Honours Project Report

ScriptView

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Mark Table

# Introduction

The management of test scripts at tertiary institutions involves collection and distribution to markers, evaluation and redistribution to students. The current methods in place rely on the physical test scripts, require a considerable amount of time and coordination between multiple individuals. These methods increase the waiting time for students who ideally need to get feedback as soon as possible in order to improve for future assessments. Current test management also lacks the collection of any data about the tests aside from the student’s final mark. This leads to a lack of historic data for educators to reference when creating new tests.

Needs more.

# Background

This section presents the relevant findings from previous and current work that either directly or indirectly influenced the design and development of the system.

## The current test management procedure

Observation

## Functionally similar software

Despite the increasing prevalence of technology in education, the marking of paper-based tests has remained largely unchanged. There has however been significant work done on trying to digitize the marking process which shows some promising results.

One of the most widely recognized techniques is that of Optical Mark Recognition (OMR) which utilizes optical equipment to interpret marks on a paper [1]. These marks are usually indicated in a grid format with cells corresponding to letters or digits. Commercial products which implement OMR are available and have had limited success. One of the key constraints of OMR is that it limits the examiner in terms of what type of questions they can ask. This is because OMR is only suited to multiple choice which implies that examiners can only ask questions up to the applying level in Bloom’s taxonomy.

An alternative to this would be to use a system that could analyze free form answers. This kind of technique has been explored, especially in terms of essay marking.

Researchers such as Christie [2] have found success applying automatic marking to the marking of essays. The researcher describes a technique used to mark both style and content which requires acceptable style metrics to be set up before marking as well as manually marking a certain amount of scripts to calibrate the algorithm. Such a system would allow for questions from all levels of Bloom’s taxonomy and would therefore be more widely applicable.

Pulman [3] did similar work in that he attempted to use machine learning techniques to automatically mark short free form answers. Although he draws no conclusions on how easy his method is to customize to different questions, there is a problem which is identifiable in both his and Christie’s approaches. That problem, is training data. A system that is more generally applicable to a wide range of test is preferred since time does not have to be spent on customizing it for each new type of test.

There are also certain issues which could arise which Thomas [4] expanded upon in his work. Thomas performed an experiment in which he compared the results of a fully automated marking system and a manual marking system. The tests intended for automatic marking were taken on a computer and the other tests were done on paper. The researcher noted that certain problems could arise during the taking of the test that could only be solved effectively by human markers.

The most problematic of these being that of ambiguity, either in the student’s answer or the examiner’s question. Students may also not be able to express themselves clearly, especially if they are taking the test in a language other than their first language. Both of these problems could be overcome by manual markers who used their knowledge of the domain and discussion with fellow markers to assign appropriate marks.

## Forms of assessment

An advantage of electronically processing tests is that it creates the opportunity for the collection of large amounts of data about students’ progress. This data can then be analyzed to predict learning patterns and activities that might indicate a risk of failure [5]. As one of the main goals of the system is to allow for the recording of such data, it was essential to understand what kind of information an educator may look for and how it would be used.

It was found that tests are often divided into two distinct categories namely formative and summative assessment. Formative assessment is used during the course of a particular section such that the results can be used to inform how the student or educator should progress [6]. Summative assessment on the other hand is used at the end of a section to gauge the extent of the student’s learning for grading, certification or the evaluation of the effectiveness of the teaching method [6].

The terms formative and summative assessment however, do not describe the format of the tests but rather their function. As a result, a range of question types can be used in both. A classification of these types based on their cognitive complexity was developed in 1956 by B. Bloom and revised (see Figure 1) in 2001 by L. Anderson [7]. The cognitive level of complexity increases as one ascends from remembering to creating. The taxonomy provides a framework which educators can use to ensure that they are testing all aspects of a student’s understanding as well as allowing them to create tests which assess the most appropriate levels for the given situation.



Figure 1: Original and Revised Bloom's Taxonomy [2]

Aboulsoud [8] claims that formative assessment is more valuable to students since it provides them with feedback which they can use to improve their future work thus increasing their chances of academic success. He suggests that for formative assessment to have this effect, it should be followed by immediate feedback which clearly indicates areas in which the students should improve while acknowledging their effort to achieve the objectives of the assessment.

This implies that any system developed to aid the marking process should allow for rapid feedback with the characteristics outlined by Adoulsoud as well as allow for the marking of questions at various levels of Bloom’s taxonomy.

