Managing Microfinance with Paper, Pen and Digital Slate

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***Abstract*— India's extensive Self-Help Group (SHG) microfinance network brings formal savings and credit services to 86 million poor households. Yet, the inability to maintain high-quality records remains a persistent weakness in SHG functioning. We study this problem and present a financial record management application built on a low-cost digital slate prototype. The solution directly accepts handwritten input on ordinary paper forms and provides immediate electronic feedback. A field trial with 200 SHG members in rural India shows that the use of the digital slate solution results in shorter data recording time, fewer incorrect entries, and more complete records. The paper-pen-slate solution performs as well as, and is strongly preferred over, a purely electronic alternative. The digital slate solution is able to comfortably move between paper and digital worlds, achieving efficiency and quality gains while catering to the preferences and budgets of low-income low-literate clients.**

***Index Terms*—Digital slates and pens, microfinance, Self-Help Groups, India**

I. INTRODUCTION

Microfinance services reach over 154 million households worldwide [1]. The largest microfinance initiative in the world is the decentralized Self-Help Group (SHG)-Bank linkage programme in India. An SHG is a savings and credit collective consisting of 10-20 low-income women who meet on a weekly or monthly basis to pool small savings together. The pooled capital is loaned to individual members at an interest rate determined within the group. The SHG is subsequently linked with a bank to maintain a group savings account and access low-cost loans from the formal financial sector. Each SHG manages its own operations with varying degrees of external support from non-governmental organizations (NGOs), banks and government agencies.

The SHG-Bank linkage programme is a centerpiece of the Indian government's strategy for rural financial inclusion, with 86 million poor households participating through over 6 million SHGs (March 2009) [3]. The total savings accumulated through this programme was over $840 million, while total loans disbursed from the formal banking sector—at an 86-90% on-time loan repayment rate—was over $3.7 billion (March 2008) [4, 5].

While outreach has been extensive, evaluations of the health, growth and impact of SHGs on members' social and economic development indicate successes and weaknesses. A recent evaluation indicates that SHGs do target the poor: 83% of members are below the poverty line or borderline, 55% are from Scheduled Tribes and Scheduled Castes, 67% work in own agriculture or as casual labourers, and 74% are not literate. SHGs provide actively-used savings and credit facilities (average savings of $53 and average loan of $230 per member). One in five SHGs was involved in a group-based enterprise or enterprise contract; one in four had a woman member who ran for local political office; and one in three was involved in community action such as improving water supply, education, healthcare, etc. [6]

Yet, there was little data to inform a reliable evaluation. Only 15% of SHGs were found to have high quality records that were complete, updated, and accurate. 40% of records were found to be weak and inadequate [6]. Unreliable records affected SHGs' ability to borrow external funds resulting in a debt/equity ratio of 1.4 compared to a maximum of 4. The evaluators conclude:

> "Record keeping at the group level has emerged as a very weak aspect of SHG functioning…Good book keeping is critical for the sustainability of financial operations and continued mutual trust among members. Good quality of book-keeping means completeness, accuracy, up-to-date information and transparency. There is a need for simple and user-friendly records and books of accounts." [6]

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Over a fifteen-month period, we engaged with a set of SHG collectives in rural India to understand the specific problems in their existing record management system and devise appropriate solutions. We describe some of the key constraints involved in SHG record management and present our solution: a record management application built on a low-cost handheld digital slate prototype that directly accepts and processes handwritten pen-based input on ordinary paper forms and provides immediate visual and audio electronic feedback.

The main contribution of our paper is the demonstration of a low-cost digital record management system that can be used effectively by low-income clients with little training. The solution is innovative in using handwritten pen and ink-based input on ordinary paper forms to directly manipulate a local digital database and allow real-time digital processing and feedback in the absence of a conventional computer. Our solution was tested with 201 SHG members from 14 groups in the states of West Bengal and Orissa in India, where we assessed outcomes of data accuracy, data completeness, and process efficiency. The pen-paper-slate solution performed as well as a purely electronic alternative, and performed better than the traditional paper-only system. Of central importance to members was the automated audio feedback on dues and balances that they received instantly.

There was a strong subjective preference for the hybrid pen-paper-slate solution over the purely electronic control. This appeared to be due to the high value placed by rural SHG members on maintaining a local paper record of their data that could be accessed by any one of them at any time. The digital slate solution comfortably straddled both paper and digital worlds, achieving efficiency and quality gains while also catering to the preferences and budgets of low-income, low-literate clients.

II. RELATED WORK

A. Digitizing front-end microfinance record management

The prospect of improving front-end record management in microfinance using technology has met with much enthusiasm over the past decade [7, 8, 9]. Prototype solutions to enable transaction record management have been designed using camera-enabled mobile phones [10], Simputers [11], handheld devices [12, 13], palm pilots [14], J2ME applications on Java phones [15], and even laptops [16]. Many of these solutions have focused on the Grameen-Bank model of joint-liability microfinance delivery, which is distinct from the Self-Help Groups' decentralized autonomous structure and self-run process.

Most of these solutions have not attained scaled deployment. The cost of investment in the technology-enabled channel is often too high to allow for financial viability over a reasonable timeframe for microfinance institutions [17]. Because application development and testing are often performed in isolation, there have been problems in integrating the prototype solution into regular microfinance workflows given field and operational constraints [18]. Moreover, clients exhibit a strong preference for maintaining a local paper record for reference [10], which has dampened uptake for purely electronic data collection systems, using mobile phones or PDAs, in which a paper trail is not left behind.

