A SYSTEMATIC EVALUATION OF MOBILE SPREADSHEET APPS

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ABSTRACT
The power and flexibility of spreadsheets have made them an essential part of modern business. The increasingly mobile nature of business has created a need to access spreadsheets while on the move. Mobile devices such as the Apple iPhone and Blackberry have enabled users to do this but the small nature of these devices has caused a number of issues for mobile spreadsheet users. This paper presents a systematic evaluation of mobile spreadsheet apps available on the iOS platform which not only includes an examination of the range of available features and functions but also examines the usability of these applications. This work also recommends some ways in which the usability of mobile spreadsheet apps can be improved.

KEYWORDS
Mobile Apps, Usability, Mobile spreadsheets, spreadsheets

1 INTRODUCTION
The spreadsheet application has emerged as one of the most important tools within the financial sector. Research (Croll, 2005) has shown that spreadsheets are an integral part of the day-to-day operations of many businesses within this sector. Consequently there is a growing need for access to the information contained within spreadsheets while on the move.

The power of mobile devices is continually increasing and users are able to accomplish more tasks using these devices. Mobile devices can now enable users to access spreadsheets while on the move, however the limitations of these devices, such as small screen size, limited connectivity and limited processing power, have caused a number of usability issues.

Section 2 of this report highlights some of these issues. Modern spreadsheets contain a large number of cells and often can spread across multiple worksheets, making it difficult for users to navigate the spreadsheet. Looking at such spreadsheets on a mobile device further exacerbates this problem because of the small screen size required by mobile devices for portability.

In order to determine which of the available spreadsheet apps available on the iOS platform is most suitable for viewing such spreadsheets, a strict protocol was developed for evaluating these apps in terms of both functionality and usability. Section 3 of this report outlines this protocol and details how suitable spreadsheet apps were identified.

Section 4 presents the results of the evaluation and highlights some of the common issues among these apps. By identifying issues in this way it is believed that solutions can be found that would further enable spreadsheet app developers to provide more usable apps. Section 5 presents a number of recommendations that have arisen out of the evaluation of these apps and in particular the common issues that exist. Section 6 then outlines the limitations of this work and how these limitations will be addressed in the future. Section 7 then concludes this paper.
2 RELATED WORK

The rapid progression of technology has led to an increase in the number of mobile applications available. Although these applications offer a number of advantages in terms of portability and convenience, they do so at the cost of usability. Zhang and Adipati (2005) have highlighted a number of issues that affect the usability of mobile applications:

- **Mobile Context**: When considering mobile applications, the user is not tied to a single location. This will also include interaction with nearby people, objects, and environmental elements which may distract a user's attention.
- **Connectivity**: With mobile devices, connectivity is often slow and unreliable, and therefore will impact the performance of mobile applications that utilise these features.
- **Small Screen Size**: In order to provide portability, mobile devices contain very limited screen size meaning that the amount of information that can be displayed is drastically reduced.
- **Different Display Resolution**: The resolution of mobile devices is reduced from that of desktop computers, resulting in lower quality images.
- **Limited Processing Capability and Power**: In order to provide portability, mobile devices often contain less processing capability and power. This has the effect of limiting the types of applications that are suitable for mobile devices.
- **Data Entry Methods**: The input methods available for mobile devices are difficult and require a certain level of proficiency. This problem increases the likelihood of erroneous input and decreases the rate of data entry.

As spreadsheets are used in a variety of ways, they can contain vast amounts of data as well as tables, charts, and graphs. These spreadsheets can become quite large, which can be difficult to navigate, even on a conventional desktop computer. This usability problem is exacerbated on mobile devices by their limitations. The small screen size requires the user to perform considerably more navigation when looking at large spreadsheets. This may cause users to find it difficult to conceptualise the overall spreadsheet and to see how the section on-screen fits with this overall picture.

Flood et al. (2008), have identified navigation as an issue that affects the performance of people debugging spreadsheets through voice recognition technology. By addressing this issue, it was found that the performance of users debugging spreadsheets could be increased. It was also found that participants audited more cells with the improved navigation system, which is an important aspect of the spreadsheet debugging process.

Mobile devices generally do not contain a traditional keyboard as the size required would be too large to enable portability. Some devices incorporate a physical keyboard which utilises small keys, while other devices use touch screen technology to present a keyboard to the user on screen. These keyboards also require the physical keys to be smaller than traditional keyboards to fit all keys on screen.