## Converting physical tests to digital format

The biggest bottle neck in the entire back-end process appears to be the scanning of test scripts so that they can be processed and stored electronically. This was noted by Doctor H. Suleman (personal communication, 24 April 2014) of The University of Cape Town who has implemented a system which involves the scanning of marked test scripts to automate the process of capturing marks on the university’s learning management system known as Vula. The system he developed only requires that the cover page of the test be processed since it is the one which contains the marks and student information. However, all pages are scanned since they will be emailed to the student as feedback. Due to this, the quality of the scanned document needed to be high enough so that the student would still be able to read the feedback written by the marker and that the image processing algorithms could successfully detect the student number on the cover page which was indicated by shading certain pre-defined areas.

To accomplish this the documents were scanned at 300dpi but it was decided that the scanning was too slow and thus proved infeasible. To improve the speed of scanning, the resolution was changed to 200dpi and the documents were scanned in black and white. This sufficiently reduced the scanning time while maintaining the readability of the document.

A problem that was not addressed by Dr. Suleman during our interview, was the size of the scanned documents. This was however addressed by Doctor J. Tangkuampien (personal communication, 1 May 2014), who also scanned documents at 300dpi and had to reduce it to 200dpi.He however, reduced the resolution due to concerns about the file size. When scanning at 300dpi the file size was approximately 4MB and decreasing the resolution halved this size. Another difference between his scanning solution and that used by Dr. Suleman is that he scanned the documents in colour. While scanning the documents in black and white would have further reduced the file size, Dr. Tangkuampien noticed that doing so interfered with the visibility of the text if students used highlighters. This is because when scanning in black and white, very light highlighters such as yellow do not show and dark ones obscure the text.

Dr. Suleman used a combination of OMR and manual name entry to name scanned files whereas Dr. Tangkuampien used a fully manual approach. With the first approach a special cover page needed to be created whereas with the second the existing test format could be used.

S. Chetty (personal communication, 5 May 2014) described a method which uses optical character recognition (OCR) to name files. This method required that a certain area of the script be reserved for the student number, which eliminated the need for a dedicated cover page as the area for the student number could be included on the same page as the first question of the test. This is essential as he suggests that a large part of the process will be a compromise between the existing process and the new electronic solution. By eliminating the creation of a cover page the overall process can also remain as simple as possible.

Minimizing file size while maintaining the readability of the final document is essential to the final system as limited storage is available; scripts for multiple tests need to be stores and image processing needs to be performed on the documents.

## Software interaction

In order to make the best use of the tablet and stylus interface, it was necessary to understand what users have found intuitive in the past.

Alisi [9] discusses the concept of natural interaction during the description of systems implemented to improve the experience of museum visitors. The researcher suggests that natural interaction can “reduce the gap between computing and ordinary physical things” however it would require that the interfaces differ from traditional human-computer interaction such as the use of menus and icons.

The Point At system described allows the user to point at a character in a picture in which they are interested in and the system will provide them with more information on that character. Since this a natural action and similar to how the user would traditionally ask a tour guide for information, it allows the technology to become a transparent medium instead of overwhelming the experience.

This point is further expanded upon by Malizia [10] who believes that a natural interface, especially gesture based ones, should allow users to interact with the software using the same gestures they would use with the actual physical object. The researcher states that users should not have to learn an arbitrary set of gestures to use the software but instead the software should allow gestures which take the user’s habits, background and cultural aspects into consideration. The researcher recognizes that this goal might not be achievable but knowledge of these aspects means that we can design interfaces that are as natural as possible by carefully considering what will be intuitive for the target audience.

In order to provide the students with useful feedback, Dr. Tangkuampien suggests that a three-pane view is the most useful. The three-pane view describes the screen and document layout used that presents the viewer with the question, student answer and model answer in a single view. During his research Dr. Tangkuampien has found that this view has proven the most beneficial to both the marker and the student. It allows the students to easily assess what they did incorrectly and how they can fix it. The software shown during the interview maintained the traditional view of a test script i.e. as a set of multiple pages exactly as they were scanned with the model answer added to the right column

Dr. Suleman observed that when working with electronic test scripts one does not have to maintain this view. He suggests that it is possible and may be beneficial to tailor the view of the test script to the device on which it will be marked. When changing the view however, the ability to add feedback should still be maintained as Fowles [11] suggests that this is both reassuring to the marker but is also essential if the marking is challenged in the future.

