Adaptive eBook

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Abstract—**A challenge identified in the current education system is that students, irrelevant of their reading capabilities, are required to follow the same literature. This paper presents a system designed to address such a challenge. The Adaptive eBook has the capability of switching the text to a simpler version, as soon as the built-in reading problem detector detects a reading difficulty. The system was developed with Year 4 students in mind and after conducting experiments with 45 Year 4 students from State and Private schools, it was seen that the Adaptive eBook does have the ability of helping students understand the text better, especially those who suffer from sentence length. From a survey given to 110 parents of Year 4 students on how they see the concept of their child having an Adaptive eBook, 80% of such parents believe that the system would help their children both from an educational perspective as well as a personal one. In addition to the positive results achieved, another success factor is the fact that the Adaptive eBook does not simply offer a helpful system to children, but it also offers an innovative concept that could be expanded and improved in several ways.**

Keywords—adaptive system; eBook; syntactic simplification; lexical simplification; eye-movements

I. INTRODUCTION

It is common knowledge that different students have different reading capabilities. Nonetheless, they are still expected to follow the same literature. This is in fact a challenge posed by the current education system. Having authors writing hundreds of versions of texts to cater for the different reading capabilities is not really a realistic option. In the past years one could notice a rise in the use of electronic books, more commonly known as eBooks. eBooks allow the users to obtain a copy of a book in a digital format, and this in turn allows for modification of its contents. Apart from eBooks, we are currently surrounded by sophisticated technology and detailed knowledge on most sectors of life. All of this inspired the investigation of whether an Adaptive eBook that employs current state-of-the-art text simplification systems, could help students understand the text better.

In a nutshell, the Adaptive eBook puts an innovative twist to the normal eBook by adding the capability of automatically detecting a reading difficulty and switching the text to a simplified version upon doing so. So as to design and implement and evaluate such a system, a set of objectives was drawn. The first was that of understanding terms like text readability, text simplification, electronic books, adaptive systems and eye-movements during reading as an indicator of text difficulty. The second objective was that of looking for systems that tackle an issue similar to the Adaptive eBook. The third objective was that of designing and implementing the system. The final objective was that of evaluating the system to see if it could really help the students understand the text better.

This paper is organized in 7 parts. The first section is used to present some background information, essential for understanding and appreciating the concept behind the Adaptive eBook. The second section is used to explain the chosen system architecture. The third section is used to present implementation details of how the system was developed. The fourth section is used to describe how the Adaptive eBook was evaluated and the results achieved. The fifth section presents ideas for Future Work and finally is a conclusion summarizing what has been achieved.

II. BACKGROUND

A. Text Readability

As defined by [1], text readability is "the ease of understanding or comprehension due to the style of writing". Readability as explained by [2] is what makes a piece of text easier to read than another piece of text and it often depends on the grammar's complexity, the sentence length and the user's familiarity with the vocabulary. As further explained by Shardlow, text readability is different from text understandability since readability deals with how easy it is for the reader to understand whereas understandability is how much information the reader actually gained. Research has shown that high readability often results in high understandability but since understandability also depends upon the time taken to read the text and the user's familiarity with the key concepts, this is not always the case. With regards to measuring the readability level of a piece of text, [1] points out that formulas using sentence length and vocabulary difficulty have been used but [2] argues that some resulting values may be inaccurate since longer sentences may be more explicit and thus easier to understand.

B. Text Simplification

Text Simplification is a Natural Language Processing (NLP) task that as explained in [3], [4], [5], [6], deals with rewriting sentences so as to reduce the complexity of a piece of

text whilst keeping the text coherent and preserving its meaning.

There are two types of simplification, namely Syntactic Simplification and Lexical Simplification. Syntactic simplification is about reducing the grammatical complexity of a piece of text [7]. On the other hand, lexical simplification is about reducing the complexity of the vocabulary used, by replacing difficult or less frequently used words with easier or more frequently used words [8], [9].

