# Adaptive Reading Assistance for the Inclusion of Students with Dyslexia: The AGENT-DYSL approach

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## Abstract

*Dyslexia is a major barrier to success in education and later on the job as reading skills are fundamental for personal competence development. Children with dyslexia have special learning needs (e.g., more teacher support), which currently only specialized institutions can provide. However, this takes children out of their peer group and causes social problems. On the other side, there is general-purpose reading support software, which are not geared towards children with dyslexia as they lack personalization. AGENT-DYSL brings together speech and image recognition as well as semantic technologies to build a truly adaptive reading support system for children with dyslexia.*

## 1. Introduction

The ability to read is recognized as the most important skill that promotes children's learning in school, and is one which gives those leaving school access to employment [1]. Learning to read for children with dyslexia problems has become a barrier to academic and personal development. So far, this has mainly been approached by providing special education facilitities for children with dyslexia. But this, in turn, has separated them from their social environment and peer group so that dyslexia has stigmatized them even more.

It is clear that children with dyslexia need extra support to develop the skills in which they have weaknesses and to enable them to find alternative methods of working and learning. While it is clear that teachers alone cannot achieve this in a traditional school environment, technology, however, offers the potential to provide this extra support in an inclusive way by enabling children with dyslexia to learn from the same materials and in the context of their class fellows.

Many software solutions [2]-[4] tend to address either one or the other of these needs being either 'enabling' or 'instructional'. Such systems, up to now, have not been designed to respond to feedback from the learner and to personalise the system in line with the user's performance.

The goal of the proposed system is not only to enable access to the reading materials within an inclusive learning system but also to promote the development of reading skills by adjusting and adapting to the environmental needs.

In this framework, children using the proposed reading system will receive personalized attention through customized presentation of reading materials. This attention will be based on individual profiles built up through "observation" of the children's reading of texts on the system's viewing area, and by recognizing their reading errors and their affective states. These individual profiles will be used in an intelligent reasoning module to optimize the text presentation.

To improve its usability and acceptance by children with dyslexia, the proposed system employs age appropriate and dyslexia-sensitive user interfaces. The proposed system will magnify its benefits to children with dyslexia by integrating into the school environment, resulting into an "accommodative learning environment". In addition the system takes into account the context of learning, i.e., interactions among normal reading and children with dyslexia, the teacher and assistants.

This paper is organized as follows: Section 2 outlines system requirements and state of the art. Next, the overview of the proposed system is described in Section 3 while the adaptive behaviour of the system is shown in Section 4. In Section 5, the user interface of for learner with dyslexia is described and finally, Section 6 concludes this paper.

## 2. Requirements and State of the Art

The basic requirements of the proposed system are included in the term “assistive technology”. Assistive technology is not designed to improve particular skills or teach particular subjects, but provides a means for the learner to work around his/her reading and learning problems.

Our target groups are people with dyslexia. Their most common problem is that they make spelling mistakes, mistake on word orders or in structuring a sentence when they write. In the same way, they have problems in reading with misinterpretation of the sentences and obviously slowness in reading. The particular problems (which types of words are difficult), however, vary between different students.

As a consequence (as current teaching practice shows), it is extremely important not to assume average difficulties, but to consider individual ones. Furthermore, as reading difficulties often cause frustration, emotional stress and distraction of the child in general have to be taken into account as well. In order to build a intelligent software tool appropriate for learners with dyslexia, it must provide not only automated assessment of reading progress, but also assessment concerning the learner’s current state.

In the market, many software programs [2],[3],[4] are often recommended as instructional software for people with dyslexia. Some of them provide reading machine which can read electronic documents out loud using a synthetic voice together with highlighting mechanism while other provide speech recognition mechanism. However, all of these programs have not adapted the presentation to the individual learners’ needs.

But, none of these programs have taken into consideration either the learner’s current state and performance or store and restore them the next time that the learner uses the software. As a result, these programs cannot provide personalized assistance.

This can be traced back to the problem that they only rely on a small set of technologies (usually highlighting and speech output). But only a combination of different technologies in an intelligent way will provide software that can be adaptive to its learners’ needs, which includes speech recognition, and image recognition to get information about the learner, which is a prerequisite for a personalised learning environment, which takes into account the individual needs of each learner with dyslexia.

For that purpose, we have created a knowledge infrastructure component using ontology-based techniques to store, augment, and retrieve learner context information and information about the current reading session. Information is collected from both speech recognition and facial analysis services. The proposed system retrieves data from the infrastructure component providing adaptive, to learner needs, environment.

