DEVELOPMENT OF A TIME STUDY APPLICATION FOR SMART PHONES

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ABSTRACT

Industrial Engineers frequently use time studies as a means of data collection. Time-studies are commonly time intensive, error prone and a skill mismatch for qualified engineers. Recognising time-studies' weaknesses, yet conscious of their necessity, a smartphone application was developed to simplify the process. This application unites all functions necessary in a time-study, which are: timing of activities, recording of data and data post-processing. This application has a short learning phase and provides scope to down-skill the data acquisition phase. This paper outlines the design and programming process that was followed in developing this application for the three most common platforms. The application was tested in a real time-study environment and these results will be presented.

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1 INTRODUCTION

1.1 Time Studies

Time studies are ubiquitous in the practice of Industrial Engineering. Pioneered by Frederick Taylor around 1900, they form a fundamental part of understanding the human behaviour in an organisation, in support of the ultimate goal: scientific management [1]. Time-studies evaluate the time taken by a trained operator to perform a certain quantum of work [2].

Time studies, though useful are prone to several operational problems. They are a skills mismatch for qualified Industrial Engineers. As a result students, interns or inexperienced people are often tasked with conducting the operational part of the study. This creates a discontinuity between research and researcher. Time studies are prone to recording of errors, as the classical approach requires manual timing and physical transcription. As a result a time study takes longer than the events being observed, as data, once collected needs processing, typically using a computer, which requires post hoc data capturing.

Gathering data for time studies is well suited for automation [3]. The manual processes, such as starting and stopping a stop watch, reading off the time, recording it in pen and later capturing this for data processing, can be simplified. To unify these functions, a smart phone application was developed to automate the data collection process of time studies. The application was developed for three operating system platforms.

1.2 What Is A Smart Phone?

Definitions of what constitutes a smart phone are inexact and only loosely overlap. Generally there is agreement that a smart phone should have an operating system, an ability to run programmes known as applications or apps, it should store and process data and may access the internet and associated services such as email and social media [4] [5]. A smart phone can be thought of as a low powered, very portable computer.

1.2.1 Smart Phone Market

The smart phone market is dominated by five major operating systems, Android (Google), iOS (Apple), Symbian (Nokia), BlackberryOS by Research in Motion (RiM) and Windows Mobile. Figure 1 shows the market share of the various platforms during 2011 and 2010 [6].

![Figure 1: Annual Handset Sales By Operating System](image-url)
1.3 What Is An App

An application ("app" for short) is a programme designed to run on a smart phone. Apps are downloadable from the internet, either directly to a smart phone, or via a conventional computer interface. Installing apps allows them to run unassisted on the phone making use of the on-board processor and memory.

1.4 Single Point Of Data Entry (SPODE)

SPODE is a philosophy which holds that interaction with data should occur only once. Recording a value presents an opportunity for the creator to make a mistake. Where data is entered on one medium and from there is entered again to another, the risk of creating errors increases. In this way risk compounds and data accuracy decreases with each step.

The exact risk of data transposition errors is unknown, but a corollary can be drawn from a recent study [7] which found that serious medical errors were made in 1.07% of investigated scripts. It is assumed that for every serious error, at least one trivial mistake is made. We therefore propose that the rate of error in transcription is at least 2% which compounds with further transcription, such as into a spread- or consolidation-sheet. After five transcriptions, the probability of error is 10%. It follows that the fewer times a user inputs the same data, the likelihood of errors is reduced and data integrity increases.

2 DESIGN PROCESS FOR THE APP

2.1 Choosing Platforms For Development

To reach as many potential users as possible, the time study app was designed firstly for the Android operating system, as this represented the bulk of new phone sales in 2011. It was decided to develop this app for two other platforms, Symbian and RiM.

iOS was rejected as the development platform was not open source or free, unlike the others - also an apple computer was required [8]. The choice between Windows mobile and Symbian was complex. On the basis of current numbers, Symbian justified development over Windows, however Nokia had discontinued Symbian development, favouring Windows as the operating system for all future phone releases, which would reduce the Symbian market penetration to pre 2012 phones. Nevertheless, lacking a phone as a test device and a test version of the operating system, and conscious of the fact, that Nokia phones, running Symbian, remain currently and foreseeably common, it was decided to design for this platform.