B. Data collection and management in resource-poor settings by low-literate users

In related areas like healthcare delivery and remittance services in remote low-income communities, there have been studies of using electronic channels for timely and error-free data collection and processing [19, 20]. Voice-based input over a phone for healthcare data collection is seen to result in lower error rates compared with using a mobile phone keypad to enter data using electronic forms or SMS syntaxes [20]. Separately, in a simulated exercise, low-literate respondents are found to complete mobile money-transfer transactions faster and with fewer prompts using a spoken dialog mobile phone User Interface (UI), though task completion rates are higher for an equivalent graphics-based UI [21]. Our work extends this line of research by allowing low-literate users to enter electronic data through a natural UI involving writing by hand using a pen on paper.

C. Interactions between paper forms and digital media

In rural settings within developing countries where digital devices are not pervasive, all written records are maintained on paper forms, which require separate transcription to be usefully aggregated and processed [8]. Several solutions have tried to build a seamless paper-digital continuum for data management in such settings, from the use of camera-enabled mobile phones to capture data from paper forms marked with barcodes [10], to using machine-readable paper forms [22].

There is a large body of technical work that explores the ways in which data can move seamlessly between paper and digital media. Anoto [23] offers a digital pen using which text written on plain paper can be memorized and later transferred to a PC either as an image or recognized text and digits for further processing. Similar solutions include the Pegasus NoteTaker and PADDs (Paper Augmented Digital Documents) [24, 25, 26, 27]. A few of these solutions like Anoto can only be used on special paper (with a pre-printed dots pattern). None of these solutions have inbuilt PC-independent processing capabilities to provide immediate electronic feedback to handwritten input on regular paper, in reference to a digital database.

From a usability perspective, the value of pen input on paper has been repeatedly recognized. Previous work

assessing support tools for students working on Math problems confirmed that "as interfaces departed more from familiar work practice [of using pen on paper], students experienced greater cognitive load and corresponding reductions in their expressive fluency and planning" [31]. Even in richer countries where digital media are widely prevalent, ink input on paper is still a preferred mode for preparing notes [32].

III. PROBLEM DESCRIPTION

In this study, we investigated the record management processes used by the SHGs supported by the non-profit NGO PRADAN in eastern India. PRADAN promotes SHGs for microfinance as the first step in mobilizing groups of rural individuals towards better livelihoods. PRADAN has supported nearly 9000 SHGs in establishing their operations, reaching out to over 122,000 rural women in remote marginalized areas [33].

A. Baseline Paper-only SHG Record Management System

The SHGs supported by PRADAN begin their operations by maintaining all financial transaction records locally in a large paper record book, also called the Regular Meeting Transaction Statement-1 or RMTS-1 ledger. The most literate member serves as the group's Accounts Writer (henceforth called the Writer). In SHGs that do not have any literate members, they hire a literate person in the village to serve as their Writer. The SHG meets once a week in the members' own village. The Writer refers to the previous page in the RMTS-1 ledger book to calculate dues for the present meeting and fresh balances based on member payments at the meeting.

As the size of the group's assets grows, this accounting process constitutes a heavy burden on the Writer, who on average has a Class 8 education. Despite long meeting times, the quality of financial records is low. Numerous conflicts in data come up at the annual financial audit of the group's records, which leads to members' low trust in the financial system that they are a part of and gradual disengagement. Larger low-cost credit flows from the banking system are also limited by the lack of reliable financial data on the group's performance.

B. The 'Computer Munshi' Record Management System

In response, PRADAN set up an alternative record management system in a number of locations (Fig. 1). A group of 100-200 SHGs (called a Federation) collectively outsources their weekly accounting and reconciliation functions to an accountant in the nearby town, called the Computer Accountant or Computer Munshi (henceforth called the CM). Each SHG's Writer is given a carbon sheet to place in their RMTS-1 paper ledger book as s/he fills in the SHG's transaction data each week. After all transactions are recorded, the carbon copy of the RMTS-1 form (Fig. 2) is removed from the book and dropped off at a local 'drop box'.

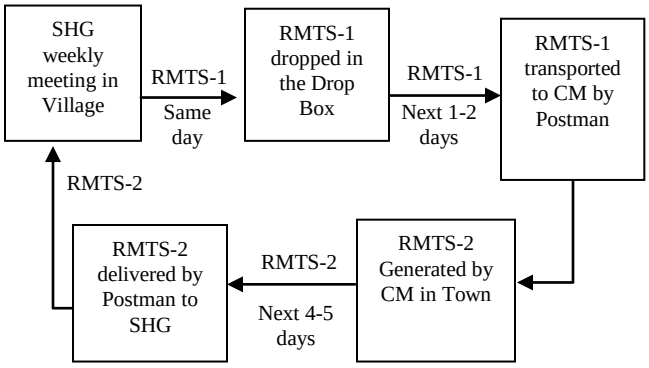

Fig. 1. The weekly 'Computer Munshi' Record Management Workflow

A postman hired by the CM picks up the RMTS-1 copies from 30-40 SHGs in an area once a week and delivers them to the CM in town. The CM transcribes the data from the paper form into a software application on the PC, reconciles the figures and prints the new statement of dues and balances for the SHG. The postman then physically delivers these Regular Meeting Transaction Statement-2 or RMTS-2 print-outs with the updated figures to each SHG before their next weekly meeting. The CM receives Rs. 3 ($0.07) per member per month as fees, from which he pays each postman Rs. 4 ($0.09) for each RMTS-2 print-out delivered.