## Summary

Summary of background work

# The proposed solution

ScriptView is an electronic test management system which enhances the current test management procedures by leveraging the advantages of technology at specific stages in the process. These advantages include the rapid processing of large amounts of data, automated error checking and the ability to efficiently maintain a digital paper trail. It is a complete test management solution which aims to reduce the time taken to mark and redistribute tests as well as capture and analyze the results.

The system allows users to scan the paper versions of the tests and mark them on either a web or tablet interface. The scanned tests are automatically sorted and stored on a central server according to the course and test name. This server will be access controlled in order to ensure the security and integrity of the tests.

Once the tests are available on the server, they can be marked on either a web or tablet interface. Each of these interfaces are optimized to offer the most intuitive marking experience given their limitations such as screen size and input type. Both interfaces aim to decrease the time that is required to mark a test while maintaining high level of accuracy.

ScriptView allows for the distribution of marked scripts to the students and for a summary of the marks of a particular test to be sent to a teaching assistant (TA). The format of the email sent to students allows them to quickly asses in which areas they lost marks and thus where they need to improve. The summary sent to the TA is in CSV (Comma-Separated Values) format which is compatible with most learning management systems and thus reduces the time needed to capture these marks on another system.

Diagram for system and what I’m doing

# Design and Implementation

## Software Development Methodology

A software design methodology is … (Mention waterfall and Agile; also touch on OOP, high cohesion and low coupling)

## User Centric Development

## Process Design

ScriptView is intended to enhance the existing test management procedures as described in section 2.1. This means that the system needed to be designed in such a way that it would not disrupt the current operations to a large degree.

Figure 2 shows the overall process flow of ScriptView. This flow was inspired by the existing test management systems but decreases the amount of human intervention required.



Figure 2: Overall process flow of the ScriptView system

The first step in the process is preprocessing. The preprocessing step ensures that all constraints on the physical test paper (see section X) are adhered to before the scripts are scanned. These checks are performed by the user but it is not time consuming since the appropriate templates for the test papers are provided and if these are used, this step can be skipped by the user.

Once scripts have been collected and scanned, they are automatically emailed to a monitored inbox. As scripts arrive at the inbox, they will undergo Optical Character Recognition (OCR) in order to determine the name of the course and the test so that they can be stored on the server. This was done to remove the need for users to manually enter this information for each test which decreases the amount of work by the user as well as reducing the probability of naming errors since all text output from the OCR methods is checked a database of test and course information. In addition to the OCR, the digital copies of the tests are also undergo image processing in order to improve their readability when they are displayed on the tablet interface. Once both the OCR and image processing has been completed the script is uploaded as a set of images, each representing a single page from the script.

Ethical concern: Image processing on tests

The act of marking a test script is largely unchanged in terms of where it fits within the process flow and how it is performed. This was done intentionally in order to decrease the amount of changes that would have to be made to the existing test management procedures if an institution wishes to adopt the use of ScriptView.

Test marks are automatically gathered, stored and analyzed by ScriptView. These marks can then be accessed by administrative users and sent to students along with their test scripts. Marks can also be exported in Comma-Separated Values (CSV) format for uploading to the institutions learning management system. (How is this different from the ScriptView section?)

## Initial Software Design

Since an agile methodology with a focus on user feedback was followed during the development of ScriptView. The final product is, in some respects, vastly different from the original design. Therefore this section only documents the initial design of the software before any implementation or user feedback sessions was undertaken.

The components of ScriptView discussed in this paper can be clearly divided into three sections namely test script processing, memorandum processing and the mobile marking application.

### Test Script Processing

Test script processing involves all tasks that are required scan the scripts; retrieve information from the scripts for storage; converting them to a suitable format for the marking interfaces and converting them into a suitable format for emailing to the students.

Two approaches were considered for scanning the test scripts. The first was the creation of a dedicated desktop application which would allow the user to select a set of tests from the local storage on the machine and upload these to the server. This would allow the operation to be strictly access controlled and thus easily traceable to a single person. The disadvantages of this approach however is that the scripts would first need to be scanned and saved to the local machine, which is not only time consuming but creates a single point of failure. The uploading would also be delayed if the user forgets to start the processing on the local machine and becomes preoccupied with other administrative tasks.

The second approach was to have the scripts automatically emailed to a monitored inbox as they were scanned. This allows for the work to be distributed among multiple individuals by allowing different people to do the scanning while still keeping the processing centralized. The process would still be traceable as each documents has a timestamp that can be checked against who was using the scanner at that particular time. The machine doing the processing, is still a single point of failure but the scanned scripts will not be lost as they will still be available in the email inbox and will be processed as soon as the applications resumes. This approach was chosen as the final design for the scanning of test scripts.