2.2 General Principles For Developing Apps

Developing apps is a relatively straightforward programming exercise. The developer must remain conscious however that smart phones do have limitations in terms of interface size, processing speeds and memory [8]. As a result, conservative programming, which is less resource intensive than common programming practice must be observed.

Development took place in programming emulators, which mimic a smart phone on a computer. These were available for all three operating systems. Android and Blackberry apps are programmed in a Java environment [9] [10], although the actual code is different, whilst Symbian apps are programmed in C++.

3 DESCRIPTION OF THE APP

The app allows a user to perform a time study through the touch screen interface of a smart phone. Activities are initialised by the user and then appear as buttons on the screen. When touched once, the timer for that activity starts running. When the button is again touched, the timer stops and records the duration of that activity. This app allows for an unlimited number of processes to run in parallel. All identical processes are stored together in a two
dimensional array. This array is stored on the phone’s external storage (SD) card in a comma separated variable (.CSV) format. The programme can store time study data for many time studies, limited only by the capacity of the SD card. Data files can be transferred to a computer for post processing, either by inserting the SD card into the computer, or by cable, email or Bluetooth.

### 3.1 Algorithm

![Flowchart of Programme](image)

**Figure 2: Flowchart of Programme**

### 3.2 Post Processing

Post processing data takes place off-device, on a conventional computer. This is because the computer has a larger screen to deal with large arrays of numbers and secondly because it seems unnecessary to encode the analysis capability which software such as Excel has natively. For that reason, a series of macros were written in Visual Basic for Applications (VBA). These macros are run in Excel and automate the analyses of data gathered for the time study.

### 4 TESTING

To test the utility of our time study apps, a simple experiment was conducted as a pilot study which compared the app to traditional time study techniques.

#### 4.1 Method

This experiment consisted of a time study which was conducted in a fast food restaurant. The app was given to two researchers, who were to use the app independently on two
separate operating systems. Similarly two researchers conducted a classical, stopwatch and clipboard time study. The four time studies took place simultaneously and measured the same events. None of the researchers were Industrial Engineers, and none of them had existing knowledge of time studies.

The users measured four activities for this experiment:

1. scrutinising the menu, the time a customer takes before deciding on a meal.
2. the time taken to place the order and to make the payment (counter interaction)
3. the time the customer waits until the meal is prepared
4. the time for collecting and checking the order.

These were chosen as they are clearly delineated functions and rely little on interpretations of the researchers. The experiments were conducted at a time of day with low volumes, so queues didn’t cause ambiguity. Idle times between actions were ignored for the purposes of this experiment.

Both groups were given very short instructions prior to starting. The experiment was conducted four times, with coaching between the first and second and the second and the third experiments. Each experiment lasted approximately ten minutes.

The techniques were evaluated for accuracy, time to complete and time to learn. Accuracy was evaluated on the level of agreement between the results within a group - i.e. comparing the results of the two similar modes of study to each other. To calculate this level of agreement, the following function, defining agreement was used:

\[
Agreement \ Coefficient = \frac{|Value1 - Value2|}{Value1 + Value2} \]

This relates range to the average value of answers. There is no established benchmark for good or poor agreement, this is used purely as a comparative tool between the two modes of conducting time studies. It should be noted that agreement improves as the value tends to zero.

The time taken by the researchers, from the beginning until the point where processed results were available, was measured. Competence acquisition was deduced by looking at accuracy trends over the four repetitions of the experiment.

4.2 Results Of The Experiment

Our experimental results are contained in Error! Reference source not found. on the next page, from which the following can be deduced:

The rate of agreement, and by extension, the accuracy is greater in an electronically conducted time study. It is interesting that the rate of agreement improves more for the traditional time study than for the time study conducted using the app. This implies that early competence in electronic time studies is higher than for classical time studies. This implies that the learning curve for the traditional method is longer and by extension requires greater skill and coaching to enable competent data collection.

The duration of the classical time study is 20 % longer than the electronic version, as data must be captured to a computer once the time study is completed, whereas the app allows for immediate transfer of the data into Excel, which is used for processing. The relative consistency of duration for the electronic study again shows that gaining competence is faster and the learning curve shorter. The outlier for the first experiment was because the experimenter had to work out how to transfer data. Once this was learned, times became consistent.

