Designing an Architecture for Delivering Mobile Information Services to the Rural Developing World

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Abstract

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Populations in the rural developing world have just as many, if not more, information needs as people living in more affluent areas. But their constraints — intermittent power, intermittent connectivity, limited education, literacy and capital — make first-world approaches to accessing information systems inapplicable. Mobile phones are on the cusp of spurring an information revolution in such regions. Long battery life, wireless connectivity, solid-state memory, low price and immediate utility make this device better suited to rural conditions than a PC. However, current software on mobile phones makes them hard to use and to program. In this dissertation, I present the design, implementation and evaluation of CAM — a mobile application framework designed to address the information needs of the rural developing world. Beginning with a two-month participatory design study, including users with varying levels of education, I propose some general guidelines for user interface and system design in this context. Motivated by these guidelines, I present CAM. CAM applications are accessed by capturing barcodes on paper forms using the mobile phone camera, or entering numeric strings with the keypad. Supporting one-step navigation, direct linkage to paper practices and offline multi-media interaction, CAM is uniquely adapted to rural device, user and infrastructure constraints. To demonstrate

the usability of this framework, I implement and evaluate several distinct CAM-based applications (one of which has already been commercially deployed). I also provide preliminary motivation for fourteen other applications that could be implemented with the same, or similar, approach.

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GLOSSARY

AGRICULTURAL EXTENSION: Agricultural extension refers to the mechanism by which knowledge and advice is delivered to farmers as an input to their farming practice. This service can be performed by a government agency, a university or NGO.

BIRD-FRIENDLY: A type of coffee certification ensuring that native shade trees are retained on coffee parcels, preventing sun damage and soil erosion and providing shelter to migratory birds.

CLUSTER: An administrative grouping of between 20-30 SHGs.

FAIR TRADE: A certification that seeks to improve the living condition of marginalized producers by assuring them a living wage, creating consumer awareness, and empowering producers to play a larger role in the marketing and sale of their products.

FEDERATION: An administrative grouping of between 10-12 clusters, or between 100-200 SHGs. Federations are often involved in agency relationships with insurance and financial service providers. Some federations may themselves take up *financial intermediation*, which means directly offering financial services to its groups and members.

FIELD STAFF: Field staff serve as the link between the rural populace and companies, banks, NGOs and government agencies working in these areas. By employing young, sometimes high-school educated people to travel from village to village, they can build an affordable and effective service delivery channel in rural areas. Field staff are benefited by knowledge of the local people and culture, and are accustomed to rural travel and living conditions.

GRAMEEN BANK: A pioneering microfinance institution in Bangladesh. The rigorous Grameen methodology, consisting of 5-member groups and usually based on a credit-first approach, has now spread to Africa, Latin America and other countries in South Asia.

GROUP: Groups serve as local financial intermediaries in microfinance by assessing members, conducting transactions, holding cash, and sometimes even offering their own financial products. Most importantly, groups provide a *mutual guarantee* — if one of them defaults on a loan, all of them suffer. This provides a very strong social incentive to repay.

ICT4D: In some areas of the developing world, an optimistic vision has emerged that if people adopt information technologies in a sustainable way, it can help them achieve many development objectives. Referred to as *ICT for Development*, or ICT4D, this carries a broad mandate providing billions of people improved access to important services such as health care, education, financial and governmental services.

MIS: *Management Information System*, a general name for business information systems used by management for improved decision making and monitoring.

MFI: *Microfinance Institution*, a general term for the many kinds of organizations that provide microfinance services across the world. Thus includes NGOs (both regional and international), private companies, non-banking financial institutions and registered banks.

MICROFINANCE: The provision of financial services to poor, underserved populations.

MMS: *Multimedia Message Service*, a protocol used to send and receive messages with attached multimedia (audio, video or images) between mobile devices, or between a mobile device and a gateway.

NGO: *Non-Governmental Organization*, usually a non-profit, social service organization dedicated to the common good. These can either be internationally, regionally, nationally or locally focused. In some countries, NGOs are the most effective and consistent service provider in rural areas.

ORGANIC AGRICULTURE: Organic agriculture is an attempt to sustain and enhance the health of ecosystems by reducing the use of chemical fertilizers and pesticides. Actual requirements for growing organic produce vary from country to country. Organic certification agencies perform farm inspections to assure quality and prevent fraud.

PAPER USER INTERFACE: Pioneered by Xerox's XAX system, a *paper user interface* (PUI) is a user interface to a computer that utilizes the size, flexibility, familiarity and accessibility of ordinary paper.

PARTICIPATORY DESIGN: A method of design pioneered in Scandinavia in the 1960s that emphasizes the role of users in the system design process.

SHGS: *Self-Help Groups* are the form of microfinance group prevalent in India. In contrast to many other microfinance groups, SHG's funds are both *community-owned* and *community-managed*. This is similar to a financial cooperative, at a much smaller scale (a SHG typically consists of between 10-20 members).

SHPI: SHGs are supported by *Self-Help Group Promoting Institutions* (SHPIs). This is most often a NGO. The SHPI helps form and support SHGs, including providing training and capacity building, linkages to other SHGs and to the formal banking sector.

SMS: *Short Message Service*, a protocol used to send and receive short text messages between mobile devices, or between a mobile device and a gateway.

SYMBIAN: An operating system for mobile phones, used by Nokia, Sony Ericsson and a few other smaller manufacturers.

SMARTPHONE: A mobile phone with advanced features, such as bluetooth and the ability to program, install and/or run third-party applications.

VILLAGE BANKING: The form of microfinance pioneered by John Hatch and FINCA in Latin America in the 1960s. Village banks share certain similarities with SHGs, although there are some operational differences. VSLAs (Village Savings and Loan Associations) in Africa are also similar to SHGs, but again, have some differences in terminology and in the emphasis between internal and external loan funds.

TAMIL: The native language in Tamil Nadu, India, where we conducted the design, evaluation and deployment of the SHG application.

DEDICATION

For Ravin, his children, and other citizens of the future.

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Chapter 1

INTRODUCTION

If today's leading economists and ecologists can agree on one thing, it is that the foremost challenge facing the world today is the struggle to raise international standards of living while reducing humanity's environmental footprint [132, 172]. It is also recognized that the response to this challenge must be global — including all societies, cultures and vocations of human beings. Nowhere is this more clearly articulated then in the Millennium Development Goals (MDGs), a mission statement for the World endorsed by the 192 member states of the United Nations [92].

As the world moves towards a global economy, access to information and communications will play a key role in creating efficient markets and sustainable economic relationships. Dealing with expanded realms of opportunity, the most successful individuals and enterprises will be those that find ways to best leverage information to make decisions. As the economy interlinks and networks expand, it will be those entities that most efficiently acquire, manage and use information that succeed where others fail.

This is as true for businesses, as it is for initiatives in conservation, poverty reduction and global health. To succeed in any of these efforts requires managing, understanding and reacting to globally distributed sources of information. In the past half-century, advances in computing and other *information and communication technologies*, or ICTs, have revolutionized the way humans create and share information. This progress in our ability to gather, store, analyze and communicate data has spurred an empirical revolution in fields as diverse and important as medicine, astronomy, biochemistry, economics and ecology.

Understanding and responding to the global challenge of development must draw upon the same empirical and scientific methods. Computing technologies will be essential in understanding the problems that face us, and in planning, executing and evaluating potential solutions, both at global and local scales. However, this process cannot be limited to the technical, social and economic elite. Considering existing disparities, it is essential to find a sustainable way for the poorest and most undeveloped communities to achieve a healthy standard of living. For this, they must be able to contribute to, and benefit from, the global pool of knowledge.

The exclusion of certain populations from the computing revolution has been referred to as the *digital divide*. In some areas of the developing world, an optimistic vision has emerged that if countries adopt information technologies in a sustainable way, it can help them achieve many development objectives. Referred to as *ICT for Development*, or ICT4D, this idea carries a broad mandate — providing billions of people improved access to important services such as health care, education, financial and governmental services.

Providing these services in rural areas of the developing world is a difficult task. Current information practices are overwhelmingly manual — paper and memory-based. This, along with local deficits in education, restricts the amount and quality of data that can be collected, and the uses to which it can be applied. This, in turn, makes it difficult to provide a consistent and efficient level of service in rural areas, for either the public, private or non-profit sectors.

The introduction of computing has the potential to alleviate some of these challenges. However, most villages in the developing world do not have the economy or infrastructure required to support a computer. Lacking this and other ICT infrastructure, rural people often must travel to larger towns or cities to access information services. Given the difficulties of transportation, this requires significant time and motivation. Once there, due to barriers of language and education, they often still must rely on the help of others to access the information and services they require.

1.1 Mobile Phones

At the same time there is a revolution in the making. Just as personal computers changed the nature of communications and information access in the developed world in the 1990s, *mobile phones* are now changing their nature worldwide [122]. Communication offers immediate utility to any user, urban or rural, rich or poor. Mobile phones have also been demonstrated to improve the economic performance of small rural producers in certain developing world contexts [63].

The numeric keypad's familiarity and long history make it comfortable for billions of users. Solid state memory, extended battery life, and a compact, rugged form are all great design choices for the village environment. The growth of wireless infrastructure, and the plummeting cost of handsets, is literally putting mobile telephony in the hands of billions of people around the world.

Mobile handsets developed by several manufacturers provide an open application platform and significant computing capabilities [141]. Given the popularity of these devices with developing world populations, and the immediate utility of voice and text communications, *smartphones* are an opportunity to bootstrap computing in the developing world. They already are small, handheld computers with some constraints and additional features. Several of these features (battery operation, solid-state memory, wireless connectivity and an affordable price) make them a better suited device for the rural developing world than a conventional PC.

Still, to foster an information revolution in the rural developing world, applications must be used by minimally educated users, developed by minimally trained developers and meant to work in a variety of connectivity and power environments. Current mobile software platforms are notoriously difficult to use and develop for, and make the assumption that there will be ubiquitous connectivity.

In this dissertation, I describe the design, implementation and evaluation of a novel mobile application framework intended for this context. To validate this framework, I present the design and evaluation of applications in two representative domains: for microfinance in India — the provision of financial services to under-served communities; and for agriculture in Central America — improving the efficiency, sustainability and market access of small coffee farmers.

1.2 Contributions of the Thesis

In summary, these are the research contributions that are described in this dissertation:

- **Identification of Systemic Information Needs and Gaps in Microfinance** — Based on a contextual study covering six months of field work and visits with eight different organizations, I provide an outline of the major information needs and gaps facing rural microfinance institutions.

- **User Interface Guidelines for Rural, Developing World Users** — After a two-month participatory design study including illiterate, semi-literate and educated users, I elicit a set of user interface design guidelines for accessibility to this population.

- **CAM: A Framework for Distributed Data Collection using Mobile Phones** — I describe the design and implementation of CAM - a novel application and user interface framework for mobile phones. Motivated by the earlier guidelines, CAM provides support for paper-based interaction, multimedia input and output, and intermittent network connection.

- **Evaluation of CAM for Usability, Breadth and Real-world Impact** — I provide an evaluation of CAM — for usability, by describing the results of usability experiments for applications in microfinance and agriculture; for breadth, by listing additional, relevant applications that can be implemented using this approach; and for real-world impact, by describing the current status of field deployments managed by *ekgaon technologies*, which I founded, a private company implementing the CAM microfinance application in India.

1.3 Outline of the Dissertation

The rest of this dissertation is structured as follows: in the rest of this chapter, I describe some characteristics of the rural developing world, highlighting categories of information needs, and specific challenges for deploying computing technologies. In chapter 2, based on the findings of a six-month contextual study, I list the current information-related limitations that I observed for microfinance institutions serving rural communities. In chapter 3, I describe a participatory design study conducted in collaboration with microfinance group members and supporting staff in Tamil Nadu, India, culminating in user interface guidelines for improved accessibility to illiterate and semi-literate populations. In chapter 4, I describe the implementation of CAM, a new application and user interface framework for mobile phones. Motivated by the earlier guidelines, CAM provides support for paper-based interaction, multimedia input and output, and intermittent network connection. In chapter 5, I discuss how CAM synthesizes and extends research in three distinct areas: mobile user interfaces, paper user interfaces, and system design for rural computing applications. In chapter 6, I present a usability evaluation for the first motivating CAM application — providing accounting and data management services for microfinance groups in India. In chapter 7, I describe the design and evaluation of two more prototype CAM applications — for improving the efficiency and market access of a small agricultural cooperative located in Barillas, Guatemala. In chapter 8, I list a number of other potential CAM applications, many of them motivated by discussions with organizations interested in implementing them. In chapter 9, I conclude the dissertation by providing an outline of unaddressed elements and ideas for future work.

1.4 Rural Information Needs

People living in the rural developing world have many of the same information needs as any other human citizen. But due to a lack of local infrastructure and capacity, they often face significant obstacles in fulfilling them.

- **Government** — Rural people need to be aware of government programs and subsidies, some of which may be specifically targeted for them. However, due to distance and lack of empowerment, even the most basic government services, such as registering ownership of a plot of land, can prove difficult and costly.

- **Health** — Accessing quality health care usually means long travel and wait times and high opportunity costs for rural populations. Moreover, the difficulties of managing patient records across clinics and visits makes it impossible to maintain continuity in any patient's treatment.

- **Education** — Teacher absenteeism, inadequacy and the heavy labor demands of agriculture often curtail the educational opportunities available to rural children.

- **Livelihood** — Learning about new business opportunities and obtaining timely information from markets can help improve the livelihoods of small rural producers.

- **Microfinance** — A critical service for village households is the ability to save and access capital in times of need, for dealing with emergencies and capitalizing on business and personal opportunities.

- **Natural Resource Management** — Rural people need to understand natural ecosystems to safeguard them for their long-term use and benefit.

1.5 Rural Information Challenges

Given the recent (and anticipated) reductions in cost, appropriate introduction of computing and related ICTs could help address these needs. However, rural areas in the developing world pose a number of unique challenges for deploying technology. In this section I discuss some of these. While most of these observations were drawn from my experiences in rural India (and, to a lesser degree, Central America), they are indicative of similar conditions existing in other developing regions around the world. An appreciation of these challenges is crucial to designing suitable user interfaces, systems and applications.

1.5.1 Environmental Challenges

Intermittent Power

The power grid in the developing world is notoriously unpredictable. Both spikes and outages are common. There is *load-shedding* in both cities and rural areas (scheduled power outages to conserve energy). A battery-powered uninterruptible power supply (UPS) is a necessity for any PC in the developing world. This creates an additional expense that consumers are reluctant to bear. Even for laptops and mobile phones, a surge protector helps to protect the lifetime of the hard disk, battery and AC power supply.

Intermittent Connectivity

As opposed to the temporally intermittent nature of power, connectivity is *spatially intermittent*. Landlines are prohibitively expensive to extend to villages with a limited revenue base. Even if a village is connected, it is probably only with low-quality copper wire. The local phone exchanges may use outdated equipment that hinders digital communications. Internet connections established over these links are slow and become frequently disconnected. Cellular penetration is growing, but thus far wireless towers are concentrated near cities, large towns and major roads. It is possible that novel wireless technologies will eventually make connectivity more accessible, but differing topographies and population densities could mean that some percentage of the world's population will never be within arm's reach of a full-time connected device.

Long Travel Times

The quality of roads is often poor in rural areas, increasing driving times considerably. Public transportation, while ubiquitous in many countries, is also delay-prone. Several transfers may be required to travel from one place to another. Travel is incredibly time-consuming, often taking an order of magnitude more time than in the developed world.

Variable Population Density

One factor that varies greatly from country to country and continent to continent is population density. To note two extremes, in Bangladesh the density is over 1000 people per square kilometer, while in some parts of Central and Southern Africa it is less than 10 [119]. This greatly impacts the economics of providing information access — in countries with less density the same physical infrastructure will serve fewer people, and have a correspondingly smaller revenue base. Infrastructure technologies must be cheap and flexible enough to serve all possible conditions, or different solutions will be required for different areas.

Lack of Secure Storage

In the developed world we are accustomed to having an office, home or apartment that we can lock to secure expensive devices. In contrast, a typical one or two-room dwelling in a village can be shared by many family members. The notion of a locked door is still unheard of in many villages. Housing structures can be easily penetrated, especially in the tropics. The only security against theft is that someone will observe the action, or that the perpetrator will be identified through the village social network. These are both usually effective safeguards. However, it is virtually impossible to limit access from friends and relatives. The only protection against the environment is to store valuables in a more solid structure, like the village school, a business or government office. However, these structures may be dominated by the village oligarchy, who can restrict access, possibly excluding lower classes and/or women. The best place for valuables is a sturdy safe.

1.5.2 User Challenges

Limited Education

The low quality of schools in rural areas, and the demands of agricultural work, often force children to abandon schooling at an early age. Those that do succeed in attaining a high school or college education seek employment in the city, where salaries are considerably higher. Less educated people have difficulty with abstraction and symbolic manipulation. Many rural people, especially those in older generations, may be illiterate. The UNESCO Illiteracy Rate Estimate estimated approximately 43% of the adult Indian population to be illiterate in the year 2000 [161]. It estimated that over 54% of women in India are functionally illiterate. In some of the underdeveloped states of northern India, the illiteracy rate can be as high as 70 to 80 percent of the population.

However, predicting that computing technologies will directly be used by illiterate or semi-literate people can also be a naive assumption. Many villages and families include an educated, literate member that they rely on for performing tasks beyond their individual capacity. At the same time, it is important that the illiterate person *understand* the process, so that they can safeguard their personal interests (for example, when performing financial transactions).

Underemployment

The lack of economic opportunity in villages, combined with the inconsistent performance of farming, creates chronic underemployment in rural areas. In large families, only the eldest sons may be accommodated in the traditional business. The rest must seek their own employment opportunities. Moreover, while farming is hard work, it is usually limited to certain seasons and times of the day. The rest of the day is spent idling in the village, at the local *paan* shop.

This idle workforce has been utilized by companies, banks, *non-governmental organizations* (NGOs) and political organizations working in rural areas. By hiring young, sometimes high-school educated *field staff* to travel from village to village, they can build an affordable and effective service delivery channel in rural areas. Field staff benefit from knowledge of local people and culture, and are accustomed to rural travel and living conditions. This model is common in microfinance, microinsurance, primary health care, FMCGs (fast moving consumer goods), and other vertical markets.

Limited Disposable Income

Almost all of poor people's income goes towards their livelihood and social requirements [131, 9]. Very little money is left for leisure or exploratory purchases. Given the dramatic difference in income and expenditure levels between cities and villages, electronic devices must be shared to even be affordable for most rural populations. A new system or technology must fulfill an immediately perceived need to be relevant in this context.

1.5.3 Things to Avoid

Given our experience developing and deploying rural computing applications, I list several features that have posed particular difficulty for this domain.

Text

Text is not only a problem because of limited literacy. Hardware and software constraints make entry, storage and display of local-language text difficult. Keyboards are designed for English. Keyboard mappings for other languages are difficult to standardize or remember. Unicode character representations are Western-centric, and do not always adequately capture the intricacies of other scripts. Rendering complex scripts requires support at the operating system level. Fonts can be expensive, difficult to find, and based on non-standard encodings. It is even harder to manage the consistency and quality of translations across many unfamiliar languages. Meeting these requirements dramatically increases the technical complexity of a development project.

Abstract Navigation

Users with limited education have difficulty applying abstractions or understanding symbolic manipulation. Rural people are accustomed to the direct manipulation world of farming and manual labor. In some of the experiments I describe later in this thesis, I found that uneducated users had great difficulty understanding the conceptual model underlying windows, icons, menus and the pointer (WIMP) [109]. Even if it is possible for users to grasp these concepts, it adds significantly to the training and documentation requirements of computing systems. For some users, no amount of experience will make them truly comfortable with anything but the simplest computing systems.

Excessive Documentation

The primary medium of communication in rural villages is *word of mouth*. Any system that requires excessive documentation or formal training limits its reach to those that can access and consume that knowledge. On the other hand, a system that is easy enough so that users can learn it from one another will have a much wider reach. The best way to leverage the strength of rural social networks is by making the operation of the system conveyable by word of mouth.

Personal Devices

A personal device is a completely foreign concept for many developing world cultures and economies. Mobile phones, computers, televisions, radios and other technologies are often shared by many people from the family and community. Not only is this often the only way for communities to afford these devices, but Western notions of privacy and personal property have very different applications in rural villages.

Online Interaction

Rural areas have spatially intermittent connectivity. By requiring online usage of an application, villagers would have to travel to a connected location to access it. This can be very inconvenient, possibly taking an entire day (or longer).

Chapter 2

MICROFINANCE: A MOTIVATING APPLICATION

Microfinance is the provision of financial services to individuals and communities who have been neglected by mainstream banking. These people can be excluded for reasons such as poverty, lack of education, class prejudice, or by living in a remote location (particularly in developing countries). Over the last twenty-five years, since the pioneering work of Muhammad Yunus and the Grameen Bank in Bangladesh and John Hatch and the Village Banking movement in Latin America, microfinance has emerged as one of the most effective methods for stimulating economic development in such communities [46].

Across the world, many kinds of organizations provide microfinance services. These include non-profit organizations (both regional and international), private companies, non-banking financial institutions and registered banks. Throughout the rest of this chapter, such organizations will uniformly be referred to as *microfinance institutions*, or MFIs. The microfinance industry also includes other participants — banks and other commercial sources of capital, regulators such as state, local and national governments, independent rating agencies, and other third-party service providers.

As finance is an information and capital-driven industry, its growth will be determined by the flow of these two important commodities. In microfinance, as of yet, no established standards have emerged for managing either of these important value chains. *Management Information Systems* (MIS) for microfinance institutions are still in their infancy. Many MFIs use basic software packages developed by local providers, leading to difficulty in scaling up their systems or processes. Most still rely on manual data collection and data entry to manage their incoming data. Money transfers are often handled in slow and inefficient ways, in the best cases by "piggy-backing" on the infrastructure of formal financial institutions.

However, the global microfinance scenario is changing rapidly. Mainstream banks have started looking seriously at the microfinance market. As clients repeatedly prove their repayment performance, microfinance portfolios are becoming a reasonable investment option for those banks seeking to diversify their portfolio, expand their outreach, cater to their social conscience or meet government regulations.

Examples of mainstream banking companies working with microfinance institutions have proliferated in recent years. Citigroup Foundation has made $17 million in grants to 178 microfinance partners in 50 countries [27]. Deutsche Bank Foundation launched the $1.5 million microfinance financial development fund [30]. The Indian National Bank for Agriculture And Rural Development (NABARD), as of 2003, had provided almost $200 million worth of capital to village microfinance groups through its bank linkage program [98]. ICICI, the largest private bank in India, has completed several portfolio securitization deals with microfinance institutions, with a total value of more than $10 million [58].

It is clear that microfinance service delivery channels must become more streamlined, efficient and easy to manage, in order to serve larger numbers of clients and to connect the various stakeholders in the industry. Sensing the same trends, ICICI has been a pioneer in implementing new low-cost financial service delivery channels for rural areas, such as banking through Internet kiosks, smart-card and ATM-based systems. In this chapter, I discuss some of the emerging information challenges in microfinance, including recent attempts to address these challenges using Information and Communication Technologies (ICTs). This survey draws upon a primary literature review, field observations with eight different microfinance institutions operating across Latin America and Asia, and discussions with many other MFIs worldwide [107].

2.1 Technology Needs in Microfinance

In my time working with microfinance institutions, I have observed three common and persistent technical challenges for them in reaching their outreach and sustainability goals: 1) the exchange of information with remote clients, 2) management and processing of data at the institutional level and 3) transferring money in and out of remote rural areas. These issues were common to all the institutions I have visited, regardless of size, location, lending methodology, philosophy, etc.

In this chapter, for each of these *information needs*, I will discuss current best practices in addressing them, in particular examining the role technology has played. This includes the use of hand-held technologies for rural information collection, implementation of MIS systems at the organizational level and strategies for introducing electronic banking to remote rural areas. I conclude by presenting some plausible models for the future of rural microfinance service delivery, based on my observations and the industry's stated goals of sustainability, efficiency and maximum outreach.

2.1.1 Need 1: Collection of Information from Clients

According to Mohammad Yunus, founder of the Grameen Bank and one of the pioneers of microfinance, "the first principle of Grameen banking is that the clients should not go to the bank, it is the bank which should go to the people" [177]. Dr. Yunus understood that financial services should be provided to poor people on their terms, in a manner that was respectful of their needs, activities and livelihoods. At the Grameen Bank, this means that "12,000 staff serve 3.2 million clients in 45,000 villages spread out all over Bangladesh, every week" [46].

Can you imagine the immense technical challenges involved in this? Conducting millions of small transactions in remote rural areas with very little infrastructure, on the barest of operating margins — this is an operations puzzle that would make most corporate managers queasy. *Bringing a bank* to 45,000 rural villages every week is not a simple thing to fathom. Most of this herculean task falls upon the shoulders of *field staff*. Every day, field staff travel from village to village, documenting clients, processing applications, conducting meetings, collecting repayments, disbursing loans, resolving disputes and doing all of the customer-centric tasks upon which the entire industry relies.

Considering the problem in terms of information flows, there is a lot of data generated in each of these villages every week that needs to be collected in a timely and efficient manner. Every week, new clients must be documented, loan applications processed and transactions posted. Moreover, expanding a microfinance institution's business requires knowledge about prospective customers as well as existing ones. Tools to research and evaluate new clients are essential in growing a microfinance institution's business.

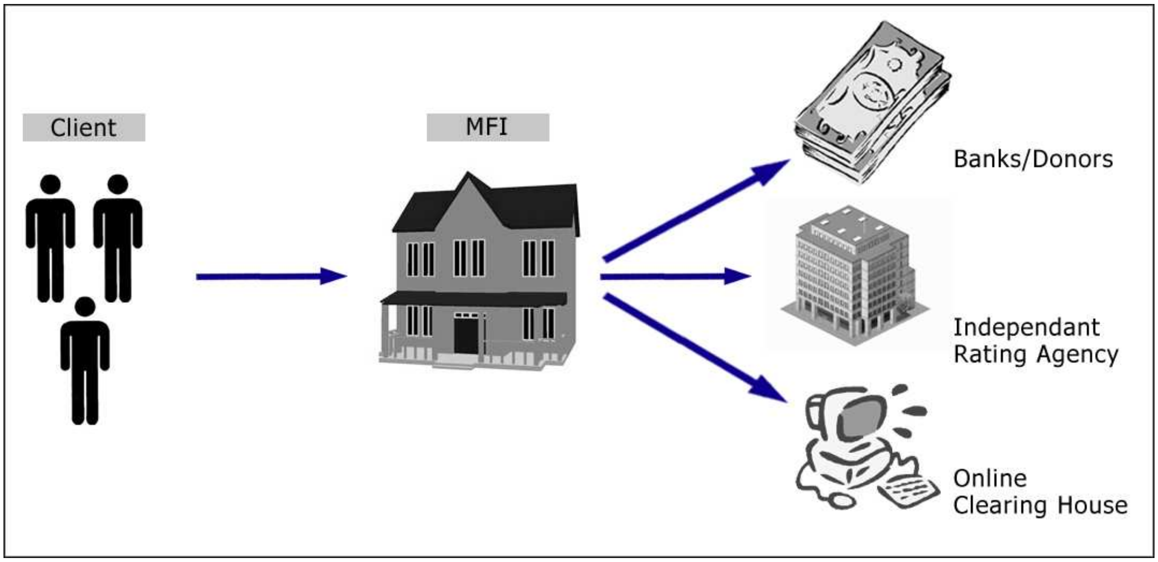

Figure 2.1: Information channels in microfinance.

Perhaps even more challenging is the literally millions of transactions that must be captured and processed every week in a timely manner, so that the institution can have an accurate view on its current loans, pinpointing delinquency and potential trouble spots. The institution must be vigilant about its loan portfolio and actively follow up on delinquent loans to earn a return on its investment.

There are several other efficiency factors that are important for the growth of a microfinance institution. Two of these are in how quickly the loan officer can conduct daily client interactions, and the number of days it takes to process a new application for credit. This determines the amount of time loan officers have to develop new clients versus deal with existing ones, and thereby the speed at which the institution can absorb more capital and expand its operations. As microfinance is a rapidly growing industry with a large untapped market, unpredictable growth is an important thing for microfinance institutions to manage, particularly in competitive markets.

To meet this challenge, several MFIs have adopted technology-based solutions to optimize data collection. This often takes the form of a hand-held device that allows loan officers to perform electronic documentation and/or evaluate credit applications in the field. Here

I give some examples of such implementations, and the subsequent results.

SKS Microfinance, a MFI working in the drought-prone regions of Andhra Pradesh in India, has been one of the fastest growing microfinance institutions in the world. Commencing operations in 1997, SKS now (as of March 2007) serves over 600,000 clients, including a 171% increase in just the last twelve months [148].

SKS has aggressively sought technology solutions that would allow them to scale more rapidly and reach more clients in a cost-effective manner. In May 2001, SKS introduced a prototype data collection system using the popular Palm Pilot PDA devices equipped with smart card readers [25]. Loan officers used the PDAs to record client transactions in the field, simultaneously recorded on the smart cards that were provided to clients as a form of data backup. During the year-long pilot program, SKS tested the new system in two client centers, making improvements in accuracy, loan officer productivity and operational efficiency. The initial pilot was supported through $125,000 in grants and soft loans received from CGAP (the World Bank's apex body on microfinance), and two US-based non-profits.

Over the year-long pilot period, SKS observed a significant improvement in the accuracy of the records collected from the field and in the efficiency of their delivery to the central database at the head office. However, the average reduction in village meeting time was only 10%. After much thought, SKS decided to discontinue the pilot, citing prohibitive hardware and software costs. SKS is still optimistic about the potential for technology as a means to improve its efficiency and expand its operations. However, they are unsure about the use of PDAs and whether or not they represent a judicious use of resources in collecting information from rural clients [147].

Compartamos, a microfinance institution working in Mexico, has also grown very fast in a short period of time and now stands as one of the largest microfinance service providers in that country. Starting as a pilot project of a large Mexican NGO in the early 1990s, Compartamos became an independent microfinance institution in 1995 [95]. As of July 2007, Compartamos reaches more than 600,000 clients across Mexico, and recently closed an initial public offering that was 22 times oversubscribed and resulted in a market valuation of more then $1.5 billion [26].

Compartamos has been supported by the international NGO Accion, which specializes in a style of microfinance called *village banking* [2]. With the support of Accion, Compartamos undertook a pilot project to use Palm Pilot hand-held devices to aid in their field operations. One of the primary motivations for Compartamos was in automating its loan application and approval process. As mentioned earlier, this is one of the key determinants of efficiency in the microfinance industry. Some organizations use detailed algorithms to decide which clients are eligible for receiving credit, and under what terms. Being able to execute those algorithms in the field, while meeting prospective clients, can dramatically reduce the turnaround time for new loans.

However, Compartamos, like SKS, has also discontinued its pilot project [61]. Once again citing high hardware and software costs, and difficulties in synchronizing the hand-held with the central MIS, management decided it had more important priorities than continuing the Palm Pilot experiment. While Compartamos and its technical advisers are still optimistic about the use of PDAs in the field, support for the project given current resource limitations has been hard to come by.

Another example of an organization experimenting with Palm Pilot technology to optimize field operations can be found in the Grameen Bank's own backyard in Bangladesh. SafeSave is a relatively small microfinance institution working in the urban slums of Dhaka, the capital city of Bangladesh. One of the novelties of SafeSave's approach is that it is a savings-led approach — the organization focuses on building clients' savings first, and only issues credit that is secured against a client's future or past savings [133].

