform.

Text and audio support. After a great effort of developing proper graphics for the target users, it is still possible that the designed icons or selected images can not convey the ideas and meanings effectively, such as abstract concepts. Visual texts for semi-literates or corresponding audio speech should be provided as well to support the insufficiency of graphical icons. Simputer and the OLPC XO laptop combined both in their systems – they are designed to have graphical interfaces with text-to speech synthesis to instruct users throughout the interaction.

Localized speech. Having audio output in local languages in the interface is one of the essential output elements when designing for rural users. Parikh et al. [2006] emphasized that local language audio feedback offered significant support for the local users. Less training is required when people are informed about the presented results and instructed how to operate the device by the audio feedback or text-to-speech synthesis.

Localized texts. Displaying texts in local languages is important on the UI although not all users can fully read it. Highlighting the texts or flashing the button which is being read with speech output motives partial literate users to learn and increase their literacy. These users would eventually be able to perform the task on the device more efficiently. Besides, localized texts on the UI give a sense of familiarity to increase the acceptance by the target users.

Color. In addition to the above options, the interface should also make use of other non-textual elements like colors to aid users' comprehension of the interface and overcome the lack of literacy. Although colors are cultural-dependent elements, they are suggestive for users in memorizing the pattern of the interaction especially using same colors in the same manner consistently throughout the interface. However, designers need to balance the usage of colors so that it does not turn into another burden to users to memorize. Another consideration about using colors in the UI that needs to be taken into account is the possibility and severity of color-blindness, as it has higher proportions in isolated communities. Thus designers should not use colors as the only way to distinguish between objects, but rather combining colors with other visual displayed items or speech output in the interface.

Auditory sounds. Another supplementary element that can be applied on the UI is the audio sounds. Non-linguistic auditory sounds could suggest users the status of the ongoing interaction, such as success or error in the interaction or whether the system is still in progress, besides visual display on the screen, to increase the usability of the handheld device.

At last, Table 3 lists how the four example applications are designed in displaying output to the end users in relation to the above discussed suggestions.

Displaying Output	CAM	Simputer	Tamil Market	OLPC XO
Representational Icons	Visual codes on paper	Icon-based UI	Graphical pictures	Icon-based UI (Sugar)
Proper Size of Icon	Large visual codes on paper		Large graphical pictures with flexi buttons	
Text and Audio Support	Text shown as image with audio	TTS support	Speech UI	TTS support with limited amount of text
Localized Speech	Yes	Yes- TTS	Yes	Yes- TTS
Localized Text	Shown as image	Support several Indian languages	Commands in Tamil on touch UI	To be localized
Color				Use a lot in identification
Auditory Sounds	Yes	Yes		

Table 3: Design considerations of displaying output in 4 example applications.

8. CONCLUSIONS

The development of ICT devices that aims at bridging the growing gap of digital divide in the rural developing world has received a great amount of attention in HCI studies. Information technology could have the potential to help people in the rural communities improve the quality of their lives. Researchers and developers have to understand the users' needs, their special contexts and the requirements before designing and prototyping as specified in a UCD design process. Nevertheless, there are obstacles in involving rural inexperienced users during the initial design process. This thesis thus has applied the approach of literature review to focus and discuss the constraints as well as UI requirements from different angles.

The target users in rural areas mostly have a low level of literacy and have little or no experience with computer systems. These are the biggest challenges for them to interact with a normal text-based user interface. Due to the environmental limitations in the rural areas, small display devices have been considered as a more viable solution to employ than conventional PCs because of their mobility, low power, low cost and the adaptability for natural interaction. Before drawing some UI design suggestions of small display devices for rural users, four ICT projects that have targeted at the rural population but with different purposes and design output were reviewed in this paper about their UI design: CAM application for microfinance activities, Simputer for the rural India, Tamil Market spoken system and OLPC XO laptop project.

Based on the common considerations of the interface design in the above projects and the comparisons with the special requirements of the users, I have summarized the design suggestions for this user group. It has shown that it is possible to develop an interface on a small-display or handheld device that low attainment users would be able to operate and perform required tasks successfully. The summary was organized into three categories: user control, information input from users and displaying output to users.

Carefully selected graphical icons or images along with localized short texts are able to communicate the information of the content and system status, while the speech output in local languages can help instruct inexperienced users throughout the whole interaction. To reduce the complexity of entering text input, designers can simplify the options and structure them into a form-based interaction by speech or touch input, or turn to numeric data entry if applicable. The implementation of touch screen or buttons as an alternative input requires more accurate interaction. Supplementary non-textual UI elements like colors, shapes, and non-linguistic audio should be utilized to support users to overcome the fear of operating the device. The ultimate goal is that rural users have easy access to the required information by operating ICT devices with considerately designed interfaces.

The study should be followed by designing, prototyping and conducting an experimental usability field research to gather users' feedback for a more in-depth evaluation. One of the possible future directions for further study in this domain might be taking the advantage of different new interaction techniques of seamless computing to apply on portable devices to make the interaction easier and more natural. Since the scope of this thesis only includes the first stage in the user-centered design process, I hope the collected design suggestions provide UI designers some directions to continue. I believe that the needs from the rural developing regions are becoming larger and larger, thus providing more diverse ICT solutions would be required to fit their needs.

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