C. Problems in the Current Record Management System

The first major constraint observed is that it is not possible to introduce the Computer Munshi record management system in all areas where SHGs function. In remote, hilly or forested areas, the severe geographic accessibility barrier precluded the weekly transport of data on paper forms back and forth from the SHGs in the villages to the CM in town for processing. Moreover, members tended to be from more disadvantaged communities in these areas having lower literacy rates and lower quality education. This led to higher error rates and more error reconciliation delays.

Where it was operational, the Computer Munshi record management system faced a number of recurring problems. We conducted a baseline written survey of four CMs, each of whom handled the weekly accounting for 100-200 SHGs. On average, one in five member's records were not fully updated at a given point in time (Table 1). While the error rate was exceptionally high in only one of the four surveyed locations, the process that had to be followed by the CMs to

reconcile errors was onerous and contributed to further delays in updating records.

TABLE 1
SHARE OF MEMBER RECORDS NOT UPDATED OR WITH ERRORS

CM No.	No. of member records maintained	Share of member records not updated	Share of member records with errors
1	778	27%	3%
2	1219	43%	4%
3	1941	0%	1%
4	2523	21%	43%

Three key areas of concern were highlighted by the data and by the narrative responses from the CMs.

1. Low Data Accuracy

a) Recording errors: The SHG's Writer sometimes made errors in recording data as it related to a transaction or event. Since SHG members have low literacy levels, there was no mechanism for them to verify the figures entered by the Writer on the RMTS-1 paper form that was sent to the CM.

b) Calculation errors: Sometimes there were errors in arithmetic calculations, such as, adding the total interest paid or checking the recorded total with the cash in the cash-box. CMs therefore noted issues such as: "Calculations in the RMTS 1 columns are incorrect (totals for group savings, interest repayment, etc.)"; "Interest outstanding is not matching"; "Tallying of group accounts with cash balance incorrect".

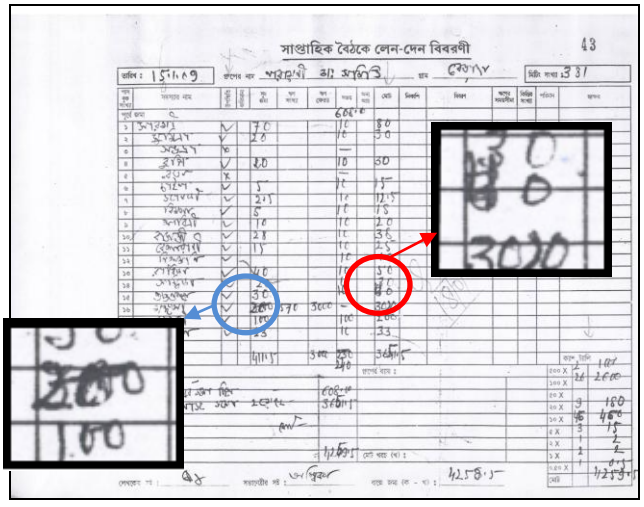

Fig. 2. Carbon copy of a filled-in RMTS-1 form; the blue area shows a case of illegible entry (the entry looks like 200 but it is 20), and the red area shows a case of overlapping entries across rows

c) Legibility errors: The paper form sent to the CM for transcription was a carbon copy of the original, which made some entries difficult to recognize and interpret (Fig. 2). One CM noted that "legibility poor because carbon paper".

2. Low Data Completeness

Often, certain mandatory fields in the paper forms were left empty. One CM notes: "Cash book writing is incomplete - rows in the RMTS-1 are not properly entered like purpose and duration of loan". Very often, the Tally module (counting the cash in hand by denomination of notes) was skipped, despite it being a required module to maintain transparency in records.

3. Low Process Efficiency

a) Error resolution: The process for resolving errors or missing entries in the RMTS-1 forms introduced long delays. One CM elaborated: "That particular SHG [with the problem] is given a special letter which describes the mistakes. It is taken by the postman to the SHG. After getting the letter the SHG will reply next week. If not clear still then the SHG will have to come to office on the correction days." In all, it could take up to 2-3 weeks to correct the errors and start issuing updated RMTS-2 statements to the SHG again.

b) Paper Form Transport Delays: Interruptions in the physical transport of paper RMTS forms from meeting to transcription location and vice versa each week were common. Seasonal disruptions especially during the Monsoons, breakdowns in the CM's PC, or members forgetting to drop off the form in the drop box were common occurrences. The weekly paper form transport task performed by the postmen was a high-effort low-return activity, with each paid Rs. 4 ($0.09) per round-trip of travel, sometimes involving a distance of 15 km.

c) Extended meeting time: When groups did not receive their RMTS-2 print-outs, the meeting time would be extended because the Writer was then required to manually perform the requisite calculations for each member's dues and balances.

IV. SOLUTION DESIGN

Design considerations

A meaningful solution to the identified problems would improve the quality of SHG data (accuracy, completeness, timeliness) through a record management system that is easily usable by Writers, reliable to members, functional in remote locations, and sustainable with user fees.