According to [10], syntactic simplification systems could be classified according to three criteria. The first is whether the system is rule-based i.e. uses handcrafted rules, or corpus based i.e. infers rules automatically from some corpora. The second criterion is on what basis the system decides simplification is possible. For example [3], [8] and [11] are given a sentence at a time; [10] and [12] use a corpus to decide when simplification is required whereas [13] and [14] let the user decide which sentences require simplification. The last criterion is about who or what will be benefitting from the system. In short, as explained by [6], text simplification systems have been used to not only benefit humans but to also improve the performance of other NLP tasks.

C. Electronic Books

As explained by [15], the idea of a book has been refashioned over time. Since things have evolved and now around 93% of the information is available online, as reported by [16], the idea of a book has been reformed once again and this time it is called an electronic book, or simply eBook. Several definitions were proposed but the main idea is that of a literary work available in some digital format, so as to store and communicate some sort of knowledge through reading [17], [18], [19].

D. Adaptive Systems

There are several types of adaptive systems, each having a specific definition. The type of adaptive system implemented by this project is referred to as user-adaptive system and [20] describes it as a system that is capable of adapting its behavior to the particular user. So as to be able to adapt, as outlined in [21], an adaptive system must have some form of learning, inference or decision-making mechanism. Since adaptive systems are used to cater for different sectors, such systems differ in the way they learn, infer or make decisions.

E. Eye-movements as an indicator of text difficulty

Eye movements are often characterized by the activity the user is engaged in. As outlined in [22] and [23], when it comes to reading, normal eye movements include fixations, saccades, return sweeps and regressions. Fixations occur when the eyes come to rest and this is when information is actually extracted. Saccades are used to transfer the eyes from one fixation point to another. A return sweep is a special type of saccade, required to take the eye to the next line. It is normally made up of a normal saccade followed by a shorter corrective one. A regression is a saccade in reverse since it moves the eyes from right-to-left to an earlier position in the text. Different eye movements also have different durations. Moreover, as mentioned in [24], as readers become more competent, their eye movement will change. Interestingly enough, this source also reports that there was a time when faulty eye movements were seen to be the reason for people finding reading difficulties. But, it is now said that eye movements can be used as an indicator of text difficulty. As agreed by [23] and [25], as the text becomes more difficult, the number of words per fixation will decrease, the fixation duration will increase, the saccade size will decrease and the number of regressions will increase.

III. SYSTEM DESIGN

When designing the Adaptive eBook, it was decided that there were five stages to it; Choose/Upload story; Simplify story; Convert and Save the story; Display the story and Detect reading difficulties. In addition, it was also decided that the chosen system architecture had to allow the user to build his own eBook by giving him the option to add the stories that he likes; have the stories simplified once but read any number of times; have the stories saved outside of the system itself to allow the user to make the necessary changes anytime the simplification system makes some grammatical mistakes; have an easy replaceable state-of-the-art text simplification system; adopt a structure to facilitate displaying the story and checking by humans; as well as have the system promote modularity to facilitate any future work

The following subsections shall give a very brief description of the responsibilities of the modules presented in the system, as could be seen in Figure 1.
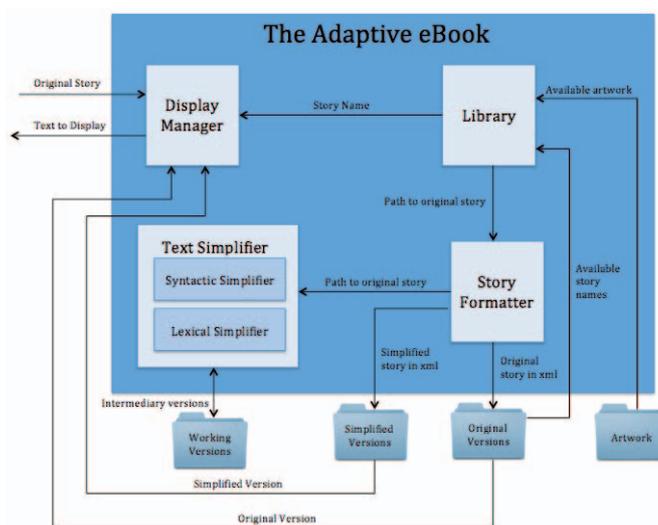

Figure 1: System Architecture

A. Library

The Library is responsible for displaying all the stories the user has available for reading as well as giving him the option to upload a new story. For the latter, the Library should provide a file upload mechanism.

