AGENT-DYSL: A Novel Intelligent Reading System for Dyslexic Learners

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Abstract: In this paper we present a novel approach for facilitating dyslexic children in learning to read fluently. We explain the motivation, general idea and initial results in terms of user requirements and system architecture. Unlike previously presented approaches, the aim of this system is to monitor the progress and perspectives of a dyslexic user and supply personalised help, taking advantage of modern ICT features. The goal of this personalised help is to gradually increase the reading capabilities of the user, gradually diminish the assistance provided, till he is able to read as a non-dyslexic learner.

1. Introduction

The purpose of this paper is to present a novel approach for facilitating dyslexic children in learning to read fluently. The approach presented is being incorporated in the AGENT-DYSL software, which is being developed in the framework of the AGENT-DYSL IST project by Atos Origin SAE, Spain, the Intitute of Communication and Computer Systems of the National Technical University of Athens, Greece, The Dyslexia Institute, UK, Herning Kommune, Børn Og Unge, Denmark, FZI Research Center for Information Technologies, Karlsruhe, Germany, Institute for Language and Speech Processing, Greece, Centro de Profesorado y Recursos de Gijón, Spain, European Dynamics, Greece and the University Lucian Blaga of Sibiu, Romania. It is funded by the European Union under the Sixth Framework Program, Information Society Technologies, eInclusion, Contract No. IST-034549. In the following, we will explain the motivation, general idea and results in terms of user requirements and system architecture.

Reading disorders, such as dyslexia, affect a significant number of people. Dyslexia is the most common cause of reading difficulty – it is estimated that one in 10 children is dyslexic. Dyslexia is not related to intelligence. History is full of examples of great people who have overcome dyslexia to achieve enormous success – Albert Einstein being probably the most famous. However, because dyslexic readers are unable to master decoding as it is traditionally taught, they are gradually left behind in the classroom and consequently in society. According to the International Dyslexia Association [1], 74% of 8-year old students

(3rd grade) who are poor readers remain poor readers when they reach 14 (9th grade) and cannot read well as adults. Over time, dyslexic learners can improve their reading skills, but the gap in reading ability between good and poor readers remains into adulthood. This gap is significant, and turns dyslexic people into low achievers in education and learning, excluding them from several aspects of social living.

Poor reading skills have an impact on the vocabulary development of dyslexic readers and to their exposure to relevant background knowledge. This leads to repeated failure in the classroom and has a negative effect on their motivation and self esteem [2]. The ability to decode every word is essential to comprehension. Good readers do not skim over words or rely on context for decoding. They read every word. In contrast, poor readers heavily rely on context or memory for decoding [3]. In order to benefit from reading independently, students should be able to decode text with 95% accuracy [4]. For students reading below this level, access to most of their text material is precluded.

The AGENT-DYSL project has completed the user requirements and technical specifications of an Intelligent Assistive Reading System, which can help school-aged readers who have dyslexia to improve their reading. Children using the reading system should receive personalized attention by the system, with customized presentation of reading material, based on individual profiles built up through “observation” of each child reading the text on the system’s viewing area and by recognizing the types of their reading errors. These individual profiles are used in deciding how to optimise the text presentation for each child and situation.

In addition to being able to “listen to children reading”, the AGENT-DYSL system is also able to “see” the children while they read. By employing image analysis techniques, the system can assess the child’s emotional and physical state, and dynamically adapt the document presentation accordingly (a tired child or a child under emotional stress is more likely to have reduced reading performance).

2. Objectives

The main objective of this paper is to present the AGENT-DYSL system, which, taking advantage of modern ICT technology features (as described in section 4) can relieve the above persons and gradually reduce the gap between dyslexic and non-dyslexic readers. The system described can:

- Monitor the performance of a dyslexic user and his current emotional and physical state.
- According to the above measurements construct a personalized user-profile and predict possible future errors of the learner.
- Provide personalized assistance to the learner, according to his profile.
- Be included in an accommodative class environment, where it will also take into account the context of learning.

In the rest of this paper we shall discuss the results obtained so far from the AGENT-DYSL work, in terms of user requirements and technical specifications.

3. Existing Technology Description

The benefits of using assistive computer software to help dyslexics with reading difficulties have been recognized [5], [6] and commercial products are now available [7], [8], [9], [10], [11]. Assistive software usually provides multi-sensory auditory and visual feedback to the dyslexic reader in order to reinforce their core reading skills, but also to improve their comprehension. The basic functionality of assistive software usually consists of audio support using speech synthesis and personalized text formatting. In order to focus the readers’ attention on specific text parts, the font type might be changed and its size increased. The text can also be emphasized by highlighting it and by changing its color.