This is notable, as offering a flexible savings product has long been one of the main challenges facing microfinance institutions worldwide. Clients have often demanded access to flexible savings products, and in fact some observers view microcredit loans as one form of "after-the-fact" savings for clients [131]. However, due to difficulties in accurately capturing savings transactions of unknown value and protecting against internal and external fraud, savings has been one of the most difficult services to regulate and to offer to rural microfinance clients. Loans are easier for MFIs to manage in that the value of the expected payments and collections for the day is known in advance before the loan officers go out for their rounds.

SafeSave, supported by a $15,000 donor grant, is in the midst of a two-year experiment using Palm Pilots in two branches, covering 3000 clients [149]. Similar to SKS, SafeSave is using relatively inexpensive PDAs (approximately $100 each) to document transactions in the field and to upload these transactions to the organization's central database. SafeSave's management has noted several benefits thus far, including better use of staff time, faster loan processing, adherence to rules and regulations and improved accuracy. However, they have also noted that "cost savings is not really the big driver — direct expenses per transaction is likely to be at least as much as paper and manual data entry." [149]

One of the few microfinance institutions that has been unequivocally positive about the use of PDAs in the field has been Basix. Basix is one of the largest MFIs in India, operating in eight states and serving over 190,000 households. Together with its technology partners, Basix has invested a lot of time and resources in IT solutions supporting its operations. This includes an MIS solution with an integrated mobile solution for the field, using high-end hand-held devices from Oregon Scientific [120]. Basix has even launched an independent consulting arm that implements this MIS at other microfinance institutions.

Basix has noted many benefits from its mobile computing solution. This includes a reduction of transaction costs, improved accountability, speedier synchronization with the central MIS (Basix's solution includes a wireless uplink feature allowing remote synchronization) and increase in customer trust by providing printed receipts in the field. The project's managers noted only small, easily overcome technical problems in the implementation. In use since September 2001, in its first 18 months of operation the system was used to process over 50,000 transactions with a cumulative value of $450,000 [120].

Basix has clearly spent a lot of money on this solution — it relies on more expensive hand-held devices with peripherals (modem, printer) not seen in other prototype deployments. Basix made a large capital investment to support the development and roll-out of this system. According to reports, Basix spent more than $500,000 in developing its information technology infrastructure, including a $350,000 assignment from the International Finance Corporation and additional support from the Small Industries Development Bank of India (SIDBI) [159]. Basix may be reaping the rewards of this investment, but it is hard to imagine many microfinance institutions having access to the capital resources needed to develop and support such a system.

As noted in a CGAP article, MFI have commonly spent between $20,000 and $80,000 on their mobile computing implementations, plus hardware costs, plus yearly maintenance costs ranging between $3,000 and $8,000. These solutions have been developed over time frames ranging from 9 months to two years [61]. It is apparent that the integration of mobile hand-held computing for data collection is an expensive and time-consuming process, and only those institutions that are willing to invest significant resources have been able to reap rewards.

2.1.2 Need 2: Management and Information Systems

Over the course of a six-month investigative project, I had the opportunity to visit eight microfinance institutions and observe their Management and Information Systems (MIS). Five of these were in India, while the other three were in Central America. They ranged in size from small to medium, between 10,000 and 50,000 clients, and practiced various forms of microfinance. Some of the observations in India were collected while working as a consultant evaluating these MIS implementations. The remaining observations were collected as an observer on field visits with the Grameen Technology Center's Microfinance Automation project [48].

Over the course of these visits, I observed many common trends. Six of the eight organizations I visited were using a system based on Microsoft's Visual Basic and Access software development packages [94]. Of the remaining two, one MFI was in the process of migrating from an existing Delphi application to a PHP / MySQL solution that was developed in-house. The last did not have a computerized MIS, managing all of its data using paper forms and ledgers.

Visual Basic is a software development platform that provides a simple programming environment to develop single-user client applications. It is closely integrated with Microsoft's Access database, a simple database meant for use on a single workstation. Due to ease of use and the abundance of training opportunities, Visual Basic and Access programmers can be found in almost any corner of the globe. As a result, applications based on this platform are the easiest to develop and maintain, and are ubiquitous in the developing world.

However, this platform has significant technical limitations. The Visual Basic programming language does not support a modular separation of the user's view of an application from its implementation, which is a fundamental driving principle in the design of modular, extensible software [74]. Moreover, the Access database is not a true relational database — it is not meant to be used in client-server applications and cannot reliably handle multiple users, excessive load or large data sets. (For example, the Windows 98 version of Access had a limit of 1GB on the size of any database.)

Many MFIs have experienced difficulty expanding or modifying software based on this architecture. Either when they sought to diversify into new financial products, adapt an existing software to their needs, or grow towards a multi-user client-server architecture — it was not found to be a flexible or scalable enough platform upon which to implement the new requirements. As a result, institutions had to spend additional time, money and resources to develop a completely new system and/or completely redesign their existing one.

Still, the Visual Basic / Access development platform is the runaway leader when it comes to microfinance MIS implementations all over the world. Why is this the case? Out of the eight organizations I visited, five of them had developed the software locally (two had developed or were developing in-house solutions and three had sourced solutions from a local software provider). Of the remaining three, two were in the process of migrating from software developed by a local provider to a specialized microfinance package developed by an international provider. Only one organization had started with a system developed by a non-local software provider that had any previous experience developing microfinance MIS systems.

In this kind of market — driven by customized, local software development — one can expect significant "re-inventing of the wheel". Microfinance institutions are constantly re-implementing custom MIS applications with little potential for scaling or future adaptation. Only those MFIs that have a full and capable in-house IT team have had any success with this approach. Frankly, this is a luxury that most microfinance institutions do not have the resources to support.

The situation is not much better for those MFIs working with an international software provider. In several cases, the international provider could not provide the training, support and customizations that the MFI required. The MFI's staff were often left no choice but to learn on their own, and adapt their processes to those supported by the software. Lack of technology capacity in many MFIs leaves them limited in their options for handling such situations.

The two international software products that I observed were both developed by relatively small software companies focused on microfinance. Again, both were based on the Visual Basic / Access platform. Higher-end microfinance software products have had difficulty in finding a market. Many of these come from a commercial banking lineage, and are often not fully compatible with some of the peculiarities of microfinance (group lending, no collateral, disconnected environments). Usually, these systems are only used in cases where there is very strong donor support for the implementation. Many have not been successful, because MFIs are far more comfortable working with local technology service providers.

So this is the situation that we are left with: a fragmented microfinance software industry where no clear standards have emerged and the vast majority of current implementations are unsuccessful, flailing or barely meeting the institution's information needs.

The demand for MIS is driven by outputs — performance reports for donors and creditors, analysis reports for directors and senior management, and operational reports for staff and clients. Currently, much of this demand is met through arduous information labor, such as picking through disparate sources to compile consolidated Excel spreadsheets. This is a grievous waste of time for already overburdened organizations. Moreover, outside information recipients, whether they be donors, creditors or third-party evaluators, can never be sure of how figures were calculated and how accurate they are. In an industry where information is such an important commodity, this is a cause for immediate and significant concern.

2.1.3 Need 3: Transferring Money In and Out of Remote Rural Areas

Another universal challenge for microfinance institutions is the collection and disbursement of money in the field. Historically, this has been conducted by most MFIs in a cash-centric, labor-intensive way. In the most common model, transactions are conducted directly between loan officers and clients. Cash payments are collected in the field by a loan officer and returned to the MFI's branch office. There, the branch manager collects money from all of the loan officers, to deposit in the bank either that or the following day. Loan disbursements are handled similarly — loan officers travel to the field to disburse the loan directly to the client.

If there is a nearby bank that will cash checks for microfinance clients, the MFI branch manager may disburse loans in the form of checks issued in the name of the recipients. It is the responsibility of the loan recipient to go and cash the check at the nearest bank branch. In India, there is a widespread regional rural bank (RRB) network supported by the central government. Many microfinance institutions in India have established relationships with these rural banks in order to make it easier for loan recipients to cash checks at the nearest possible location.

Sometimes bank branches are not accessible nearby, or will not deal with whom they perceive as poor, uneducated microfinance clients. In such cases, loan officers would still need to travel to villages regularly with large amounts of cash. Due to the safety and security issues, MFIs generally do not do this and instead require clients to come to its own branch office (usually in pairs, again for security reasons) to collect the loan.

For clients, cash transactions are clearly the most convenient. However, security issues make cash difficult to transport into and out of villages. As microfinance groups often meet according to a regular schedule, it would be easy for a potential thief to predict when a loan officer might be traveling through an area with a significant amount of cash. In one of our visits, I heard of a loan officer that was murdered during such a robbery. In another case, an MFI had to equip all of its officers with private vehicles because it was not safe to ride the public bus to meetings.

Transacting in cash also increases the potential for fraud by loan officers. In several cases, I heard of loan officers who had under-represented loan repayments, only to be caught days or weeks later. This is one reason that microfinance institutions cannot offer flexible savings products to their clients. Even if it was allowed by the government, it would be too difficult for the MFI to track how much money a loan officer should be bringing back and forth from the office every day. This would leave the door wide open for fraud that could take weeks,

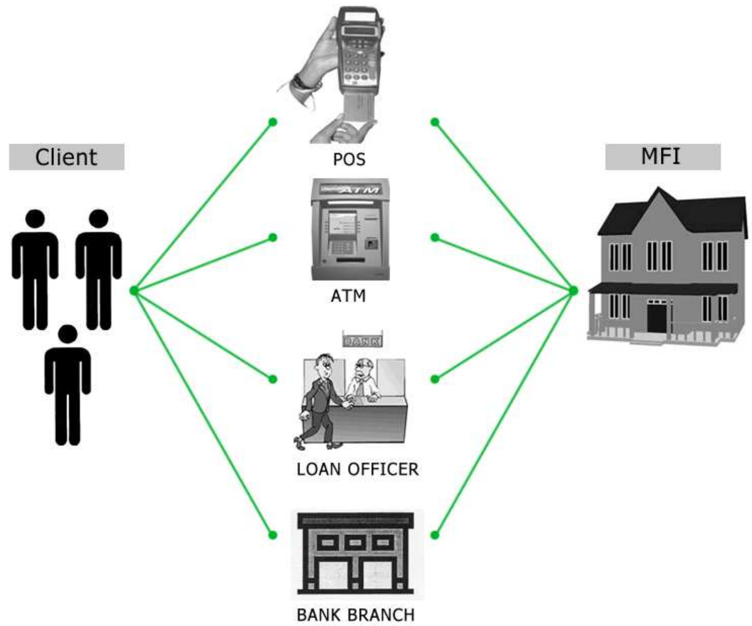

Figure 2.2: Rural cash handling options for MFIs.

if not months, to track down.

To meet these challenges, many microfinance institutions lean heavily on local bank branches for handling their cash transactions. In addition to issuing loan disbursements via check, they have started collecting repayments by asking clients to make deposits in specified accounts. The clients bring the processed deposit slip to the group meeting as proof of their payment. The MFI eventually can transfer these funds out of local accounts into their main institutional accounts. Of the eight microfinance organizations I visited in the study, all of them collected some or all of their loan repayments in this manner.

However, this is not seen by most observers as a long-term, internationally applicable solution. Rather, this is a short-term way to shift risks and expenses from microfinance institutions to clients and regional rural banks (and indirectly, to the government that subsidizes them). In many countries, there are not these extensive rural bank branch networks for MFIs to rely on. Then, it is the client that must spend the time and money to travel to bank branches and conduct transactions.

In India, regional rural banks are essentially providing a free service to microfinance institutions. The money is not left in their accounts for long enough to earn any interest, nor do they charge a per-transaction service fee. Due to the small value of microfinance transactions, a reasonable charge would be proportionately too small to make any business sense for the bank. Therefore, with no sound business case linking them, the relationship between microfinance institutions and regional rural banks is tenuous. Often, the MFI must spend time lobbying the bank's local management before they will provide service to their clients. If this does not work, they must appeal to the bank's central management.

I observed an example of this during my visit to CASHPOR, a microfinance institution operating in eastern Uttar Pradesh, India. CASHPOR is collaborating with ICICI bank in a new model for microfinance. In this model, CASHPOR manages all of the field operations — recruiting clients, managing group meetings, processing loan applications, issuing disbursements, collecting repayments and following up on delinquent loans. For their part, ICICI provides the loan capital. To meet its operating expenses, CASHPOR receives a 5% service charge on each loan disbursed. All of the remaining interest and principal payments go directly back to ICICI.

More precisely, the payments *should* go directly between ICICI and the clients, but that is really not the case. Once again, the regional rural bank network must handle the brunt of the cash handling. When ICICI sanctions a loan, it transfers the required capital to CASHPOR's account with ICICI. After collecting its 5% service charge, CASHPOR transfers this money into an account with the regional rural bank, so that it can issue a bearer check to clients to disburse the money. Deposits work the same way. Clients deposit money into CASHPOR's account at the regional rural bank, which CASHPOR then transfers to its account with ICICI, which is eventually debited back to ICICI's consolidated portfolio account.

Because the loan capital is provided by ICICI, CASHPOR is able to focus on its role of developing clients and their businesses. They do not have to worry about where the capital will come from as long as their clients can find a way to use it. This gives them the opportunity to aggressively pursue new clients and expand their operations. However, the regional rural bank branch must handle the thankless task of processing cash transactions, for which they receive no financial gain.

Another problem with this approach is cash inactivity. Due to inefficiencies in India's funds transfer network, money transfers from a central bank to a rural bank branch take a long time. For example, the transfer between ICICI's consolidated account and CASHPOR's rural bank account can take up to seven days in each direction.

Bindu Ananth and Bastavee Barooah of ICICI Bank's Social Initiatives Group discuss the indirect costs associated with these slow cash transfers [5]. While funds are in transit and therefore financially idle, someone must pay for the interest that should be accruing on that money. This can be a major cost for microfinance institutions, and has been an issue at every microfinance institution that I have visited. In most cases, this cost is passed on to clients in the form of fees and higher interest rates on loans. In other cases, the institution has to bear this financial cost. In inflationary economies, the problem is exacerbated.

As Ananth and Barooah mention in their article, "the challenge for banks is to innovate a low-cost network / delivery channel with a high outreach and flexibility with respect to the timing of its operation." [5] As a result, electronic transaction processing has been one area of intense technological innovation for MFIs.

There are many factors in the successful design of an electronic banking solution for remote rural areas. These include hardware costs, communication costs, geographic accessibility, power requirements, connectivity requirements, government regulations and customer acceptance. A successful solution must address all of these issues.

Several initiatives have developed low-cost ATMs for the microfinance market. ICICI is working with IIT-Madras, one of the premier technology universities in India, on the development of a low-cost ATM [155]. The current prototype carries a price tag of 30,000 Indian Rupees (approximately $700). This is a quantum leap from a typical commercial ATM, which can range in cost anywhere between $15,000 to $30,000. It is planned that IIT Madras's ATM will include built-in fingerprint identification and web cameras for identifying clients.

Another project using low-cost ATMs is underway in Bolivia. PRODEM is a large Bolivian microfinance institution that is one of the widest-reaching financial service providers in that country. Starting in early 2001, PRODEM has established a dedicated ATM network across all of its branch offices and at many other standalone locations [31]. Clients have found it convenient to conduct transactions at any time using this extensive network.

PRODEM's ATMs leverage technologies such as touch screens, fingerprint recognition, smart cards and a multi-lingual voice interface to serve its mostly illiterate, ethnic minority clients. This was done at a cost of only $18,000 per ATM — still significantly less than the costs of commercial vendors. PRODEM achieved this cost savings by building its own machine sourced from local hardware providers.

While this project has been a success for PRODEM, the cost and infrastructure requirements of ATMs have remained prohibitively high for most microfinance institutions. Even "low-cost" ATMs are out of the financial reach of most MFIs.

A more economical approach relies on *human-mediated transaction processing*. In this model, the client conducts transactions with a human proxy (often, a local merchant or trader) equipped with a Point-of-Sale (POS) device connected to the MFI's server. These transactions are conducted by the proxy on behalf of the MFI, and securely stored on the client's smart card. The MFI can later collect the deposits from the merchant, in exchange for payment for his/her services.[1].

Several initiatives in Africa are testing this approach. One project is led by Hewlett Packard and an association of international NGOs. They have developed the *Rural Transaction System*, or RTS, a POS device suitable for conducting many kinds of transactions [160]. POS devices have been used in trials by ICICI bank and the Warana sugar cooperative in India, and several initiatives in Africa [38].

One major impediment to widespread adoption has been the cost of the POS device, which can range between $100 and $300 dollars. It has been difficult to convince merchants of the value of this device, without a proven cash flow in place. POS devices have been successfully used in closed-loop economies, such as the Warana sugar cooperative in Maharashtra. In this case members of the cooperative are paid via deposits on a smart card, which can later be used to buy agricultural inputs and other goods from the coop-

[1] In January 2006, Reserve Bank of India (RBI) circular 288 authorized "banks to use the services of Non- Governmental Organisations / Self Help Groups (NGOs/ SHGs), Micro Finance Institutions (MFIs) and other Civil Society Organisations (CSOs) as intermediaries in providing financial and banking services" [121].

erative's stores. While this is not strictly a microfinance scenario, it does illustrate that effectively implementing a smart card solution requires having influence on both the source and eventual destination of currency.

Another human-mediated approach relies on an Internet kiosk instead of a POS device, again to connect to the MFI's on-line banking application. The merchant records transactions on the kiosk, and the client is provided with a paper receipt. ICICI Bank prototyped such a solution with its MFI partners in Madurai, India. ICICI had been supporting several community Internet kiosk projects in the region, and using these facilities to provide banking services was a natural extension of these efforts [134].

Mobile phones, have been successful in increasing outreach in several African countries [101]. The obvious value of voice and text communications has made the mobile phone a much easier sell then a POS device. Some agents even double as airtime retailers. In the base case, the mobile phone is used by the agent to process incoming transactions, similar to the POS and kiosk-based scenarios described above. Clients can use their own mobile phones to check the status of their account and upcoming payments. In Africa, customers have started using airtime as virtual currency — by purchasing airtime, and transferring it to a distant airtime vendor, who then issues cash to a recipient (authenticated via a back-channel password). This might be a friend, relative or business relation.

2.2 Emerging Scenarios

We must keep in mind that microfinance is a young and evolving industry. Only very recently has it been seen on an international scale as a viable commercial opportunity, and not a fringe activity for non-profit organizations. As the industry develops, it is likely that we will see some shifting of roles and responsibilities in the microfinance sector. In this section I discuss some ways in which that could happen.

Currently, several large banks have already or are seriously considering entering microfinance as a commercial market. Some examples have been discussed in this paper, and there can be no doubt that there is a buzz around this trend in the industry. As long as microfinance clients continue to prove their repayment performance, and low-cost delivery channels continue to be invented, there is no reason to believe that commercial banks will

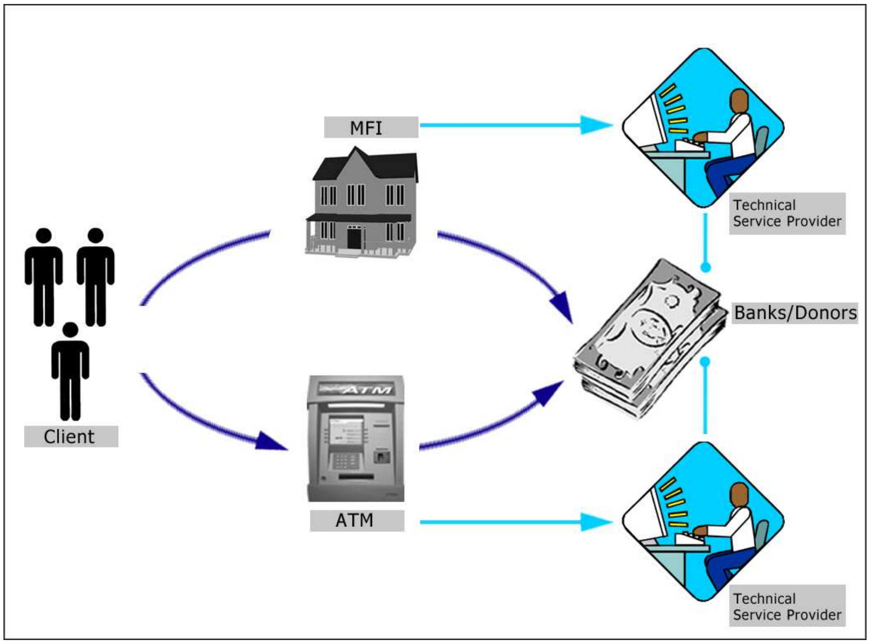

Figure 2.3: Future scenarios in microfinance.

not become more involved in microfinance in the coming years.

However, there are some aspects of providing microfinance services that most banks probably will never do, at least not as they are currently structured. Most people familiar with microfinance will agree that there are three very important factors in running a successful microfinance operation — 1) vision from the top, 2) reliable information systems, and 3) quality field staff. If the top-level visionary provides the brains, and the information systems are the nerves, then it is the field staff who form the heart and soul of any microfinance institution. Field staff carry out the key tasks in managing relationships with clients. It is they who are the true *bankers to the poor*, and it is on them that the economic development (and repayment performance) of clients truly depends.

Good field staff are themselves local, grassroots people who understand the rural scenario and can relate to microfinance clients. They must interact daily with clients — training them in microfinance and advising them in their financial decisions. Moreover, this relationship must be driven by a coherent vision from the top that directs their activities for the financial betterment of clients. While a bank is certainly better equipped in terms of access to resources, capital and information systems — it is the NGOs and MFIs and their understanding of the local context that provides the vision and forms the grassroots backbone of the industry.

While private banks may eventually choose to develop their own grassroots arms for reaching out to new clients, it is unlikely to happen any time soon, and in all cases. More likely, we will see an increase in partnerships such as the one between ICICI Bank and CASHPOR — where a mainstream bank looks at a microfinance institution as a grassroots partner that allows it to effectively offer financial services to the rural poor.

However, the same trend may represent a fork in the road as far as MFIs are concerned. Most microfinance institutions are happy to partner with banks in order to access more capital for their clients. At the same time, many institutions are finding it difficult to cope with the strain of rapid growth and increased accountability that goes along with these new formal relationships. They find that they do not possess the capacity to manage the new requirements effectively, and may even see it as a distraction from their core social agenda.

As a result, we may see more out-sourcing of IT-related tasks from MFIs to partner banks or other third-party service providers. The MFI may still handle basic data collection, but the processing, analysis and reporting could be out-sourced to institutions with more technical capacity. This could be a partner bank, with a single consolidated department that looks after the MIS systems of several partner MFIs, or it could be a private service provider that specializes in maintaining the MIS systems of MFIs on a contractual basis (an *application service provider*, or ASP).

2.3 Conclusion

It is an exciting time to be working in the microfinance industry. As the microfinance movement evolves from a social undertaking to a commercial one with strong social underpinnings, it will be interesting to see how it handles some of the conflicts that are sure to arise. A unique case of merging capitalism and the common good, which, if handled properly, could prove to be a truly international success story where the end result is the upliftment of many human beings.

Chapter 3

HISAAB: CONTEXTUAL, PARTICIPATORY DESIGN

In this chapter, I discuss a contextual design study that I conducted with microfinance groups in rural India [109]. This work was done while I was a researcher at Media Lab Asia, with the collaboration of several researchers at Human Factors International [55]. The goals of this study were to 1) understand a particular instance of microfinance — what happens, who does what, and the benefits and limitations of the current system; 2) observe the local context — the human and physical environment where this is happening; and 3) establish a working relationship with group members and local NGO staff.

Subsequently, I conducted a two-month participatory design study with microfinance group members, with the goal of designing a prototype user interface that they could use for entering transactions and producing internal accounting reports. Many of the group members were semi-literate or illiterate, a population that had not previously been considered in the context of user interface design. In this chapter, I describe the process and results of this study, and conclude with a list of design guidelines for providing improved accessibility to these users.

3.1 SHGs: Self-Help Groups

One of the unique features of microfinance is the *group* concept. Groups serve as local financial intermediaries in microfinance — assessing members, conducting transactions, holding cash, and sometimes even offering their own financial products. Most importantly, groups provide a *mutual guarantee* — if one of them defaults on a loan, all of them suffer. This provides a very strong social incentive to repay. From the *Grameen* groups in Bangladesh, to the *Village Banks* of Latin America, this approach has been remarkably successful in reaching out to the poorest and most remote communities.

Self-Help Groups, or SHGs, are the form of microfinance group prevalent in India. In contrast to other kinds of groups, SHG's funds are both *community-owned* and *community-managed*, similar to a financial cooperative, at a much smaller scale. There are estimated to be more than 2 million SHGs in India, with a membership of more than 33 million (90% of whom are women) [151]. This constitutes one of the largest and fastest growing microfinance programs in the world. A SHG consists of between 10-20 members. While the education level and affluence of members varies by group, most are very poor and minimally educated or literate (if at all) [60]. The vast majority of SHGs in India consist exclusively of women.

Transactions (including payments, loans, withdrawals, deposits, etc.) occur during monthly meetings of the SHG. Individual members deposit money into a common fund, which is in turn lent to other members at a mutually agreed interest rate, usually for some productive purpose, such as making an investment in their farm or business. SHGs also access loans from banks and other financial institutions, that are then divided up as smaller loans to individual members. No collateral is required, as the community liability among members of the same village is enough to enforce repayment. At close to 98% in some cases, repayment rates can out-perform loans to the general populace.

SHGs can form super-structures by linking with other groups in their geographic area. A set of 20-30 groups can come together to form a *cluster*, and a set of 20-30 clusters can come together to form a *federation* (see figure 3.1). These larger groupings allow SHGs to transfer funds between groups, and to attract larger sources of investment and institutional capital.

SHGs and SHG Federations are supported by *Self-Help Group Promoting Institutions* (SHPIs). This is most often a non-profit *non-governmental organization* (NGO). The SHPI helps form and support SHGs, including providing training and capacity building, linkages to other SHGs and to the formal banking sector. While most SHPIs in India are NGOs, for-profit microfinance institutions (MFIs), commercial banks, government agencies, farmers cooperatives, or even private individuals are also involved to varying degrees [138, 88].

SHPIs employ *field staff* to form and train groups. Field staff are recruited from villages and rural areas near the districts where they will work. They usually have at least a partial high school education and are paid a small salary or commission per group.

Mature SHGs are expected to document their own meetings and manage their internal

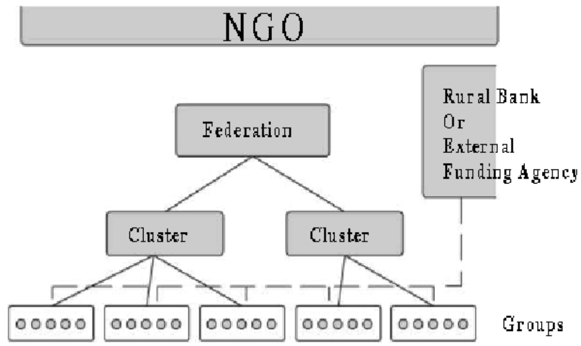

Figure 3.1: A diagram of the typical organization of an SHG Federation.

accounts and lending. If nobody of the members is capable, a local educated person or school-going child is enlisted as the *bookkeeper*. However, most SHGs are still not able to produce financial statements and lending reports. They have inadequate accounting controls and systems for monitoring risk in the loan portfolio. Banks and other lenders find it difficult to assess SHGs' stability and financial history when considering loan applications.

Thus, especially for young SHGs, it often falls to the field staff to maintain their records and vouch for them when dealing with financial institutions. Even for field staff with a basic education, the current accounting and documentation processes are onerous. We have been working with a NGO based in Tamil Nadu, India to make the SHGs' manual paper-based accounting processes easier to learn and maintain [112]. Using this greatly simplified system, it has taken over six months to train field staff to produce basic reports and statements. These are inconsistently prepared, and errors are frequent.

Documentation is also important for SHGs to maintain transparency. Elite capture has been a problem for other forms of community-owned microfinance worldwide [60]. By instilling transparent and rigorous bookkeeping standards, group members can remain vigilant about the use of their funds and the status of outstanding loans. The ability to reason about past performance could allow SHGs to better manage their funds, making loans for purposes that will maximize repayment and overall benefit to the community.

For these reasons and more, having an integrated top-to-bottom management information system (MIS) for managing grassroots micro-finance operations is an attractive possibility. If there was some way to capture local transactions and handle accounting and report preparation automatically, it would dramatically reduce the workload of field staff, and improve the efficiency and transparency of SHGs. Currently, very few SHPIs have succeeded in computerizing at the SHG level.

3.2 Contextual Design Studies

3.2.1 Field Visit #0: Ahmedabad

The initial genesis of this project came when I was working with the Self-employed Women Association (SEWA) bank in Ahmedabad, one of the largest and most well-established microfinance programs in India, to assess their branch office computing infrastructure and to investigate ways of extending the reach of SEWA's documentation process into villages.

In an early meeting with SEWA group members, we discovered that most of them had little or no formal education. Out of a select group of about 25 members, most of whom were very active in group activities, only two or three were literate to any level. Given these circumstances, I was not very confident of being able to develop an effective user interface for this group.

Still, I was curious to learn how the women were able to track their transactions and financial position, and how they were able to manage their personal and group accounts. In response, the women heartily stated (in the local Gujarati language) "Oh, we can understand numbers fine. We can even do most simple calculations ourselves. It is only text and words we have a lot of difficulty with." This opened up the idea of numeric literacy, and how we might leverage this and other literacies in our designs.

3.2.2 Field Visit #1: Aurangabad

Given this motivation, we started by designing paper prototypes. These prototypes ranged from numeric keypad-like devices (see figure 3.2), to full desktop systems. With these designs in hand, we set out to visit a set of SHGs located near Aurangabad in Maharashtra. These groups had been promoted and supported by an Aurangabad-based NGO named

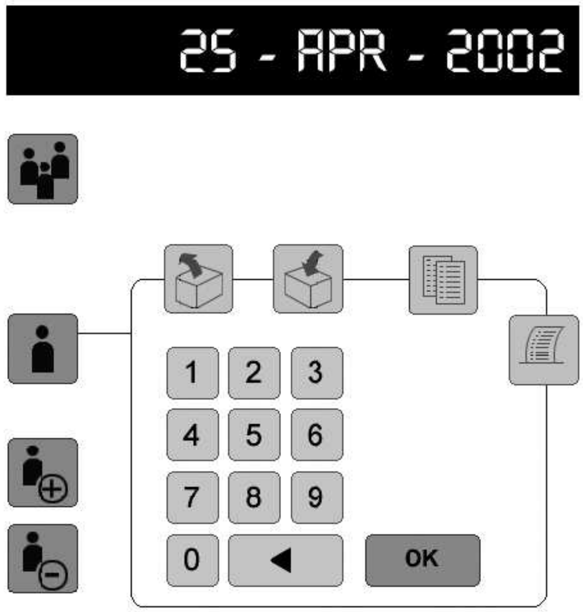

Figure 3.2: An early keypad-based paper prototype.

Dilasa, which had originally started its work in the area of watershed development. Dilasa had initiated support for SHGs to respond to the inability of many of its constituents to access loans from banks and through government programs.

Over a two-day period, several of Dilasa's management team and field staff were kind enough to take us to six villages, and visit the SHG members in each village. Our purpose was to assess the user's reactions to our paper prototypes, and also to get a better understanding of local micro-finance operations.

Contextual Observations

Upon entering each village, we were welcomed by the village elders, while the members of the local SHG (or SHGs) were assembled by the Dilasa field staff to answer our questions. We were often seated in chairs in the center of a large circle, the women sitting around us on the ground (see figure 3.3). This made it difficult to have an equal exchange of ideas. As we would soon find out, to overcome this limitation we would have to hang around long enough to no longer be "novelties" from the big city.