Chen et al. (2010) conducted an evaluation of users entering text on a small size QWERTY keyboard. This evaluation required 15 participants to enter a passage of text using a small sized keyboard. On average, participants used 540 keystrokes to enter the passage of text. The most prevalent type of error made by these participants during the task was a key ambiguity error, which occurred when a user entered a character other than the target character. It was found that on average, participants made 9.33 key errors on the first typing task. It is also worth noting that all participants made at least one error of this type during the study.

Errors of this type, when made on a spreadsheet, may result in a misspelled word or in an incorrect reference in a cell formula, which could alter the bottom line value of a spreadsheet substantially. It has been shown repeatedly that even on desktop computers, errors like this persist. Powell, Baker and Lawson (2009) have found that over 85% of operational spreadsheets contain errors. This study furthers previous research by Panko (1998) which found similar levels of spreadsheet error.

The limited processing power of portable devices has meant that existing spreadsheet applications may not function correctly when run on these devices. In an attempt to address this issue, developers have created a number of spreadsheet apps which scale down the level of functionality to enable users to view and use...
spreadsheets in a mobile context. Most of these applications however, are limited in terms of functions available and spreadsheet size.

3 EVALUATION PROTOCOL

The iOS operating system runs on most portable Apple devices such as the iPhone, the iPad and the iPod touch. It was decided to focus on this platform initially as Apple are one of the leading providers of mobile devices. It is planned to extend this evaluation to other platforms such the Blackberry OS and Google Android. Apps for the iOS platform are distributed through the app store maintained by Apple, and can be downloaded directly on to the handset. In order to evaluate these apps a strict evaluation protocol was developed and is presented below.

1. **Identify all potentially relevant applications.** There are a number of ways to conduct a search for appropriate applications, including a standard web search, and current software distribution methods make this increasingly easy. Most of the major mobile phone platforms now have an associated online application store. As this work is focused on spreadsheet apps for the iOS operating system, a search of the App store was conducted. The search string “Spreadsheet” was used during the search.

2. **Remove light or old versions of each application.** Many software developers release trial versions of their systems, which are often free. Some of these versions include only a subset of the functionality offered by the full application whilst others allow full access to the application but for a limited time period. These types of applications should be removed if the full version of the app is also included within the search results.

3. **Identify the primary operating functions and exclude all applications that do not offer the required functionality.** The primary operating functions include frequently used functions and also occasionally used functions that are essential for the correct operation of the system in a desired context. For example, the initial system setup might include language and currency settings that would depend upon the country of use. The primary functionality of interest is to allow a user to perform spreadsheet tasks on a mobile device. This does not include the ability to access online spreadsheets as an internet connection cannot always be guaranteed.

4. **Identify all secondary functionality within the remaining apps.** In addition to the primary operating functions, mobile apps will offer users a range of secondary functionalities which can enhance the application. A thorough knowledge of these functions will enable the application developers to see what functionality is available and may present opportunities for additional functionality to be included in future applications.

5. **Install each of the remaining applications, and test each of the tasks using**
   a. **Keystroke level modelling.** Keystroke Level Modelling (KLM) is a well established technique (Card et al., 1983) for estimating the time taken to complete certain tasks. This will provide a quantitative measure of the difference between the efficiency of applications. Time estimations are based on the number of interactions required to complete the task. The time for each interaction may vary between individuals. KLM was used to measure the average number of interactions required to enter each of a set of 5 single digit numbers as well as the number of interactions to enter a subsequent formula to total these five numbers.
   b. **Heuristic evaluation.** Standard heuristics (Nielsen and Molich, 1990) can be used to evaluate desktop applications. These have been modified for the evaluation of mobile applications (Bertini et al., 2008) so that contextual information can be taken into account.

3
4 RESULTS

4.1 App Search

After searching the App store 23 potential spreadsheet apps were identified. After removing light and free versions of other apps and those that did not allow users to create or view spreadsheets offline 12 spreadsheet apps remained. A full list of the apps evaluated can be seen at http://tech.brookes.ac.uk/groups/pacmad/

The App store allows users of an app to give each app a rating between 0 and 5. Figure 1 shows the number of apps by rating. It can be seen that the majority of spreadsheet apps have been given a rating of 2 or under. This indicates that users, in general, did not rate these apps very highly. It should be noted that 3 of the apps had not received enough ratings for an average rating to be produced and are therefore not included. It can also be seen that none of the applications were given an average rating of 2.5. The highest rated app was Spreadsheet by AppAuthours receiving an average user rating of 4.0.