Finally, the line length and the line spacing can be modified since research indicates that they are important factors influencing reading fluency [12], [13]. It should be mentioned that some of these techniques have been successfully long employed with visually impaired persons [14], [15].

The importance of using assistive computer technology and of making computers accessible to users with cognitive and non-cognitive disabilities has been recognised by the software industry and by the research community [16]. Practical suggestions have been made on design issues regarding software development and material (text, images, error messages) presentation. For material presented through the World Wide Web, the W3C consortium [17] has established the Web Accessibility Initiative [18] (WAI) the mission of which includes the development of guidelines for the accessibility of web sites, browsers and authoring tools, in order to make it easier for people with disabilities to use the web [19].

4. Methodology

Despite the fact that several assistive reading software packages are available, which incorporate most of the features listed in the previous paragraphs, there are some prominent features that are absent from these tools. The key innovation of the AGENT-DYSL reading assistance is the combination of (1) a deep knowledge about the user and the current context or situation, (2) context-aware pedagogical knowledge about how to respond to a particular situation and (3) appropriate adaptation possibilities in the reading software user interface. Furthermore, the system allows for (4) teachers and experts gaining new insights into the effectiveness of certain pedagogical strategies.

1. The characteristics of the learner and their current situation are derived from different inputs like speech processing, and image analysis. Speech processing is used to detect anomalies in the reading performance like hesitance, but also reading errors. Image processing can be used to capture attention patterns and emotional state of the learner. This is done in the Reader's State Monitoring component. Another input can also come from teachers who encode their knowledge of the individual learner (e.g., type of errors, Reader's Profile Module). Result of processing these different inputs is a semantically rich user model that represents an up-to-date image of the real-world situation.
2. With the help of state-of-the-art ontology-based techniques like OWL and rule languages like SWRL, expert pedagogical knowledge can be encoded in a descriptive way. Part of this expert knowledge takes the form of rules that take contextual variables from the user model as an input and yield adaptation actions as an output (Knowledge Module). This encoded knowledge will certainly only represent a subset of teachers' experience, but it still yields a substantial improvement compared to traditional reading software. It will be stored in a central server, along with the knowledge derived from users' profiles. User will have to log on this server, in order to take advantage of all the encoded knowledge, according to their specific needs.
3. One output of the reasoning process in the previous step are adaptation actions that can be applied to the user interface like predictive highlighting of difficult words in various forms, adaptation of the reading speed, presentation of additional help and pronunciation clues. Because these adaptive features are defined in an open way, this provides a very flexible framework for implementing different pedagogical strategies (Personalization Module). The user requirement study revealed the following adaptive features:
   - Modifying font type, size and colour of the whole text, but also of individual letters
   - Highlighting
     - Style of highlighting.

    - Speed of highlighting
    - Highlighting syllables
- Segmentation at paragraph-level, sentence-level, and word-level.
- Hiding parts of words
- Display of help cues
    - hyphenation
    - synthetic speech
    - pictures
    - suggestions for further reading or exercises

4. This flexibility together with the descriptive modelling of expert knowledge allows for a closed-loop approach in which we do not only apply pre-defined expert knowledge, but in which experts and teachers themselves learn about the efficiency of their pedagogical strategies. For that, the system provides the possibility to analyze usage data. Experts can then modify the adaptation rules.

5. Development

The features described above are implemented with the use of the following system architecture, as depicted in Figure 1. The accommodative learning system consists of the following components:

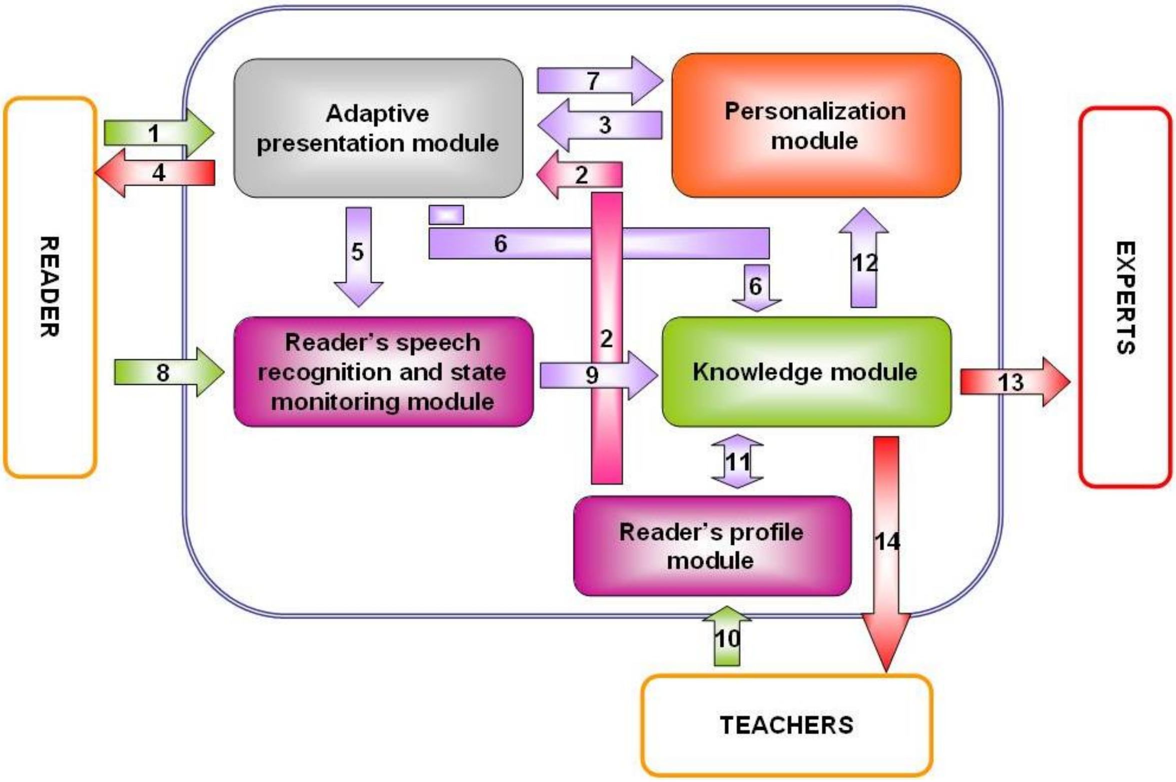


Figure 1: Overview of the proposed accommodative intelligent dyslexia reading environment.

5.1 Adaptive Presentation Module

This module offers to the dyslexic reader a simple graphical user interface, age appropriate and sensitive to the needs of dyslexic users. The main functionality of this module is the presentation of reading content, personalized according to the reader's profile and the reader's preferences. When required by the user, the module scrolls over the text, highlighting the words the user must read, at a speed determined by the user's profile. Furthermore, the module is able to adapt on-line the presentation of the content, responding to the reader's current state and performance.

5.2 Reader's profile module

By using this module, teachers are able to manually create user accounts for their dyslexic pupils. During the account creation, users are prompted to take an evaluation test, so as to collect the necessary information that forms the individual profile of the reader. Afterwards, the users are regularly asked to take a re-evaluation test, so as to update their profile. The module allows manual update to the profile, if necessary.

5.3 Personalization module

The reader's profiles, besides being manually updateable by the teacher, or automatically by the system itself, may be also updated by the reader, by expressing preferences through the GUI. Profiles are also automatically updated based on the reader's performance and the reader's state. The purpose of the personalization module is to collect, store and transmit these profile modifications. Furthermore, it is responsible for aggregating collected information pieces into more stable profile features, e.g., it combines data from the speech recognition and state monitoring and it derives "typical error types" from individual errors.

5.4 Knowledge module

The aim of this module is to provide the conceptual as well as technical infrastructure for intelligent learning support. In order to achieve true adaptability of the system, it is necessary that the system has a deep understanding of the learner's context, consisting of long- and mid-term characteristics and short-term situation, which includes not only their performance in the learning environment (e.g. mistakes made), but also their reading state, which is provided by the Personalization Module. The Knowledge Module is driven by rules that derive teaching strategies from the reader's state and current performance. For that purpose, it analyzes the text to read in order to identify in advance, based on the reader's profile and past performance, words where the reader may experience difficulties.

The Knowledge Module is also responsible to log the performance of the readers, which will be used later on, not only for the automatic reasoning, but also for the consult of teachers and experts on dyslexia.

5.5 Reader's speech recognition and state monitoring module

This module uses ASR techniques to register the speech of the dyslexic reader and transcribe this speech into text. By comparing this text with the original input text, the module identifies reading mistakes. The module also uses the speech and the video capture of facial and body expressions, posture and movements to determine in real time the emotional state of the reader (active/passive, engaged or not, hyperactivity or not, positive/negative).

The information about reading mistakes and reader's emotional state are forwarded to the knowledge module, for reader performance storage, and potential automatic modification of the reader's profile and modification of the way the content is presented to the user (providing for instance on-line help on the words the reader experienced problems in).