B. Story Formatter

The Story Formatter is responsible for converting and saving the text from the uploaded plain text files into an XML file. It is also responsible for invoking the text simplification systems and saving the results in an XML file of the same format as seen in Figure 2.

C. Text Simplifier

As the name implies, the Text Simplifier module is responsible for simplifying the text both syntactically and lexically. Since most text simplification systems are either syntactic simplifiers or lexical simplifiers, it was decided to keep the simplification systems separate.

D. Display Manager

The Display Manager is responsible for displaying the correct version of the story. Thus, it is also responsible for detecting reading difficulties and keeping track of the last sentence displayed and from which version.

IV. IMPLEMENTATION

This section shall give details on how the Adaptive eBook was implemented.

A. Library

The Library is populated by creating a button for each file in the Original Version folder. If a file with the same filename is available in the Artwork folder, an image is also assigned to that button. If the user clicks on one of these buttons, the story name is extracted from it and passed to the Display Manager module. If the user chooses to upload a new story, the JFileChooser presents all the available .txt files on the system. Once the user chooses a file, the path is passed to the Story Formatter.

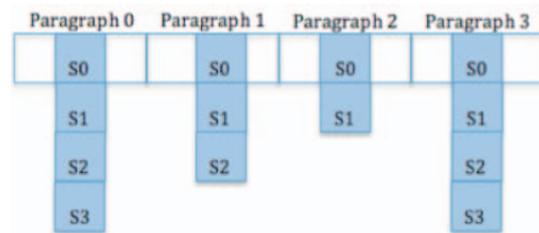**Figure 2: XML files for the Original (left) and Simplified (right) story**

Figure 3: A list of linked lists used to hold the sentences of the story

B. Story Formatter

The Story Formatter contains a method called *manager()* which then calls the relevant methods to simplify and store both versions of the story in an XML file. Basically, this module creates two structures, one for the original story and one for the simplified as seen in Figure 3. This structure is a list of linked lists and its aim is that of presenting the paragraphs and sentences of the story in a way that the original and simplified versions are kept in sync. The original story is split in paragraphs and each sentence is added to a list called *sentencesOfOrigPar* (eventually forms a column of blue boxes|) and written to a file for simplification. The syntactic simplification module is activated and upon completion, the resulting sentence is passed through the lexical simplifier before it is written to a similar list, this time called *sentencesOfSimpPar*. Once all the sentences in this paragraph are traversed, *sentencesOfOrigPar* and *sentencesOfSimpPar* are added to the main list (white box) as shown in Figure 3.

C. Text Simplifier

The Text Simplification module is made up of two other modules; the Syntactic Simplifier and the Lexical Simplifier. The chosen state-of-the-art syntactic simplification system used was that described in [26] and [27]. It was packaged separately from the Adaptive eBook and since it is written in Perl, a ProcessBuilder is used to call the relevant scripts. Since it was seen that the simplification system is not consistent in the way it presents the output and requires the input to be in a file, it was decided to write to file one sentence at a time. It is understood that this is inefficient but coherence and robustness were more important than speed, considering a story is only simplified once but could be read any number of times.