![Figure 1: Frequency of App Ratings](image)

4.2 App Findings

4.2.1 Transferring data

<table>
<thead>
<tr>
<th>Method</th>
<th>Copying to the device</th>
<th>Copying from the device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td>41.67%</td>
<td>58.33%</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>58.33%</td>
<td>58.33%</td>
</tr>
<tr>
<td>Google Integration</td>
<td>25.00%</td>
<td>25.00%</td>
</tr>
<tr>
<td>iTunes</td>
<td>58.33%</td>
<td>58.33%</td>
</tr>
</tbody>
</table>

Transferring data is an important aspect of mobile spreadsheet apps. A user may wish to access an existing spreadsheet on a mobile, during a meeting for example or while travelling. If the user subsequently
changes this spreadsheet they may wish to then transfer the spreadsheet back to the original location once it has been updated. Mobile spreadsheets primarily offer 4 ways in which spreadsheets can be transferred between a mobile device and a desktop or laptop computer: Email, Wi-Fi, Google Integration and via the iTunes application.

One of the most convenient features of mobile devices is that they provide access to emails while on the move. A common way of transferring digital content, such as spreadsheets, is via email. It would be therefore desirable for mobile spreadsheet apps to allow users to open a spreadsheet on the mobile directly from an email. Approximately 42% (5) of the evaluated apps allow users to do this. If a user has altered the spreadsheet they can save the changes by emailing the completed spreadsheet directly from inside the app. 58.33% (7) apps allow users to do this.

As a number of mobile devices feature Wi-Fi capability, 58.33% (7) mobile spreadsheet apps allow users to transfer files in this manner. Once the mobile device is connected to the same network as the desktop computer, the user can mount the mobile device as an additional drive and copy spreadsheets to and from the device. Some of the spreadsheet apps allow a user to connect to the device through the IP address of the device and access the files through a web based interface.

A quarter of the apps reviewed allowed users to access spreadsheets stored on the Google spreadsheets online account. This facility requires the mobile device to be connected to the internet, which may not always be available. It also assumes that users have a Google account and their spreadsheets are stored on Google servers. These applications may offer similar facilities to other online storage solutions such as drop box.

The final method of transferring data to and from mobile devices is through the iTunes application. Apple devices, such as those running the iOS, transfer data to and from the device through the iTunes application. Through the 'Apps' tab of this application, 58.33% of the mobile apps evaluated allow users to transfer spreadsheets to and from the device.

The iTables application does not allow users to transfer files to the device. It only allows them to create and access spreadsheets on the device.

4.2.2 KLM Analysis

The spreadsheet apps evaluated allow users to create spreadsheets on a mobile device. Due to the limitations of these devices, the way in which users interact with the apps varies. In order to evaluate which app features the most efficient interaction method, the same spreadsheet was created using each of the apps. The number of keystrokes required to create the spreadsheet was recorded for each of the twelve apps and is presented below.

Table 2: Number of keystrokes by task

<table>
<thead>
<tr>
<th>App</th>
<th>Total Keystrokes</th>
<th>Average Numerical Entry</th>
<th>Entering Sum Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreadsheet</td>
<td>19</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sheet²</td>
<td>19</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Beepad</td>
<td>19</td>
<td>2.4</td>
<td>4</td>
</tr>
<tr>
<td>Docs to go</td>
<td>26</td>
<td>2.2</td>
<td>7</td>
</tr>
<tr>
<td>Cellroid G</td>
<td>26</td>
<td>2.2</td>
<td>8</td>
</tr>
<tr>
<td>iSpreadsheet</td>
<td>27</td>
<td>2.2</td>
<td>10</td>
</tr>
<tr>
<td>Discount Spreadsheet</td>
<td>28</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Quick Sheet</td>
<td>29</td>
<td>2.2</td>
<td>9</td>
</tr>
<tr>
<td>Spreadsheet LX</td>
<td>29</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>i123</td>
<td>33</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Mariner Calc</td>
<td>34</td>
<td>3.8</td>
<td>10</td>
</tr>
<tr>
<td>iTables</td>
<td>36</td>
<td>4</td>
<td>11</td>
</tr>
</tbody>
</table>
As can be seen in Table 2 the Spreadsheet app required the fewest keystrokes to create the spreadsheet. This application contained a number of features which reduced the number of interactions required to complete the task. Firstly by default the user is located in cell A1 and can enter data by simply opening the keyboard and entering the desired text. A number of applications, including Spreadsheet, open the default iPod keyboard to numerical input as numbers are the most common type of input.