One of the first things we found upon observation of the local work practices was the central importance of notebooks and ledgers. The women would come to meet us armed with a stack of six or seven notebooks, prepared to display their proficiency and accuracy in recording the local transactions. Obviously, the Dilasa staff had been there many times before to train and to assess in their conformance to the proscribed documentation protocols.

There was a set of seven ledger formats which were recommended for use by the state government, which Dilasa had adopted and spread among these groups. Some of the ledgers were clearly more important than the others. The most important ledgers included the *cash book*, in which were recorded all of the cash transactions of the group, the *member pass book*, a personal bank book for each member, and a *proceedings book*, for recording SHG rules, announcements and decisions.

If nobody of the SHG members was literate, the transactions had to be recorded by someone else. This was often a child of one of the members, someone who attended school and could read and write reasonably well. A child was paid ten rupees ($0.20) for this service. If a child was not available, a local literate man who was not a member of the group would be hired to perform the same service, charging 25 rupees ($0.50) or more per meeting. Younger groups who had not yet fully learned the basics of the system had to wait for an NGO staff member to conduct meetings. In most cases SHGs only recorded their transactions in a simplified spreadsheet format, and waited for the staff member to come and prepare the other ledgers and reports.

Each of the members had a sequential number in the group, and transactions were conducted in this order. Often, the child did not write the names of each member, but sequentially noted down the amounts of the transactions next to the appropriate member number. This is also how illiterate and semi-literate members were able to locate their records in the tables. They had memorized the tabular structures (rows for members, columns for different types of transactions) and located their sequential position in the table to quickly identify their transaction records.

These books served as an important shared resource for the SHG. They could be communally viewed and edited during a group meeting, and all of the members could ensure

Figure 3.3: Testing paper prototypes in Aurangabad.

the accuracy of the entries as they were being made. Storage of the books was also an important matter. The books were stored in one of the group leaders' homes, who was obliged produce them on demand if asked by another member.

Paper Prototype Evaluation

After we had spent some time talking with local group members, in two villages we proceeded to show them some of the paper prototypes that we had developed (see figure 3.3). Initially the villagers were very confused as to what we were showing them. But once we had explained a little about what we were working on and what our purpose was, things became a lot clearer. In fact, the SHG members were very excited that someone was working to build a system to meet their needs.

Several users were able to understand the intent of the system quite clearly. Most could identify the numeric keypad and its purpose, as well as most of the icons included in the interface. We were encouraged by these results and decided to continue the design process.

3.2.3 Field Visit #2: Madurai

Armed with this experience, we set out to do more detailed contextual studies and evaluations of potential designs. This time we chose a more mature set of SHGs, located in Tamil Nadu in the south of India, approximately 50 kilometers from a city called Madurai. These SHGs were promoted by an NGO named CCD (Covenant Centre for Development). CCD had been supporting SHGs and other community-based enterprises for over ten years. The goal of CCD's work was to stem rural migration by providing sustainable livelihood opportunities in rural areas.

Contextual Observations

We stayed with CCD in the field for a full week, and were able to spend much more time understanding the context, culture and practices of the SHGs. We attended two meetings per day, one in the afternoon and one in the night, for periods of two to three hours each. Between meetings we would review our notes and discuss our observations with the CCD staff, confirming and verifying our impressions. While the local language in Aurangabad was Marathi, a language fairly close to Hindi, which all of us spoke and understood, the local language in Madurai was Tamil, which none of us were conversant in. Therefore we had to rely solely on CCD staff to translate for us during meetings and interviews.

These SHG members, being used to occasional outsiders visiting their meetings, took much less note of us, and after some initial greetings conducted their meetings much as normal. Here we visited all levels of meetings, ranging from individual group meetings, to cluster meetings to federation board meetings, and made detailed observations of the operations and documentation practices.

Like with Dilasa, every SHG maintained a complicated set of ledgers and forms, centered around a set of seven ledgers and data formats, this time prescribed by the Tamil Nadu state government. This again included the *cash book*, the *member pass book*, and *proceedings book*. Much of the data in the other formats was thought to be redundant and unnecessary,

Figure 3.4: An SHG group meeting.

and we received many complaints about the tediousness of maintaining so many overlapping documents. We have since helped CCD revise the paper-based documentation formats to be more streamlined [112].

In practice, there was just one crucial data format in which data was initially entered, from which it was eventually copied into the other ledgers (sometimes inconsistently). This was a spreadsheet document developed by CCD which was intended to document all of the transactions during a group meeting, as well as the financial position of the group before and after the meeting.

During this visit we were also able to appreciate more of the local context. Group meetings most often occurred at night, after the day's agricultural labor was completed. Around 8 or 9 pm, after everyone had eaten and the day's chores had been completed, the group members would assemble in the local square, under the village "street-light" (many villages in Tamil Nadu have electricity, although it is intermittent). The local square was

Figure 3.5: One of the villages near Madurai where we conducted design sessions.

a shared community space, and many children, youths and men would also congregate in the center during the meeting. During our visits there were probably more observers than usual.

We observed many of the same things we did in Aurangabad, including the importance of the notebooks as a shared resource, the safe-keeping and accessibility of the notebooks and the cross-verification capabilities of notebook entries. We again observed the sequential ordering of members, memorization of tabular formats and ability to read and understand numbers as a common method for illiterate and semi-literate users to understand their accounts and verify that their transactions had been recorded accurately.

Children were again often enlisted as substitute record keepers. Sometimes a local literate man who was not a member of the group would also be hired to perform record keeping, charging about 25 rupees ($0.50) per meeting for the service. We observed that literacy was sometimes much higher here than among groups we had observed in Aurangabad

Figure 3.6: An interactive prototype we tested on our first trip to Madurai.

and Gujarat, but that it varied dramatically between villages and communities.

Interactive Prototype Evaluation

For this trip, we developed an interactive prototype based on a standard PC screen resolution to give us more flexibility in evaluating design alternatives. We had improved the design considerably based on our observations from Aurangabad and our improved understanding of local microfinance operations (see figure 3.6). We tested the prototype using a laptop machine at several group meetings and one federation board meeting.

Several potential users, particularly at the federation board meeting, were familiar with technology and had even seen (but not used) computers. One of them had traveled to nearby Pondicherry to visit the M.S. Swaminathan rural telecenter project [96]. Because of this (and also due to their position within the federation), they were more comfortable with the technology, and more confident in the evaluations. After some initial hesitation, the users quickly took over the laptop and began to experiment. They were quickly able to understand the touch-pad pointing device and use it to navigate the interface.

Some of the users, particularly the federation board members, were quite pointed in their feedback about our designs. We were informed that our layout only contained five columns, while the spreadsheet format they used in meetings required seven. One of the designs that we had developed had a stylish gray-scale color scheme. The women commented that while the design was attractive, Tamils were fond of colors, particularly yellows and reds, and that some of the users would be illiterate, so that these colors would be helpful to them in identifying relevant parts of the interface.

One interesting occurrence was when a user right-clicked on the screen and the usual menu options appeared. The user and the assembled observers were thrown off by this abrupt occurrence, and deftly moved the mouse to a different area of the screen where they might not disturb the new apparition. The federation president, a tailor, asked us what the cost of our laptop was. When told, she decided that while a single SHG could not afford such a device, the federation might eventually be able to. This demonstrated an understanding of the economics of technology, and its potential for benefit to the organization.

3.2.4 Field Visit #3: Back to Madurai

Given these positive results, we developed some more advanced prototypes and returned to the field for an extended period of testing. We scheduled two months in September and October for this purpose.

Upon reaching Madurai, we worked with the CCD staff to organize four groups of volunteer SHG members for our studies. Overall, 32 women were included in the evaluations, ranging in age from 19 to 55. 27 of the 32 women made their livelihood as agricultural laborers. The women were organized into four groups of 6-10 women, ranging from more (Group A) to less (Group D) literate. This was to ensure some homogeneity in our evaluations. 22 of the 32 women were literate to some degree, at least being able to identify Tamil characters and short Tamil words. All except four of the women (three of them in Group D) could identify single-digit numerals.

We situated the sessions at the CCD field office, located in a village nearby to many of the SHG groups. The environment was not different than that of a well-equipped village home, and the users were familiar with the location, so that the context was not much out of the ordinary. Most of the participants lived between 5 and 25 kilometers from the site, and could reach the location by bus and/or walking.

3.2.5 Association Tests

We had been experimenting with numeric literacy since the early phases of the design process. Our idea was to represent navigation paths in the interface as a sequence of numbers. For example, users could navigate between screens and between screen elements using numeric "shortcuts". A particular position in the interface could quickly be reached using a memorized sequence of numbers. This is similar to numeric shortcuts available on mobile phones.

To use numbers as navigational aids, we had to ensure the users' ability to associate numbers with abstract ideas and actions. To test this, we constructed a set of informal tests, where users were given time to memorize associations between different kinds of identifiers and specific nouns or actions. The identifiers were selected from a set of numbers, icons, and images.

The tests were conducted as follows: users were shown a sequence of images, icons or numbers. We then showed the users an image or told them a word that would be associated with each of them. Users were given as much time as they needed to memorize the relationships. Then, under different contexts and over different spans of time, users were asked to recall the concepts or images associated with particular identifiers.

As a result of these tests, we found that abstract signifiers such as numbers were very difficult for the users to relate. Users had difficulty remembering what concept a number was meant to represent. They were much more successful in associating ideas and actions with highly representational icons (using the terminology of Familiant and Detweiler [39]), that could somehow be visually related to the idea they meant to represent. This observation was later corroborated in our interface evaluations and collaborative design exercises.

Figure 3.7: A participatory design session.

3.2.6 Participatory and Iterative Design

With this knowledge, we set out to test some interactive prototypes. The users and the the testing location were the same as before. Our goal was to develop a simple system that would replace the paper spreadsheet currently used to record transactions. We developed the prototypes using Macromedia Flash, a popular interactive scripting language [85]. We used a laptop PC as the testing platform for the most flexibility in location and size.

Over the course of two days we were able to test all four groups on a specific design (or set of designs), conducting two three-hour sessions each day, one with each group. Between sessions we would modify the designs based on our observations and the suggestions of the users. Sometimes we would change the interface during the course of a session, often when we had made some glaring error in the data representation or organization.

During each session, we would go through a specified protocol, asking users to identify screen features and perform certain tasks. The process was interactive — as the users

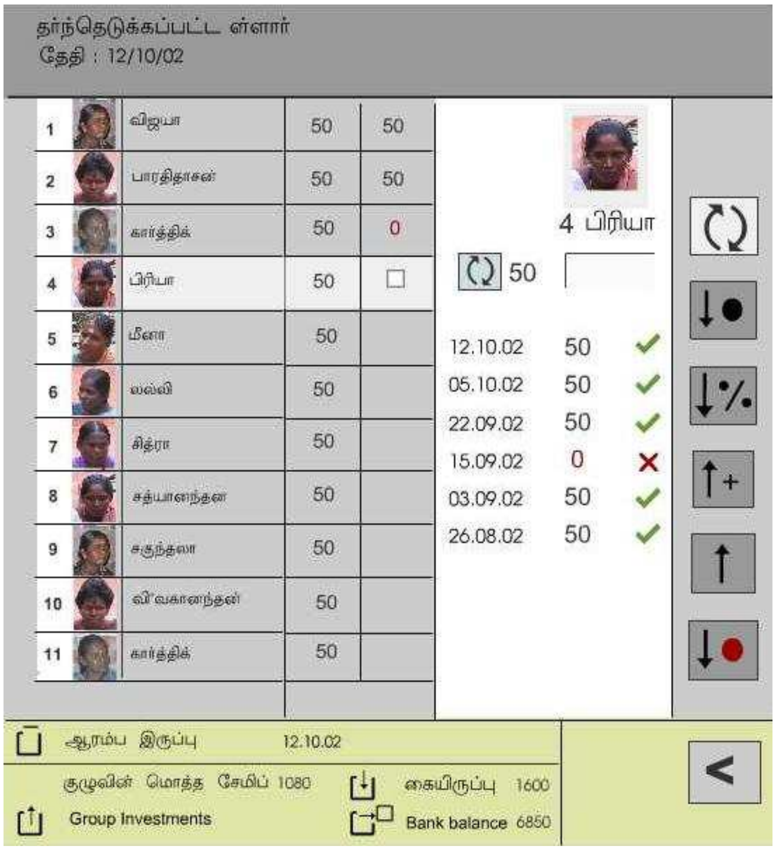

Figure 3.8: One of our final interactive prototypes.

navigated the interface they could ask questions, make suggestions and recommend improvements (through the CCD staff translator). The users' responses were documented and occasionally recorded on video for transcription and translation.

In all, we conducted four half-day sessions with each group, for a total of eight days of joint design sessions. At the conclusion of this process, we had arrived at a design which was reasonably well understood by all of the groups except Group D (consisting of the least literate users). Members of these three groups could interact comfortably with the interface, and were able to complete several tasks independently. Members of Group D had developed some familiarity with the interface and could identify screen components and actions associated with specific buttons. A screen-shot of one of our final prototypes can be seen in figure 3.8. More screen shots from throughout the design process can be seen in appendix B.

3.3 Design Guidelines

In this section, I list some design guidelines synthesized from this study.

Importance of Paper Formats

The users had a practiced knowledge of the organization of their paper ledgers, especially the tabular data format used for initial data collection. Repeated entry into this format led to a deep understanding of its organization and significance. Moreover, we observed several times that even illiterate users used the tabular organization to identify important transactions. To leverage this knowledge we focused on maintaining the same tabular data formats and orderings wherever possible.

Numeric Input / Output

In the course of our initial testing protocols, we found that numeric literacy was more common than other forms of literacy in our users. Basic exposure to number-based formats and tools such as calendars, bus time tables and phones was also found. Calculators were used for arithmetic during group meetings. In our prototypes, most users found it easy to enter numbers using the PC keyboard, even in groups C and D. In fact, numeric data (dates, interest percents, sums, etc.) provided cues for overall interface comprehension. From the positioning of numeric data values users were able to understand much of the rest of the interface relative to the numbers and tables. It was important that text, where required, was in the local language, even if users could not fully read it. This gave users a greater sense of familiarity and ownership.

Audio Feedback

We observed that the meanings of screen elements were most often learned through the effects that they caused. To leverage this active learning, we designed an interface feature called an *iconic legend* (see figure 3.9). An iconic legend is an area of the screen where a set

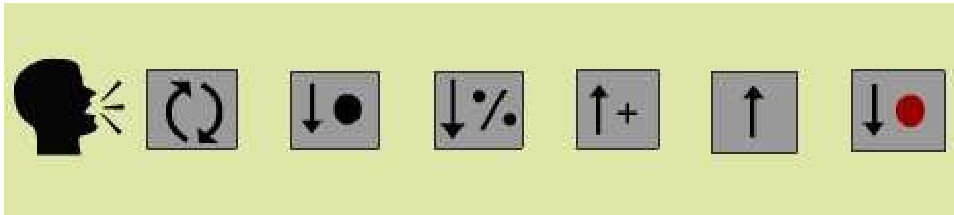

Figure 3.9: The *iconic legend*. Clicking on each button activates an audio prompt indicating the meaning of the icon.

of iconic buttons are associated with audio feedback that describes the meaning associated with that icon. Pressing a button in the legend has no effect other than generating audio feedback. Audio feedback proved to be a tremendous draw to the application. Users initially considered the laptop an expensive and foreign device, and were hesitant to do anything that might damage it and make them liable. However, once they heard the machine *speaking Tamil*, they became more comfortable. Using the iconic legend, users were able to learn iconic meanings comfortably through repetition and association, without fear of undesired actions or results. In the process, they also learned how to use the mouse and/or touchpad. This decreased the amount of guided training and documentation required.

Guided Interaction

With the users' limited means of identifying distinct screen elements, we found that minimizing the number of tasks possible at one time made it easier for users to comprehend a screen's overall purpose and structure. We therefore followed a design pattern of *guided interaction*, where users were guided from task to task through a sequence of discrete but consistent screens, each containing a number of well-ordered sub-tasks. For example, during a SHG Meeting, a number of different types of transactions (savings deposits, loan repayments, loan disbursements) are conducted for each member. We found that limiting each screen to one type of transaction proved more successful than a screen from which it was possible to record several different transactions for each member at one time.

Difficulty with Abstraction

While numeric values as data were well-comprehended, numeric representation of actions and navigation did not work well at all. Evidence of this was given by our association tests, and later corroborated during design and evaluation sessions. Initially, we had thought that we could leverage numeric literacy to allow simple, accessible methods for navigation and task execution. However, after our cognitive test results and design iterations it appeared that users were not able to make associations between concepts and abstract numeric identifiers. Therefore, we found that navigation or action-based elements were best represented through the judicious use of highly representational identifiers such as pictures or icons.

Color

We have already discussed how non-textual landmarks such as tables, numbers and icons aided in interface comprehension. Another feature we found useful in this regard was color. Color was used in the screen background to distinguish discrete elements, and used in the foreground to draw attention to aberrant or noteworthy data. For example, the color red was successfully used to represent delinquent payments or negative values. Increased use of color was suggested by the users themselves as a tool to overcome their lack of literacy.

Local Context

Staying in the local area and doing design work in the field was a very important part of the design process. Over months, we were able to imbibe local culture, and understand to some degree the pace of life and perspectives of the user community. The users got to know us much better, and were not afraid to give pointed feedback and criticisms about our designs. While this is an important consideration in any design study, it might have been more of a factor due to large differences in culture, environment and perspective between ourselves and the user group.

3.4 Conclusion

In this chapter, I have presented some of my initial experiences in designing accessible information systems for SHGs in rural India. Through this I developed a better understanding of users' work processes, abilities and interaction preferences.

One consistent result obtained during these studies was the importance of physical models and tangible artifacts. Having experience using ledgers and notebooks, and a day-to-day life filled with numerous physical tasks, these users were much more comfortable with artifacts that they could handle and touch, and had some correlation with the paper-based data entry mechanisms they are used to. Moreover, current information practices are built around shared physical ledgers that can be communally viewed, exchanged and audited among members of the group. Illiterate users have even learned to interpret data from paper forms. For the time being, it's unlikely that any affordable digital interface will be suitable for this kind of use.

However, paper is not appropriate for many uses. It is difficult to search, index, or archive it. Performing calculations and consolidating reports manually using paper is tedious and error-prone. Somehow, we need to digitally capture information from paper and let computing systems do the things they're good at. In the next chapter, I describe an information services framework that I implemented to address this requirement.

Chapter 4

THE CAM FRAMEWORK

Based on these results, I set out to develop a real and practical information services framework for this and similar rural computing applications. Given the corresponding increase in mobile phone ownership in many developing countries (including India and China), this became an obvious alternative for the client device.

4.0.1 Benefits of Mobile Phone Hardware

A mobile phone is a much more useful and familiar device in the rural context than a PC. Its voice and text communications offer immediate utility to any user. Solid state memory, extended battery-life and a compact, rugged form factor are all great design choices for the village environment. From a UI perspective, a camera-equipped mobile phone has the ability to support many key design requirements — linkage with paper processes, audio feedback and numeric input and output.

Mobile phones also offer a cost benefit. As shown in the example of Grameen Phone, if a phone is shared by a group of people, it can be afforded by even the poorest communities [47]. Volume manufacturing makes mobile phones more affordable then most other special purpose devices. The current market cost of even high-end smartphones is about half that of an entry-level Celeron PC. By reducing staff trips to the office (where a PC would hypothetically be located), travel costs can also be reduced. Field staff could spend more time in the field, allowing them to service more clients. Field agents carrying mobile devices could offer a variety of services to rural residents.

Wireless infrastructure exists in almost every country, making this approach flexible enough to deploy anywhere. Because phones are are portable, they can be carried back and forth between connected and disconnected regions, ferrying data back and forth [117]. While still requiring travel, now one device and one person can perform this task on behalf of a village or region. In the future, field offices might not be required at all — commercial banks without a rural branch infrastructure are already paying agents on a commission basis to form and manage SHGs [60]. These agents could operate using only a mobile phone and a printer or fax.

4.0.2 Limitations of Current Mobile Software Platforms

While mobile phone hardware is well-suited to rural conditions, the same is not true for software. Mobile web interfaces are notoriously difficult to use, even for developed world users [21]. Typing URLs with a numeric keypad is slow and painful. Therefore, users must rely on a portal or set of bookmarks to access web sites. Most web pages are designed for large screen resolutions, making navigation within a page also problematic. Interaction is based on a constrained rendition of the WIMP metaphor that is awkward at best. Mobile phones also do not provide a way to work with web content without an active connection. Web-based applications also do not take advantage of the built-in features of mobile phones, like a microphone, speakers or even a camera.

Developing custom applications for mobile phones is becoming more common. However, this requires knowledge of new APIs (some of which require licensing). Distributing applications is cumbersome. Either providers must push content to users, or users must navigate to web sites and download the software. Due to the difficulty of using the mobile web and the latency in the mobile data network, the easiest way to install an application is by using a PC to download the installer and transfering it to the phone using bluetooth or USB.

4.1 The CAM Framework

In this section I present CAM, a mobile phone application platform that addresses these mobile user interface and software limitations. By supporting one-step, paper-based navigation, a simple scripted programming model and off-line multimedia interaction, CAM provides a platform uniquely adapted to rural computing requirements [111].

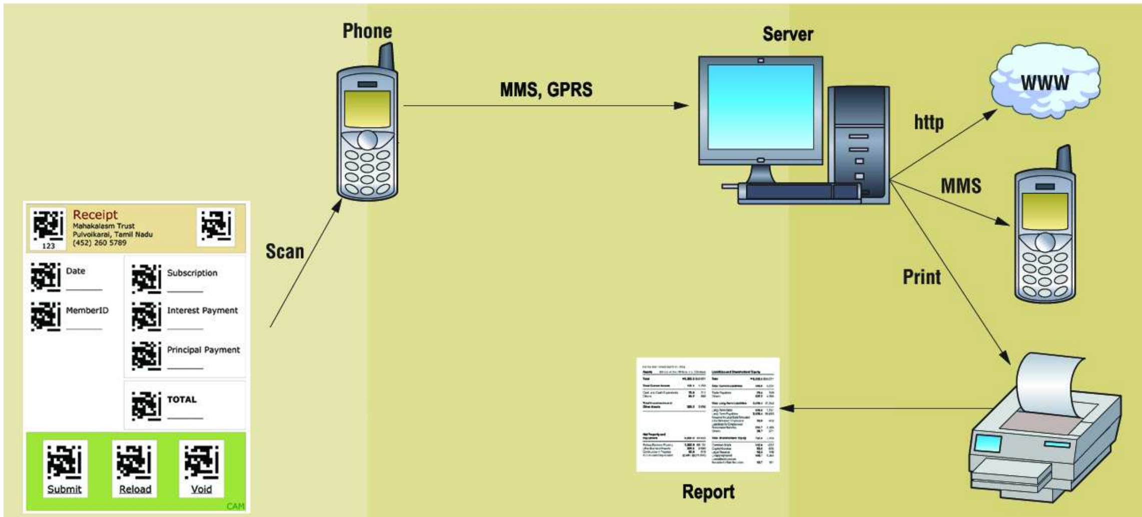

Figure 4.1: Three-tiered CAM framework. CAM provides the appropriate information medium for each context. Rural users transfer paper- based information to roving smart-phone middleware, which uploads the data to remote storage for distribution in various ways.

4.1.1 System Overview

CAM, so-called because the phone's camera plays a key role in the user interface, is a three-tier, document-based architecture for providing remote rural information services. The user tier comprises a set of paper *CqmForms* that are used to record information, perform queries, conduct transactions and disseminate results. The server tier is a standard Web application server, which can reside locally, in a nearby town, or virtually in the Internet ether. The *CamBrowser* application, running on a mobile phone, acts like a roving, human-operated middleware, playing the role of scanner, user interface, network, cache, and preprocessor. Figure 1 presents the CAM architecture's overall structure.

User interaction in the CAM framework is driven by the relation of two artifacts: the CamBrowser mobile phone application, and CamForm paper documents. CamBrowser is a mobile phone application that acts both like a one-button mouse and a virtual window for augmented paper documents. It has been implemented using the Nokia Series 60 SDK, and runs on a variety of phones based on this platform [1]. All of the implementations and experiments in this paper were conducted using a Nokia model 6600 mobile phone.

Users navigate within and between CAM applications by capturing barcodes using the mobile phone's built-in camera, or by entering numeric strings. These barcodes and numbers are printed directly on paper CamForms for ready access (see figure 4.2). Forms-based data entry is extremely common in the developing world. Analogs of existing paper forms serve as efficient offline clients for CAM applications. Data is first entered on paper, from where it can be transcribed, processed and uploaded using the CamBrowser. Data transfer can happen either immediately, or later when the phone has a connection.

The CamBrowser downloads and executes applications written in Simkin, an XML-based scripting language which provides support for function calls, control flow, arithmetic and basic datatypes [145]. CAM provides an API for accessing the mobile phone's user interface, networking and multimedia input and output capabilities. Applications are downloaded on demand from an online source, either via the web or a multimedia message (MMS). The XML is cached locally on the phone along with any associated files, in a directory structure organized according to the data server and application ID.

In the following sections I describe the details of the CAM implementation, including its navigation, content, networking and security features, and discuss how each of these addresses the rural developing world's computing requirements.

4.1.2 Navigation

In my earlier experiments, I observed the navigation difficulties encountered by semi-literate rural users when using a traditional PC interface [109]. These problems can be exacerbated by the limited display and input capabilities of a mobile phone. Even if users are literate, traditional menu-based navigation is complicated, especially on a mobile phone, requiring significant time to understand and convey. Moreover, in a menu-based system, only a limited number of options can be accessed at one time. Other researchers have noted the difficulty of hierarchical navigation for rural, developing world users [17]. Entering a URL in English

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[1] I intend to port CamBrowser to other platforms in the future.

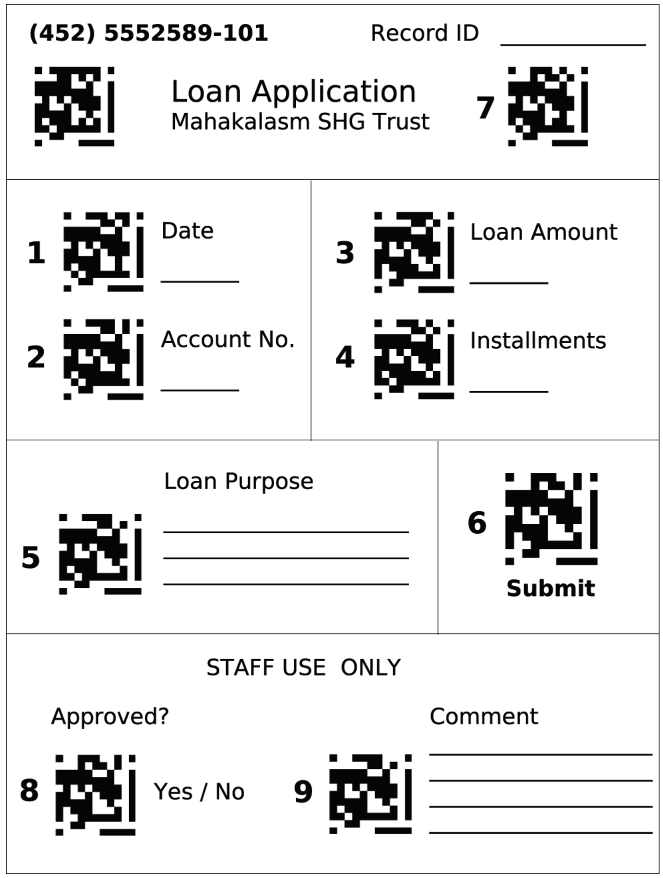


Figure 4.2: An example CamForm, for submitting a microfinance loan application.

using a numeric keypad is completely unrealistic.

To circumvent the limitations of standard navigation methods, I have taken a different approach. Applications and application functions are indexed using numeric strings, encoded either as barcodes to be captured via the mobile phone camera, or as numbers to be entered via the keypad. Both barcodes and numbers can be printed directly on paper forms. In this way navigation and search are both directly tied to a paper representation of the task. The paper form can also serve as a local record if a printer is not available.

For barcode recognition and generation, I am using the open source toolkit developed by Rohs and Gfeller [128]. This includes a 2D barcode recognition library for Nokia Series 60 phones. A user can capture a barcode by taking a picture of it using the mobile phone

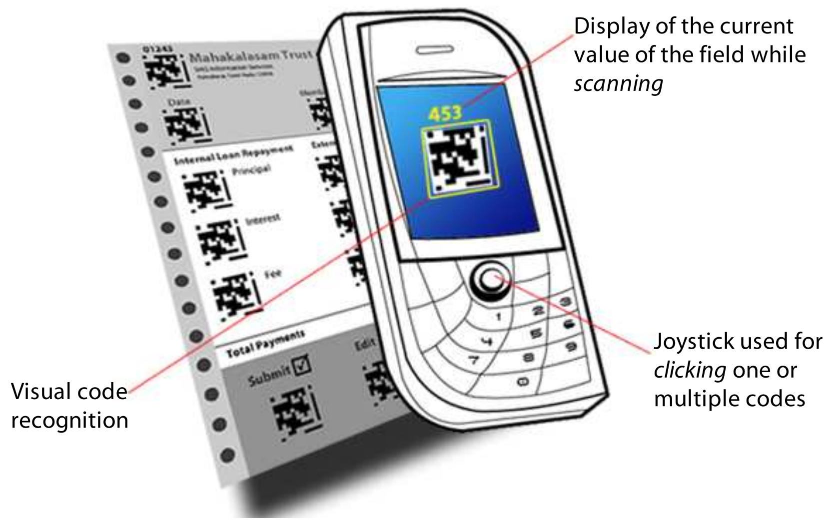


Figure 4.3: The CamBrowser application. The current value for the field is displayed beside the visual code.

camera. Each barcode contains 83 bits of data, 7 of which are being used for error correction (leaving 76 bits of data capacity). Several barcodes can be detected from a single camera image.

To navigate to a new application, the user captures a barcode in the top-left corner of a CamForm (see figure 4.2). This barcode has its first two bits set to 0. The next two bits represent the protocol to be used for downloading the code and data (currently either HTTP or SMS), and the next 48 bits encode the address (either an IP address or an SMS phone number). The last 24 bits specify a server-specific application index. Based on this index, application code and data is requested from the server and cached locally on the phone for offline access (this will be discussed in the networking section).

The same application can be accessed by entering a numeric string using the phone keypad. This is useful for mobile phones without a camera, or for applications that do not have an associated paper representation. The numeric string is based on a phone number, providing a familiar metaphor for rural users. An application is "dialed" by entering an arbitrary length phone number (or 12-digit IP address) for the server, a '*' delimiter (two '*'s for an IP address), and then a server-specific application ID. If the address or phone

Table 4.1: Barcode and numeric inputs for accessing CAM applications and functions.

Application	
Barcode	00-Protocol(3 bits)-Addr(38)-AppID(24)
Numeric	[Addr-*]-AppID-[FuncID[#Param]]
Function	
Barcode	11-FuncID(8 bits)-Param(66)
Numeric	FuncID[#Param]

number is omitted, it is treated as a local application that may have been downloaded to the phone previously (the equivalent of accessing localhost in a web browser).

Users navigate within an application in the same way. The functions exported by each application are specified as elements in an XML file, written in the Simkin scripting language. Barcodes with the first two bits set to 1 refer to application functions. The next 8 bits specify an application-specific function ID (each application can export up to 256 unique functions). The rest of the bits in the barcode are sent to the function as a static parameter. This can be used, for example, for labeling purposes (ID cards, account numbers, inventory, etc.).