With regards to the lexical simplifier, it was decided to follow the methodology suggested by Jan De Belder after personally contacting him. A list of around 2000 word pairs is used to replace the difficult words. This list is loaded into a TreeMap whereby the key is the complex word/phrase and the value is its simplified equivalent. Once the lexical simplifier receives a sentence for simplification, the different words are stored in an array. For each element in this array, the system checks for any non-letter characters and extracts only the word part. The simplifier then checks that the letter does not start with a capital letter if it is not the first word of the sentence. All those keys starting or matching exactly the word to simplify are put in a list. This list is then traversed and each key is checked if it exists in the sentence. If it is not present in the sentence, it is removed from the list. In the case the list ends up empty, the word remains not simplified. This is either because the original word was not complex or because it is not included in the list of word-pairs. If a key remains in the list,

the value is retrieved from the TreeMap and the complex word is replaced by it.

D. Display Manager

As mentioned in the Design section, the Display Manager is responsible for two main things: choosing the sentences to be displayed on the screen and detecting reading problems. At a particular point in time, the story being displayed is either the original version or the simplified version. In the case that it is the original version and a reading problem is detected, the simplified version is displayed once the user starts reading the next page. So as to create a flawless transition, the system must be constantly aware of the last sentence in a particular page and the version it was extracted from. To do so, the XML files mentioned in the Story Formatter section are loaded into two similar structures, one for the simplified version and one for the original version. These structures are the same as used previously and shown in Figure 3. Variables held by this module include the version of the story being displayed (original or simplified), paragraph index and sentence index. The page is filled by adding sentences from the appropriate structure using the current indices and then updating the indices appropriately.

The reading problem detector implemented in this system is a time-based one. For this reason, the story is not allowed to be in a scrollable view. Buttons leading to the next and previous pages are thus used for navigation purposes. Each time, a new page is filled by displaying the sentences that fit till the scrollbar becomes visible. At this point, the system time is recorded.

Once the user hits the next page button, thus indicating he has read the page, the system time is recorded once again. The total time elapsed is calculated by subtracting the two values. This time together with the number of lines used to display this page are then passed to a method that calculates the ideal time the user should have spent reading that page. This threshold is calculated using formula (1). In the case that the time spent reading the page exceeds the threshold, the version is changed to the simplified one.

$$((50*(T_{fixations}+T_{Saccades}+T_{ReturnSweeps}))/37) + Buffer \quad (1)$$

It is important to note that we derived the formula presented above for Year 4 students and thus, changes need to be made if it is to be used by a different age group. In addition, the values for $T_{fixations}+T_{Saccades}+T_{ReturnSweeps}$ could be calculated as indicated in the derivation of Figure 4. The reason for adopting a time-based approach was to remove the costs required for eye-tracking technology but still incorporating research from eye-movements as an indicator of text difficulty.

Let the passage be N-words long and displayed on L lines

On average, 1.2 words are covered by 1 fixation

$\therefore$ Expected number of fixations $ENOF = \frac{N}{1.2}$

The mean fixation duration for Grade 4 children is 266ms

$\therefore$ Expected time spent of fixations $T_{fixations} = 266 \times ENOF$

Every fixation is followed by a saccade

$\therefore$ Expected number of saccades $ENOS = ENOF - 1$

The maximum mean duration of a saccade is 40ms

$\therefore$ Expected time spent on saccades $T_{Saccades} = 40 \times ENOS$

For L lines, $\exists\ L - 1$ return sweeps and a return sweep is normally a long saccade followed by a short one.

$\therefore$ Expected time spent on return sweeps $T_{ReturnSweeps} = 55 \times (L - 1)$

For Year 4 students, regressions occur 26% of the time

$\therefore (T_{fixations} + T_{Saccades} + T_{ReturnSweeps}) + \frac{26}{100}T = T$

$100(T_{fixations} + T_{Saccades} + T_{ReturnSweeps}) + 26T = 100T$

$100(T_{fixations} + T_{Saccades} + T_{ReturnSweeps}) = 74T$

$T = \frac{100(T_{fixations}+T_{Saccades}+T_{ReturnSweeps})}{74} = \frac{50(T_{fixations}+T_{Saccades}+T_{ReturnSweeps})}{37}$

Including buffer for user to move his eyes to the first word:

$Buffer = 3000ms$

$\therefore Threshold = \frac{50(T_{fixations} + T_{Saccades} + T_{ReturnSweeps})}{37} + Buffer$

Figure 4: Derivation for the Reading Problem Detector

V. EVALUATION AND RESULTS

The Adaptive eBook was evaluated by carrying out the four tasks described below.