The Spreadsheet app also provides quick access to the sum function. As the cursor is placed in cell A6, the user only needs to press the ‘fx’ button, press ‘Sum’ and then press ‘Done’. The first function in the list is the Sum function and will recognise by default that the user wants to total the numbers located in the cells above the currently selected cell.

The most interactions are required for the iTables app. The main reason for the relatively high number of interactions required is how the system treats data input. When the user wants to enter data they first click on the cell they wish to enter the data into. The default character keyboard is presented which will require the user to manually change to the numerical keyboard. In a number of spreadsheet apps the system will allow the user to select another cell while the keyboard is still open but iTables does not. It automatically closes the keyboard when the user selects another cell requiring the user to reopen the keyboard and to reselect the numerical keyboard.

The Average numerical entry shows the average number of keystrokes required to enter a number into a cell. As each number was entered to the cell sequentially, it was possible to leave the keyboard on screen during the entry of all the numbers, reducing the number of interactions required for the second and subsequent cells. One or two additional keystrokes are required for the first cell entry depending on the app. The minimum number of interactions required to enter a number is two. The first interaction is to select the cell while the second interaction is to enter the desired digit.

Some apps such as Sheet2 and Beepad use the context of the cursor to determine the parameters for functions like the Sum function, enabling the user to enter such a function in three or four interactions. Other apps require the user to manually select these parameters and often require the user to open the keyboard (which needed to be closed to access the functions) to select the ‘:’ character to indicate all cells between the first selected and last selected are included as input to the function. All applications except i123 and iTables, feature a menu which allows the user to see and select all available functions. In the case of both the aforementioned applications, the user is required to manually type in the function name and parameters.

4.2.3 Incorporated functions

A function performs a set of mathematical transformations on a series of inputs to produce an output. Spreadsheet applications contain a large number of pre-implemented functions which allow spreadsheet users an easy way to perform complex calculations. The inclusion or exclusion of these functions can impact both the effectiveness and efficiency of users completing their desired task through the spreadsheet app.

Table 3: Number of Functions by App

<table>
<thead>
<tr>
<th>Spreadsheet</th>
<th>104</th>
<th>MarnerCalc</th>
<th>145</th>
</tr>
</thead>
<tbody>
<tr>
<td>i123</td>
<td>27</td>
<td>Spreadsheet LX</td>
<td>51</td>
</tr>
<tr>
<td>Cellroid G</td>
<td>61</td>
<td>iSpreadsheet</td>
<td>13</td>
</tr>
<tr>
<td>Beepad</td>
<td>21</td>
<td>Discount Spreadsheet</td>
<td>23</td>
</tr>
<tr>
<td>Documents to go</td>
<td>112</td>
<td>Sheet2</td>
<td>146</td>
</tr>
<tr>
<td>Quicksheet</td>
<td>80</td>
<td>iTables</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3 shows the number of functions that are included within each of the spreadsheet apps evaluated. It can be seen that a number of the spreadsheet apps contain only a small number of functions, which will limit the number of pre-existing spreadsheets that can be viewed and manipulated on the mobile device. The Sheet2 features the most extensive range of features incorporating 146 functions, while the iTables app only features the sum function.

While evaluating the types of functions available on mobile apps, it was found that the range of specialist functions, such as statistical or financial was quite limited. Ten of the fourteen spreadsheet apps contain
financial functions, however most of these apps only feature 5 or less financial functions. It was also found that only two of the spreadsheet apps contain base conversion functions, which enable users to convert between different number bases.

Although there are a lot of similarities between the functions available on mobile apps, it was found that different apps implemented different functions. For example Sheet offers users most functions, however it does not include a large number of financial functions that are offered by MarnerCalc. However, it should be noted that MarnerCalc does not offer any Base Conversion functions.