One core constraint in the CM system was the remote processing of data. Gains in data accuracy, completeness, and timeliness of updates could be achieved through local processing, using a robust and low-cost portable computing device. Entering transaction data digitally at the SHG meeting and having it immediately processed in reference to the database would remove the need for physical transport of paper forms and print-outs back and forth each week, as well as remove redundant data entry.

In choosing an appropriate input mechanism for digital data in the field, we considered the following alternatives:

- *Handwritten input*: Allow Writers to continue with handwritten pen-and-paper-based data entry but with digital pens.
- *Stylus, keypad or keyboard input*: Allow Writers to enter data electronically using a stylus on a touch screen, or accessories such as numeric keypads or keyboards.
- *Voice input*: Allow the Writer to use his/her voice to enter data, either locally on a phone or through an IVRS system in which s/he would communicate by voice with a server or agent in real-time.

Our field locations required an entirely local solution for real-time processing and feedback, as these areas are not covered by reliable wireless networks yet. This precluded an IVRS solution.

Between handwritten input, stylus, phone keypad and keyboard input, we pursued the most natural of these user input mechanisms. Our design therefore focused on handwritten pen-based input and stylus-based navigation, with audio as a key feedback channel.

Selected device

Given the requirements, we selected an existing third-party handheld digital slate and pen prototype as the device of choice (Fig. 3). This device was originally designed and prototyped as a note-taking PC accessory for an educational application. We found it well-suited to serve as a standalone paper-based handwritten input digitizer with inbuilt processing capabilities.

The slate has an A-5 size (210mm X 145mm) digitizing pad on which ordinary paper or a book can be placed, and anything written on the paper using the device's digital ballpoint pen is simultaneously digitally captured as raw strokes. The device also has a 3.5-inch touch screen display and runs on Windows CE. The back of the device's pen, fitted with the pen cap, serves as a stylus for touch screen input.

The device has a memory of 512 MB and an inbuilt SD card reader that allows expandable storage as required. The slate has an audio-out port. It runs on rechargeable batteries with a battery life of 5-7 hours after a full charge. The active pen runs on a single AAAA battery. While the device has no immediate commercialization plans, a single unit that includes the digital slate and pen, is expected to cost ~US$100 under mass manufacture.

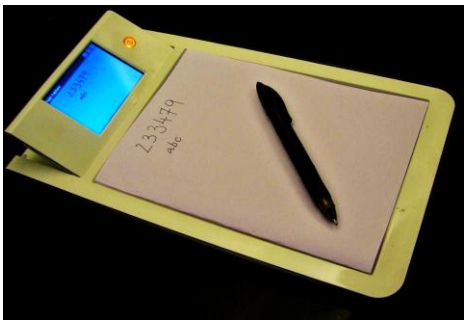

Fig. 3. The prototype digital slate and pen device used in the study

Application components

We built a .NET Compact Framework record management software application to run on the digital slate prototype. Our application's design matched the format and workflow of the existing RMTS-1 and RMTS-2 paper form templates and SHG meeting process. The device and application would be operated by each SHG's Writer.

Navigation through the screens of the application is done using the stylus (i.e. the capped end of the device's pen) on the touch screen. After starting the application, the Writer selects the SHG's name from a list, which leads to a screen displaying members' names and a button to initiate the day's meeting. This leads to the meeting home screen that displays the date and the current meeting number, and allows navigation through the five required tasks/modules. :

1. Entering individual member attendance and payments data (interest, savings, loan principal repayments)
2. Entering group income data
3. Enter individual member receipts data (new loans, savings withdrawal)
4. Entering group expense data
5. Tallying the cash in hand with the total balance calculated based on transaction data

The application allows the user to work through these modules in a linear sequence. There is also an error correction module and features to view reports, past meeting transactions, and individual members' records.

Once a module is selected, numeric data input is done by writing on an ordinary RMTS-1 paper form placed on the device's digitizing pad using the digital pen (Fig. 4). A digital version of the RMTS-1 sheet is saved within the application. The application detects the cell of the RMTS-1 paper form that is being filled based on the pen's location on the digitizing pad. Each handwritten numeric digit written on paper is simultaneously digitized, run through a digit recognizer, and placed in the corresponding field on the screen. These values are then used for subsequent computation.

The digital slate did not come with any support for handwriting recognition. We evaluated several mechanisms and finally chose a third-party digit recognition library that used a convolutional neural network with five layers [34]. We reconfigured the recognition module for execution in a Win-CE environment. Every handwritten digit on the paper generated a 29X29 bitmap image that was recognised and displayed on the touch screen within one second of a pen stroke being completed.

All the text labels are displayed in the local language (Bengali, Oriya) following the RMTS-1 design. We attached cheap ($4) portable speakers to the device's audio-out port. On pressing a speaker icon associated with each field on the touch screen, a voice-over in the local language reads out that field's name and the entered values. Listening to a summary voice-over of each member's payments and dues at the end of recording all her individual transactions is made mandatory.

A set of checks are built in to the application based on current SHG practice. For example, a new loan cannot exceed the group's cash in hand, a member with an outstanding overdue loan cannot take a fresh loan, etc. Certain fields such as attendance and loan number during principal repayment are made mandatory. In the Tally module, if the cash in hand does not match the total amount calculated on the basis of the meeting's transactions, the meeting's records are not considered validated. The Writer is directed to the error correction module to detect and rectify the mistake. Only after the totals match can the Writer save and end the session.