The file structure on the server required that the course and test name of a scanned script be known. Since scripts are automatically emailed from the scanner, this information cannot be retrieved from the user at the point of scanning. It was decided that the best solution to extracting this information, would be to perform OCR on the scanned test pages.

Once the OCR has been completed the test needs to be uploaded to the server. It is at this point that it has to be converted to a format which is suitable for the marking interface. It was decided that the tests would be uploaded to the server as a set of images in Portable Network Graphics (PNG) format. This would allow for easy access to a single page within the document but was also influenced by the capabilities of the target device. The decision to do the conversion at this point was influenced by the limited computational power available on the target device for the mobile marking application (See section 4.5.3). It also improves the speed at which the mobile application can provide access to the test scripts to the user.

Before tests can be emailed to the students, the sets of images need to be converted to individual Portable Document Format (PDF) documents. This was designed as a standalone application which will be available to the students.

The diagram in Figure 3 shows the flow of a single test script through the system. It was used to ensure that the script was always in the expected format at a given stage.

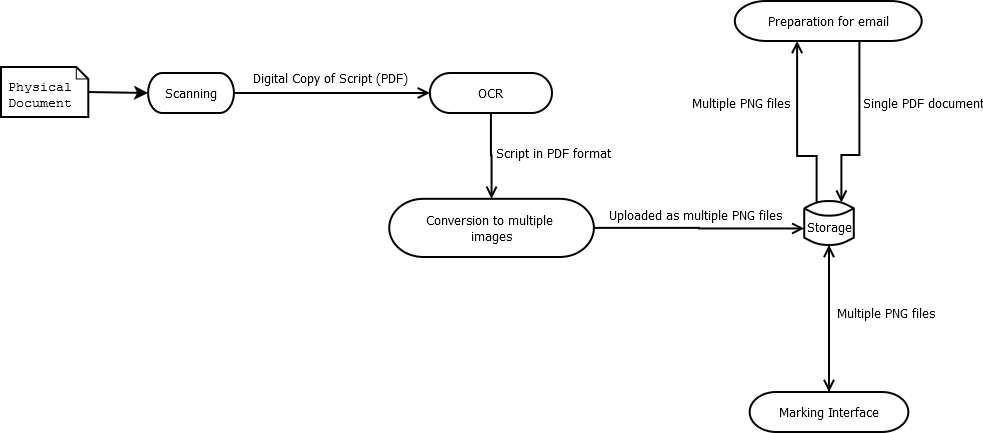


Figure 3: The flow of a script through the system

The diagram in Figure 3 was used to create the analysis class diagram in Figure 4. The aim was to design classes that would be as decoupled and cohesive as possible so that if changes needed to be made to any of the existing stages in Figure 3 or a new one added, then it would have a low impact on the number of classes that would be affected.



Figure 4: Analysis class diagram for script processing component

The EmailMonitor class handles all tasks which involve the email inbox this includes downloading new emails as they arrive as well as downloading the PDF attachment to be send to the PDFProcessor. The PDFProcessor will split the PDF into a series of images as well as perform the OCR on the document to determine the course and test name which will be used in the upload directory. The FileUploader will construct the upload directory, which is the test script’s destination on the server, and upload the images.

### Memorandum Processing

In order to create the mobile marking application, the questions and answers of the test is required. To avoid having the user enter this data, the memorandum will be uploaded to the server via a web interface. It will be processed by a standalone application which will need to extract the questions, answers and answer regions. The answer regions are the start and end y-coordinates of the space left open for the student to answer. For more detail on why this is required see section X.

To accomplish this the memorandum will be split into multiple pages, similar to what is done to the scanned script, and OCR will be performed on each page. String comparison and text position will be used to categorize extracted text into question and answer categories. The position of the answer text will then be used to extract the answer regions.

### Mobile Marking Application

The mobile marking application is the core of the three ScriptView components discussed. It is the only part that is exposed to the user and thus its design needed to be focused around usability and increasing marking speed.

As mentioned in Section 4.5.3 the target device for the mobile marking application runs on the Android operating system thus the application was designed with the Android design guidelines [12] in mind. The principles which have the greatest influence on the design are discussed below:

1. **Real objects are more fun than buttons and menus**

This principle states that it is better to allow users to directly interact with objects in the application than to have them use buttons or menus. This principle directly influenced the decision to allow the user mark the test script through the use of gestures. Using the stylus, the user is able to annotate the test script using one of the gestures shown in Figure 5 below. Each of these already has a meaning to the marker as these are the annotations they would have made had they been marking the physical test paper. From left to right the annotations indicate a single marks, half a mark and no marks.