Using the keypad, functions are accessed by entering just the numeric function ID. Parameters can be specified using an optional '#' delimiter. This string can be concatenated at the end of the application string described in the previous section, separated by another '#' delimiter. This creates a unique *numeric URL* that can be used to remember (and share) references to arbitrary application functions. Table 4.1 details the barcode and numeric keypad inputs used to access specific CAM applications and functions.

Barcodes and IDs for functions can be printed on paper forms and other artifacts for contextual access. Several different CamForms can be composed in a single application. Each can represent a distinct query or data entry action, one step in a sequence of actions (as in the case of a multi-page form), or even the result of a previous action. Result forms can include links to further content, or be constructed based on prior input. In short, CamForms provide a view of the current state and provide various interaction options with a distant server, not unlike a traditional web client.

CamForms are designed using standard word processing software. Barcodes are generated using a PHP script, and pasted into the forms manually. Eventually, I plan to implement an IDE that will support integrated authoring of CAM forms and applications.

4.1.3 Content

Figure 4.2 shows a CAM-enabled loan application designed for a microfinance institution. The barcode in the top right, when clicked, activates a function that displays a sequence of prompts for the user to enter each of the values from the form. A section of the code for this function is shown below. *input_date*, *conf_note*, *recordaudio* and *put* are all CAM API functions. A full list of API functions is given in Table 4.2.

```
<function name="7_click" params="param1">
if (!input_date(date, "dprompt.wav", "dprompt.bmp"))
    return false;
...
if (!conf_note("purpprompt.wav", "purpprompt.bmp"))
    return false;
recordaudio("data\".recordid."\purp.wav");
if (!conf_note("cprompt.wav", "cprompt.bmp"))
    return false;
put("mms","+12065551695","data\".recordid."\");
</function>
```

The prompts are displayed in sequence rather than laid out spatially like in a web-based entry form. Time-multiplexing is better suited to the small screen of the mobile device, where it is difficult to display or enter several pieces of information at one time. I call this *wizard interaction*, as it resembles the task wizards used for installing or configuring software applications. Users are guided step-wise through the process, reducing navigation requirements. This method avoids additional cognitive decision points, where the user has to

Figure 4.4: On the left, reviewing an entered value by focusing on a barcode. On the right, clicking brings up a prompt for editing the value. An audio prompt is also played.

pause after each action to decide what to do next (and how to do it). This pause can create unnecessary confusion for novice users. Instead, in CAM, users just choose a high-level task and then follow the prompts.

We have avoided using optical character recognition because of its high error rate and associated usability concerns. Users must manually transcribe all the CamForm data using the phone's alphanumeric keypad. In the future, I am considering adding simple recognition features, such as automatic population of checkboxes or selection ovals, and delegating some recognition tasks to more powerful upstream machines.

Figure 4.4 shows a CAM prompt in the regional Tamil language. However, at the time of my implementation, the mobile phone operating system did not support Tamil data entry or display. How did I achieve this miracle? Simple — the text is displayed as a bitmapped image, accompanied by a voice clip indicating the name of the field. In this way, every CAM prompt can be associated with arbitrary audio and graphics.

This increases the flexibility of the system, especially for dealing with unsupported scripts (a common problem) or illiterate users. Even if someone else is performing the task, an illiterate user can listen and hear the prompts as data is being entered [108]. The audio feedback contributes to the wizard metaphor — the interaction proceeds like a conversation between the user and the device. The device asks a question, and the user answers. When we tested CAM in rural India, users didn't even need to look at the screen before entering

Table 4.2: Functions provided by the CAM API. All prompts and messages can be accompanied by arbitrary audio and/or images.

input_int, *input_date*, *input_password*, *input_pin*, *input_phone_number*, *input_time*, *input_number*, *input_text*	Prompts asking the user to enter different kinds of values
record_audio, *take_picture*	Ask the user to record an audio clip, or take a picture of a form or other object
message_note, *conf_note*	Send a message to the user, or display a confirmation dialog
get, *put*	Retrieve or submit application data to the server using using http, sms or mms
encrypt, *decrypt*	Encrypt or decrypt application data with a specified key
sms, *mms*, *email*	Send arbitrary messages
phonecall, *browser*	Make a phone call or launch a web browser
log	Write a string to the application log

a value [110].

To address the problem of local language text input, I took several approaches. Most of the values to be entered from the form in figure 4.2 are numeric values. Instead of asking for the loan applicant's name or login, I rely on a numeric account number. The loan purpose is captured by recording an audio clip. I could have also prompted the user to capture an image of the entire form, or a specific entry field. If required, voice and image data can be transcribed later at the bank office, where a PC is available, by staff trained in local language keyboard input. The metadata allows us to index these multimedia files for later access.

After data has been entered, the user can review values before submitting them to the server. By focusing the mobile phone camera on the appropriate barcode, the currently entered data is displayed on the screen, usually next to the value entered on paper (see figure 4.4). This allows both the record keeper and the SHG member to confirm that data was entered properly (mimicking the transparency of the earlier paper-based process). By focusing on the loan purpose field, the recorded audio clip is played. If a value is incorrect, the user can capture an image of just that barcode, displaying a prompt to edit the value.

The implementation is the same as that for other functions. Each barcode is linked to separate *scan* and *click* callback functions. When scanned, the value returned by the scan callback is displayed. This is usually the value of the field. When clicked, a prompt is displayed to edit the value. Example scan and click callback functions are shown below.

```
<function name="1_scan">
return date;
</function>

<function name="1_click">
input_date(date, "dprompt.wav", "dprompt.bmp");
</function>
```

4.1.4 Networking

The first time CamBrowser encounters an application, it attempts to download the code and data from the specified server. The barcode or numeric string specifies the protocol to submit the request. Currently, the options are sending a HTTP request to a web server, or a SMS to a phone number. In the first case, the response is received immediately as XML over HTTP. In the second case, the application code and data is sent by the server as a MMS message with a SIS attachment [2]. Local applications can be pre-loaded over a bluetooth OBEX connection.

The SMS-based method supports offline use. The first time a disconnected phone tries to access an application, it is probably not locally available. So it creates a SMS request, which is cached in the phone's outgoing message queue. I have implemented a tool that

[2] A SIS file is a self-extracting installer for the Series 60 platform. I have not yet automated the server-side delivery of applications, so this currently requires the intervention of a human operator.

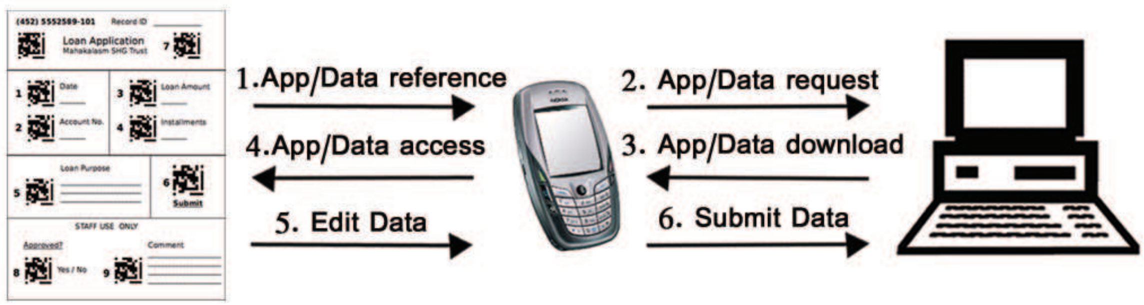


Figure 4.5: An example set of steps in accessing and using a CAM application. Except for steps 4-5, there can be arbitrary time and distance between each step, supporting an offline, asynchronous interaction model appropriate for rural areas.

allows messages from the queue to be sent when the phone enters a connected area. After the SMS is received by the server, it sends back the appropriate SIS file to the sender as a message attachment. The phone will download the message when it is connected. When the user opens the message, they will be guided to install the application in the proper location. The complete code for the application is cached on the phone for offline use. The next time the phone returns to the village, the application can be used.

Eventually, some applications may have to be flushed from the cache to make room for others. By implementing an intelligent caching scheme, we can ensure that the most frequently used applications are retained. This has not been a requirement thus far due to the small number of CAM applications that have been developed. All of these fit within the available flash memory of the phone (32 MB, expandable to 1 GB). The user can also manually request a flush of the local cache, or force a server refresh of a particular application. The CAM API also supports sending a refresh request to the server programmatically.

Application data can also be cached locally. Captured data values can be exported as delimited text, while recorded audio and images are stored as binary files. Data can be stored in a specific directory for each application. Multiple records can be cached using a unique numeric ID for each record instance. This record ID can be printed on a form (either as a numeric string or barcode), or automatically generated and displayed when first saving the data. The user can copy the generated ID back to the form for future reference (for example, in the top right of figure 4.2). Later, the user can review or edit previously entered records by entering the right ID or barcode.

The phone's memory serves as a local cache of the data stored on the server. The application can programmatically copy the data for any directory from the phone to the server, and vice versa. This is accomplished using the *get* and *put* functions. For a *put*, the application sends data either as a HTTP POST request, as an attachment to a MMS message, or as an OBEX file transfer over a bluetooth connection (not yet implemented). Once again, the MMS message is cached in the outgoing queue until a connection is available. The application is responsible for choosing the right protocol based on its requirements, the configuration of the server and the available connections.

The *get* function works in a similar way, using HTTP, SMS or bluetooth (again, bluetooth is not yet implemented). In the former case, a HTTP GET request is sent to the specified server, with an optional set of parameters. The response is sent as a XML message. SMS can again work in an offline fashion. The request is cached in the outgoing message queue until the phone is connected. The response is sent as a SIS file attached to an MMS message [3]. If a *get* is issued in an offline environment, the requested data will be downloaded and cached by the next time the phone returns to the village.

Trying to access an application that is not cached on the phone generates an implicit *get* request for the application directory. Similarly, if the user is trying to access a record directory that is not cached, a *get* request for the record sub-directory can be issued. In this way, users can request data for a specific set of records without the phone having any prior knowledge of the application. Given the high latency of the village roundtrip, it is important to capture as many data requests as possible up front.

The server-side functionality can be implemented in a variety of ways. It can be a standard web application backed up by a database, or it can be a simple filestore. The server can receive and process SMS and MMS messages via an attached phone with its own phone number. The server-side application is responsible for maintaining coherency and ordering conflicting messages in a logical way.

[3] Due to security restrictions on the phone, this requires a slightly awkward workaround.

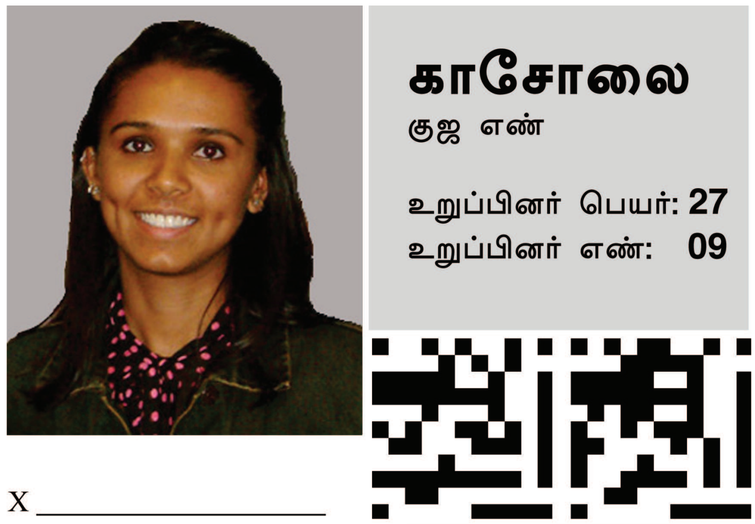


Figure 4.6: A hypothetical CAM ID.

4.1.5 Security

The CAM architecture's distributed nature makes security an important concern. The CAM API provides instructions for performing encryption and decryption. Application developers can use these instructions to create secure and/or signed communications channels between a CamForm client and the server.

Keys can be embedded as barcodes either directly in CamForms or within special CAM IDs. These can remain with the end user, precluding others from accessing the data without it. Later, when the user wants to access the data again, they can provide the associated decryption key to the CamBrowser application. A password or PIN provides additional safeguards.

Usability concerns in maintaining system security have recently received attention in the literature [170]. Remembered tokens such as passwords and PINs have come under fire as being inflexible and insecure. On the other hand, humans have a long history of trust practices built around exchanging physical tokens (for example, money). Physical keys, as implemented in CAM, are a better solution for rural areas because:

- They carry more information. Most rural users are unlikely to remember long or unfamiliar combinations of letters, making their remembered passwords vulnerable to attack. Physical tokens can carry much more data and would be easier to replace if compromised.

- Users can enter them securely. Rural users are unlikely to have the capacity or unfettered access to enter a conventional password or PIN without others observing it.
- Users can explicitly share and distribute them. Physical, paper-based tokens can have an arbitrary duplication cost, so users can distribute, lend, or share them with fixed risk.

The notion of uniting physical and information security isn't novel. Magnetic stripe cards, smartcards, and radio frequency identification tags (RFIDs) all take this approach. CAM IDs stake a middle ground between these alternatives and the remembered token schemes popular on the Internet.

While they're not as hard to duplicate as other physical approaches, they would require an explicit and protracted action to forge or steal in a village. In rural areas, a printer or photocopier might be hours to days away. At the same time, the production cost isn't completely out of reach for the community. This allows the community to potentially create and issue IDs, in contrast to smart cards and RFIDs, which require external manufacture and administration. Several rural microfinance institutions have found it difficult to provide affordable smartcards to clients [169]. Decoding watermarked documents using the mobile camera could make the CAM approach almost as secure [93].

Researchers have shown that most secure information isn't kept private, but is shared within a circle of people who have some temporal trust relationship [3]. This is even more true in the family-based but tumultuous environment of a rural village. With CAM IDs, village users can easily experiment with different security schemes.

Public, private, and shared one-time keys can all be encoded as barcodes. These can be used to create PGP-like secure communication channels between independent parties or to provide one-time secure channels between a user and a service provider. Because security tokens can be exchanged physically through readily available "back-channels," we avoid using a centralized public key infrastructure (PKI), that plagues other public key implementations.

End-User Trust

Trust was another important consideration in the CAM user interface design. In most cases, CamForm users won't have direct access to a mobile phone and will therefore have to rely on local phone-equipped agents to capture and transmit their data. Because of the mobile phone's size, it is difficult for these users to ensure that the information entered in the CamBrowser matches the values they've provided on the form. There are several ways to address this issue:

- The system can transmit the form's scanned image to the CamServer to provide an online digital representation of the form as the user entered it.
- Users can retain the physical CamForms as a record of their transactions.
- The service provider can send a printed summary to the user acknowledging receipt of the transaction and its content.
- The agent can review the entered values with the user by scanning the appropriate barcodes (see figure 4.4).
- Text-to-speech, while not yet implemented, would let users hear the data as it is being entered.

System implementers can choose any of the methods outlined above to ensure user trust in their application.

4.2 An Example Application

To better illustrate the actual operation of a CAM application, I describe a hypothetical microfinance loan application scenario in more detail. Prospective bank clients fill out CamForm loan applications at their leisure. These applications may have been obtained at the bank branch, or distributed by a bank field agent. If they are illiterate, a literate friend or family member can help them. The loan application includes fields for the client's current account number, the desired loan amount, term, and the loan purpose. The loan purpose is a summary of the client's reason for requesting the loan (buy livestock, start a small business, pay for health bills, etc.).

The next time the field agent comes to the village, she transcribes the loan application using her bank-issued mobile phone. First she captures the application ID, which loads the appropriate CAM application. It is likely that the application is already cached on her phone (if not, it will be the next time she comes). The agent captures the barcode in the top-right. Guided by the prompts, she enters the account number, the desired loan amount, the loan term and captures an audio clip of the client describing the intended purpose of the loan.

The client listens to the audio prompts to follow in the process. If she wants to verify that the data has been entered correctly, she can ask the agent to focus the camera on each of the fields to display the entered values. Once they are both satisfied, the agent captures the 'Submit' barcode to generate a MMS message. The message contains a XML file with the entered data, and an audio recording of the loan purpose. This MMS file is cached in the outgoing message queue. It will be sent when the field agent travels on the highway (a connected area) on her way to the next village. The client keeps the paper form for her own records.

At the office, the manager reviews his incoming messages and sees the new loan applications. Based on the purpose of the loan, and the clients' past credit history, he decides which loans should be issued. He uses a web-based interface to enter the corresponding approvals in the database. These decisions are automatically packaged and sent to the field agent's phone as a MMS message.

When the agent opens the message, new XML files are placed in the directory corresponding to each form instance. By reviewing the 'Accepted' field on each form, both the field agent and the client know which have been approved. The clients whose loans have been approved are asked to come to the bank branch to collect their money. For those that were denied, the bank manager includes an audio or textual comment indicating the reason. A summary can be hand copied to the paper form for later reference. The whole loan approval process has been accomplished without the field agent ever returning to the distant bank office.

4.3 Advantages of CAM for Rural Computing

In this section I outline some of the advantages of the CAM platform for developing rural computing applications.

- **Easy to Use** — CAM interaction is based on a simple one-step primitive that does not require knowledge of extended metaphors. Learning to use an application is as easy as taking pictures of barcodes, or entering numeric strings, and then following the prompts. The limitations of the smaller display and a numeric keypad dovetail nicely with this approach.

- **Easy to Document** — This understanding is easily conveyed from person to person, without training or user manuals. In my testing, users explained the system to each other without any intervention. Being able to convey knowledge of how to use the system by word of mouth will allow CAM applications to scale virally and increase their impact correspondingly.

- **Tied to Paper Forms** — By linking CAM interaction to forms, the process becomes more familiar to users accustomed to paper-based tasks. Preliminary data entry can be done completely offline, without access to a phone. Query results can be sent as printed, possibly interactive, reports. Given that one phone will probably be used for many tasks in many villages, this maximizes the efficient use of available time and resources. When the phone is available, data entry and review is done in the direct context of the paper form, reducing errors and increasing the trust of village users.

- **Localized without OS support** — Using multimedia input and output, a paper-based UI and a numeric index to applications and data, CAM applications can be localized even without OS-level support for the target language. Given the tremendous variety of languages and scripts in the developing world, and the difficulty of developing applications for languages not supported by the OS, this removes a tremendous practical obstacle to application development.

- **Easy To Distribute** — Because most people will not have their own dedicated device, distributing electronic references to applications and data to individuals is not feasible. By referring to applications and data using paper forms and numeric strings, they can be distributed via both person-to-person and paper-based channels. These can be exchanged without access to a device or any electronic technology.

- **Can be used Offline** — CAM applications can be used without an active network connection. While this increases the latency of information exchange, it is still much better than having to make a trip to the city for each task individually. In fact, by sending messages asynchronously, *unexpected latency* is reduced (a common frustration in using mobile data services is the time required for establishing a connection). Users can also perform preliminary data entry on paper forms without any technology, providing another level of offline access.

- **Easy to Bootstrap** — Due to the demand for voice communications, a mobile phone is much easier to introduce to rural areas than a more expensive and less immediately useful PC. Service providers can generate an initial revenue stream by offering calling services [47]. Later, other applications can be bootstrapped as demand increases and network effects set in.

Chapter 5

RELATED WORK

The CAM system draws upon prior research in three areas: mobile user interfaces, paper user interfaces and system design for rural computing applications.

5.1 Mobile UIs

Many researchers have looked at the problem of interacting with content and applications given the limited display and input capability of mobile devices. Most of the early work in this area used a proxy server to adapt and optimize web pages for presentation on a mobile device [14, 65, 41, 16, 22, 135]. One common optimization has been the decomposition of web pages into smaller fragments, indexed by keyword extraction and/or text summarization [16, 173, 10, 77]. Another approach has been the flattening of web structure through link and form field extraction [22, 135, 67]. A recurrent problem for this technique has been finding effective naming heuristics for links and form fields.

Brewster demonstrated that non-speech audio could improve the usability of small buttons on PDAs and other mobile devices [20]. The Satchel project used lightweight electronic tokens to work with and share documents, reducing bandwidth and storage requirements on the mobile device [79]. Pascoe et al. designed a PDA application for mobile fieldworkers studying giraffes in Kenya. They observed that displaying prompts in sequence made the interface easier to use if the user was moving or occupied by another task [113].

The Wireless Application Protocol (WAP) is a specification used to develop custom web content for mobile devices [136]. Researchers have found WAP applications difficult to use, with the protocol being referred to as a "a temporary aberration that delivers substandard services" [21]. More recently, XHTML has become the standard representation for both desktop and mobile web applications. With XHTML, researchers found a tension between long pages that require excessive scrolling, and sequences of short pages resulting in several high latency downloads [66].

Because there is a negligible legacy content or application base in the rural developing world, CAM is not constrained by the limitations of current platforms or protocols. Instead of using menus, CAM applications are navigated with barcodes and numbers. Rather than optimize spatial layout of pages, CAM displays prompts in sequence to reduce screen requirements and user decisions. Instead of being written declaratively, CAM applications are scripted, generating sequences of actions. To support offline use, the entire application is downloaded at once, rather than page-by-page. CAM also takes full advantage of the mobile phone's multimedia input and output capabilities.

SMS-based services are becoming very popular, particularly in Europe, Asia and Africa. As mentioned earlier, SMS is being used in some countries as a way to perform microfinance transactions, including money transfer [101]. CAM provides an interactive, multimedia client on top of an underlying SMS-based transport layer, allowing the user to perform more structured queries and data entry actions, and leveraging the ability to capture and transfer audio and images.

In a different sense, CAM is similar to an Interactive Voice Response (IVR) system [154]. In an IVR system, an online system asks the user a number of questions that he responds to by selecting a numeric option or providing a voice response. While IVR is implemented with an active voice connection, CAM applications can work offline. CAM also takes full advantage of the mobile phone's screen and other UI features. Researchers have found the combination of IVR with a visual display to be beneficial for usability [126, 176].

5.2 Paper UIs

Paper is a cheap, accessible and flexible information medium. It provides a large display and interaction space at very low cost. Several researchers have commented on the importance of paper in workplace settings [139, 83]. However, paper is notoriously inefficient in other ways. It cannot easily be searched, indexed or archived. This has driven a rich tradition of research that seeks to improve the coordination between paper and digital media and combine their benefits.

The DigitalDesk was an *augmented reality* system, using a camera to track physical document position, identity and user input, and a projector to display digital content overlaid on a physical desktop [167]. XAX pioneered the idea of a *paper user interface* to document services [64]. Users could trigger actions by making entries on a paper-based form. The form was identified by scanning and decoding a printed *registration mark*, allowing the system to interpret the underlying content. The Paper PDA was a similar system, that introduced the notion of linking between individual paper resources, and synchronizing between paper and digital content [54].

Want et al. were the first to use *electronic tags* (in their case, RFID) to link physical locations to digital actions [166]. The FieldMouse extended this with position input, using a pen-mouse attached to a barcode reader [144]. Navicam could display database-driven content linked to barcodes detected from a real-time camera image [124]. Cybercode was the first system to recognize 2D barcodes from a low-resolution image taken by a mobile camera [123]. This allowed a mobile device to determine its orientation and position relative to a printed barcode to overlay graphical menus on physical objects. Dataglyphs allow embedding data in physical images, recognizable from high-resolution images. [53]

The Audio Notebook indexed audio lecture recordings relative to notes made simultaneously in a paper notebook, by using a digitizing tablet and microphone [152]. The Listen Reader played an audio soundtrack when users turned storybook pages tagged with RFIDs [8]. Palette allowed users to cue presentation slides using cards tagged with barcodes [100]. Books with Voices used a PDA equipped with a barcode reader to link recordings of oral histories directly to their paper transcripts [72]. Paper++ provided a platform for linking barcodes to various kinds of data objects [102]. The A-book digitized writing on paper using a graphics tablet [84]. Based on the earlier idea of a transparent user interface [15], in this system a mobile device tracked by a 4d mouse was used to transparently overlay digital content and functions on top of the paper representation. The Cooltown project used RFID, barcodes and other sensing technologies to retrieve context-specific HTML documents on a PDA [71]. Users navigated to web pages in a standard browser, with sensed objects being sent as form parameters. This allowed different service providers to bind the same ID (such as a product barcode) to independent services.

With the increased availability and programmability of camera-equipped mobile phones, these are becoming the standard device for such experiments. Several systems have allowed embedding URLs and other kinds of digital content in 2D barcodes printed on signs, posters and documents [140]. The Mobile Server Toolkit (MST) is a visual tag-based system that allows mobile devices to access site-specific information services [157]. By determining the position and orientation of the camera relative to visual tags, the tags can function as interactive widgets. The MST transmits UI events to an application running on a nearby bluetooth-connected server. The visual code widget library developed by Rohs provides a declarative UI specification linking visual codes to a rich set of data entry widgets, including physical menus, checkboxes, radio buttons, free form text input, dials, sliders and buttons [127]. Rohs also documents a conceptual framework for visual code interaction, including actions like pointing, tilting, rotating and panning [129]. McCune et al. proposed using visual codes for exchanging trusted public keys between mobile devices [90].

Several paper UIs have been built using the Anoto digital pen technology [6]. Anoto paper is printed with a faint pattern indicating both the sheet ID and the location on the page. Strokes can be captured and recognized by using a camera-equipped digital pen that decodes this pattern while writing. Based on the Anoto technology, Guimbretière et al. developed Paper-Augmented Digital Documents (PADD), where hand-written notes are synchronized between paper and digital versions [51]. ButterflyNet used PADDs to link field biologists' notebooks with other rich media annotations [175]. Belotti et al. developed an Anoto-based platform for rapid prototyping of multi-channel, multi-modal, context-aware, paper-based applications [11]. These systems require the additional expense of a digital pen that must be used to enter data. Also, the paper required by the Anoto system can not be printed using a standard printer, and has been expensive and difficult to acquire otherwise.

5.3 Systems for Rural Computing

As discussed in an chapter 2, several microfinance institutions have pilot-tested electronic data collection using PDAs or handheld computers[106, 61]. Financial transactions in Africa are already being conducted using SMS [101, 24]. The TeNeT group at IIT-Madras has developed a low-cost rural ATM with fingerprint identification [130]. Hewlett Packard developed the Remote Transaction System (RTS), consisting of a receipt printer, a smartcard reader and a POS device with a GSM modem [169]. Three of the main problems this system faced were that 1) the system was not flexible enough for adapting to different business processes, 2) the time for a meeting was increased by up to an hour, and 3) the system did not work well with organizations' existing back-office solutions[68]. Being a programmable system linked to paper formats, CAM is meant to complement existing processes, not replace them. As opposed to smartcards, paper receipts are a more accessible client record that can directly be referenced.

There have been several efforts to develop tools for health data collection and epidemic reporting using PDAs and other handheld devices [37, 29, 116]. However, thus farnone of these have supported multimedia input and output, and integration with paper-based practices. Grisedale et al. designed a mobile data collection application for uneducated auxiliary nurse midwives (ANMs) in rural India [49]. Their interface was designed for an Apple Newton, and relied on an iconic graphical language. Blake also used icons in the design of a field computer for semi-literate animal trackers in Africa, and noted the difficulty of hierarchical navigation [17]. The HomeBox provides a tangible interface to web publishing for developing world users. Users could put pictures and other other content into physical drawers, from where they were scanned and posted to personalized web locations [118]. Goetz and Strothotte proposed automatically generating embedded pictures on web pages as graphical reading aids for illiterate users [45]. Huenerfauth provided a set of design guidelines for illiterate users, focusing on speech-based techniques [57]. The latter three projects were not informed by or tested with actual users.

Several researchers have discussed the challenges and opportunities of conducting computing research in the developing world [33, 19, 150, 111]. The Simputer was an early attempt to develop an affordable, usable and useful device for rural, developing world users [146]. The One Laptop Per Child (OLPC) project is a more recent and ambitious effort along the same lines, with a focus on education.

Researchers have also proposed store-and-forward networks based on transport of physical media as a high-bandwidth, high-latency communications alternative for remote rural areas [117, 165, 19]. Our work is orthogonal to these efforts. We propose an end-to-end mobile information service architecture that can utilize both lower cost devices and improved asynchronous networking protocols.

TEK is a web-based asynchronous search engine that works over email [156]. Queries are sent to a proxy server, which collects and formats results and then returns them for offline viewing. The Digital Study Hall project combines a TV display, an online content repository and physical data transport (using the postal system) to provide high-quality educational content to rural schools in India [164]. CAM addresses very different application requirements. In particular, CAM is used for mobile data collection, rather then PC-based web searching or TV-based video browsing. CAM would provide a flexible input and content generation mechanism for either of these systems.

Chapter 6

USABILITY EVALUATION FOR MICROFINANCE

In this section I present a usability evaluation of a CAM-based interface for collecting and processing data from SHGs. The results will help us determine whether CAM meets the performance, accuracy and accessibility requirements for this application. I also compare the CAM interface to web-based data entry on a PC. While I do not expect CAM to be more efficient (given the smaller display and buttons), we can determine whether it is a viable alternative given the phone's other advantages in cost, utility and portability.

The quantitative experiment consisted of a set of timed user trials measuring the speed and accuracy of data entry using CAM. Ease of learning and recall were assessed by repeating the experiment over a period of four days, followed by another test five to twelve days later. Qualitative data was collected on the basis of self-report questionnaires, spot polls, informal feedback, and direct observation. This study was conducted with the support and assistance of staff from ekgaon technologies, HFI, CCD and Microsoft Research India[110].

6.1 Experimental Setup

6.1.1 Application Background

In the pilot scenario, field staff were equipped with a mobile phone to record member-level transactions. These field staff work with the same SHG Federation described in chapter 3. CamForms representing different kinds of transactions were printed in bulk and physically distributed. Transactions are entered on the phone using the CamBrowser application, at the time of the meeting, or afterward from the paper records. This data is posted to an on-line server via an SMS message. Less common documentation requiring textual data entry or human verification (such as registering a new group or member) are faxed to a central office, where the data is entered by a trained local language data entry operator. These faxes can either be sent from a field office, or from a fax shop, common even in smaller

Figure 6.1: Helping users learn how to use CAM.

towns. Users can even use the mobile phone camera to transfer these documents.

The resulting reports and financial statements are printed from a secure access point, or faxed from the Federation head office to the field office, where they are picked up by the group or delivered by the staff. Reports can contain interactive CAM content, for example, for accessing up-to-date account balances. These reports are filed in a set of folders, taking the place of the shared notebooks. They are used by the group for monitoring their portfolio and applying for loans and other services. Paper remains the main display and storage medium for SHGs and their members.

6.1.2 User Group

The subjects in our user study were staff from two Federation field offices that are participating in the pilot. All of the subjects were educated rural women from the Indian state of Tamil Nadu. In the Pulvoikarai field office, the education ranged from 8th to 12th grade completion, with an average of 9.7 years of education. In the Natham field office, the women averaged 11.9 years of education. A group of Computer Science graduate students were tested in Seattle, WA as a benchmark for experienced technology users.

Table 6.1: Basic demographics for each of the user groups.

Group	Users	Avg Age	Avg Educ.	M	F
Pulvoikarai	6	27.8	9.7	0	6
Natham	8	22.4	11.9	0	8
Seattle	9	26.6	18+	5	4

While all of the Tamil Nadu users were literate and could perform arithmetic, they had very little technology exposure. Some had participated in our earlier experiments [109]. In Natham, a few had been using drawing applications on a recently purchased office computer. This had conferred the important skill of using the mouse. In Pulvoikarai only one of the women had previous PC experience. All had used phones before, either mobile or landline. All of the staff used calculators for their current accounting tasks.

6.1.3 Task Description

The task I evaluated was recording the payments made by one group member during a meeting. Following accounting convention, this transaction was recorded as a group *receipt*. The receipt included input fields (and barcodes) for the Date, Member ID, Savings, Interest and Principal Repayment amounts. The Total was auto-calculated and displayed upon scanning the appropriate barcode. Buttons were included for submitting or reloading the data from the database or for voiding the transaction.