An erase box area was added to the RMTS-1 paper form, which, if tapped with the pen, erases the last digit entered. Misrecognised or mistaken entries can be erased (like a backspace button) and rewritten on the paper. Similarly, other digital operations can be mapped to and executed from locations on the paper form.

Fig. 4. Device being tested in the field by an SHG member who serves as the group's Writer

Key design elements

We conducted multiple field visits and repeated usability tests with target users over a nine-month period. Users reacted to filling up the RMTS-1 form after placing it on the digital slate device as an extension of their normal process (Fig. 4). Initially, some users were nervous when interacting with the touch screen using the stylus. With practice, this apprehension waned.

The feedback from the Writers and SHG members who tested the application led to specific design choices, a few of which we highlight here:

1. For the audio feedback, the entered digits were initially read out one digit at a time in the local language. This created confusion as some members could not make out that 2 and 5 make twenty five. *In the current version all voice-overs speak out a field's value as an entire number and not just as individual digits. In certain areas, specific local systems of reading numbers were required (for example, 43 is read as 2 twenties and 3 in our Orissa field location).*
2. Screens with a uniform or similar orientation confused users (Fig. 5). *In the subsequent version, different colors were used to differentiate various screens and regions within a screen. The borders of read-only text boxes were removed to distinguish them from text boxes in which users needed to input values* (Fig. 6).

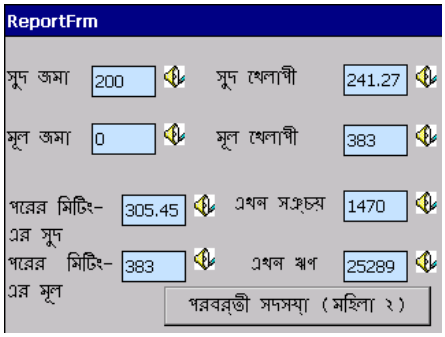

Fig. 5. Original design of the RMTS-2 screen with updated payments, balances, and dues information

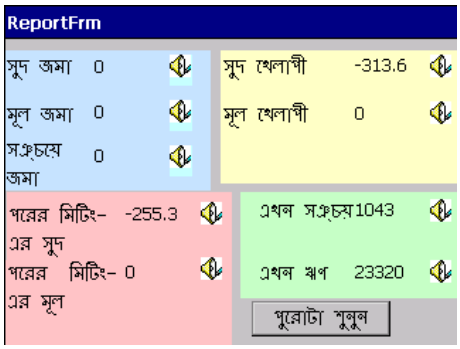

Fig. 6. Revised design of the RMTS-2 screen displaying updated payments, balances, and dues in color-coded quadrants

3. Users found combo-boxes and scrollbars difficult and unintuitive. *In the subsequent version the number of combo-boxes and scrollbars were minimized*.

Overall, our application on the digital slate included the following key design elements:

1. *Single point of data entry*
   The Writer records the group's transaction data only once, writing with a pen on the RMTS-1 paper form placed on the digital slate. This simultaneously generates a paper and electronic record.
2. *Natural input mechanism*
   Handwriting was the input mechanism used in the baseline system. The application retains the same mode of data entry,
3. *No need for manual calculations*
   Automated calculations allow Writers to record meeting data faster and with fewer errors.
4. *Instant updates reported*
   The current meeting's data is processed locally and the next week's dues are reported instantaneously. There is no longer any dependence on a remote processing location and the weekly transport of paper forms.
5. *Audio output for verification*
   Any data entered into or generated by the application, can be played as a voice-over. This allows each member, even if illiterate, to listen to details of her payment and point out any errors.
6. *Completeness checks*
   The application enforces completeness and does not let the Writer omit essential parts of a meeting. The user receives notifications and cannot save and end a meeting until the required fields and modules are complete.

Evaluating the cost of the solution

While our intervention targets gains in SHG data quality and process efficiency, the proposed solution would have to cost the same or less than the existing Computer Munshi record management system to be financially sustainable.

We assume here that the digital slate will cost $100 per unit and a single device can be shared by 10 SHGs in a proximate geographic area since each SHG only uses the device once a week. Under these conditions, the digital slate solution's estimated cost is not higher than the existing CM system, and may even allow for marginal cost savings (Table 2). A major component of the digital slate solution's estimated cost is the Rs. 3150 ($70) for a solar charging unit per Cluster. When these areas are connected to the national electricity grid, the solution's cost will further decrease.

TABLE 2
ESTIMATED COST COMPARISON OF COMPUTER MUNSHI AND DIGITAL SLATE SHG RECORD MANAGEMENT SYSTEMS

Expense Item (Cost per Cluster of SHGs)	**CM system (Rs. per month)**	**Digital slate solution (Rs. per month)**
Writer fees (if non-member)	400	600
Paper reports	48	16
Computer	37	9
Computer Munshi & Postman fees	450	0
Digital slate	0	125
Speaker	0	8
Solar charger	0	88
Maintenance	50	100
TOTAL Cost per Cluster per month	985	946
No. of SHGs per Cluster	10	
TOTAL Cost per SHG per month	99	95

Note: $1~Rs.45

V. FIELD TRIAL & EVALUATION

After the design phase, we conducted a field trial of our solution against the baseline system. We compared data accuracy, data completeness and process efficiency outcomes from the use of the baseline paper-only record management system (henceforth referred to as 'Paper-only' or PO) with our pen-paper-digital slate record management solution (henceforth referred to as 'Digital slate' or DS).