A. Statistics on the Simplified Story

The first evaluation task follows the calculation of statistics as described in [7], [8] and [28]. The aim was to understand the amount of simplification carried out and the effort required in modifying the produced simplified version before making it available for children. The statistics showed that the number of sentences increased by almost half, indicating the sentences became shorter. In addition, only two simplified sentences required modification to correct the grammar. Most modifications were required for the formatting.

The changes in reading difficulties after activating the simplified version

- Problem reduced a little — 25%
- Problem reduced a lot — 17%
- No need for help — 42%
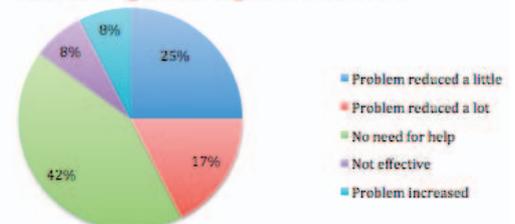- Not effective — 8%
- Problem increased — 8%

Figure 5: Shows how the simplified version affected the reading performance. This also includes the percentage of students who initially did not have a problem

B. The Reading Experiment

The Adaptive eBook is an innovative system so literature on how it should be evaluated was scarce. It was thus decided to carry out a reading experiment by first having the child read the story from the Adaptive eBook out loud and the researcher records information such as time taken per page; difficulties encountered; and reading speed. The child was then required to fill in a survey about how he found the story; what he found difficult; what he would have preferred to be different; as well as a short multiple-choice comprehension test. The students' teacher was then asked to answer a short survey per participating student on their reading speed; any known reading difficulties; and whether the story used in the reading experiment should be difficult to the student. 45 students from State and Private schools took part in this experiment.

Results from this experiment have shown that the reading problem detector suffers from reading speed and the threshold proved to be fast for most students. But, after considering the results achieved and the observations made, it is safe to say that the Adaptive eBook helped students understand the text better, especially those who find long sentences challenging. 87% of the children felt the story was good for them and the researcher observed that for 72% of the children who required help, their reading performance improved for the better (Figure 5).

C. The Sentence Pairs Activity

Another experiment was carried out on 109 Year 4 students and the reason for doing so was to see how most children prefer the different sentence types to be written. The activity follows that presented in [29] but instead, 10 sentence pairs were presented to the children. Each pair was made up of a sentence in its original version and in the produced simplified version. The participants were then asked to mark the sentence from each pair that they think it's easier to read and understand.

The results have shown that overall, children prefer the original sentences as much as they prefer the simplified sentences, even though the preference varies by sentence type. But, after dividing the participants according to the school they attend, it was seen that 45% of children coming from a school where a minimal amount of reading difficulties were observed during the experiment, prefer mostly the original version. On the other hand, it was seen that 68% of children coming from a school where a considerable amount of reading difficulties were observed, prefer the simplified version (Figure 6).
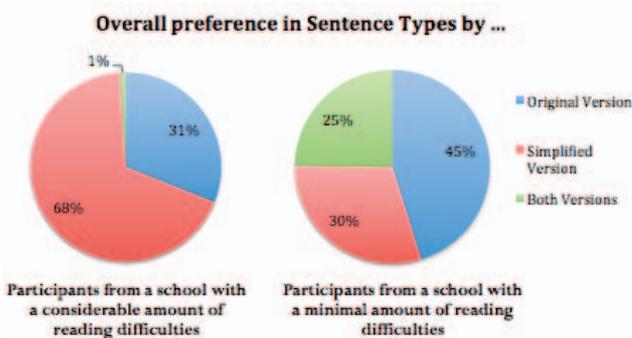

Figure 6: Results of the Sentence Pair activity after dividing the participants according to the school they attend

D. Parents' Survey

Being that the Adaptive eBook introduces an innovative concept, it seemed interesting to see what the parents of some Year 4 students think about the idea of their child using an Adaptive eBook. Thus, a short survey was given to 110 parents / guardians.