We measured the execution time and error rate for entering and submitting four receipts in sequence. The paper receipts were pre-populated with written values for each field. The user had to capture an image of the form including each of the fields — either together or in sequence. Each barcode brought up a prompt to enter the value of the field. The prompts were displayed in Tamil (as a bitmap since the phone did not have a Tamil font

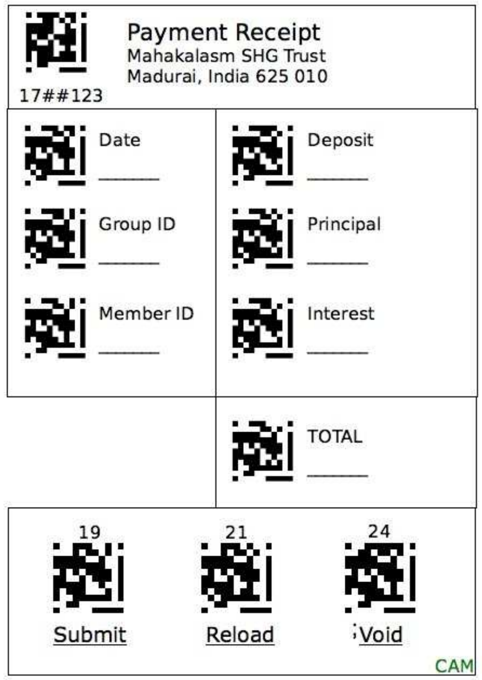


Figure 6.2: An English version of the receipt format used in the testing.

installed), accompanied by Tamil audio indicating the name of the field. The data entry was all numeric (member identity was recorded as a numeric ID). After entering all the values, the user captured the 'Submit' code to post the transaction to the web server. For the purpose of this experiment, the web server was running on a laptop connected to the phone via a bluetooth serial connection.

The use of the application was explained and demonstrated to each of the users on the first day, after which they were given up to ten minutes to practice. On subsequent days the practice period was limited to 2-3 practice trials. After the task, the data on the server was reviewed to determine if there had been any errors. Each database value different from what was written on the paper form was considered an error. Execution time was measured by an observer with a stopwatch, from when the user focused the phone camera on the form until the data for the fourth receipt had been received by the server.

To compare these results to PC-based data entry, each user performed the same task

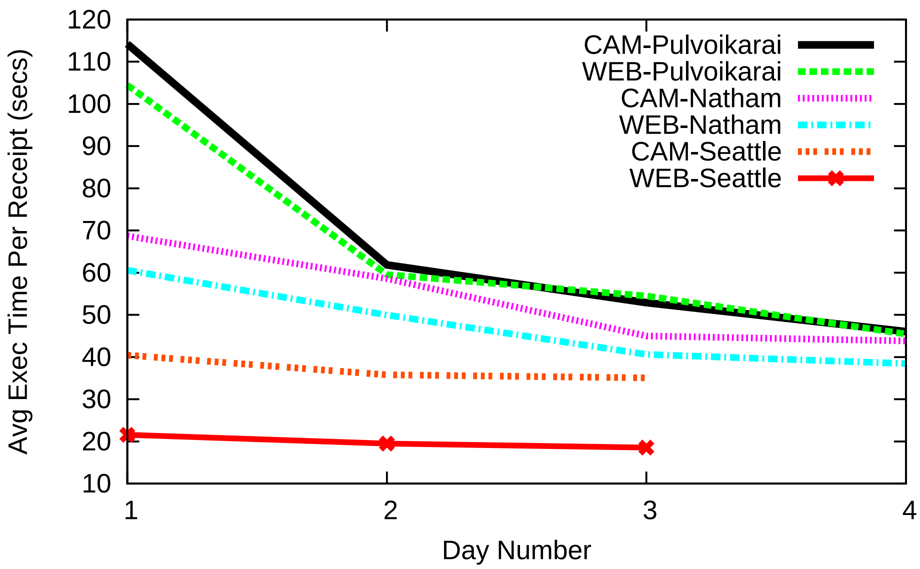


Figure 6.3: Graph showing average execution time (per receipt) on each day for the basic variations. CAM performance is comparable to the WEB for Tamil Nadu users. The standard deviation was high on the first day, especially in Pulvoikarai (73 sec. for CAM, 72 for WEB), but then stabilized (7-11 sec. by the last day for all conditions).

using a similarly designed web form. This test was conducted using a Sony Vaio laptop with an attached USB mouse. The same receipts and written values were used. The user had to enter one more three-digit value — the sequence number of the particular receipt instance (embedded within a barcode for the CAM version). When the user submitted the form, the data was posted to a server running on the same laptop. The order of the two variations was counter-balanced and randomized. The test was repeated each day for four days (three for the Seattle users).

6.2 Results

6.2.1 Efficiency and Learnability

Figure 6.3 shows that CAM was learned effectively by all user groups within a three day period. In Pulvoikarai, CAM performed equally well to the Web alternative. In Natham, CAM performed only slightly worse (averaging 10% to 12% slower). In neither case was the last day's difference statistically significant. In contrast, the Seattle users performed the task much faster with the Web variation ($p<0.001$). Partly this was because they used the Tab key to switch between form fields and pressed Return to activate the 'Submit' button. The Tamil Nadu users were not aware of these shortcuts.

This was significant, as some of them had difficulty using the mouse and the mobile phone camera as targeting devices. They often had trouble quickly accessing the desired field. Shortcuts like the Tab key can speed up data entry when the random access functionality of a general purpose interface is not needed. I introduced a similar shortcut to the CAM receipt, in the form of a barcode button linked to a function that iterated through all of the required data entry prompts and actions. This optimized for the common case when the user wants to enter the data for the form and submit as fast as possible.

We developed another variation where the phone was placed in a cradle on top of a wooden box, with the camera looking through a hole at the document inside (see figure 6.5). This was a prototype of a kiosk or ATM version of the application, where the mobile phone is part of a larger installation with the capacity to store receipts and money. From a usability perspective, this further reduced the motor control problem, by placing the paper at a fixed distance from the camera, and removing the phone from the user's potentially unsteady hand. A holder for a flashlight was included inside the box to improve the clarity of the captured image.

With the Natham user group, we tested all three of the new variations (Web, after telling users to use the TAB key; CAM, after introduction of the shortcut CODE; and CAM, using both the shortcut code and the BOX), at the same time as the earlier protocol, counter-balanced and randomized with the earlier variations. The results are shown in figure 6.4.

All of the shortcuts led to improvements in average execution time - both first and last day performance were significantly improved for the CODE and BOX variations ($p<0.005$). The variance was also reduced. The first day standard deviation was 4.6 seconds for the BOX variation, 6.9 seconds for the CODE variation and 14.9 seconds for the regular CAM variation. By the fourth day these were reduced to 2.4 seconds for both the CODE and BOX, and 7.2 seconds for CAM. The last day average was between 32 and 33 seconds per receipt for all three new variations.

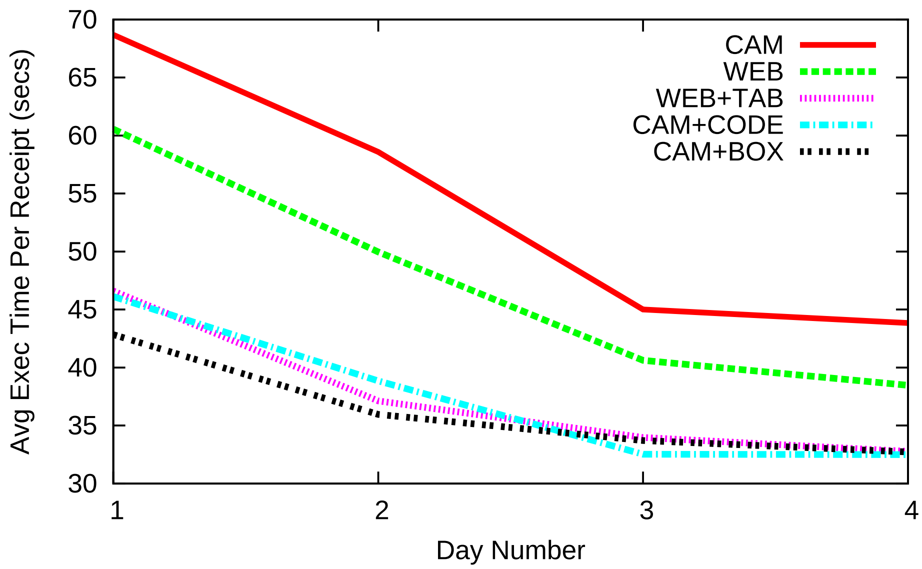


Figure 6.4: Graph showing average execution time (per receipt) for all variations conducted with the Natham group. The new variations improved efficiency and speed of learning. Standard deviations were reduced for the BOX and CODE conditions, starting at 5-7 sec. and reaching 2 sec. by the last day.

To show that these improvements were applicable to the Pulvoikarai group, we tested these variations on the fourth day of their protocol. They averaged 36 seconds for the CODE variation, 39 seconds for the BOX and 42 seconds for the web using the TAB key. Again, the shortcut code was a significant improvement over the basic CAM variation ($p<0.05$).

6.2.2 Error Rate

On each receipt a total of five values were entered — the Date, the Member ID, the Savings amount and the Interest and Principal repayments. The error rate was defined as the percentage of these values stored in the database that did not match the value written on the receipt. As Table 6.2 shows, the observed error rates were 1% or below for each of the conditions. The two Tamil Nadu groups made more errors than their Seattle counterparts.

Table 6.2: Error rate of the variations.

Group	Variation	Error Rate
Pul	CAM	0.5%
Pul	WEB	0.6%
Nat	CAM	1.0%
Nat	WEB	0.6%
Nat	WEB-TAB	0.8%
Nat	CAM-CODE	0.6%
Nat	CAM-BOX	0.6%
Sea	CAM	0.0%
Sea	WEB	0.1%

6.2.3 Memorizability

To evaluate the memorizability of this interface, a follow-up test was conducted five to twelve days later without intervening use of either application. Table 6.3 shows that except for the Pulvoikarai group, the difference between the last test in the first set of trials (day 3 or 4) and the repetition test (5-12 days later) was less than 5% for all conditions. In Pulvoikarai the effect could have been increased due to the longer time interval, but even there the difference was not extreme.

6.2.4 Qualitative Survey

On the last day of the protocol users were asked to complete a short survey asking them to rate on a 1-5 Likert scale (5 being very easy) how easy it was to perform various actions using each interface. From the results in Table 6.4, it is clear that both the CAM and WEB interfaces were considered easy to master by almost all users. Nobody found either interface difficult or very difficult.

Table 6.3: Memorizability of the variations.

Group	Variation	Last	Repetition	Interval
Pul	CAM	46 sec.	49 sec.	12 days
Pul	WEB	45 sec.	52 sec.	12 days
Nat	CAM	44 sec.	42 sec.	8 days
Nat	WEB	38 sec.	38 sec.	8 days
Nat	WEB-TAB	33 sec.	33 sec.	8 days
Nat	CAM-CODE	33 sec.	34 sec.	8 days
Nat	CAM-BOX	33 sec.	34 sec.	8 days
Sea	CAM	35 sec.	37 sec.	5 days
Sea	WEB	19 sec.	18 sec.	5 days

6.2.5 Other Tests

We conducted the following experiments after completion of the basic protocols described thus far.

Audio

To assess the importance of the voice prompts, we tested versions of the CAM interface without audio (text-only), without text (audio-only), and with both text and audio (normal). This experiment was conducted with 13 users from the Pulvoikarai and Natham groups. The order of the variations was counter-balanced and randomized. The shortcut code was included.

The text-only variation was slightly faster on average, maybe because users did not always wait for the voice prompt before entering a value, but the difference was not statistically significant. In fact, users unanimously preferred the audio accompaniment — some users even mentioned that the text was not necessary. The removal of audio was disconcerting, particularly after five days of using CAM with audio. This is reflected in the higher error rate for the text-only condition.

Table 6.4: Number of respondents rating ease of use of each interface on a 1-5 Likert scale. None found either interface difficult or very difficult.

Group	Variation	Very Easy	Easy	Medium
Pulvoikarai	CAM	6	0	0
Natham	CAM	2	6	0
Seattle	CAM	5	3	1
	TOTAL	13	9	1
Pulvoikarai	WEB	6	0	0
Natham	WEB	5	3	0
Seattle	WEB	9	0	0
	TOTAL	20	3	0

Table 6.5: Execution times and error rates for the audio variations.

Variation	Exec. Time	Error Rate
Audio-only	32 sec.	0.0%
Text-only	29 sec.	2.2%
Audio and Text	32 sec.	0.0%

Numeric Indexing

We tested numeric indexing using a prompt that asked the user to enter the form ID and instance ID directly. This would trigger the correct interaction sequence for each form. We tested this variation with the Pulvoikarai users. The users were asked to enter a 2-digit value for the form ID, and then a 6-digit value for the sequence number of the particular form instance (embedded earlier in one of the barcodes). These values were printed on the receipt for ready reference. The results are shown in Table 6.6.

The additional data entry had a significant impact on the execution time ($p<.001$). The impact would have been greater if we had asked users to enter a URL or file name to access the correct form. As most of the programmable smart phones that run the CamBrowser application have a built-in camera, at present there is no reason to consider this alternative. However, in the future, this technique could be used for smart phones that do not have a camera. Entering a numeric ID is more convenient on a phone than a textual URL or traversing a deeply nested menu structure. Designers at Nokia have cited inflation of menu items as a prime usability concern when adding features to mobile devices [81].

Table 6.6: Comparing use of CAM with and without the camera.

Variation	Avg. Exec. Time	Error Rate
CAM w/ Camera	35 sec.	0.0%
CAM w/o Camera	49 sec.	0.0%

Mobile Web Browser

With the Seattle group, we also tested the same task by asking users to fill out a web form using the Opera browser on a mobile phone. This browser implementation had several significant usability defects that I will not detail here. Users averaged 61 seconds per receipt, almost twice the average time for the CAM variation and four times the average for the PC browser. Due to poor performance and negative user feedback, I decided that it would not be fruitful to test this variation with the Tamil Nadu users.

6.2.6 Other Observations

Motor Skills

Fine motor control was a consistent problem for the Tamil Nadu users, particularly for the older and less educated. This problem manifested in several ways. Using the mouse, when users had positioned the pointer they often changed their hand position to deliberately press the button, in the process shifting the mouse out of the intended focus area. Using the camera was a completely new experience for this user group. It took them time to understand the correlation between shifting the camera position and the change in the scene observed through the viewfinder. Finding the correct focal distance between the

Figure 6.5: The BOX variation was a major improvement for users that had trouble with fine motor control. It fixed the paper document at the correct distance from the camera and stabilized the phone.

camera and the paper document was also a problem, even for some Seattle users. It was difficult to hold the camera steady while pressing the joystick button, leading to the image being captured out of focus. I also noticed some Tamil users' hands shaking when using the mouse or phone. I attributed this to their nervousness at being tested and in using a device that they considered expensive.

For those users that had extreme difficulty in using the camera and keeping their hand steady at the correct focal distance, the BOX variation was a major improvement. The box fixed the paper document at the correct distance from the camera, and allowed the user to keep the phone in a stable location when pressing the button. After using the box, one of the Tamil Nadu users exclaimed "The box is GREAT! Now I can use the system with confidence!". I believe this led to improved performance overall. I also note the benefits gained by removing actions requiring extra motor coordination and/or explicit decision points. By *guiding* the user through the interaction sequence, accompanied by audio feedback, the task becomes a dialog between the user and the machine that is natural to execute.

Phone Buttons

Users had difficulty pressing the buttons on the phone interface. The small size and physical closeness of the buttons sometimes led to incorrect key presses. Identifying the purpose of some buttons was also a problem. All test subjects could easily recognize the 12 keys on the numeric keypad. However, the six soft keys and the four-way directional joystick were unintelligible. Users had difficulty looking at the device screen and correlating a label listed there with a button on the phone body. In some cases this label conflicted with the labels printed on other buttons (for example, when the two soft-keys to the right and left of the joystick were labeled with 'OK' and 'Cancel', they conflicted with the green and red keys adjacent). It was confusing for users to decide which key to press. We reinforced that they needed to be concerned with only three soft-keys - the joystick button to take an image, and the OK and Cancel buttons to confirm or cancel an entry. Eventually some users learned that the OK key could also be pressed to capture an image, meaning that they could perform the entire task using only one soft-key.

Lighting

The system worked best in natural or diffuse lighting conditions. When the light came from an overhead point source, the mobile phone cast a shadow that made it difficult to decode visual codes from the captured image. This could be rectified by adding a flash. When using the BOX variation at night we attached a flashlight inside the box to ensure proper lighting of the document.

Group vs. Individual Use

All of the tests described thus far were conducted in the NGO or Federation field office. This is far from a typical laboratory setting. Other field staff, SHG members and passers-by

Figure 6.6: In situ testing. The Federation field staff is capturing SHG records while the members watch.

were commonly present. Unrequested guidance, cajoling and sometimes even intervention were difficult to avoid. In another experiment, I found that users performed significantly better when allowed to complete tasks in relative isolation[108].

6.2.7 In Situ Testing

Following the success of our laboratory study, we decided to simulate CAM data entry in situ. We traveled with Federation field staff to five separate SHG meetings. Four out of the five staff we accompanied were users that had participated in the laboratory experiment. After the normal meeting and documentation was completed, we measured the time it took to capture the same meeting records using CAM, and the number of errors that were made. We used either the CODE or BOX variation of CAM, as per the user's preference.

All the meetings consisted of between 13 to 21 members, and took between 6 to 8 minutes to capture using CAM. Given that the length of a normal meeting averaged between 60 to 90 minutes, this was only a fraction of the overall time. Moreover, several of the conventional records and ledgers could now be automatically generated. Even considering the time of physically conducting transactions, one field staff estimated that using CAM the average length of an SHG meeting could be shortened from 90 to 45 minutes. Amazingly, all five meetings were also recorded without error. This gave us confidence that the system was ready for a real deployment.

Acceptance by SHG Members

Testing CAM in situ also gave us an opportunity to evaluate CAM for another important class of user — SHG members. During the pilot SHG members will not capture their own transactions, but are *secondary users* in the documentation process[108]. Such *intermediated information tasks* are common in the developing world, where access to technology is limited due to cost and educational constraints. We wanted to understand the members' appreciation of CAM interaction, and whether they would accept this new technology.

First, we explained the purpose of the new process to the members, and what would be the resulting benefits for the group. Then, after the CAM data collection, we conducted an informal qualitative interview with the group as a whole. Most aspects of the interaction were not intelligible to the SHG members as they could not see the screen or keypad. They repeatedly mentioned the audible prompts as their only indication about what was happening. Several members requested that their names and the amounts of each transaction be audibly repeated so that they could confirm the correct data was entered for each member.

In general, members were confident their data had been captured correctly due to their familiarity with the field staff. Still, they were adamant that their individual paper records (the member passbooks and receipts) be retained in any future system. Initially, some group members insisted that the group ledger be retained also. It was only after we showed them an example of a printed report that they agreed the paper ledger was no longer necessary. This paper report was an important artifact from the group perspective that clarified the operation of the new system. Once they understood the time they would save in accounting and documentation, the group was very enthusiastic about the new system.

All of the groups we visited unanimously voted for immediate introduction of the system. It was not apparent whether this was because they understood the benefits, or that they wanted to be associated with modern technology. It is likely that a combination of these factors contributed to their decision. It is equally clear from their insistence that the individual paper records be retained, and their happiness with the paper report, that they did not trust or understand the new technology entirely. They required a local record that could be referenced independently.

6.3 Discussion

In this section I discuss the results of our usability evaluation, and whether our implementation meets the requirements of the tested application.

Efficiency

In microfinance where the cash value of individual transactions is very small, the only way to be profitable is to serve many clients efficiently. This is an important measure of efficiency in the industry. If we can make an interface faster to use, it will allow each staff to serve more clients. In this experiment an optimized CAM user interface performed as efficiently as an equivalent PC interface. In fact, on average, novice rural users were able to complete the task using the CAM interface only 44% slower than experienced technology users on a PC. It is unlikely that any mobile interface could provide significantly better performance.

Accuracy

Obviously, in an application dealing with financial transactions, accuracy is of the utmost importance. The observed error rates of 0.6-1.0% were good but not completely satisfactory. In all the variations conducted after the main protocol (audio, without camera), and during the in situ experiments, users did not make a single error (except for the text-only case that I noted). This leads me to believe in the main protocol some users were either bored or so concerned with speed that they were not fully careful. When we asked them to complete the task under new circumstances they became more attentive and the error rate again verged on zero. Still, in the pilot it will be important to be vigilant about errors and to audit the paper records regularly.

Accessibility

Federation field staff are entry-level employees recruited from rural areas. The lower the bar for this position, the more potential recruits. In this experiment I have only tested users with a base level of literacy and education. For now, this can be assumed for the field staff and SHG accountants in charge of documentation for SHGs. While it took six months to train staff to prepare financial statements manually, the same staff learned to use CAM within four days.

We believe that much of the CAM interface is also appropriate for a less educated demographic. I have already discussed the SHG members' reaction to CAM as secondary users. Eventually, I hope that SHGs will purchase their own phones and avail CAM services directly. First we must demonstrate the feasibility and benefits of the system so that such an investment would be justified. It was a conscious choice to conduct the initial evaluation with younger, more educated subjects that will likely be the first adopters of this technology.

6.4 Current Status

This application was successfully piloted from October 2006 through March 2007 by CCD, the Natham SHG Federation and ekgaon technologies, a company that I have co-founded. This pilot covered approximately 75 groups, and three staff members. Over 5000 forms were processed during this period. In general, the staff, management and SHG members' reaction to the system has been positive.

Based on these results, ekgaon has signed contracts to implement the application with several other SHG Federations, with a total outreach of almost 1500 SHGs (or 25,000 members). The complete software has already been translated from Tamil to Telugu in preparation for a recent deployment with 600 groups in Andhra Pradesh.

The company is developing a business model providing free accounting services for SHGs, in exchange for paid credit ratings and training services. The company also plans to release its software under an open source license, to facilitate the emergence of other providers serving different geographies.

Chapter 7

APPLICATIONS AND EVALUATION FOR AGRICULTURE

With globalization, small rural producers must compete in an increasingly competitive economic market. Due to their small size and limited financial capacity, they face significant technical and operational challenges in doing so. Deficits in infrastructure and planning capacity increase their transaction costs when compared to larger producers. To counteract this, small producers can try to avail a quality or brand advantage — by highlighting specialized production techniques (such as organic or bird-friendly cultivation), geographic specialization and social capital. However, the lack of physical infrastructure, enforceable production standards and efficient marketing channels limits these advantages, causing small producers to continue to sell at commodity prices.

The global coffee market is an acute example. Coffee is now the second most traded commodity in the World — trailing only petroleum in that regard. However, rural small producers have not benefited from the increase in coffee trade and consumption. One reason is a corresponding increase in production. In the early 1990s, Vietnam started producing coffee. Coinciding with an increase in Brazilian coffee production, the market was flooded, and worldwide coffee prices fell sharply. As a result, growers in Latin America, facing higher production costs (but growing better coffee), were decimated [44].

There have been several certification efforts around the World that seek to help small coffee farmers capitalize their quality advantage and sustainable growing practices, by improving access to markets and earning a premium price for their efforts.

- **Fair Trade** Fair Trade certification seeks to improve the living condition of marginalized producers by creating consumer awareness, promoting change in trading practices and empowering producers to play a larger role in the marketing and sale of coffee [75]. Certifying agencies monitor producer organizations' labor and environmental practices. Coffee farmers are guaranteed a minimum price of \$1.26 per pound, or \$0.05

above the current international market price, whichever is higher. Fair Trade also encourages the establishment of direct relationships between coffee importers, roasters and producers.

- **Organic Agriculture** According to the International Federation of Organic Agriculture Movements (IFOAM), organic agriculture is an attempt to *sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings* [59]. Actual requirements for growing organic produce vary from country to country. One priority is on reducing the use of chemical fertilizers and pesticides. Organic certification agencies perform farm inspections to assure quality and prevent fraud.

- **Bird-friendly** Bird-friendly certification ensures that native shade trees are retained on coffee parcels, preventing sun damage and soil erosion and providing shelter to migratory birds that are a natural insecticide [142]. Originally, all coffee was shade grown, until a sun-resistant hybrid was developed to maximize the amount of cultivable land. This hybrid has replaced 17% to 69% of the total coffee cultivation in different countries, severely impacting the migratory bird population. Bird-friendly certification was introduced in 1996 to address this problem.

The idea behind each of these certifications is that consumers will pay a premium for certified products meeting ethical and environmental standards. However, *monitoring* — ensuring that producers are conforming to standards, and *marketing* — conveying the "story" behind the certification, are both significant challenges faced by these and similar efforts.

7.1 Asobagri: The Coffee Cooperative

Asobagri was founded in 1989 in Barillas (figure 7.1), a city in the Guatemalan highlands with a population of about ten thousand people. Barillas is accessible only by unpaved road, helicopter or small airplane. The nearest major city is Huehuetenango, 8 hours away on the local bus. Barillas' urban zone has cellular coverage and Internet access.

Figure 7.1: Barillas from the sky

Asobagri is a producer/exporter cooperative. Namely, Asobagri is responsible from soil care and seeding until the *oro* (unroasted coffee beans) leaves the port on its way to one of their five customers in North America, Europe and Japan. Asobagri's coffee carries four different international certifications: FLO International's Fair Trade certification, OCIA International's Organic certification (for Europe), JAS' Organic certification (for Japan) and Bird-friendly certification.

Asobagri's main goals are to provide market access to over 800 small coffee producers of the Barillas region, support education amongst its members, ensure farmers a living wage (in accordance with Fair Trade) and to promote maintenance and respect for the environment. The staff that work at Asobagri's office are primarily college-educated. The coffee producers themselves live in the remote, mountainous areas around Barillas, where there is often no electricity or phone coverage. Many are illiterate. Some family members have moved to the United States (perhaps illegally) in order to provide additional income for their family.

Along with Yael Schwartzman, another graduate student I have advised on this project, we have designed, developed and evaluated two prototype CAM applications for automating Asobagri's procurement and farm monitoring processes [137].

The first application, CAM DPS (Delivery Processing System), allows the cooperative to accurately and efficiently capture coffee deliveries and payments to farmers, in a mobile context or in areas with limited infrastructure and connectivity. The second application, CAM RANDI (Representation AND Inspection tool), allows farm parcel inspectors to gather multimedia data based on a structured questionnaire. The results are used to monitor production techniques and compliance with certification requirements.

The rest of this chapter is organized as follows: Section 2 discusses related work. Section 3 presents the design, evaluation and current status of the prototype CAM DPS application. Section 4 presents the design, evaluation and current status of the prototype CAM RANDI application. Section 5 discusses the overall status of the project and plans for future work.

7.2 Related Work

In this section we discuss previous IT systems addressing agricultural procurement, extension, inspection, certification and marketing in a developing world context.

7.2.1 Procurement

Agricultural procurement refers to the collection and processing of deliveries from individual producers. Akashganga is a project that automates the milk collection process at dairy cooperatives in India [143]. A digital scale is connected to a PC that maintains local transaction records and prints payment slips. The Warana Wired Village project implemented a system for sugar cane farmers in the state of Maharashtra, India [23]. Farmers are equipped with smartcards allowing them to register their property, obtain permits, process payments, access their funds and purchase fertilizer at 54 PC-based village information kiosks. eChoupal is another Indian effort implemented by ITC-IBD, the agri-business division of ITC. By visiting the eChoupal information kiosk, farmers can find out the current price of soy at various markets and, if they choose, sell directly to a local ITC-IBD representative — reducing their transaction costs and maximizing their revenue. JAMEX is a network of “chill centers” distributed across Jamaica [87]. Chill centers are procurement and storage locations for farmer-supplied produce. An integrated IT solution coordinates delivery, storage, transport and sales to customers.

7.2.2 Extension

Agricultural extension refers to the transfer of agricultural (and other) knowledge to farmers through various communication and learning activities. Finctrac implemented a system in Honduras where extension workers were equipped with a GPS device, laptop, digital camera, portable printer, cell phone, portable weather station and a floppy disk drive [86]. Extensionists are able to access location-specific agricultural information, provide immediate technical advice to farmers and track their extension activities. AGIS is a PC-based system implemented in South Africa that allows extension workers to access a geo-referenced database with information essential to agricultural planning and decision making. An electronic question and answer system that would allow extensionists to communicate with agricultural scientists and researchers is in development [153]. eSagu is a research system developed at IIIT Hyderabad. Extension workers are equipped with a digital camera to document farm conditions and current problems [7]. Using a PC-based kiosk, they submit text and image reports to agricultural experts at a central location. Later, they download advice to be conveyed back to farmers. aAQUA is a web-based system implemented by IIT Bombay, providing a message board connecting farmers directly to experts [1].

7.2.3 Inspection, Certification and Marketing

e-cert is a commercial field monitoring and certification system using a Tablet PC to perform field inspections [35]. A separate database application provides for the creation of inspection templates, scheduling of inspections and management of data. A group of UK food retailers developed the Social and Economic Development Exchange (SEDEX), a web-based tool used to track and audit labor standards along the wine, fruit and cut-flower supply chain [80]. ACTRES is another web-based system that allows flower growers to share information about their water and energy consumption, use of fertilizers and waste generation [73]. This is used to ensure compliance with certification requirements, and for growers to track their use of natural resources. QualCheck captures quality assurance data during the processing, packaging, storage, distribution and serving of food and agricultural products [4]. Utzkapeh, an independent certifier of ethical and sustainable coffee, has developed its own web-based system to track certified coffee through the supply chain from producers to consumers [162]. Anacafe, Guatemala's coffee trade association, has developed a web portal to document the geographic specialization of coffee growing regions and to provide an Internet presence for small coffee producing organizations [50].

7.3 DPS: Delivery Processing System

7.3.1 Current Delivery Process

During harvesting season, producers bring their coffee *quintales* to the Asobagri office to receive their payment check. When the office opens at 8AM, there is often a line of farmers waiting with their coffee. Many would have started the arduous journey from their villages hours earlier, sometimes even the previous day.

Before producers can receive payment for their coffee, they have to go through several steps, illustrated in Figure 7.2. First, the producers need to register in a paper notebook, and wait until the person in charge of data entry is ready to enter their information in the computer. An Excel spreadsheet is used to record producer deliveries and payment amounts. After this information is entered, the coffee's weight and humidity is checked. This is also entered in the spreadsheet. The producer's log book is stamped, indicating the delivery's weight and net price to be paid to the producer. Finally, a payment slip is printed. The producer takes the payment slip upstairs to the accounting department and waits to receive his check.