The overall goal of the proposed system is to contribute in development of a *next generation assistive reading system* and to incorporate it into learning environments, helping each learner with dyslexia difficulties to improve its reading. By incorporating the proposed system into the school environment, an “accommodative learning environment” is created which also takes into account the context of learning, i.e., interactions among normal and children with dyslexia, the teacher and the assistants.

## 3. System Overview

The architecture of the proposed system consists of four main components (see Figure 1): a) Recording and Analysis Component (consisting of image and speech recognition), b) Knowledge Infrastructure, c) Profiling component, and d) Content Presentation component. The activation of each component depends on the current operation mode. The system provides two operation modes to the learners: a) *Everyday* and b) *Profile re-evaluation.*

In the **re-evaluation mode** the full range of components is used to assess the learner’s profile that will personalize the reading environment. In this mode the learner is asked to read aloud a text which is presented in the software window while both microphone and camera are activated. The data from microphone and camera are analysed using a speech recognition and face analysis services, respectively.

The speech recognition and the face analysis services are parts of Recording and Analysis component. The scope of *speech recognition service* is to process the speech signal and to perform feature extraction. Then, by allowing acoustic phoneme models, the speech recognition service estimates the similarity of the features, with a given sequence of words. The output of this process is not only plain text, representing what the speaker has uttered, but also word-based confidence scores.

The scope of *face analysis service* is to process the learner’s online video while he/she interacts with the proposed system. Head pose as well as eye gaze and the distance from the monitor are essential elements for estimating a learner's attention to the monitor of a computer. A mapping between detected feature points leads to extract possible learner states such attentive, frustrated, distracted, etc.

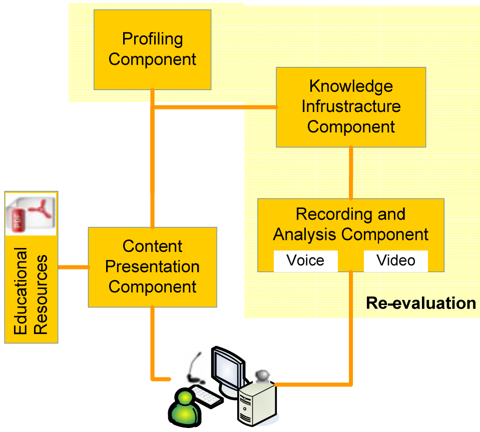


**Figure 1**: Intelligent Reading System's Architecture

The analysis of these services is further evaluated by *Knowledge Infrastructure* component. This component is considered as the manager of the proposed system and it is responsible to provide the system with the learner's error profile. The functionality of the Knowledge Infrastructure component is described in the next section. The learner's error profile is stored into the Profiling component.

The *Profiling* component includes not only individual error profiles but also individual preferences which the learner maybe has defined. The Profiling component uses the Knowledge Infrastructure both for storage and retrieval. At the end of a re-evaluation mode, the learner's current profile is stored into Profiling component. This profile is actually stored into the server database from which it can be retrieved every time the learner run the proposed software and connected to the server. In addition, the learner's profile can be portable using a USB stick.

The *Content Presentation* component receives a file in PDF format as input and after proper analysis, the text and the images from it are extracted and an XML file is produced. With the help of the Knowledge Infrastructure, this text is analyzed and with respect to words likely to cause problems for the learner. For these words, appropriate changes to the presentation are determined (e.g., augmented with specific highlighting color and speed, word and line spacing). So, learners using the proposed reading system will receive personalized attention through customized presentation of reading materials.

In the **everyday mode** only two components are activated: the Content Presentation component and the Profiling component. In this way, the presentation of any PDF file can be adapted to the learner profile. In addition, the face analysis service can be activated in this mode in order to detect learner' state like 'not attentive' and temporarily pause the text presentation till learner be back to attentive state.

## 4. Adaptive Behavior

The knowledge infrastructure constitutes the semantic glue of the AGENT-DYSL system. It uses the results of image and speech analysis as well as profiling to adapt the content presentation so that the reading support is most appropriate for the situation of the learner. Adaptive features include changing speed and style of highlighting, pre-emptive reading, or providing clues to the learner where difficulties have occurred or are expected.

Adaptation must be based on background knowledge from dyslexia experts. As elaborated in [7], this background knowledge itself is still subject to further research must be easy to modify so that within AGENT-DYSL we rely on descriptive ontology-based formalisms for that purpose.