An assumption is made, that due to the absence of SPODE in the classical time study, the rate of error in the computer system is around 4% due to doubled transcription. By
comparison, the assumption is made that the same error in the electronically gathered time study is at or around zero, as no transcription takes place. It is believed that the waiting time for the classical experiment number three is an example of a transcription error.

It was observed, that those conducting the classical time study were busier, looked down more, became confused more often and had to juggle more activities. Eventual errors for the group conducting the electronic time study were caused by boredom and consequent distraction. Experimenters were being challenged by nothing more than having to touch buttons on a cell phone screen. This is possibly a result of the purposefully simplistic study. Future research can test this app for more taxing environments to see whether error due to boredom can be alleviated by a more complex environment.

<table>
<thead>
<tr>
<th>App</th>
<th>Conventional</th>
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<tbody>
<tr>
<td></td>
<td>User 1</td>
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<td>X</td>
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**Experiment 1**
- **Menu Scrutiny**: 118 | 121 | 0.0251046 | 108 | 134 | 0.214876
- **Counter Activity**: 248 | 236 | 0.04958678 | 230 | 241 | 0.046709
- **Waiting**: 343 | 332 | 0.03259259 | 344 | 330 | 0.041543
- **Checking**: 56 | 61 | 0.08547009 | 56 | 66 | 0.163934
- **Cycle**: 765 | 750 | 0.01980198 | 738 | 771 | 0.043738
- **Duration**: 690 | 960 | 920 | 900

**Experiment 2**
- **Menu Scrutiny**: 131 | 138 | 0.05204461 | 112 | 126 | 0.117647
- **Counter Activity**: 230 | 224 | 0.02643172 | 218 | 219 | 0.004577
- **Waiting**: 351 | 360 | 0.02531646 | 344 | 356 | 0.034286
- **Checking**: 44 | 51 | 0.14736842 | 53 | 60 | 0.123894
- **Cycle**: 756 | 773 | 0.02223676 | 727 | 761 | 0.045699
- **Duration**: 680 | 720 | 900 | 850

**Experiment 3**
- **Menu Scrutiny**: 141 | 136 | 0.03610108 | 118 | 152 | 0.251852
- **Counter Activity**: 241 | 230 | 0.04670913 | 224 | 235 | 0.04793
- **Waiting**: 288 | 299 | 0.03748781 | 391 | 288 | 0.303387
- **Checking**: 53 | 66 | 0.21848739 | 52 | 55 | 0.056075
- **Cycle**: 723 | 731 | 0.01100413 | 785 | 730 | 0.072607
- **Duration**: 680 | 730 | 882 | 890

**Experiment 4**
- **Menu Scrutiny**: 114 | 126 | 0.1 | 104 | 112 | 0.074074
- **Counter Activity**: 200 | 194 | 0.03045685 | 188 | 199 | 0.056848
- **Waiting**: 306 | 316 | 0.03215434 | 311 | 304 | 0.022764
- **Checking**: 38 | 61 | 0.46464646 | 65 | 61 | 0.063492
- **Cycle**: 658 | 697 | 0.05756458 | 668 | 676 | 0.011905
- **Duration**: 700 | 720 | 900 | 830

Figure 3: Summary Of Experimental Results
5 DISCUSSION

Classical time studies are useful as they have low barriers to entry. The only requirement is a stopwatch and a pen and paper. They can also be performed at short notice as no particular infrastructure is required. Classical time studies are however prone to errors and due to there being no control, allow for easy invention of data.

The app by comparison requires a researcher to own a smart phone, the cost of which is a barrier to entry. The researcher also needs to have the time study app installed. If errors are made, they are directly transcribed into the database, and are therefore difficult to correct. Due to the single point of data entry, errors are reduced and because data capture is a black box operation, purposefully false data is more difficult to introduce. The shorter learning curve and faster competence means that the operator can start with lower skill, reducing labour cost - which is reduced even further by the shorter duration of the study. Parallel operation means that a single operator can time tens of operations simultaneously, which would be almost impossible using a stopwatch. With the fewer pieces of hardware, the operator is also able to concentrate more on what is going on, thus enriching the observations.

6 CONCLUSION

The benefit of automated time studies is beyond dispute. Using smart phone technology and the app we developed, time studies can have fewer errors, be completed faster and competence can be attained in less time.

Future work could include the development of apps for other time standard measurement methods, for example work sampling.

7 REFERENCES