5.5.1 *Speech recognition component*

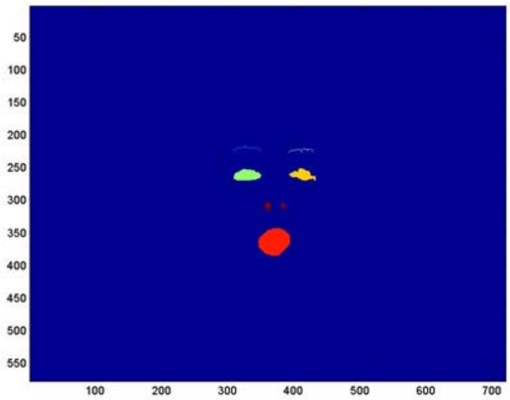
The main difficulty encountered when designing the speech recognition components has been the fact that real-time speech recognizers are based on a system vocabulary and can only recognize words included in that.

However, we know the types of possible errors and it is possible to increase the size of the vocabulary by including in it words that are artificially created (by applying the types of errors to the basic system vocabulary words). For example, if the word “capital” is in the initial vocabulary, and there is an error-type for “letter reversals”, then the word “catipal” might be inserted in the recognizer’s extended system vocabulary. Given the extended system vocabulary, the system is able to recognize words from that larger group, and more importantly, from each of these words it will be able to infer (since it knows the initial word written on the screen) the type of error with high confidence.

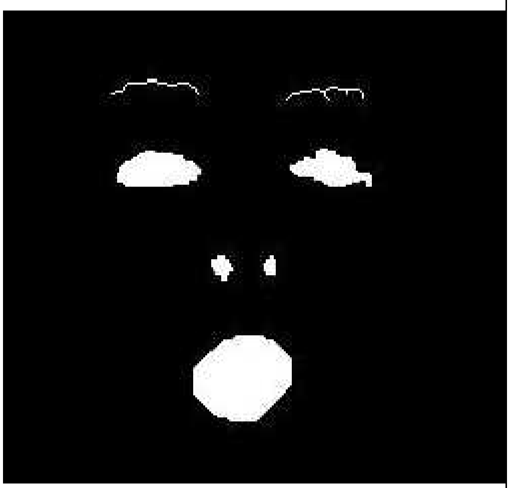
5.5.2 *State monitoring component*

Aim of the detection by the Reader’s State Monitoring component, is the recovery of state related signs, traditionally been handled by separate disciplines. In particular, initially the most important states will be selected. Among them, some interesting states that are tightly related to the learning process are the states active/passive, engaged or not, hyperactivity or not, positive/negative and nervous or calm.

(a)



(b)



(c)

(d)

Figure 2: Extraction of facial features and feature points: (a) Original Image (b) Extracted mask that localizes main facial features (c) Extracted Mask (Zoomed) and (d) Feature Points.

In order to classify a learner to one or more of these states the human face and body should be detected and analysis of the activity of a human face should be performed. This process requires a number of pre-processing steps, which attempt to detect or track the face, to locate characteristic facial regions such as eyes, mouth and nose on it, to extract and follow the movement of facial features, such as characteristic points in these regions. Facial analysis extracts the features to be used for state/emotion detection. Some facial features that, when tracked, provide useful information about the state/emotions of a person are mouth, eyebrows, eyes and nose. In Figure 2 an example of facial features and feature points detection is provided.

It should be also mentioned here that both the facial features selected and the states distinguished and chosen, are further investigated in order to select the best representatives, without significantly increasing the complexity of the system.

6. Conclusions

Unlike previously presented approaches, the presented AGENT-DYSL system is able to monitor the progress and perspectives of a dyslexic user and supply personalised help, taking advantage of modern ICT features. The goal of this personalised help is to gradually increase the reading capabilities of the user, gradually diminish the assistance provided, till he is able to read as a non-dyslexic learner. Since the design phase is now over, the analysis of the system components and the design of system architecture have indicated several innovative features. Their implementation is based on modern techniques of user profiling, knowledge databases along with speech and image processing.

In future, AGENT-DYSL's Intelligent Assistive Reading System expects to magnify its benefits to dyslexic children by incorporating it into the school environment, resulting into an accommodative learning environment, which also takes into account the context of learning, i.e., interactions among normal and dyslexic children, the teacher and assistants. Within one year's time, pilots will be set up in schools in the UK, Denmark and Greece, so as to test in practice the operation and usage of the AGENT-DYSL system.

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