We also tested a touch screen-only version of the application (henceforth referred to as 'Touch screen-only' or TO), which required direct electronic data input using the stylus on the device's 3.5-inch touch screen (ignoring the device's paper digitizing pad). In this version, when the user arrives at a field that requires data input, tapping on that field on the touch screen with the stylus results in a soft numeric keypad pop-up. Data is entered by tapping on the soft keypad using the stylus. This solution was designed to mimic a mobile phone-based purely electronic solution that deviates from the SHGs' current paper-based practice.

The aim of the evaluation was, therefore, twofold:

1. To systematically compare performance outcomes between the baseline PO system against two alternative treatments: the hybrid DS solution involving handwritten input on paper that is simultaneously digitised, and the TO solution involving stylus input on the device's touch screen.
2. To compare user assessment and feedback on their valuation of the DS and TO solutions. In particular, we wanted to understand if there was a preference for one of these alternative solutions and if so, why.

Test Location and Participants

We performed two field trials of the solution. Trial 1 was conducted in the Kashipur and Saltora blocks of Purulia and Bankura districts respectively in West Bengal state. This area had an established but periodically dysfunctional Computer Munshi record management system. Trial 2 was conducted in Kalahandi district of Orissa state, where there was no established Computer Munshi system, owing to the inaccessibility of the villages from the nearest town. Here the SHGs only maintained their weekly records locally in paper form.

The Writer of each SHG operated the application on the device. The median education of the Writers was Class 8 in Trial 1, and Class 10 in Trial 2. In nine of the ten groups in Trial 1, the Writer was a woman member of the SHG. In Trial 2, only one Writer was a woman member of the SHG. One Writer was a young non-member woman, and the remaining two Writers were young men hired to write the SHG's accounts each week. All Writers were familiar with local language and English numeric digits.

In Trial 1, the average size of the SHGs was ~16 members per group (minimum 11, maximum 20). The average age of the sampled SHGs was 5.8 years (minimum one year, maximum eight years). For 37 SHG members who reported their education level, median schooling was Class 7.

Trial 2 groups were smaller (~11 members per SHG). For the five non-Writer SHG members who shared their schooling background, median level of education was Class 3.

Methodology

We followed a within-subjects comparison protocol, given that the inherent skill of the Writers and the complexity of records maintained would vary substantially from one SHG to the next.

Trial 1

In Trial 1, we used random sampling to identify eight SHGs from the 160 SHGs that belong to the Kashipur Federation in Purulia district of West Bengal. We also identified two SHGs in a neighboring Federation in Bankura district to allow for variation in the supervising CM. The field trial was conducted during a regular weekly SHG meeting. At each test session, the group followed its regular PO record management process first. This was a conscious choice because we did not want any potential errors in the trial application or device to affect the baseline financial records of these groups.

After the regular PO process was concluded, a single demonstration of the device and the application was made. The Writer then used the digital slate to enter the same meeting's data. Each of the Trial 1 groups tested both the DS and the TO versions of the application. However, the sequence of using each version was changed at each meeting to eliminate any systematic bias.

Before the second and third round of each meeting, 'play money' (from the board game Monopoly) was handed out to all members. This was done to ensure that members could simulate actual monetary payments and meeting activity during these trial runs.

Time taken to record entries, number of incorrect entries, and number of incomplete or untouched entries were recorded for all the three sessions. The number of misrecognized digits during the use of DS was also recorded. At the end of each meeting, a short feedback survey was administered orally, one person at a time, to the Writer and to four other members who were randomly picked in advance. 52 members participated in the post-test feedback survey, of whom 10 were the SHGs' Writers.

We worked with the CM responsible for each group to collect baseline information and import the sampled groups' current records into the device prior to their meeting.

Trial 2

We followed the same methodology described in Trial 1 for Trial 2, with a few exceptions. We identified four SHGs in the Kalahandi district of Orissa for the field trial. Here, we had each SHG first conduct its regular meeting in the PO format, after which they used the DS version of the application to record the same meeting's transactions. The TO solution was not tested here. Post-test feedback was gathered through collective discussion with 30 SHG members. Member's data was manually transcribed into a database prior to the meeting since there was no existing Computer Munshi record management system at this location.

Field Trial Results

We report our measurements on performance outcomes related to process efficiency (meeting time), data accuracy (error rate in entries), and data completeness (completion of mandated Tally module) below. Results from Trial 1 (blue bars) and Trial 2 (orange bars) are shown separately in Figures 7, 8 and 9.

Both DS and TO solutions delivered significant gains in process efficiency compared to the baseline PO system. The use of the digital slate reduced meeting time nearly by half (Fig. 7). Combining results from both trials for the DS solution, the average meeting transaction recording time per member was reduced from 3.4 to 2.2 minutes ($t(28)=2.5$; $p=0.02$).

The use of either DS or TO versions of the application increased the accuracy of entered data compared to the baseline (Fig. 8). The recording error rate was reduced nearly by half from use of the application. Combining results from both trials for the DS solution, the average data entry error rate was reduced from 5.6% to 2.4% ($t(28)=2.48$; $p=0.02$).