### 4.2.4 Spreadsheet features

Spreadsheets are often used for more than just performing complex calculations. A number of features exist within spreadsheet applications that allow users to see beyond the numerical data. Charts and graphs allow users to see different representations of data which can make identifying patterns easier and can also help in allowing users understand what the data means. Only 25% (3) of the spreadsheet apps evaluated featured this functionality. These applications feature only a small subset of the chart types that are found in desktop spreadsheet applications.

In addition to the ability to view chart data, spreadsheet users often use the Sort feature to arrange data in a particular order. This feature is most useful when a large amount of data is stored on the spreadsheet in a table and users need to evaluate the data in a particular order or in groups based on a particular attribute. Of the twelve apps evaluated 50% (or 6 apps) allowed users to sort the data.

The final spreadsheet feature considered was the freeze pane. Freeze panes allow a user to keep a certain number of rows or columns on screen while the rest of the spreadsheet scrolls down or across. This is usually done to keep headings visible while the user is looking through the data. Of the evaluated applications, 33% (4 apps) contained this feature.

One feature that was noticeably absent from all of the apps was Filters. When dealing with large lists of data, filters can enable users to reduce the amount of data that appears on screen, to only rows that meet a specific criterion. On a mobile device, where the screen space is limited, any feature that would allow users to focus on only the data that is relevant would be advantageous.

## 5 RECOMMENDATIONS

During the evaluation of the spreadsheet Apps, a number of usability issues were observed. The spreadsheet paradigm is just one example of a mobile app however; the issues observed can be seen in other types of mobile app. The following guidelines, if implemented could help to improve the usability of these apps.

- **Consider the big picture.** In some cases the spreadsheet being viewed can be larger than the screen size available and therefore it can be difficult for users to navigate to different sections of the spreadsheet. The same issue has been seen on large web pages, large images and large text documents. In these cases the use of a mini-map can be used to show the user the entire spreadsheet, on a small scale, with the area that is currently displayed on screen highlighted. This approach would give the user an idea of where on the current worksheet they are looking.

- **Consider the type of input.** The most common form of input for spreadsheet cells is numeric or formulaic. A number of the spreadsheet apps however, open the text based keyboard when a user indicates they would like to enter data onto the spreadsheet. If a user does want to enter numeric data into the cell they need to switch keyboards before they can do so. Mobile app developers should consider the type of input they are expecting, textual, numeric or special characters and open the keyboard to this type of entry.

## 6 THREATS TO VALIDITY AND FUTURE WORK

For the evaluation presented here applications were selected for the Apple iOS. Devices that contain this operating system only account for part of the entire mobile application market. The Google Android and Blackberry collection of smart phones also feature a range of mobile spreadsheet applications not available
on the iOS. It is therefore intended to extend the evaluation to include spreadsheet apps available for these smart phones.

Part of the protocol presented above requires the use of heuristics to evaluate the usability of the apps. Heuristics of this nature are usually rated by multiple usability experts and these ratings are then compared to identify the most prevalent usability concerns of the application. The validity of this work could be improved by increasing the number of usability experts involved.

During the KLM analysis it was not possible to effectively record swipe actions on the device. This type of action was used on multiple applications to move the visible area of the screen during the creation of the spreadsheet. This was seen consistently across all apps and therefore does not affect the results presented here.

7 CONCLUSIONS

This report has evaluated twelve spreadsheet apps available for mobile devices featuring the iOS operating system, such as the iPhone, iPod touch or iPad. These apps provide users with access to spreadsheets while away from a desktop or laptop computer. A number of issues with mobile devices such as small screen size and limited processing power have caused these apps to change the way users interact with them from traditional spreadsheets.

This evaluation has found that there is a wide range of differences between mobile spreadsheet apps. Some apps allow users to view existing spreadsheets on a mobile device while others only allow users to create new spreadsheets in a mobile context. The method by which the user creates the spreadsheet also changes between apps. A KLM evaluation of the apps has shown that the number of keystrokes required to create a simple spreadsheet can vary by as much as almost 90%.

This evaluation has also identified a number of guidelines that app developers should follow to improve the usability of mobile Apps. It has been found that a number of apps do not optimise the input method for data, therefore complicating the way in which the user enters data. By considering the most common type of data to be entered into a cell, the developers could optimise this.

REFERENCES