From the feedback gathered through this survey, it was observed that 49% of the participating parents had seen an eBook but only 26% had actually used one. In addition, the number of children exposed to eBooks was minimal. Nonetheless, 80% of the parents still believe that their child could benefit from an Adaptive eBook, even though 90% of such children do not suffer from a learning difficulty. A worrying result was that 49% of the parents reported that they would not want their child to start reading a book of a certain level and end up reading a book of a lower level, even though the child would not be really understanding the harder text. Since throughout the survey the Adaptive eBook was mostly judged in a good light, it was concluded that either the parents did not understand this question well or the children of such parents could be students who do well, so the parents believe that their children are capable of rereading and slowly analyzing a hard piece of text until they understand. Moving on to the benefits that could be offered by having an Adaptive eBook, the parents believe that the Adaptive eBook does have potential to encourage their child to read more; positively affect their school grades; as well as allow them to be more independent. Finally, results have shown that 64% of parents believe the Adaptive eBook could be used everywhere; 70% would also love to have a built-in dictionary; and 95% are in favour of introducing support for Maltese.

VI. FUTURE WORK

Evaluating the system has shown that the concept has potential and has already achieved some success but there is room for further improvement as well as for expanding the concept even more.

So as to improve the system, the reading problem detector needs to be replaced, possibly avoiding issues due to reading speed. A possible solution is that of using eye-tracking technology. This would also allow for images and the child to have reading breaks. Until text simplifiers are improved to an extent that they do not produce any more grammatical mistakes, adults are still required to check the produced simplified versions. Even though it is very simple to do so as it is now, finding a way of facilitating such a process even more could also be listed as future work. An interesting addition would also be that of having different levels of simplification to cater for different students; using a larger list of word-pairs for lexical simplification together with a substitution-checking mechanism and allowing different file types to be uploaded.

With regards to expanding the concept, it would be nice to have the system work for different age groups and also as an App. It would also be interesting to have a website with story packages (original and simplified). Additional tools such as a built-in dictionary, text-to-speech as well as suggestions for further reading have the potential of helping students understand the text better, and are thus recommended for the expansion of the Adaptive eBook. Another interesting idea would be that of employing the technology of the Adaptive

eBook in the form of a plug-in, to be used by children when searching the Web.

VII. Conclusion

This project allowed for the investigation of whether current state-of-the-art text simplification systems could help students understand the text better. An Adaptive eBook was developed and then used by 45 Year students. Apart from the performance of the reading problem detector, the results achieved were satisfactory. Reason being, the experiment has shown that eBooks coupled with current state-of-the-art text simplification systems do have the potential of helping students understand the text better. Moreover, from a survey given to 110 Year 4 students' parents, it was seen that 80% of the parents believe the Adaptive eBook could be beneficial to their child, not only to positively affect their grades but to also help them become more independent and encourage them to read more. A particular parent also gave feedback on one of the survey papers, explaining how the Adaptive eBook holds the power of creating a sense of pride in the children, that they could achieve results on their own.

Apart from the results achieved, this project also offers a prime example of how creativity coupled with existing technologies, has the potential to finding a solution for a non-trivial challenge. The Adaptive eBook merges technologies such as text simplification systems and eBooks, with knowledge from the cognitive science such as eye movements during reading as an indicator of text difficulty.

To sum up, it is believed that the first version on the Adaptive eBook was mostly successful and the parents' feedback was also very encouraging. Last but not least, we believe that the Adaptive eBook is of scientific value since not only does it propose a framework for future work as more sophisticated technology is released, but it also presents a concept that has the potential of changing the lives of many students once further improved.

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