Meanwhile, a second identification slip is handwritten, the coffee quintal is sewn shut and the identification slip is attached to it. This label provides a way to know, for each quintal of coffee, what kind of coffee it contains and which producer and land parcel it came from. When the coffee is later organized into lots and shipping containers for export, the entire lot is identified solely by the lot number — indicating the source coop (Asobagri),

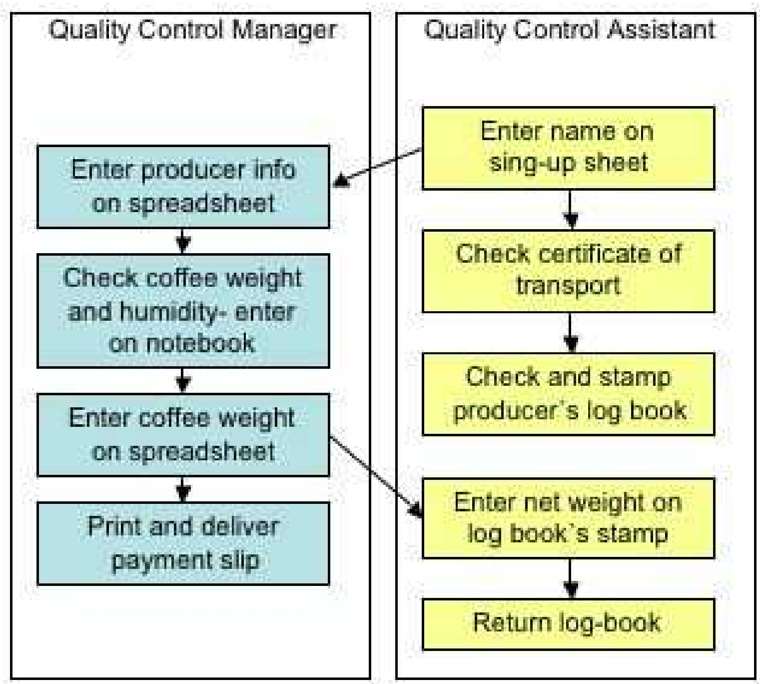


Figure 7.2: Asobagri's delivery process flow chart

state (Huehuetenango), and a categorization of the coffee based on the altitude where it was grown (hard, semi-hard or strictly hard). The cooperative internally maintains a record of specific deliveries corresponding to lot numbers, conforming to international traceability regulations on food products [158, 103].

Delivery processing is one of Asobagri's most inefficient procedures. At busy times of the season, the delivery process can take up to three hours for an individual farmer (including the time spent waiting in line). This could mean having to spend another night in the city, incurring extra expenses and losing out on a day's work.

One source of inefficiency is repetitive data entry. Each producer's identifying information is hand-recorded three times: on the payment slip, payment receipt and on the label for their quintal (see Figure 7.4). The existing automation tools (Excel spreadsheets) are used inefficiently. Three spreadsheet formats are maintained, each a different view of the same data. Some potentially useful information, such as the reason for rejecting a coffee delivery, is not captured at all.

Figure 7.3: Configuration of Asobagri's delivery processing desk

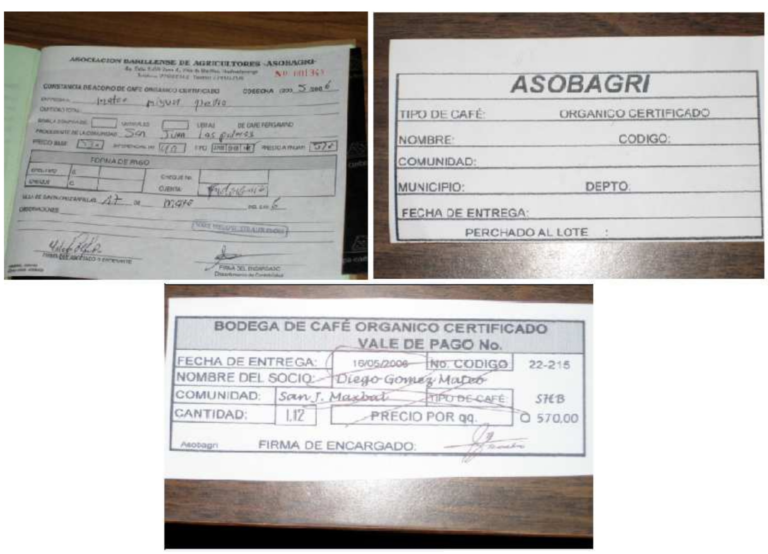


Figure 7.4: Repeated manual entry of the same information — a payment receipt (top left), quintal label (top right) and payment slip (bottom)

Another limitation faced by Asobagri is storage space. Asobagri can store four to five distinct coffee lots in its current warehouse in Barillas (in fact, the last lot limits access to the office bathroom, forcing employees to "hold it" until after the growing season). These are assigned to different types of coffee, classified by altitude and certification requirements. Lack of space limits further differentiation, and the corresponding ability to maximize revenue by attracting premiums for its highest-quality coffee.

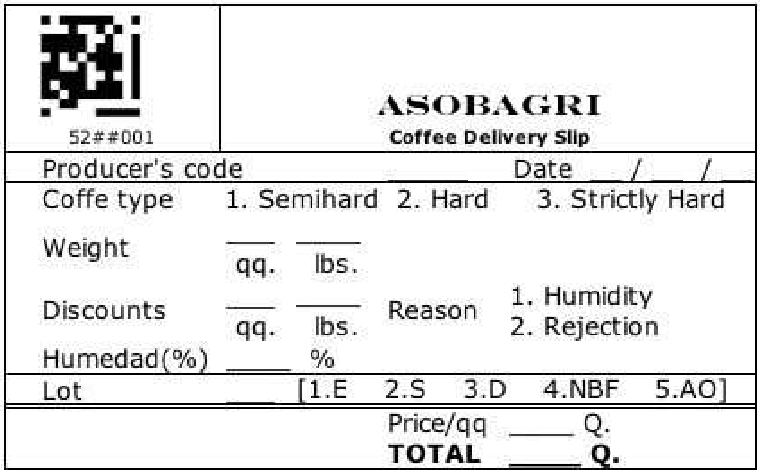
Asobagri is planning to build more storage points closer to producer farms. This will increase the total storage space and potential for differentiation, and also drastically reduce farmer costs in delivering coffee. However, due to limited infrastructure (power, network connectivity, shelter, etc.), Asobagri's current PC-based delivery processing tool is unsuitable for such locations. A mobile phone-based tool would be more appropriate for these conditions.

7.3.2 Prototype Design

We developed a CAM-based mobile delivery processing tool based on existing paper artifacts and extensive discussions with Asobagri's management, staff and members. Our goal was to provide a tool that could aggregate the information from each delivery into a database, from which reports could later be printed. Similar applications are used in the supply chains of commercial retailers and transport specialists. However, these employ proprietary hardware, software and support services that make them all but inaccessible to small, developing world businesses.

The resulting CAM delivery receipt is shown in Figure 7.5. The receipt contains the producer's code, the current date, the type, weight and humidity of the coffee, the amount of coffee rejected (or purchased at a discounted price), the reason, the assigned lot number, the price paid per quintal and the total price paid. Each receipt has two carbon copies — for the delivery and accounting records respectively. The original is given to the producer for their own records.

During the delivery process, the paper receipt is filled out. Then, the delivery copy of the receipt is entered using CAM. A single click of the barcode with the camera prompts



52##001

ASOBAGRI

Coffee Delivery Slip

Producer's code		______	Date __/__/__	
Coffe type	1. Semihard	2. Hard	3. Strictly Hard	
Weight	___ qq.	___ lbs.		
Discounts	___ qq.	___ lbs.	Reason	1. Humidity 2. Rejection
Humedad(%)	_____ %			
Lot	___	[1.E 2.S 3.D 4.NBF 5.AO]		
		Price/qq	_____ Q.	
		TOTAL	_____ **Q.**	

Figure 7.5: CamForm delivery receipt. A single barcode click prompts the user to enter the information from the receipt, accompanied by audio and textual prompts.

the user to enter each of the data fields from the receipt in sequence, accompanied by an audio prompt for each field. As Asobagri's weight scale can only hold four quintales at a time, there can be several weight entries per delivery slip. This is supported by looping through weight entry prompts until the user exits the sequence. To edit the entered data, the data entry operator simply clicks on the barcode again, re-playing the prompts.

After the data has been entered, the user is prompted to send it to the server application. Similar to our India deployment, this can be done via an SMS message. The message would be received by a mobile phone at the Asobagri head office that is connected to a gateway application running on the server computer. Data can also be physically transferred using the mobile phone's built-in memory card. This card could be brought to the head office and inserted into a card reader. The data would then be extracted and processed by a server-side script. Thus far these options are hypothetical, as we have not yet integrated the server-side software for the DPS application.

Potential Advantages

The delivery tool seeks to alleviate the challenges mentioned in the previous section by:

- Consolidating data entry in one paper slip. This will speed up producer throughput during the peak harvesting season. Labels and other reports can be printed automatically, reducing manual data entry.

- The reduced infrastructure requirements of mobile phones allow for mobile / remote delivery points. Providing delivery points close to producer farms is a noted best practice for rural producer cooperatives [62].

7.3.3 Preliminary Evaluation

In this section we describe a preliminary evaluation of CAM DPS. We compared the efficiency and accuracy of this tool to an equivalent Microsoft Excel format (simplified from the existing version).

Participants

All five of our study participants were office staff of Asobagri, and were familiar with the current delivery processing system. Four males and one female, their age ranged from 22 to 44, with a mean age of 29.6. All had at least a high school education, and moderate experience with mobile phones, computers and Microsoft Excel. None had used CAM before.

Experimental Design

We measured the execution time and error rate for entering and submitting ten delivery slips in sequence. The slips were pre-populated with realistic quantities collected from a sample day at Asobagri. For the CAM version, we used a Nokia 6600 phone running the CamBrowser application. For each slip, the user captured a single barcode and entered the data as prompted. Each prompt consisted of a message on the screen accompanied by a short audio description, both in Spanish. All data entry was numeric, with the exception of the producer ID, which was captured as a barcode located on the reverse of their printed Asobagri membership card.

The entered data was stored in a text file on the phone. After each test, this was reviewed to determine the number of errors. Execution time was measured by an observer with a stopwatch, from when the user focused the phone camera on the first form until the last value for the tenth receipt had been entered. Each user performed the same task using an Excel spreadsheet on a PC. The same delivery slips and written values were used. The only difference in the PC version was that the user had to manually enter the producer ID. The order of the two variations was counter-balanced.

Before starting, the use of the application was explained and demonstrated to each of the users, and they were given time to practice until they felt comfortable with both systems. After the test, the participants completed a short questionnaire assessing the ease of use of each version and for gathering other subjective feedback.

Table 7.1: The mean execution time and number of errors per delivery slip for each participant with the Excel and CAM variations.

P.	**Excel**		**CAM**	
	time	error	time	error
1	28.85	0.2	66.87	0.2
2	39.97	0.4	42.41	0.0
3	55.13	0.1	65.35	0.0
4	38.06	0.1	38.61	0.1
5	48.10	0.0	70.10	0.1
mean	42.02	0.16	56.67	0.08

Quantitative Results

As shown in Table 7.1, the average execution time was 15 seconds faster using Excel than CAM. However, the average number of errors was twice as high with the Excel version. Due to our small sample size, none of the differences were statistically significant.

Given that this was the users' first day using CAM, and that they were already familiar with Excel, it is expected that this difference would have leveled out over a period of a few days. This is supported by our earlier evaluation results in microfinance [110].

Table 7.2: Participant's rating of the ease of use of each interface on a 1-5 Likert scale, with 1 being easiest.

P.	**CAM**	**Excel**
1	4	2
2	2	3
3	2	3
4	1	1
5	2	3

Qualitative Results

As shown in Table 7.2, four out of five users found CAM either as easy or easier than the Excel version. Generally, the more familiar they were with the existing system, the faster they performed using Excel and the more comfortable they felt with it. For example, the one user that did find Excel easier to use had significant experience with the existing delivery processing system. Those users that did not use Excel on a daily basis felt more comfortable with the CAM version.

Participants mentioned that they liked CAM because it could be used without consistent power, as power outages are common in Barillas (usually once every three or four days). The form factor was also desirable, in that it could be used in mobile settings, without sitting at a desk. They also liked the audio prompts, with some users suggesting that this reduced errors. This is corroborated by our earlier experimental results, where a text-only interface resulted in significantly more errors then an audio-enhanced version [110].

One feature that was requested was an *undo* or *back* button that could be used when the user had made a data entry error. Currently the solution is to cancel the data entry sequence, and start again by clicking on the original barcode. In the future we plan to use the joystick on the phone interface to provide *back* and *forward* navigation.

7.3.4 Discussion

Our early results indicate that the CAM-based delivery processing tool can provide comparable performance to an Excel-based PC version. Given the mobile phone's other advantages in cost, utility and infrastructure requirements, it should be the clear choice for Asobagri's future remote/mobile delivery points, if not for the main warehouse itself. This was confirmed by Asobagri's current executive director and production supervisor.

In the future, we plan to test this system longitudinally, accounting for learning effects. We are also planning to implement the server-side of the system. This will consist of either developing or customizing an existing inventory management system, and connecting the CAM-based delivery processing tool to it. After this system is implemented and deployed, we plan to collect data regarding the impact on farmer waiting times and transaction costs, on system "uptime" (the time it is working and functional) and on the transparency, efficiency and profitability of the cooperative.

CAM DPS is flexible enough to connect to a variety of back-end systems. As a result, this tool can be used by any organization interested in monitoring inventory levels at storage warehouses or in documenting transactions between producers and cooperatives. For example, a Fair Trade certifying agency could connect the tool to its own back office systems, allowing it to monitor inventories and farmer payments around the World.

7.4 RANDI: Representation AND Inspection tool

7.4.1 Current Inspection and Monitoring Practices

Maintaining the quality and certification of Asobagri's coffee requires continual training, monitoring and inspection. The bulk of this work is carried out by *agricultural extensionists*. Asobagri has a staff of five part-time extensionists, each covering a distinct region. Extensionists are recruited from the ranks of producers. They live in the region, spending most of their time farming their own land parcels. Their role with Asobagri is to recruit, train and work with producers to produce high-quality, organic and bird-friendly coffee.

The extensionists travel regularly to monitor the progress of each producer's land parcels. Each producer keeps a log book where he records the agricultural activities that he performs.

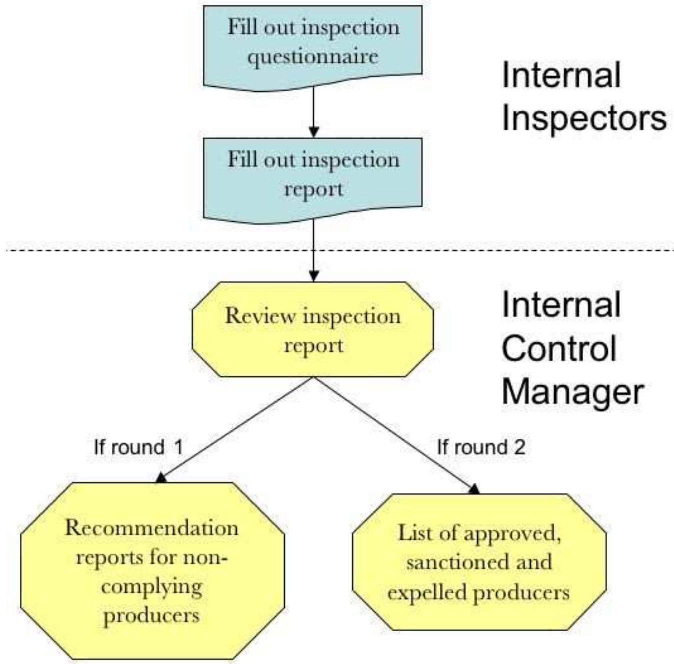
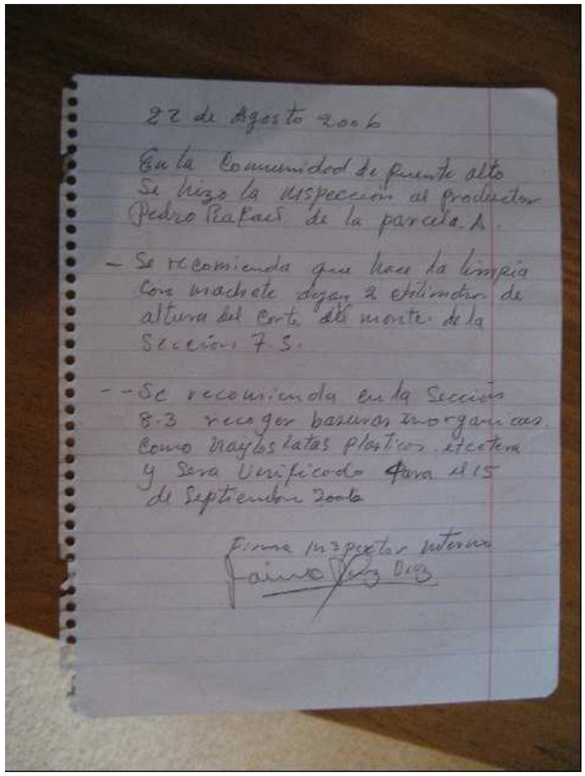


Figure 7.6: Internal inspection flow-chart

The extensionist inspects this log book, and the land parcel itself, to make sure activities are being performed correctly. The extensionists visit the Asobagri office in Barillas every two months to report to Asobagri's internal control manager, a coffee-growing expert, about their region's progress and issues.

Asobagri conducts bi-annual internal inspections. These are in addition to the external inspections conducted by certifying agencies, and are used to ensure the producers' timely compliance with recommended practices and certification requirements. The internal inspections are conducted by twenty experienced extensionists, staff and management of Asobagri. They are each assigned to regions outside their own home area, to reduce the opportunities for bias and collusion. The overall inspection process can be seen in Figure 7.6. The process lasts two weeks, covering every parcel of every producer, with each inspector covering up to ten coffee parcels a day. This is a tremendous data collection task. Some parcels are more than three hours away from the road by foot, over rough terrain.

Inspectors complete a three-page paper inspection form for each producer. Part of this



22 de Agosto 2006

En la Comunidad de puente alto
Se hizo la inspeccion al productor
Pedro Rafael de la parcela A.

– Se recomienda que hace la limpia
con machete dejar 2 centimetros de
altura del corte del monte de la
Seccion 7.5.

– Se recomienda en la Seccion
8.3 recoger basuras inorganicas
como naylos latas plasticos etcetera
y sera verificado para el 15
de Septiembre 2006

Firma inspector interno

Figure 7.7: A hand-written inspection report is prepared by the internal inspectors for each producer. It outlines mild and severe breaches of Asobagri's production standards and certification requirements.

form is completed while in the parcel itself, where they enter data such as the soil quality, coffee-tree quality, disinfectants used and crops grown on the neighboring parcels. All of these can have an impact on coffee quality and certification requirements. The inspector then visits each producer's processing area, including the depulper and/or washer, located either at their home or elsewhere, to document the various tools' presence and hygiene. At the end of the day, the inspector prepares a hand-written parcel report for each producer (see Figure 7.7). In this document, they detail mild and significant breaches of Asobagri's standards and certification requirements, and provide recommendations to correct the same.

During the inspection period, inspectors go back to the office after each week to hand in inspection reports and forms to be reviewed by Asobagri's internal control manager. If it is the first internal inspection of the year, the control manager will issue a final set of recommendations for each producer. These will be communicated back to the producer by their local extensionist, who will attempt to ensure their execution during future monitoring visits. If it is the second inspection, the control manager will make a list of producers to sanction or expel from the cooperative.

The main challenges faced in this process are:

- *Unsuitability of paper forms* Paper forms are not suitable for internal inspections because they are difficult to write upon and prone to get wet or dirty during visits to the parcels.

- *Evidence of inspection* Inspectors cannot visually document their presence on each parcel, and the breaches they have discovered. In cases of dispute, producers can allege that the breaches were fabricated by the inspector, or that the inspector was never there. Some inspectors may skip parcels that are difficult to reach.

- *Breach of contract standards* There are no documented standards for mild and severe breaches, making the inspection reports subject to the inspectors' bias.

7.4.2 Prototype Design

RANDI is a mobile phone application that allows inspectors to capture multimedia inspection data using a CAM-enhanced version of the current inspection form. Inspectors can visually document breaches of Asobagri's certification and quality requirements and their physical presence on each parcel. They can also generate useful media content about farms and producers for Asobagri to display on its web site. Therefore, we call this tool RANDI — the Representation AND Inspection tool.

RANDI includes a small laminated booklet to guide the inspectors through the inspection process (see Figure 7.8). During our initial usability trials, we found letter-size paper forms cumbersome to carry up the steep inclines to the parcels, and also prone to get torn, wet or dirty. Moreover, entering data on paper was challenging under these conditions, and created unnecessary work for the inspectors.

Figure 7.8: Final design of the inspection booklet. Compact, laminated, rain and dirt-proof design allows inspectors to enter data directly on the phone, including relevant images and audio.

During an initial user trial, one of the inspectors suggested to stop writing on the paper form entirely and to enter data only using CAM. After discussing this with the internal control manager, we agreed that a laminated half letter-size booklet supporting only digital data entry was preferable. The laminated booklet contains the full text of each question (important for questions that do not fit on the small mobile screen), and numeric options with their corresponding values for multiple-choice questions.

The booklet has eleven sections that are accessed via a corresponding barcode on the booklet (see Figure 7.9). After clicking on the barcode, inspectors are prompted to answer each question in the section sequentially. Two more barcodes allow the user to capture image and audio data for each section. These are stored on the phone and tagged with metadata indicating the appropriate producer and form section. For example, inspectors can capture images documenting an observed breach, or record an audio clip while making their recommendations to the farmer.

As in the delivery processing application, the identity of the producer is captured as a barcode image on the reverse side of their cooperative membership card. The inspector's

Section 10: Storage	90##10 record audio	91##10 take picture	80 Section 10
10.1 Do you have a storage room?			1. Yes 2. No
10.2 Do you have a platform in your storage room?			1. Yes 2. No
10.3 Are there risks of contamination with other products?			1. Yes 2. No
Immediate recommendations			

Figure 7.9: Part of the CAM-enabled inspection format — each section has its own "take picture" and "record audio" barcodes.

physical presence on the parcel is documented by capturing a picture of himself, with the producer, on the specified parcel. In the future, we can also use GPS to confirm this information [62].

Asobagri's current paper-based inspection form contains a mix of open-ended questions, and questions that require a numeric or discrete Yes/No answer. Example question topics include: the organic status of the coffee parcel, the number of fruit trees that are growing on the parcel, whether or not the producer has used a disinfectant for the coffee seeds and the percentage of soil covered by live matter. In the CAM version, due to the difficulty of mobile text entry, we converted all of the open-ended questions to multiple choice or to numeric responses. This required iterating with staff and management to determine the set of possible responses to each question.

One side benefit is that now responses were now standardized across all of the inspectors. For example, instead of recording the organic status of the parcel as an open-ended text field, we asked the user to choose from the following options: 1) conventional, 2) natural, 3) organic and 4) in-transition. However, as we continued our testing, more and more possible

Figure 7.10: The inspection blog replaces the paper inspection form and the hand-written report. The blog can be indexed by producer ID, group ID, form section and type of breach.

options emerged for some of the open-ended questions. One solution was to allow the user to record an audio clip. For example, this was used for recording the recommendations made by the inspector to the farmer.

All of the captured data is stored on the phone's external memory card. When the inspections are completed, the inspector goes back to the office and transfers the data by removing the phone's memory card and inserting it into a USB card reader connected to the PC. We decided to adopt this kind of *physical networking* solution because of the limited cellular coverage and services in the region, and to save on connectivity costs [165]. It is not essential that the inspection data be transferred to the head office immediately, and the inspectors will have to return to discuss their observations with the control manager anyway. Under different conditions, it would also have been possible to implement remote data transfer using HTTP or a messaging protocol, like MMS or e-mail, and an appropriate gateway application.

After the data is downloaded to the PC, we run a script that processes the data, adds the corresponding tags (producer id, group id, section id and/or type of breach), and posts the result as a blog entry. Breaches are automatically classified according to rules specified by the Asobagri management. The internal control manager can search entries by inspector, producer, region, form section or type of breach.

We used Wordpress as the blogging software, and Postie to automatically format the images and text for each post [174]. Wordpress provides many standard blogging features, including embedding images and audio, allowing users to add comments, make new posts, edit existing posts and create new categories. While a blog does not provide the same functionality as a custom database application would, this approach has thus far been sufficient, and has required very little server-side development effort.

Potential Advantages

The challenges mentioned in the previous section are addressed by:

- Requiring the inspector to carry a mobile phone and a single laminated inspection guide (versus a 3-page paper form *per producer*) drastically reduces the weight of paper they must carry.

- Audio and image data allows the inspector to document breaches, recommendations made to the producer and their physical presence on the parcel more convincingly. This data can be used by the internal control manager and extensionists to better understand each parcel's status and to document best/worst practices.

- Providing discrete options for some questions, and a standard definition of mild and severe breaches, reduces the opportunity for bias in the earlier open-ended report format.

- Data captured during inspections can be used to create a visual history of each parcel, and to market Asobagri's products, helping foster more direct producer-consumer relationships.

Figure 7.11: Taking a picture of a coffee tree during an inspection.

7.4.3 Preliminary Evaluation

In this section we present the results of a preliminary evaluation of the CAM RANDI tool. Our goal was to assess the impact of this application when compared to the current paper-based inspection process, both in the field, and also on the later use of this data by the internal control manager.

Participants

Four inspectors' were included in the evaluation. All were male. Their age ranged between 31 and 50, and their education ranged between 1st and 6th grade completion (with the exception of the internal control manager, who has a college degree). All of the participants were experienced, certified inspectors who had been performing internal inspections for at least five years. All had previously used a mobile phone, but had no experience with CAM.

Experiment Design

We compared two inspections conducted using the RANDI tool, and two inspections conducted using a paper form. For consistency, the paper form had the same multiple choice questions as used in the RANDI variation, including additional space for open-ended comments. We gave the paper form users a digital camera (Canon SD 500, 7.1 megapixel) and audio recorder (integrated with a Nokia 6235 mobile phone) to use while conducting the inspection, to approximate the same functionality in RANDI and to assess the impact of the integrated CAM approach.

A between-subjects protocol was used, with different inspectors being tested with CAM and the paper-based version. Due to long travel times between producer communities, and the arduous climbs into the parcels themselves, we did not have enough time to conduct a controlled, within subjects experiment.

Furthermore, it was difficult to maintain a sterile testing environment, given that the inspectors, and especially the producers and their families, were very excited to witness this new technology. During the inspections we visited, there were many people around, and the inspectors often got distracted, both with people and nature. They were roaming around taking pictures of spiders, beehives, fruits on trees, etc. While this was a distraction for our testing, we hope that this excitement carries forward when using the system in practice.

The inspections were conducted in two producer communities — Palo Alto and La Palestina. The RANDI users were first trained on how to use CAM and navigate the forms. For those using the paper forms, we allowed them to review and become familiar with the new format, and also taught them how to use the camera and audio recorder. All users were given time to practice until they said they were comfortable with the new tools.

They then performed a full inspection of a parcel, completing eleven sections, taking pictures and recording audio whenever they saw fit. In the RANDI version, the inspectors were explicitly prompted to take three pictures (one each of the inspector and producer signing the inspection receipt, and one of the producer at the parcel), and to record one audio message (their final recommendations to the producer).

After conducting the inspection, we asked each inspector to produce a report, either by hand or using the RANDI blog tool (depending on which version they had used). We then asked the internal control manager to review these reports, and provide his feedback. At the end of the evaluation each participant completed a subjective questionnaire, indicating the ease-of-use of the system, and the potential for use in a real setting.

Table 7.3: Average number of pictures and recommendations captured using the RANDI and paper variations (recommendations were recorded in audio in the RANDI version, and hand-written in the paper version). The RANDI variation explicitly prompted users to capture three pictures and one audio recommendation.

Media Type.	**RANDI**	**Paper Form**
Pictures	3.5	1.5
Recommendations	2.5	3.5

Quantitative Results

The data that we gathered suggests that it takes about the same amount of time to complete the inspection using paper forms versus CAM (an average of 44 minutes using CAM versus 42 minutes using paper). However, the inspectors said that it ordinarily takes them 20-30 minutes to inspect parcels. The extra time was probably due to the distractions mentioned earlier. A longer controlled study would be needed to understand the effects of RANDI on inspection completion time.

We also measured the average number of pictures, audio comments and recommendations that were recorded during each of the inspections (see Table 7.3). Recommendations were written in the paper experiment and audio recorded using RANDI. It should be noted that inspectors were explicitly prompted to capture three pictures in the RANDI version. While our data does not show much difference in the quantity of data that is captured, in the future we plan to compare the impact of this multimedia data on follow-up actions taken by the internal control manager and extension workers.

Table 7.4: Participants' rating of ease-of-use of each variation on a 1-5 Likert scale (1 being easiest)

P.	**CAM**	**Paper Form**
1	1	5
2	2	1
3	2	2
4	1	2

Qualitative Results

While none of the participants used both versions of the system for a complete inspection, we gave them time to become familiar with both and then give their opinions. 3 out of 4 inspectors found the CAM version as easy or easier then the paper version (see Table 7.4).

All of the inspectors agreed that the main advantages of CAM were the ability to provide audio and image evidence of the inspection, the lighter carrying load and the rugged nature of the plastic guide. Some participants commented that it was easier to talk to the producers, because they didn't need to worry about writing all the time. Another advantage that was mentioned was that using CAM it was not possible to alter the inspection information after it was entered. This reduced the possibility of foul play.

Some inspectors felt that it was hard to capture the barcodes in the shade. There was a consensus among users that if they had more practice, they would become much more comfortable. The mobile phone hardware and software presented problems for some users. The menu was described as difficult to navigate, and they did not understand the purpose of all the buttons on the keypad. In general, there was some hesitation to use the mobile phone, due to its perceived cost and complexity. The same effect was not seen with the digital camera and voice recorder, possibly because they were both perceived as single-purpose devices.

Three out of four inspectors mentioned that the ability to capture motion video would also have been useful, because it could provide evidence of how producers actually performed the work, and would also be a good source of content for training materials.

Even though we added multiple choice options during each of the design iterations, we still found more to be added during the last round of testing. There were also some questions that we were not able to convert to multiple choice. Additionally, using RANDI, some users wanted to but were not able to write down open ended inspection details. However, the internal control manager responded that this additional data was not necessary, and that the inspection form could be even more concise.

The internal control manager found the blog tool to be very useful for browsing and searching inspection data. The generated reports were similar to the handwritten reports prepared by the inspectors earlier, with additional audio and image data. However, while the blog was useful, it did not provide the full functionality of a database application. For example, it was not possible to query on more then one type of field, or to produce the producer summary report currently hand-aggregated by the inspectors.

All the study participants were very excited about the tool and told us that they were looking forward to the full implementation. The internal control manager, who is in charge of the inspection process, wanted to the system in the field for the next internal inspection (starting two weeks after the usability tests).

7.4.4 Discussion

During the design and evaluation period, we were able to refine the RANDI documentation tool and get people excited to use it in the future. All of the staff and members of Asobagri that we interviewed were unanimously supportive of the system and our efforts.

Like we described earlier for the CAM DPS system, the RANDI mobile application is also flexible enough to connect to different back-end systems. For example, an agency involved in organic or bird-friendly certification could equip its field inspectors with a RANDI-like tool, and avail the same benefits that have been discussed.

Given the positive response of study participants, and the potential for impact in the agricultural sector, we are planning to continue our design studies, and develop a full implementation of the system. We plan to have a working system ready by the next inspection cycle, in Spring 2007.

7.5 Discussion and Current Status

Small producer cooperatives face significant challenges in managing their supply chain, monitoring production and accessing markets. CAM (as instantiated in the DPS and RANDI prototype applications) provides the first integrated mobile phone platform for delivering these (and other) important services. We have conducted a preliminary usability evaluation of these applications with actual users, considering a variety of delivery technologies (PCs, mobile phones and paper). Our results suggest that both applications are accessible to target users and will serve a real and viable need. Based on this positive response, we are planning further evaluation and implementation of both systems.

During our final discussion with Asobagri's executive director, he told us that these tools are directly addressing the most important challenges that Asobagri is facing in its efforts to grow and reach new markets. These thoughts were echoed during a meeting with the managing director of Anacafe, the national coffee trade association of Guatemala. He told us that Anacafe would look forward to pilot testing and implementing our tools with other cooperatives in the future.