Insert image of tick, half tick and X

1. **Keep it brief**

This principle states that instructions to the user should be kept as short as possible. Since the users of the system will have had some experience with marking test scripts. The instructions need only inform them about how to accomplish what they would usually do on paper and not the technicalities of marking. There will also not be a lengthy tutorial on how to use the application but rather tooltips for graphical elements. This guideline also influences the design of error message as the aim is to keep them brief and user friendly.

1. **Only show what I need when I need it**

Tasks which the user cannot perform in a given context will be hidden while those that are possible will be shown using an icon rather than being hidden in a menu. This guideline also applies to the use of tooltips as the user will only need to see this additional information when they need it.

1. **I should always know where I am**

This says that users should be confident about where they are within the app and how to navigate to previous screen. This has inspired the use of tabs at the top of the application for each of the questions that need to be marked. This will allow the user to easily move between questions beyond just moving to the previous or next question.

1. **If it looks the same, it should act the same**

This principle ties into the concept of recognition versus recall. Which states that it’s faster to interact with an object if you recognize its purpose than if you have to think about it. To aid recognition standard Android icons will be used for common actions like undo and redo. Since the user encounters these in multiple other applications they will easily recognize their function within the marking application. However, care must be taken in ensuring that the correct actions are tied to the correct icons as an incorrect mapping will cause frustration and may lead to users becoming reluctant to use the application.

While always keeping these concepts in mind the design of the application started at analyzing the various tasks a user may want to perform when using the application. To facilitate this a use case diagram was used as shown in Figure 5.



Figure 5: Use case diagram of mobile marking application

These use cases where then grouped according to how often they would be used together to ensure that all functionality on a given screen was related and would adhere to the third android design guideline stated above. Once use cases had been grouped, the first screen that was designed was the one that users would use to mark a script. This was prioritized since it is the screen that the user uses for the longest time and thus having it ready for user testing would be beneficial.

Based on the findings from the interview with Doctor J. Tangkuampien the marking screen was designed to offer the marker a view of the question, answer and student test script (Hereafter referred to as the three-pane view). This three-pane view (see Figure 6) would increase the markers marking speed as it would always have the current question and answer in view thus decreasing the amount of work required by the marker. A mockup of the design of the marking screen can be found in Appendix A.1. As can be seen in the diagram, tabs were used to allow the user to navigate between questions and the largest area of the screen was dedicated to the student answer since it is the focus of this screen.

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Figure 6: Three-Pane view which served as a guide for interface design

The next screen which needed to be designed was the script selection screen. The purpose of this screen is to allow the user to select which test script they wanted to mark. The challenge presented by this screen was that it needed to show mainly navigational information such as the test and course name. Appendix A.2 shows a mockup of the design of this screen. The decision to use an Android Navigation Drawer layout was influenced by the third Android design guideline since it enables the application to hide the course information when the user is looking at tests. This was the same motivation behind using an expandable list view for the test information as scripts for another test could be hidden or shown at the users command.

The final screen that was designed was the script upload screen, a mockup of which can be found in Appendix A.3. The purpose of this screen is to allow the user to check their mark allocations, name the script according to the student number and upload the script. As can be seen in the diagram a table was used to display the mark summary as this is a familiar format to the marker and thus improves usability. The screen also displays a scaled down version of the test to allow the user to verify that marks on the test paper were accurately counted.

All screens were designed to make use of the Android Action Bar, an example of which can be seen in Figure 7. This is a bar along the top of the screen which contains the application name, action items and an overflow menu. The decision to use the action bar with familiar icons for each action item was influenced by the fifth Android design principle.



Figure 7: An example of an Android Action bar that includes (1) app icon, (2) two action items, and (3) action overflow [13]

## Constraints

ScriptView is intended to enhance an existing procedure and as a result certain constraints needed to be established. This was to ensure that the system would be easily adopted by potential users as well as decrease the amount of changes that would have to be made to their current workflow. This section describes theses constraints and how they arose.

### Scanned Test Script

During the design of ScriptView, sample test scripts were provided by the project supervisor. These scripts were previous tests that were used in a single course. Figure 5 shows the variation that exists in the formatting of the first page of each of the scripts.