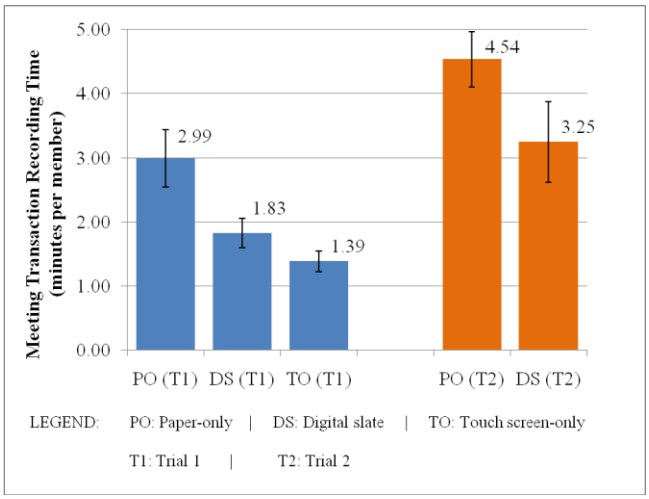

Fig. 7. Average time taken to record meeting transactions per member (minutes); n=201 members; Error bars indicate standard error.

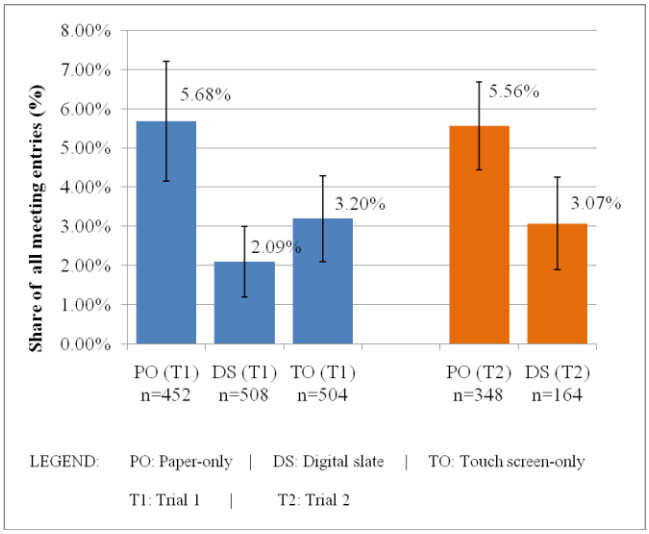

Fig. 8. Average error rate when recording transaction data (% of all entries at meeting); Error bars indicate standard error.

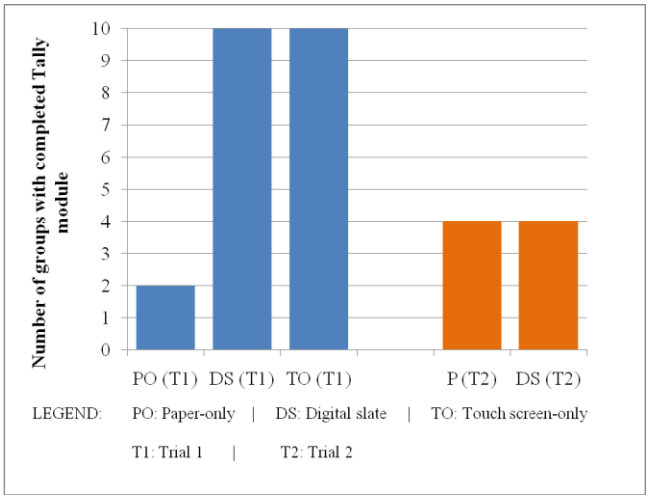

Fig. 9. Number of groups with completed Tally module; n(T1)=10 groups, and n(T2)=4 groups.

The results on the completeness of records varied by location (Fig. 9). In Trial 1, where baseline behavior indicated regular skipping of the Tally module, there was a large increase in the completion of the mandatory Tally module from use of either version of the application (20% to 100% completion rate). In contrast, the Tally module completeness measure of the Trial 2 groups was high to begin with and remained the same in the DS solution.

DS and TO modes produced comparable results on all measures. Stylus-based input on the touch screen allowed marginally faster data entry compared to handwritten input on paper placed on the slate's digitizing pad (1.39 vs. 1.83 minutes per member; p=0.13). Mistaken entries were marginally but not significantly higher during stylus-based input compared to handwritten input (3.2% vs. 2.1%; p=0.45). The application's digit recognition rate was recorded to be 90.17% in Trial 1; in all instances of misrecognition, the digit was cleared and rewritten on the paper form. DS and TO modes recorded the same gains in completeness, since they share the application feature that makes completion of the Tally module mandatory.

The differences in results between Trial 1 and Trial 2 are revealing. In the baseline PO system, each location had a different key problem: meeting transaction recording time was longer in Trial 2 SHGs; data recording error rate was equivalent across both locations; and data completeness was substantially worse in Trial 1 SHGs. Despite this difference in initial levels, the DS solution significantly reduced meeting transaction recording time (process efficiency) as well as the data recording error rate (data accuracy) across both locations. Trial 1 SHGs saw a strong improvement in data completeness, given the substantial room for improvement from baseline levels.

Survey and interview results

Members of each participant SHG described their assessment of the solution they had just used at the end of the meeting. Responses to the survey of 52 SHG members in Trial 1 are summarized in Table 3 below.