Currently, we are testing the applicability of these tools with small farmers in Gujarat, India (cotton, grains) and Oaxaca, Mexico (coffee). In Mexico, we have just started a limited RANDI pilot with one user. In time, we hope to validate the utility of these systems, but it is not clear that can be done exhaustively through a usability experiment. The real impact of these systems will only be visible once they have been adopted and integrated into the operations of small producer cooperatives, and the results are apparent in their business performance.

Chapter 8
MORE CAM APPLICATIONS

In this chapter, I list fourteen other potential applications of the CAM framework. The list is organized into categories of applications supporting 1) economic development, 2) public health, 3) civil society, and 4) education.

Leveraging a common hardware (mobile phones), software (CAM) and often human (field agents) infrastructure in rural areas allows us to amortize cost and risk across many services. Realistically, some services will subsidize others (financial services and health, for example), and some users will subsidize others. Including advertising as a revenue stream could further reduce the cost (potentially to zero for some users and some services).

8.1 Economic Development

8.1.1 Remote Transaction Processing

As described in chapter 2, a significant challenge in providing rural financial services is the difficulty of processing cash transactions in remote areas. The *business correspondent model*, approved by the Reserve Bank of India in January 2006, allows the agents of several different rural institutions — including NGOs, cooperatives and post offices, to conduct financial transactions on behalf of registered banks [121]. The goal is to leverage their human and physical infrastructure to provide cost-effective and secure financial services. One of the key accounting requirements is that all transactions conducted by a correspondent must appear in the bank's accounts by the end of the next working day. CAM can be used by agents to authenticate customers, process transactions and communicate data efficiently. While commercially available *point of sale* (POS) devices can be used for the same purpose, they are not cost-effective for NGOs to provide to field staff. Smartcards are also expensive to manufacture and issue to clients. Mobile phones provide the immediate utility of voice and text communications. Moreover, as described earlier, CAM can also be used to process

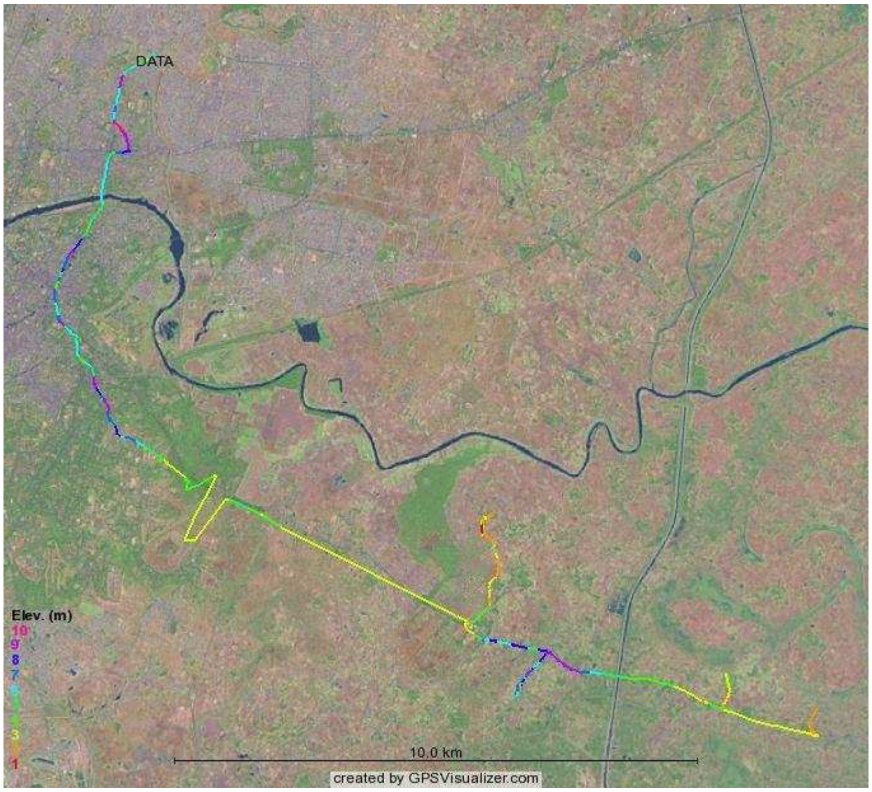


Figure 8.1: Mapping the route of a rural sales agent using GPS

loan applications and provide other banking services, potentially making it cost effective for banks to subsidize the purchase of phones by correspondents.

8.1.2 Tracking Rural Supply Chains

Companies distributing products in rural areas face significant challenges in managing their supply chains and understanding the market potential of remote localities. Along with undergraduate student Paul Javid, and working with a company involved in the manufacture and sale of contraceptive health products in rural India, I developed a prototype CAM application that tracked the movement and transactions of field sales agents [62]. Field agents were responsible for selling inventory to retail shops along a pre-determined sales route. The system used a GPS device and cell tower sightings to determine the agent's approximate position [78]. The collected data was plotted on a map, allowing the company

Figure 8.2: Small shops like these could use CAM to maintain accounts and monitor inventory

to understand the purchasing behavior of different villages, manage inventory levels and monitor sales agents. Without such a monitoring system, some agents would dump inventory in town markets to save the time and effort of traveling to villages. This ran counter to the company's goal of expanding the sale and use of their products in rural areas.

8.1.3 Accounting for Small Businesses

CAM can also be used by small retailers and vendors as an improvised cash register. Like in the SHG system described in chapter 6, we could issue CAM receipt and voucher books, which could be processed by the shopkeeper using a mobile phone. This data could be used to manage inventory and maintain accounts. Periodically, the shop keeper would be sent accounting and inventory statements, by fax or mail. This would be especially helpful during tax season — India's transition to a value-added tax (VAT) has frightened small retailers reluctant to part with their informal, paper-based systems [43].

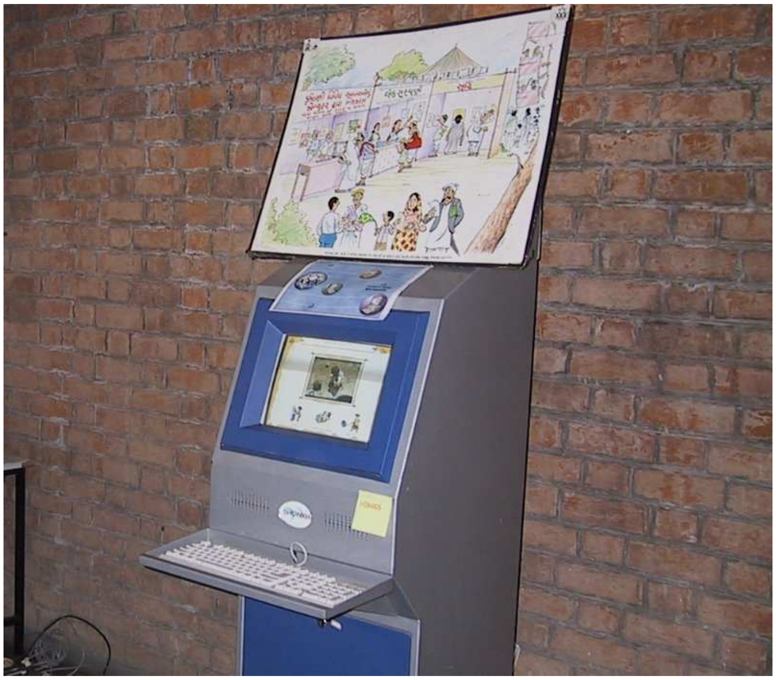


Figure 8.3: A kiosk-based Knownet-Grin installation.

8.1.4 Documenting Village Inventions

My first introduction to rural computing was with SRISTI, a NGO based in Ahmedabad, Gujarat, India. Working with a small development team, I developed the Knowledge Network for Grassroots Innovators (Knownet-Grin) — a PC-based application for documenting and disseminating village innovations [56]. Farmers, herbalists, craftsmen, and other rural people could use this application to submit information about their inventions — for example, new farm implements, herbal pesticides and livestock disease treatments. This data was supplemented by SRISTI's field staff, who were employed to scout and document innovations, using paper notes and sometimes a still and/or video camera. These stories were aggregated in a multimedia database, search-able by farmers, academics and potential investors — any of whom could contact innovators with advice, encouragement and opportunities for partnership. Two of the main limitations we found to the wide adoption of this system were 1) the complexity of the user interface, and 2) the limited installed PC base. CAM would provide an accessible way to capture information about innovations, either by field staff, or submitted by innovators themselves.

8.1.5 Facilitating Local Economic Connections

The SHG federation we have been working with in Natham operates a communal grocery store. A group of SHGs pool money every few months to buy household necessities (rice, grains, oils, etc.). Buying these items in bulk allows them to negotiate better prices and quality. Using CAM, we are developing an application for SHG members to submit their orders to the grocery manager electronically. Members fill out order forms to be collected and processed by field staff, along with the monthly microfinance transaction receipts. Based on this information, the grocery manager can plan for that month's purchasing and avoid excess inventory. We are also planning to distribute a barcoded identification card that groups can use to purchase groceries on credit, or against a locally denominated currency.

8.2 Public Health

8.2.1 Managing Medical Records

Poor patients often receive inconsistent medical care because providers don't know about their existing conditions and treatment history. This is a particularly important problem with the treatment of HIV/AIDs, which requires complex and expensive combinations of anti-retroviral (ARV) drugs based on the state of the disease and previous treatment. Small clinics in Africa do not have the IT resources or capability to manage this data, relying on an assortment of paper forms and electronic spreadsheets. The OpenMRS project is an effort to develop a simple, flexible, open-source medical records system for the developing world [104]. I am collaborating with the OpenMRS implementers on integrating CAM into their mobile data collection efforts. Service providers will be able to publish surveys and patient data to mobile phones, to be used by field staff involved in monitoring and treating remote patients.

8.2.2 Administering Clinical Protocols

Due to the shortage of doctors and nurses in sub-Saharan Africa, it often falls to non-medically trained staff to provide primary care, especially at rural clinics [99]. The World Health Organization has published the Integrated Management of Adult Illness (IMAI) and Integrated Management of Child Illness (IMCI) as simplified sets of guidelines for primary care in resource-poor conditions. Primary caregivers can follow well-defined algorithms for determining which patients can safely continue their current treatment, and which need to be referred to a specialist for further consultation. The current paper-based approach for conducting these protocols is difficult to teach, lets staff skip sections they are uncomfortable with, and does not allow for the aggregation of data. In collaboration with researchers from the University of Washington and the Harvard School of Public Health, I am investigating the use of mobile devices for this application, which we hypothesize would be easier to learn, more standardized, and will allow for the automated collection and analysis of treatment data. A CAM-based approach would also allow for the collection of audio and image data, which has been found useful in some surveying methods [115].

8.2.3 Processing Health Vouchers

Output-based Aid (OBA) is an approach to reducing corruption and inefficiency in health aid programs [82]. Rather then make grants to health care providers up front, aid organizations issue vouchers to the intended target group. These vouchers are redeemed by patients in exchange for services from participating providers, who are reimbursed based on the services actually provided to patients. In collaboration with researchers from the University of California, Berkeley, I am exploring the potential for using CAM to authenticate and process these aid vouchers. Their pilot in Uganda is using a voucher with a unique identification number that provides for one complete STD diagnosis, and treatment if positive. Currently, the care provider must manually prepare paper report with a complete list of voucher IDs and patient details in order to receive payment. This results in excessive paperwork and delays in payment, taking up to four months in some cases. A CAM-based approach would allow service providers, even those located at remote clinics, to authenticate vouchers and submit the data directly to the aid organization. The aid organization would be able to remotely monitor the provision of services, allowing it to target promotion campaigns and issue payments more promptly.

8.2.4 Responding to Epidemics and Adverse Reactions

Public health organizations need to continuously monitor suspicious diagnoses around the country in order to respond to the outbreak and spread of disease. A regular stream of clinical health data is also required to allocate resources and respond to chronic problems. For extended clinical trials of drugs, patients and clinicians need a way to report results, particularly for adverse reactions. Several initiatives have used PDAs, phones and other mobile phone devices to collect this kind of recurrent health data. Voxiva provides a set of tools for health data collection and management, supporting intelligent voice recognition (IVR), SMS, Web and Smartphone access [163]. These were used to monitor the outbreak of avian flu in Indonesia [40], and adverse reactions from clinical medical trials in Peru [168].

8.3 Civil Society and Governance

8.3.1 Conducting a Census or Election

Governments and other civil society organizations have many large-scale data collection and surveying tasks. For example, conducting a census — obtaining information about every member of the population. In India, a census is conducted by visiting every household individually [171]. Using CAM, we can automate the collection of this data, while avoiding redundant data entry. Linking CAM with a location-sensing technology such as GPS or PlaceLab [78], we can also geocode this data, useful for populating *geographic information systems* (GIS). For an election, something similar to the "wooden box" (see figure 6.5) could be used as an improvised polling machine, allowing voters to capture their votes from paper ballots. This has the benefit of retaining paper as an auditable record, which is a noted best practice for conducting secure elections [32]. By retaining an image of the election form, electronic data can be traced visually to the source.

8.3.2 Reporting Human Rights Violations

Mobile phones are emerging as a way to empower citizens in the reporting and documentation of human rights violations. In the Democratic Republic of the Congo, a NGO provided mobile phones to community groups to report incidences of children's rights violations or abuse [125]. SMS was used to monitor the 2007 Nigerian elections [28]. This allowed ordinary citizens to comment on conditions in their localities, a right usually reserved for selected external observers. Once documented, this sensitive data has to be kept secure, from governmental agencies and others. Benetech's software allows organizations to document, encrypt and upload violations to a secure, out of country server using an Outlook-like PC client [12]. Using CAM, we can expand the system's outreach by providing another secure interface using camera-equipped mobile phones.

8.3.3 Applying for Government Services

Some of the earliest and most successful efforts to provide IT-based services in rural India have been for providing government services — most notably, access to land records [52, 34, 13]. Earlier, land records were requested through local administrators, who manually requested and retrieved the records, introducing delays and opportunities for corruption. Now, the process has been automated and made more transparent by adopting an information *kiosk* approach [105]. This approach relies on a dedicated operator, who receives a fee to access land records from an online web application using a PC . During a visit to an early deployment of this service in Madhya Pradesh, India, I noticed that farmers still had to travel long distances to reach the kiosks. Using CAM, we can increase the outreach of this service, including the potential to make requests for land records and other government services from the comfort of your own village.

8.3.4 Monitoring Energy Distribution

The United Nations Energy Programme's (UNEP) eCARE project provides loans to qualifying local entrepreneurs in Ghana to purchase a self-sufficient telecommunications center in a box — including a shipping container equipped with doors and windows, solar cells, batteries, fixed-line cellular phones, a PC and a printer [36]. This provides the entrepreneur an opportunity to start a business providing communications services in remote areas without grid power or phone connectivity. The batteries can be charged by the solar cells and rented out to local villagers for their own energy needs. Researchers from UNEP are interested in using CAM for administering and monitoring the use of the telecommunications and clean energy services. This also reduces the need for the PC, making the overall package less expensive and power-hungry.

8.4 Education

8.4.1 Administering Standardized Exams

The quality of primary education in rural India is a major concern. Teachers are under-motivated and frequently absent. A start-up educational company in India approached me with the idea of using CAM for monitoring the attendance of teachers, and the progress of rural students. Students would be administered regular exams assessing their progress. These could be printed on CamForm exam sheets. The students' responses would then be captured by the teacher using CAM, meanwhile also documenting his/her own presence. The results are aggregated in a database, allowing the company to monitor the progress of students, and the performance of teachers. Theoretically, the company could then refine its curriculum and teaching methods based on empirical analysis of student performance.

Chapter 9

CONCLUSION AND FUTURE WORK

In this dissertation, I have presented the motivation, design, implementation and evaluation of CAM — a novel mobile application framework for the rural developing world. Not being constrained by an installed application base or pre-existing assumptions about the delivery of computing services, I have started from first principles to develop a mobile client-side software architecture that is uniquely suited to rural users, infrastructure and environmental conditions

9.1 Contributions

Here, I list the contributions that I originally claimed, with a summary of how each was achieved.

9.1.1 Identification of Systemic Information Needs and Gaps in Microfinance

Based on an extended contextual study, covering field visits with eight different microfinance-supporting organizations, I identified the following consistently observed information needs in providing microfinance services to remote rural clients:

- **The exchange of information with remote rural clients**
- **Management and processing of data at the institutional level**
- **Transferring cash into and out of remote rural areas**

9.1.2 User Interface Guidelines for Rural, Developing World Users

I conducted a two-month participatory design study with self-help groups in rural India to understand their current information practices and to experiment with new ways that computers could help them manage data and connect to new sources of capital. This study included users of different educational backgrounds — ranging from the college-educated to uneducated and illiterate. As a result of this study, I derived the following guidelines for designing user interfaces accessible to this population:

- Paper formats are essential to maintain users' current understanding.
- The use of numeric input and output improves accessibility.
- The use of audio feedback improves accessibility and trust.
- Guide the user through a sequence of steps to complete each task.
- Abstract representations of actions are not understood.
- Appropriate use of color was appreciated by users.
- It is essential to design within the local context.

9.1.3 CAM: A Framework for Distributed Data Collection using Mobile Phones

Based on this understanding, I designed and implemented CAM, a software toolkit for distributed data collection using mobile phones. Instead of using menus, CAM applications are navigated with printed barcodes and numbers. The rich indexing capabilities of embedded physical tokens provides fine-grained contextual access to applications and content. Rather than optimize spatial layout of pages, CAM displays prompts in sequence to reduce screen requirements and user decisions. Instead of being written declaratively, CAM applications are scripted, generating sequences of actions. To support offline use, the entire application is downloaded at once, rather than page by page. CAM also provides multimedia input and output capabilities, providing rich interaction modes for rural users.

9.1.4 Evaluation for Usability, Breadth and Real-world Impact

Mobile user interfaces are frequently cited as less usable than PC interfaces due to their limited screen size and input capabilities. My quantitative results in microfinance show that a CAM-based user interface is efficient, accurate, can quickly be learned by rural users, and is competitive with an equivalent web-based UI on a PC. Qualitatively, CAM was described as easy to use by almost all users. To demonstrate CAM's breadth of applicability, along with graduate student Yael Schwartzman, I implemented and evaluated two prototype CAM applications in agriculture. I also provide motivations for fourteen other potential CAM applications. Implementing these would provide an important set of services to rural communities. For microfinance, the most mature application, CAM is already being by used by more than 500 self-help groups for their data management and reporting needs.

9.2 Unaddressed Elements

The evolution of computing in the rural developing world requires the development of a robust *ecology* — with local enterprises involved in the design, implementation, support and maintenance of information systems. In this dissertation, I have primarily addressed the client-side user interface requirements. Here, I describe other components required to achieve the full vision.

9.2.1 Cross Platform Deployability

So far, CAM only works on a fairly narrow spectrum of phones. Differences between hardware capabilities and software APIs, along with the rapid evolution of both, has made developing cross-platform mobile phone applications a laborious task. One hopes that response to consumer demand will drive the industry towards further openness and standardization. However, thus far, "walled garden" approaches to providing mobile services have dominated.

9.2.2 Forms Authoring

Appropriation of a technology means that local people should be able to improvise their own solutions using it as a component. Information technologies are notoriously difficult to appropriate in this manner. However, local innovators have demonstrated a remarkable ability to innovate in other, more physical environments [56]. I plan to investigate new programming metaphors that would allow local people to build their own computing systems, including visual and physical means of composing computer programs [97, 70]. One example is the ability to author CAM applications using existing paper forms as input.

9.2.3 Server-side Tools

How CAM makes it easier for rural users to access information services, I would like to make it easier for rural content and application developers to *offer* such services. Toolkits like Kannel, Mbuni and FrontlineSMS support the basic processing and sending of SMS and MMS messages [69, 89, 42]. However, in the future, I believe that asynchronous message-based services should be as easy and intuitive to author as a home page.

9.2.4 Communications and Networking

This dissertation has not addressed the question of how to build communication and data networks serving rural areas. CAM relies on existing networking technologies such as bluetooth and SMS. Other groups are actively pursuing new networking paradigms for rural computing — including adapting 802.11 hardware for long distance, and using store-and-forward networks based on physical transport of media [117, 165, 19, 114].

9.2.5 Information Dissemination

This dissertation has primary addressed *data collection*, and not *information dissemination.* For the applications I have described, we have relied on more traditional models for dissemination of data — using the web, and generating printed reports. Other projects, like Digital Studyhall, have had success using TVs connected to low-cost DVD players [164].

9.3 Future Work

In this section, I outline some other ideas for future work.

9.3.1 *Implications for Other Naive Users*

Working with such a inexperienced user group could lead to designing solutions applicable to a wider range of *non-digital* users. Unpolluted by standard abstractions and conventions, such users provide a blank slate to judge the *immediate usability* of a user interface [76]. Results may also be applied to other user groups, such as the elderly, disadvantaged and otherwise disconnected user communities in the developed world. The extent of the applicability, as well as the divergence from *wired* users, is an interesting point of future study.

9.3.2 *Implications for Device Design*

I would like to understand the implications of this work for mobile phone hardware design. Where navigation is driven by the camera and a one-step interaction model, one can significantly reduce the number of physical buttons. Experiments like our wooden box (see figure 6.5) imply that alternate device configurations might be required to make the mobile phone a better bulk scanning and data entry device. I plan to experiment with new hardware prototypes that explore the design space for such devices.

9.3.3 *Making Software Engineering more Accessible*

Developers adopt software development platforms for many reasons — including ease of programming, integration, deployment and maintenance. Due to its simple programming model and tight linkage with the Access database, Microsoft's Visual Basic has dominated the entry-level developer market in the developing world — including most of the software developed and used by NGOs. However, many such applications have not been found suitable for wide deployment and long-term maintenance. I want to investigate the accessibility of software development platforms in the developing world context.

9.3.4 *Local Information Exchanges*

SHGs are an example of a village-level financial exchange. With preliminary work in agriculture, healthcare and retail supply chains, I am now working on other local information exchanges. The goal is to build a mobile architecture that is leveraged across a number of value-added services derived from the users' own data. These services will improve local communities' ability to plan and compete in the new global economy.

9.3.5 Design for Sustainability

Designing sustainable technology implies designing for re-use, sharing, longevity and minimal impact [18]. While sustainable design has had a noticeable impact on other design and engineering fields [91], it has yet to receive widespread attention in the design of computing technologies. To the contrary, design for obsolescence and redundancy is the rule rather then the exception for consumer digital electronics. Proposing a several-fold increase in the number of computing users requires a critical re-thinking of this trend. By actively designing computing technologies to support re-use, sharing, longevity and minimal impact, we can address such concerns while supporting a local service economy.

9.3.6 Post-disaster Information Systems

What information systems will work when major communications, transportation, power and economic systems fail? I have worked on relief and rehabilitation efforts after two major disasters — the 2001 Gujarat earthquake and the 2004 Indian Ocean tsunami. Coordinating first-response relief efforts and rebuilding economic infrastructure are two important opportunities for technology-mediated solutions. I plan to develop new system architectures and applications that can help humans coordinate and plan under adverse infrastructural conditions.

9.4 Closing Remarks

The CAM framework that I have described facilitates the management of data across a distributed, infrastructure-poor landscape dotted with novice users. This is similar to many existing systems — even to the Internet as a whole. As we've seen in the developed world, if this service is made available in an affordable, accessible way, there are many new markets just waiting to be created.

Given the early stage of research in this field, I believe that one must first be a pragmatist.

If the ideal of using computing to help the poorest people in the world is going to reach fruition, we have to ground our research in applications that provide immediate and definite value to these communities. The work I have described has been driven by the demands of real users and real applications, and I expect its evolution to come about by the same means.

BIBLIOGRAPHY

[1] aAQUA homepage, July 2007. http://www.aaqua.org.

[2] Accion International homepage, December 2005. http://www.accion.org.

[3] Anne Adams and Martina Angela Sasse. Users are not the enemy. *Commun. ACM*, 42(12):40–46, 1999.

[4] http://www.agriquality.com, October 2006.

[5] Bindu Ananth and Bastavee Barooah. Leveraging technology for micro banking. i4donline magazine, January 2004. http://www.i4donline.net/issue/jan04/leveraging_full.htm.

[6] Anoto homepage, April 2006. http://www.anoto.com.

[7] Venkata Ratnam Bachu, Krishna Reddy Polepalli, and G.S. Reddy. eSagu: An IT based personalized agricultural extension system prototype - analysis of 51 farmers' case studies. *International Journal of Education and Development using ICT*, 2(1), 2006.

[8] Maribeth Back, Jonathan Cohen, Rich Gold, Steve Harrison, and Scott Minneman. Listen Reader: an electronically augmented paper-based book. In *CHI '01: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 23–29, New York, NY, USA, 2001. ACM Press.

[9] Abhijit Banerjee and Esther Duflo. The economic lives of the poor. CEPR Discussion Papers 5968, C.E.P.R. Discussion Papers, December 2006. http://ideas.repec.org/p/cpr/ceprdp/5968.html.

[10] Patrick Baudisch, Xing Xie, Chong Wang, and Wei-Ying Ma. Collapse-to-zoom: viewing web pages on small screen devices by interactively removing irrelevant content. In *UIST '04: Proceedings of the 17th annual ACM symposium on User interface software and technology*, pages 91–94, New York, NY, USA, 2004. ACM Press.

[11] Rudi Belotti, Corsin Decurtins, Moira C. Norrie, Beat Signer, and Ljiljana Vukelja. Experimental platform for mobile information systems. In *MobiCom '05: Proceedings of the 11th annual international conference on Mobile computing and networking*, pages 258–269, New York, NY, USA, 2005. ACM Press.

[12] Benetech Martus, August 2007. `http://www.benetech.org/human_rights/martus.shtml`.

[13] Bhoomi homepage, August 2007. `http://bhoomi.kar.in`.

[14] Timothy W. Bickmore and Bill N. Schilit. Digestor: device-independent access to the world wide web. *Comput. Netw. ISDN Syst.*, 29(8-13):1075–1082, 1997.

[15] Eric A. Bier, Maureen C. Stone, Ken Pier, William Buxton, and Tony D. DeRose. Toolglass and magic lenses: the see-through interface. In *SIGGRAPH '93: Proceedings of 20th annual conference on Computer graphics and interactive techniques*, pages 73–80, New York, NY, USA, 1993. ACM Press.

[16] Staffan Björk, Lars Erik Holmquist, Johan Redström, Ivan Bretan, Rolf Danielsson, Jussi Karlgren, and Kristofer Franzén. West: a web browser for small terminals. In *UIST '99: Proceedings of the 12th annual ACM symposium on User interface software and technology*, pages 187–196, New York, NY, USA, 1999. ACM Press.

[17] Edwin H. Blake. A field computer for animal trackers. In *CHI '02: CHI '02 extended abstracts on Human factors in computing systems*, pages 532–533, New York, NY, USA, 2002. ACM Press.

[18] Eli Blevis. Sustainable interaction design: invention & disposal, renewal & reuse. In *CHI '07: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 503–512, New York, NY, USA, 2007. ACM Press.

[19] Eric Brewer, Michael Demmer, Bowei Du, Melissa Ho, Matthew Kam, Sergiu Nedevschi, Joyojeet Pal, Rabin Patra, Sonesh Surana, and Kevin Fall. The case for technology in developing regions. *Computer*, 38(6):25–38, 2005.

[20] Stephen Brewster. Overcoming the lack of screen space on mobile computers. *Personal Ubiquitous Comput.*, 6(3):188–205, 2002.

[21] George Buchanan, Sarah Farrant, Matt Jones, Harold Thimbleby, Gary Marsden, and Michael Pazzani. Improving mobile Internet usability. In *WWW '01: Proceedings of the 10th international conference on World Wide Web*, pages 673–680, New York, NY, USA, 2001. ACM Press.

[22] Orkut Buyukkokten, Hector Garcia-Molina, Andreas Paepcke, and Terry Winograd. Power Browser: efficient web browsing for PDAs. In *CHI '00: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 430–437, New York, NY, USA, 2000. ACM Press.

[23] Simone Cecchini and Monica Raina. Warana: The case of an Indian rural community adopting ICT. *Information Technology In Developing Countries*, 12(1), April 2002.

[24] Cellular microfinance: An African safari. *Small Change*, February 2006.

[25] CGAP IT innovation series - smart cards, December 2005. http://www.cgap.org/docs/IT_smart_card.html.

[26] CGAP reflections on the Compartamos initial public offering, June 2007. http://microfinancegateway.org/content/article/detail/41181.

[27] Citigroup homepage, April 2004. http://www.citigroup.com/citigroup/citizen/community/.

[28] Citizens use SMS to monitor Nigeria's presidential election, August 2007. http://www.shareideas.org/index.php/Citizens_Use_SMS_to_Monitor_Nigeria%\%27s_Presidential_Election.

[29] Datadyne homepage, August 2007. http://www.datadyne.org.

[30] DB Microcredit Development Fund, December 2005. http://www.community.db.com.

[31] Digital Dividend PRODEM case study, 2004. http://www.digitaldividend.org/case/case_prodem.htm.

[32] David L. Dill, Bruce Schneier, and Barbara Simons. Voting and technology: who gets to count your vote? *Commun. ACM*, 46(8):29–31, 2003.

[33] Susan M. Dray, David A. Siegel, and Paula Kotzé. Indra's net: HCI in the developing world. *Interactions*, 10(2):28–37, 2003.

[34] Drishtee homepage, August 2007. http://www.drishtee.com.

[35] http://www.e-cert.at, October 2006.

[36] eCare homepage, August 2007. http://www.ecareghana.org.gh.

[37] Epihandy homepage, August 2007. http://www.epihandy.com.

[38] Experiments with point of sale technologies underway in Africa. Microfinance Gateway, 2004. http://www.microfinancegateway.org/content/article/detail/19469.

[39] M. Familiant and M. Detweiler. Iconic reference: Evolving perspectives and an organising framework. *International Journal of Man Machine Studies*, 39:705–728, 1993.

[40] Fighting avian flu with mobile phones in Indonesia, August 2007. http://www.shareideas.org/index.php/Fighting_Avian_Flu_with_Mobile_Phon%es_in_Indonesia.

[41] Armando Fox, Ian Goldberg, Steven D. Gribble, David C. Lee, and Eric A. Brewer. Experience with Top Gun Wingman: a proxy-based graphical web browser for the 3Com PalmPilot. In *Proceedings of Middleware '98, Lake District, England, September 1998*, 1998.

[42] FrontlineSMS homepage, August 2007. `http://frontlinesms.kiwanja.net`.

[43] Anand Giridharadas. India uses VAT in tax-evasion battle. *International Herald Tribune*, April 2005.

[44] The global coffee trade, February 2004.

[45] M. Goetze and T. Strothotte. An approach to help functionally illiterate people with graphical reading aids. In *Smart Graphics Symposium UK*, 2001.

[46] Grameen Bank home page. `http://www.grameen-info.org`, 2003.

[47] Grameen Phone home page. `http://www.grameenphone.com`, March 2005.

[48] Grameen Technology Center - microfinance automation, December 2005. `http://tech.gfusa.org/technology_center/microfinance_automation/`.

[49] Sally Grisedale, Mike Graves, and Alexander Grünsteidl. Designing a graphical user interface for healthcare workers in rural India. In *CHI '97: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 471–478, New York, NY, USA, 1997. ACM Press.

[50] Guatemalan coffee growers association increases member support while reducing costs. Microsoft Visual Studio .NET Customer Solution Case Study, September 2004.

[51] François Guimbretière. Paper augmented digital documents. In *UIST '03: Proceedings of the 16th annual ACM symposium on User interface software and technology*, pages 51–60, New York, NY, USA, 2003. ACM Press.