Figure 8: Variation on cover pages

This variation meant that the scanning component of ScriptView would need to be able to handle all of them as well as any unseen cases. To accomplish this OCR was performed on each cover page and the resulting text was searched for keywords. These keywords were related to the information which needed to be extract for example name, surname or test name. This approach had limited success. The location of fields that needed to be completed by the test taker such as name and surname were accurately detected but the handwriting recognition which was then performed on these regions was unreliable and inaccurate. Text that was typed by the educator such as test name was accurately detected by the OCR but determining whether or not text was part of the test name required that some intelligence be incorporated into the algorithm and this was beyond the scope of the system.

In order to overcome these challenges it was decided that the formatting of the first page of the test would need to be constrained. This would allow the OCR algorithms to categories recognized text based on their position on the page and relative to each other. An example of this is that the algorithm could now determine that text after the institution name is the name of the course.

A disadvantage of this approach was that the student number was no longer detected. Since the student number is essential to the system a compromise had to be made. This compromise was that the system requires the user to enter the student number before uploading the test. This compromise was acceptable as it promoted blind marking (define and reference blind marking) and checks could be coded to ensure that the student number was accurate.

Keeping the goal of reducing changes to the current procedures in mind one of the sample tests was chosen as the accepted format and it only constrains the top half of the first page. The chosen format can be seen in Figure 5 highlighted in green.

### Memorandum

The memorandum for any test that will be marked using ScriptView needs to be uploaded via a web interface in PDF format. This enables the system to manipulate the way in which the questions and answers are displayed on the marking interface. In order to accomplish this, the text of both the questions and answers needed to be extracted as well as the location of the answer regions.

Extracting the text was accomplished using a similar technique as was used on the first page of the test. However, instead of using OCR the text is simply extracted from the document. This is possible since the memorandums must always be typed and are not scanned documents. Since the length of both questions and answers could vary and neither the question nor answer positions were known categorizing the text as on the first was not effective.

To mitigate this problem, the use of annotations on the memorandum was explored. This approach involves having the educator place annotations at certain location on the test paper which would indicate the start and end of an answer region. The annotation that was used to indicate the start of an answer was the mark indication which was already a part of the test. To indicate the end of answer a new annotation would need to be created. An example of these annotations can be seen in Figure 6.



Figure 9: A question and answer with the appropriate annotations

These annotations allowed for algorithms which could accurately categorize text into either being a question or answer based on their location relative to the annotations. These annotations were also used to extract the start and end y-coordinates of the answer regions which were needed for mark allocation on the marking interface.

Although this technique was effective, through testing, it became apparent that the spacing on the memorandum and the test script that is handed to students is not always identical. This meant that the coordinates for the answer regions which were extracted would not always be accurate and would as a result skew any analytics performed on the test results.

To avoid this inaccuracy it was decided that the user would need to upload both the memorandum and the test script as it is handed to the students, both in PDF format. Using these it was possible to categorize questions and answers without the use of the annotations as answers were not present on the test handed to students so categorizing text could be achieved by comparing the extracted text from both documents. Answer region detection is now performed on the test as it is handed to students by using image processing to detect the lines left open for a student to write the answer.

The use of annotations was thus discarded but it was now necessary for the user to upload two documents instead of only the memorandum and the space left for students to answer needed to be indicated by lines as seen in Figure 7. Figure 7 also indicates the accepted location for the mark indication.



Figure 10: The accepted format for a question

### Target Device

The final version of the mobile marking application needed to run efficiently on a Samsung Galaxy Note 10.1 and use the Samsung S Pen stylus as input. The operating system on the device was Android Version X (Jelly Bean).

The key constraints introduced by this device was making effective use of the 10.1” (255.8mm) screen and managing the memory when handling a large amount of images.

### Summary

Is this necessary?

## Project Planning

With four months to fully implement the system and the goal of involving users in the development process, a clear plan needed to be established for all phases of the project. Since the agile methodology was going to be used, the project was divided into four iterations. At the end of each of the first three iterations, there would be an opportunity for potential users to provide feedback on the current state of the system. This feedback could be on any aspect of the system irrespective of whether or not they had been fully implemented.

Tasks within each iteration were prioritized based on their importance in terms of achieving the overall goals of the software such as improved marking efficiency and reducing the probability for error. User feedback also influenced the priority of tasks as highly requested, yet in scope, features were prioritized.

## Project Feasibility

Choice of language. Other language introduced when they were used. Scanning at 300dpi

## Core Functionality Development

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