The core of members' confidence in the demonstrated solution lay in the automated localized audio feedback feature that announced members' transaction payments and overall dues and balances information after the data had been recorded. One member described the advantage as follows, "I like that the machine is speaking. We are illiterate people. We don't know what goes on. But when it speaks, we can know."

The Writers found it very useful that errors were caught immediately in the DS and TO systems and that s/he was forced to resolve the error at the meeting. Given poor training in school, Writers bear their record-keeping responsibility with considerable stress, hoping to get all the calculations right. The application significantly reduced that burden. The number of written entries Writers had to make

to complete the records was greatly reduced, since all calculations based on the raw data were automated.

TABLE 3
SUMMARY OF SURVEY RESPONSES

1. Getting updated RMTS-2 dues and balances figures (n=52)	**Share of responses**
a. Immediately	0.98
b. One week later	0
c. No preference	0.02
2. Solving mistakes (n=52)	
a. Immediately	0.96
b. One week later	0
c. No preference	0.04
3. Listening to updates (n=52)	
a. Writer saying figures and passbook entry	0.06
b. Machine saying figures and passbook entry	0.88
c. No preference	0.06
4. Final format for group records (n=52)	
a. Paper form and digital slate record	0.81
b. Just digital slate record	0.17
c. Just paper form record	0.02
d. No preference	0

Finally, 81% of respondents stated a preference for the DS pen-paper-slate hybrid solution. Members explained that they "must have the khaata (paper form)" as well as the digital record. When the possibility of maintaining the same records using a mobile phone was discussed, members indicated the need for an attached printer to generate a paper copy. In terms of preferred input mode, DS was considered more user-friendly. A Writer commented, "I can use a calculator and I have used others' mobile phones. But writing by hand is a habit. I feel it is better."

VI. DISCUSSION

We discuss our results from the field trials in view of the potential impact that our solution can have on SHG microfinance operations and its possible limitations.

Our study demonstrates that an appropriate digital solution, such as the hybrid paper-pen-digital slate solution demonstrated here, can substantially enhance the quality of SHG records and record-keeping by:

- Automating all computation of figures at SHG meetings, thereby reducing errors and meeting time
- Allowing data verification by members through automated audio feedback and immediate error correction options
- Enforcing completeness of data by indicating to the Writer fields with missing entries
- Reconciling records immediately, without the need for subsequent transcription and reconciliation with the database
- Eliminating dependence on the timely physical movement of paper records over vast geographies for record update and maintenance
- Gaining user acceptance by relying on known input mechanisms like handwriting on paper and simultaneously delivering a local paper record for reference

Our results from testing the TO version of the solution indicate that a purely electronic solution delivers comparable gains in data quality and process efficiency to the DS solution. Yet, the generation of the paper record and use of handwriting-based input in the DS version delivers distinct value to users. We expect that it will be difficult to match the ease of use, simultaneous paper copy generation, and low cost of the paper-pen-digital slate solution using alternate devices such as a mobile phone or a netbook with an attached printer, and alternate input mechanisms involving a phone keypad or keyboard. This is an area for further testing.

Our estimates of process efficiency gains in this field trial are affected by two biases. For each SHG, the baseline PO input mode involved dispute resolution discussions that did not need repeating in the DS and TO input modes that followed. Our estimate of meeting time reduction would therefore be higher than the true effect. Yet, this is the first time that the Writers were using a digital slate, without any prior training except for an instant demonstration by the researcher. In subsequent usage of the same device, Writers can be expected to perform the same tasks faster. In this case, our estimate of meeting time reduction would be lower than the true effect. Whether these two biases cancel each other will be a focus of subsequent testing.

The current solution is entirely local and self-contained, only requiring a periodic update sent to the backend database once every 1-2 months when the SD card is taken to the server location for a batch data upload. This is suited to the existing connectivity limitations in our target areas. However, as wireless cellular network coverage expands and becomes available as a reliable and low-cost data transport mechanism in these locations, there is nothing to stop our solution from allowing real-time updates to the server from the digital slate in the field.

Looking ahead to an extended deployment of the solution, it is important to improve the digit recognition rate to approach 100%; work with local language numeric digits; render Indic scripts optimally on the digital slate; add security protocols to suit the shared usage of the device; and seamlessly integrate the device's application with the backend database. Integrating the digital slate into microfinance operations at a larger scale will involve

resolving workflow issues around sharing of the device, reliably accessing non-grid recharging facilities, device maintenance, and remuneration of various stakeholders.

VII. CONCLUSION

In this study, we experimented with a solution on a digital slate prototype that combines handwritten pen-and-paper interaction with immediate electronic feedback to enhance SHG microfinance record management. We performed a field trial of our solution in situ in rural West Bengal and Orissa at fourteen microfinance group meetings during which the records of 201 members were processed using the solution. The digital slate solution performs as well as a purely electronic alternative, and better than the purely paper-based baseline system, in terms of accuracy of entries, recording time and data completeness. While the purely-electronic alternative performs comparably well in delivering improvements over the paper-only baseline system, users showed a strong preference for the pen-paper-slate system that allows a paper and electronic record to be created simultaneously. Achieving these improvements in SHG record-keeping processes and data quality directly affects the scope for millions of households to steadily improve their usage of quality financial services. Beyond microfinance, the digital slate solution can be adapted to the many contexts in which it can play a useful role seamlessly integrating paper and digital worlds in resource-constrained settings.

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