[52] Gyandoot homepage, August 2007. `http://gyandoot.nic.in`.

[53] David L. Hecht. Printed embedded data graphical user interfaces. *Computer*, 34(3):47–55, 2001.

[54] Jeremy M. Heiner, Scott E. Hudson, and Kenichiro Tanaka. Linking and messaging from real paper in the Paper PDA. In *UIST '99: Proceedings of the 12th annual ACM symposium on User interface software and technology*, pages 179–186, New York, NY, USA, 1999. ACM Press.

[55] HFI homepage, April 2003. http://www.humanfactors.com.

[56] Honey Bee Network homepage. http://www.honeybee.org, November 2005.

[57] M. Huenerfauth. Developing design recommendations for computer interfaces accessible to illiterate users. Master's thesis, University College Dublin, August 2002.

[58] ICICI Social Initiatives homepage, December 2005. http://www.icicisocialinitiatives.org.

[59] IFOAM organic farming principles, 2005. http://www.ifoam.org/about_ifoam/principles/index.html.

[60] Jennifer Isern, L.B. Prakash, Anuradha Pillai, Syed Hashemi, Robert Peck Christen, and Gautam Ivatury. Sustainability of Self-Help Groups in India - two analyses. *CGAP Occasional Paper*, (12), August 2007.

[61] CGAP IT innovation series: PDAs in microfinance, June 2004. http://www.cgap.org/docs/IT_pda.html.

[62] Paul Javid and Tapan S. Parikh. Augmenting rural supply chains with a location-enhanced mobile information system. In *ICTD '06: Conference on Information and Communication Technologies for Development*, May 2006.

[63] Robert Jensen. Information, market performance and the well-being of the poor: Evidence from south Indian fisheries, 2006.

[64] Walter Johnson, Herbert Jellinek, Jr. Leigh Klotz, Ramana Rao, and Stuart K. Card. Bridging the paper and electronic worlds: the paper user interface. In *CHI '93: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 507–512, New York, NY, USA, 1993. ACM Press.

[65] A. Joshi, S. Weerawarana, and E. N. Houstis. On disconnected browsing of distributed information. In *RIDE '97: Proceedings of the 7th International Workshop on Research Issues in Data Engineering (RIDE '97) High Performance Database Management for Large-Scale Applications*, page 101, Washington, DC, USA, 1997. IEEE Computer Society.

[66] Anne Kaikkonen and Virpi Roto. Navigating in a mobile XHTML application. In *CHI '03: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 329–336, New York, NY, USA, 2003. ACM Press.

[67] Oliver Kaljuvee, Orkut Buyukkokten, Hector Garcia-Molina, and Andreas Paepcke. Efficient web form entry on PDAs. In *WWW '01: Proceedings of the 10th international conference on World Wide Web*, pages 663–672, New York, NY, USA, 2001. ACM Press.

[68] Matthew Kam and Tu Tran. Lessons from deploying the Remote Transaction System with three microfinance institutions in Uganda. In *Proceedings of the UNIDO-UC Berkeley "Bridging the Divide" Conference*, April 2005.

[69] Kannel homepage, August 2007. `http://www.kannel.org`.

[70] Caitlin Kelleher and Randy Pausch. Lowering the barriers to programming: A taxonomy of programming environments and languages for novice programmers. *ACM Comput. Surv.*, 37(2):83–137, 2005.

[71] Tim Kindberg. Implementing physical hyperlinks using ubiquitous identifier resolution. In *WWW '02: Proceedings of the 11th international conference on World Wide Web*, pages 191–199, New York, NY, USA, 2002. ACM Press.

[72] Scott R. Klemmer, Jamey Graham, Gregory J. Wolff, and James A. Landay. Books with Voices: paper transcripts as a physical interface to oral histories. In *CHI '03: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 89–96, New York, NY, USA, 2003. ACM Press.

[73] Anja Kodde. Green thumbs and green practices. *ICT Update*, (32), July 2006.

[74] Glenn E. Krasner and Stephen T. Pope. A cookbook for using the model-view controller user interface paradigm in Smalltalk-80. *J. Object Oriented Program.*, 1(3):26–49, 1988.

[75] Jean-Marie Krier. Fair trade in Europe 2005: Facts and figures on fair trade in 25 European countries. *Fair Trade Advocacy Office*, 2005.

[76] Bill Kules, Hyunmo Kang, Catherine Plaisant, Anne Rose, and Ben Shneiderman. Immediate Usability: Kiosk design principles from the CHI 2001 photo library. `http://citeseer.ist.psu.edu/571542.html`.

[77] Heidi Lam and Patrick Baudisch. Summary Thumbnails: readable overviews for small screen web browsers. In *CHI '05: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 681–690, New York, NY, USA, 2005. ACM Press.

[78] A. LaMarca, Y. Chawathe, S. Consolvo, J. Hightower, I. Smith, J. Scott, T. Sohn, J. Howard, J. Hughes, F. Potter, J. Tabert, P. Powledge, G. Borriello, and B. Schilit. Place Lab: Device positioning using radio beacons in the wild. In *Proceedings of*

PERVASIVE 2005, Third International Conference on Pervasive Computing, Munich, Germany, 2005.

[79] Mik Lamming, Marge Eldridge, Mike Flynn, Chris Jones, and David Pendlebury. Satchel: providing access to any document, any time, anywhere. *ACM Trans. Comput.-Hum. Interact.*, 7(3):322–352, 2000.

[80] Pete Lewis. Wine, workers and web applications. *ICT Update*, (32), July 2006.

[81] Christian Lindholm, Turkka Keinonen, and Harri Kiljander. *Mobile Usability: How Nokia Changed the Face of the Mobile Phone*. McGraw-Hill, NY, NY, USA, 2003.

[82] B. Loevinsohn and A. Harding. Buying results? Contracting for health service delivery in developing countries. *The Lancet*, 2005.

[83] Wendy E. MacKay. Is paper safer? The role of paper flight strips in air traffic control. *ACM Trans. Comput.-Hum. Interact.*, 6(4):311–340, 1999.

[84] Wendy E. Mackay, Guillaume Pothier, Catherine Letondal, Kaare Boegh, and Hans Erik Sorensen. The missing link: augmenting biology laboratory notebooks. In *UIST '02: Proceedings of the 15th annual ACM symposium on User interface software and technology*, pages 41–50, New York, NY, USA, 2002. ACM Press.

[85] Macromedia Flash, April 2006. `http://www.macromedia.com/software/flash/flashpro/`.

[86] Charles Mahoney. Fintrac's mobile office: delivering agribusiness support in Honduras. *ICT Update*, (14), November 2003.

[87] Huntley G. Manhertz. JAMEX: An ICT initiative supporting agricultural development in Jamaica. *ICT Update*, (14), November 2003.

[88] Manual for SHGs for use of branch managers, August 2005. `http://www.nabard.org/roles/microfinance/files/publications/bmgrmanual.%pdf`.

[89] Mbuni homepage, August 2007. `http://www.mbuni.org`.

[90] Jonathan M. McCune, Adrian Perrig, and Michael K. Reiter. Seeing-is-believing: Using camera phones for human-verifiable authentication. In *SP '05: Proceedings of the 2005 IEEE Symposium on Security and Privacy*, pages 110–124, Washington, DC, USA, 2005. IEEE Computer Society.

[91] William McDonough and Michael Braungart. *Cradle to Cradle: Remaking the Way we Make Things*. North Point Press, 2002.

[92] Millennium Development Goals. http://www.un.org/millenniumgoals/, 2005.

[93] Eric Metois, Paul M. Yarin, Noah Salzman, and Joshua R. Smith. Fiberfingerprint identification. In *Proceedings of the Third Workshop and Automatic Identification*, pages 147–154, 2002.

[94] Microsoft - Access 2003 homepage, December 2005. http://office.microsoft.com/en-us/FX010857911033.aspx.

[95] MIX Market profile - Compartamos, December 2005. http://www.mixmarket.org/en/demand/demand.show.profile.asp?ett=237.

[96] M.S. Swaminathan Research Foundation home page. http://www.mssrf.org, 2003.

[97] Brad A. Myers, John F. Pane, and Andy Ko. Natural programming languages and environments. *Commun. ACM*, 47(9):47–52, 2004.

[98] NABARD and microfinance, November 2004. http://www.nabard.org/roles/mcid/introduction.htm.

[99] Neal Lesh. personal communication, August 2007.

[100] Les Nelson, Satoshi Ichimura, Elin Ronby Pedersen, and Lia Adams. Palette: a paper interface for giving presentations. In *CHI '99: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 354–361, New York, NY, USA, 1999. ACM Press.

[101] Chris Nicholson. In poorer nations, cellphones help open up microfinancing. *The New York Times*, July 2007.

[102] Moira C. Norrie and Beat Signer. Web-based integration of printed and digital information. In *Proceedings of the VLDB 2002 Workshop EEXTT and CAiSE 2002 Workshop DTWeb on Efficiency and Effectiveness of XML Tools and Techniques and Data Integration over the Web-Revised Papers*, pages 200–219, London, UK, 2003. Springer-Verlag.

[103] Linus U. Opara. Traceability in agriculture and food supply chain: a review of basic concepts, technological implications, and future prospects. *Food, Agriculture and Environment*, 1(1), January 2003.

[104] OpenMRS homepage, August 2007. http://www.openmrs.org.

[105] Jeremy Page. Villages log on to escape bribery and the clutches of the last Raj. *Times Online*, August 2007. http://www.timesonline.co.uk/tol/news/world/asia/article2237920.ece.

[106] Palm Pilots in microfinance: Lending efficiency to microfinance, Fall 1999. http://www.accion.org/PDF/ventures_fall99.pdf.

[107] Tapan S. Parikh. Rural microfinance service delivery: Gaps, inefficiencies and emerging solutions. In *ICTD '06: Conference on Information and Communication Technologies for Development*, May 2006.

[108] Tapan S. Parikh and Kaushik Ghosh. Designing for intermediated information tasks in the developing world. *IEEE Pervasive Computing Magazine*, 5(2), April 2006.

[109] Tapan S. Parikh, Kaushik Ghosh, and Apala Chavan. Design studies for a financial management system for micro-credit groups in rural India. In *CUU '03: Proceedings of the 2003 conference on Universal usability*, pages 15–22, New York, NY, USA, 2003. ACM Press.

[110] Tapan S. Parikh, Paul Javid, Sasi Kumar, Kaushik Ghosh, and Kentaro Toyama. Mobile phones and paper documents: Evaluating a new approach for capturing microfinance data in rural India. In *CHI '06: Proceedings of the SIGCHI conference on Human factors in computing systems*, New York, NY, USA, 2006. ACM Press.

[111] Tapan S. Parikh and Edward D. Lazowska. Designing a mobile information services architecture for the rural developing world. In *WWW '06: Proceedings of the 15th international conference on World Wide Web*, New York, NY, USA, 2006. ACM Press.

[112] Tapan S. Parikh, Kannaiyan Sasikumar, and Sundarmoorthy Olaganathan. Promoting quality bookkeeping in Self-Help Groups: The Mahakalasm Management Information System MIS, November 2006. http://www.seepnetwork.org/content/article/detail/4712.

[113] Jason Pascoe, Nick Ryan, and David Morse. Using while moving: Hci issues in fieldwork environments. *ACM Trans. Comput.-Hum. Interact.*, 7(3):417–437, 2000.

[114] Rabin Patra, Sergiu Nedevschi, Sonesh Surana, Anmol Sheth, Lakshminarayanan Subramanian, and Eric Brewer. Wildnet: Design and implementation of high performance wifi based long distance networks. In *4th USENIX Symposium on Networked Systems Design & Implementation*, pages 87–100, 2007.

[115] Cooley P.C., Miller H.G., Gribble J.N., and Turner C.F. Automating telephone surveys: using T-ACASI to obtain data on sensitive topics. *Comput. hum. behav.*, 16(1):1–11, 2000.

[116] Pendragon homepage, August 2007. http://www.pendragon-software.com.

[117] Alex (Sandy) Pentland, Richard Fletcher, and Amir Hasson. Daknet: Rethinking connectivity in developing nations. *Computer*, 37(1):78–83, 2004.

[118] Ben Piper and Rebeca Eun Young Hwang. The HomeBox: a web content creation tool for the developing world. In *CHI '01: CHI '01 extended abstracts on Human factors in computing systems*, pages 145–146, New York, NY, USA, 2001. ACM Press.

[119] Wikipedia - Population Density, Nov 2005. http://en.wikipedia.org/wiki/List_of_countries_by_population_density.

[120] V. Chandra Rao. Mobile computing for microfinance. i4donline magazine, January 2004. http://www.i4donline.net/issue/jan04/mobile_full.htm.

[121] RBI circular 2005-06/288: Financial inclusion by extension of banking services - use of business facilitators and correspondents, January 2006. http://rbidocs.rbi.org.in/rdocs/notification/PDFs/68417.pdf.

[122] The real digital divide. *The Economist*, March 2005.

[123] Jun Rekimoto and Yuji Ayatsuka. Cybercode: designing augmented reality environments with visual tags. In *DARE '00: Proceedings of DARE 2000 on Designing augmented reality environments*, pages 1–10, New York, NY, USA, 2000. ACM Press.

[124] Jun Rekimoto and Katashi Nagao. The world through the computer: computer augmented interaction with real world environments. In *UIST '95: Proceedings of the 8th annual ACM symposium on User interface and software technology*, pages 29–36, New York, NY, USA, 1995. ACM Press.

[125] Reporting child rights violations in the Democratic Republic of Congo, August 2007. http://www.shareideas.org/index.php/Reporting_Child_Rights_Violations_i%n_the_Democratic_Republic_of_Congo.

[126] T. L. Roberts and G. Engelbeck. The effects of device technology on the usability of advanced telephone functions. In *CHI '89: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 331–337, New York, NY, USA, 1989. ACM Press.

[127] Michael Rohs. Visual code widgets for marker-based interaction. In *IWSAWC'05: Proceedings of the 25th IEEE International Conference on Distributed Computing Systems – Workshops (ICDCS 2005 Workshops)*, Columbus, Ohio, USA, June 2005.

[128] Michael Rohs and Beat Gfeller. Using camera-equipped mobile phones for interacting with real-world objects. In Alois Ferscha, Horst Hoertner, and Gabriele Kotsis, editors, *Advances in Pervasive Computing*, pages 265–271. Austrian Computing Sociery (OCG), Vienna, Austria, 2004.

[129] Michael Rohs and Phillip Zweifel. A conceptual framework for camera phone-based interaction techniques. In *Pervasive 2005, Third International Conference, Lecture Notes in Computer Science (LNCS) No. 3468*, Munich, Germany, May 2005.

[130] Rural ATM, April 2006. `http://www.tenet.res.in/Activities/Products/doc/ruralATM.php`.

[131] Stuart Rutherford. Money talks: Conversations with poor households in Bangladesh about managing money. *Journal of Microfinance*, 5(2), Winter 2003.

[132] Jeffrey Sachs. *The End of Poverty: Economic Possibilities for Our Time*. Penguin Press, March 2005.

[133] Safesave homepage, November 2004. `http://www.safesave.org`.

[134] SARI homepage, December 2005. `http://edev.media.mit.edu/SARI/`.

[135] Bill N. Schilit, Jonathan Trevor, David M. Hilbert, and Tzu Khiau Koh. Web interaction using very small Internet devices. *Computer*, 35(10):37–45, 2002.

[136] Albrecht Schmidt, Henning Schröder, and Oliver Frick. WAP: designing for small user interfaces. In *CHI '00: CHI '00 extended abstracts on Human factors in computing systems*, pages 187–188, New York, NY, USA, 2000. ACM Press.

[137] Yael Schwartzman and Tapan S. Parikh. Using CAM-equipped mobile phones for procurement and quality control at a rural coffee cooperative. In *MobEA V: Mobile Web in the Developing World*, May 2007.

[138] Hans D. Seibel. SHG banking: A financial technology for reaching marginal areas and the very poor: NABARD's program of promoting local financial intermediaries owned and managed by the rural poor in India. *IFAD Rural Finance Working Paper No. 167910*, March 2001.

[139] Abigail J. Sellen and Richard H.R. Harper. *The Myth of the Paperless Office*. MIT Press, Cambridge, MA, USA, 2003.

[140] Semacode homepage, April 2006. `http://semacode.org`.

[141] Series 60 platform, Nov 2005. `http://www.s60.com`.

[142] Shade-grown coffee, October 2006. `http://nationalzoo.si.edu/ConservationAndScience/MigratoryBirds/Coffee`.

[143] Ajay Sharma and Akhilesh Yadav. What works: Akashganga's IT tools for the Indian dairy industry : Using IT to increase efficiency in rural dairy cooperatives. *World Resources Institute*, 2003.

[144] Itiro Siio, Toshiyuki Masui, and Kentaro Fukuchi. Real-world interaction using the FieldMouse. In *UIST '99: Proceedings of the 12th annual ACM symposium on User interface software and technology*, pages 113–119, New York, NY, USA, 1999. ACM Press.

[145] Simkin language, May 2005. `http://www.simkin.co.uk`.

[146] Simputer home page. `http://www.simputer.org`, 2003.

[147] SKS. personal communication, October 2003.

[148] SKS news, March 2007. `http://www.sksindia.com/07mar31.htm`.

[149] Mark Staehle. personal communication, January 2004.

[150] Thad E. Starner. Wearable computing for the developing world. *IEEE Pervasive Computing*, 4(3):87–91, 2005.

[151] The state of the Microcredit Summit campaign report, 2006. `http://www.microcreditsummit.org/pubs/reports/socr/2006.htm`.

[152] Lisa Stifelman, Barry Arons, and Chris Schmandt. The Audio Notebook: paper and pen interaction with structured speech. In *CHI '01: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 182–189, New York, NY, USA, 2001. ACM Press.

[153] TechTip: AGIS. *ICT Update*, (14), November 2003.

[154] Tellme Networks homepage, April 2006. `http://www.tellme.com`.

[155] IIT TENET - connecting rural India, December 2004. `http://www.tenet.res.in/Publications/Presentations/ruralShortDec04.pdf`.

[156] W. Thies, J. Prevost, T. Mahtab, G. Cuevas, S. Shakhshir, A. Artola, B. Vo, Y. Litvak, S. Chan, S. Henderson, M. Halsey, L. Levison, and S. Amarasinghe. Searching the World Wide Web in low-connectivity communities. In *WWW '02: Proceedings of the 11th international conference on World Wide Web, Global Community Track*, 2002.

[157] Eleanor Toye, Richard Sharp, Anil Madhavapeddy, and David Scott. Using smart phones to access site-specific services. *IEEE Pervasive Computing Magazine*, 4(2):60–66, April 2005.

[158] Traceability implementation in developing countries, its possibilities and its constraints, September 2006. http://www.fao.org/ag/agn/food/control_essaytrace_en.stm.

[159] Janaki Turaga. Opportunities and challenges in India: Crafting the MF/IT paradigm-the Indian experience. i4donline magazine, January 2004. http://www.i4donline.net/issue/jan04/opportunities_full.htm.

[160] Uganda Remote Transaction System pilot. Microfinance Gateway, 2004. http://www.microfinancegateway.org/content/article/detail/19145.

[161] UNESCO Institute for Statistics, Regional adult illiteracy rate and population by gender, July 2002. http://www.uis.unesco.org/en/stats/statistics/literacy2000.htm.

[162] http://www.utzkapeh.org, October 2006.

[163] Voxiva homepage, August 2007. http://www.voxiva.com/solutions.asp.

[164] Randolph Wang, Urvashi Sahni, Sumeet Sobti, Nitin Garg, Jaswinder Pal Singh, Matthew Kam, Arvind Krishnamurthy, and Thomas Anderson. The Digital Study Hall. Technical Report TR-723-05, Department of Computer Science, Princeton University, March 2005. http://dsh.cs.washington.edu/StudyHall/.

[165] Randolph Y. Wang, Sumeet Sobti, Nitin Garg, Elisha Ziskind, Junwen Lai, and Arvind Krishnamurthy. Turning the postal system into a generic digital communication mechanism. In *SIGCOMM '04: Proceedings of the 2004 conference on Applications, technologies, architectures, and protocols for computer communications*, pages 159–166, New York, NY, USA, 2004. ACM Press.

[166] Roy Want, Kenneth P. Fishkin, Anuj Gujar, and Beverly L. Harrison. Bridging physical and virtual worlds with electronic tags. In *CHI '99: Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 370–377, New York, NY, USA, 1999. ACM Press.

[167] Pierre Wellner. Interacting with paper on the DigitalDesk. *Communications of the ACM*, 36(7):87–96, 1993.

[168] Curioso WH, Karras BT, Campos PE, Buendia C, Holmes KK, and Kimball AM. Design and implementation of Cell PREVEN: A real-time surveillance system for adverse events using cell phones in Peru. *AMIA Annual Symposium Proceedings*, pages 176–180, 2005.

[169] What works: Scaling microfinance with the Remote Transaction System, August 2005. http://www.sevaksolutions.org/docs/RTS\%20Uganda\%20Case\%20Study.pdf.

[170] Alma Whitten and J.D. Tygar. Why johnny can't encrypt: A usability evaluation of pgp 5.0. In *Proceedings of the 8th USENIX Security Symposium*, August 1999.

[171] Wikipedia - Census, August 2007. `http://en.wikipedia.org/wiki/Census#India`.

[172] E.O. Wilson. *The Future of Life*. Alfred K. Knopf. Inc., January 2002.

[173] Jacob O. Wobbrock, Jodi Forlizzi, Scott E. Hudson, and Brad A. Myers. WebThumb: interaction techniques for small-screen browsers. In *UIST '02: Proceedings of the 15th annual ACM symposium on User interface software and technology*, pages 205–208, New York, NY, USA, 2002. ACM Press.

[174] `http://wordpress.org`, October 2006.

[175] R. B. Yeh, C. Liao, S. R. Klemmer, F. Guimbretière, B. Lee, B. Kakaradov, J. Stamberger, and A. Paepcke. ButterflyNet: A mobile capture and access system for field biology research. In *CHI '06: Proceedings of the SIGCHI conference on Human factors in computing systems*, New York, NY, USA, 2006. ACM Press.

[176] Min Yin and Shumin Zhai. Dial and See: tackling the voice menu navigation problem with cross-device user experience integration. In *UIST '05: Proceedings of the 18th annual ACM symposium on User interface software and technology*, pages 187–190, New York, NY, USA, 2005. ACM Press.

[177] Muhammad Yunus. Is Grameen Bank different from conventional banks?, October 2005. `http://www.grameen-info.org/bank/GBdifferent.htm`.

Appendix A

MILLENNIUM DEVELOPMENT GOALS (MDGS)

Reprinted from `http://www.un.org/millenniumgoals/`.

- **Eradicate extreme poverty and hunger**
- **Achieve universal primary education**
- **Promote gender equality and empower women**
- **Reduce child mortality**
- **Improve maternal health**
- **Combat HIV/AIDS, malaria, and other diseases**
- **Ensure environmental sustainability**
- **Develop a global partnership for development**

Appendix B

SCREENSHOTS FROM HISAAB STUDY

In this appendix, I include some of the screenshots from the Hisaab participatory design study, roughly in chronological order. Kaushik Ghosh, Sarit Arora, Abhijeet Thosar, Punit Syal and Apala Lahiri Chavan were involved in this study, and in producing the following designs.

Figure B.1: Screen 1

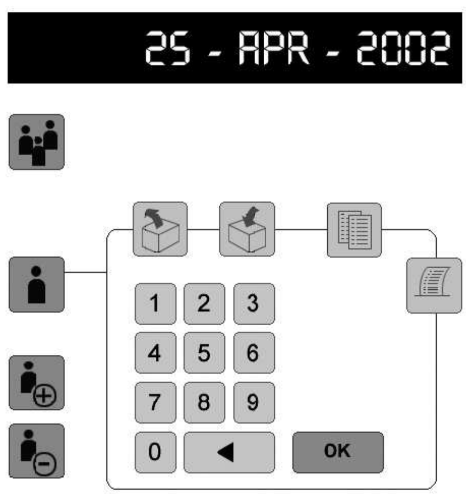


Figure B.2: Screen 2

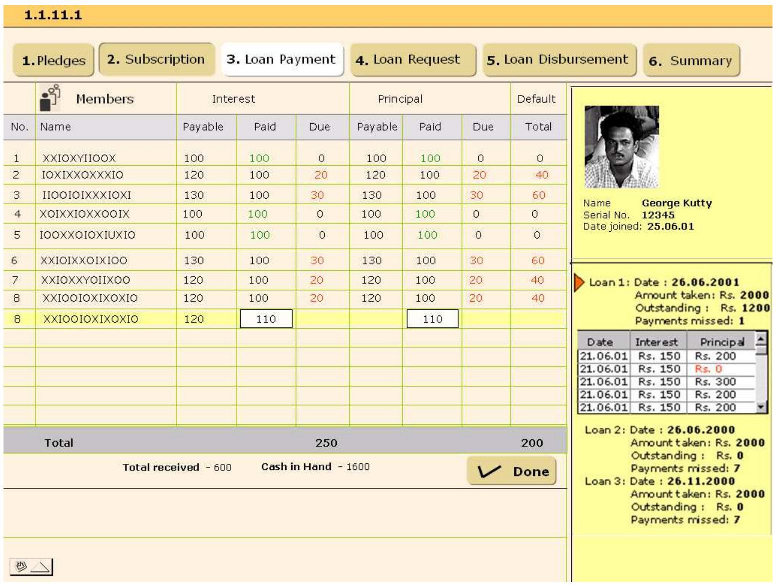


Figure B.3: Screen 3

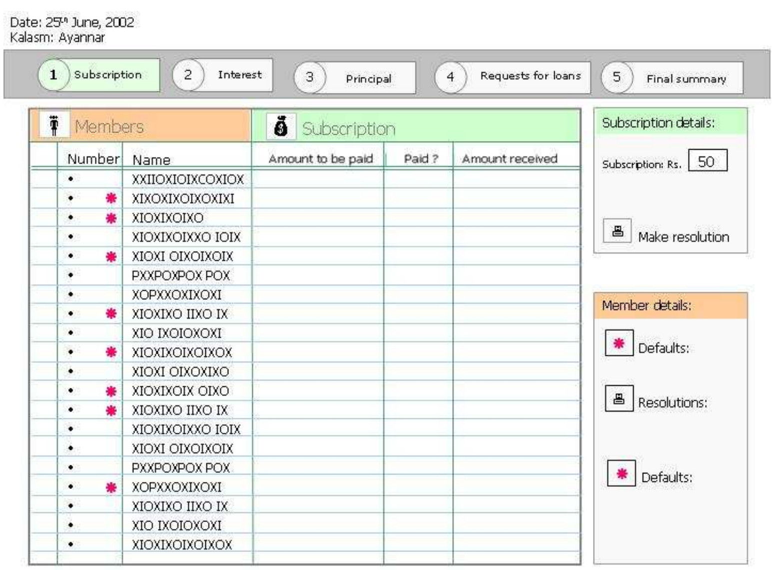


Figure B.4: Screen 4

Figure B.5: Screen 5

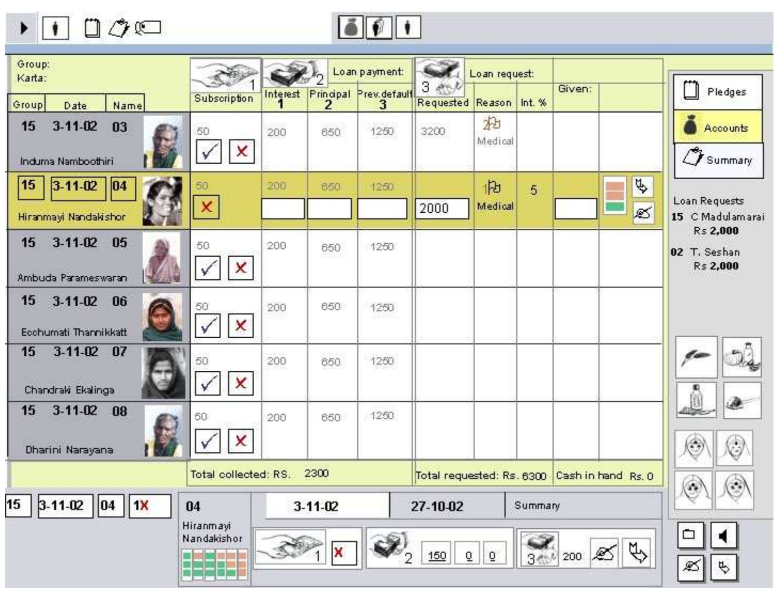


Figure B.6: Screen 6

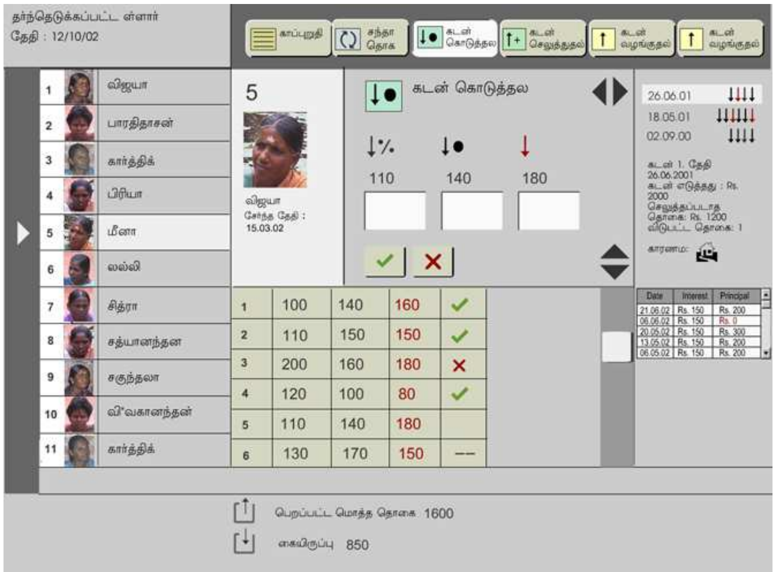


Figure B.7: Screen 7

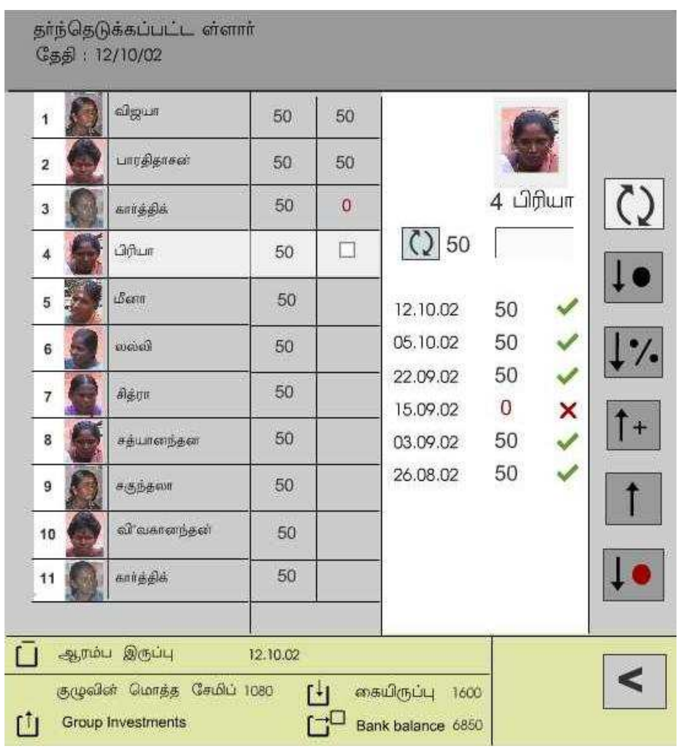


Figure B.8: Screen 8

VITA

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