The key idea here is to have a semantic abstraction of errors: the error type (see Fig. 3). In terms of background knowledge, each error type is associated with the following: a) Words these ErrorTypes are likely occur in, b) TeachingStrategy as the pedagogical measure that tries to help the learner to overcome this ErrorType and c) DetectionStrategies as methods for deriving error types from speech recognition input (as part of profiling).

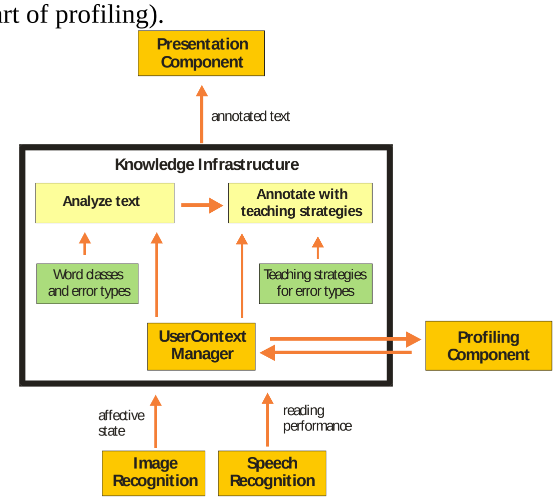


**Figure 2:** Adaptation components

With this adaptation knowledge (Fig. 2) it is possible that (1) the profiling component can analyze the result from the speech recognition in re-evaluation mode to detect error types of the learner, (2) the

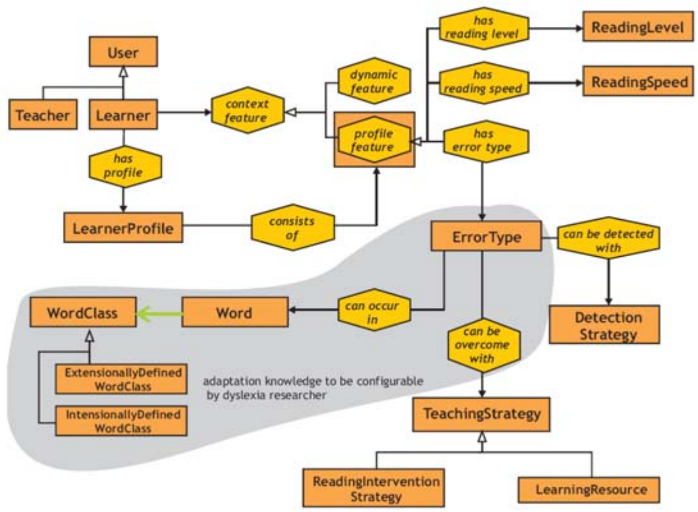


**Figure 3:** Part of the AGENT-DYSL Ontology

adaptation component can analyze a text for "dyslexia-sensitive" words and (3) apply teaching strategies (like highlighting, or pre-emptive reading) to certain words in a certain situation (e.g., dependent on learner's current state).

Image recognition (for learner's current state) and speech recognition (for reading performance) is fed into the knowledge core and stored in the user context manager. The profiling component can augment the context information (especially in re-evaluation mode), e.g. by computing typical error types.

The actual adaptation has two steps: first, the text is analyzed for dyslexia-sensitive words based on the words and word classes associated with error types. In word classes level, error types are associated with syllable omission, substitution of functionally/ semantically plausible word, word or syllables insertion. In word level, error types can be semantic and morphological (substitution of semantically related word, omission of ending, addition), visual (substitution, letter reversal), phonological (regularization, partial sound attempts, phonological reductions) and visual and phonological (sound sequencing errors, syllabification errors). Second, for these words, features of the presentation are adapted based on teaching strategies. This adaptation defines the presentational preferences like font attributes, highlighting speed for a specific word in the text, the decision, if a word has to be preemptively spoken by the system, or if a word has to be printed in a hyphenated style and highlighted syllable or word wise.

While the first step only takes place once, the second step may be invoked repeatedly, e.g., to take into account changes in the physical state of the student. This may become necessary, e.g., when the learner is getting frustrated or distracted.

## 5. User Interface for Learners with Dyslexia

The proposed system provides a user interface, which is appropriate for learners with dyslexia. When the application starts, the learner is asked to login using an age-appropriate login mechanism [6]. After verifying the learner login, the proposed system provides two operation modes to the learners: *Everyday* and *Profile re-evaluation* mode.

Having chosen the *Everyday* mode, all information about the learners profile and preferences will be loaded into the application. The profile and preferences data are retrieved either from the AGENT-DYSL server if learner's PC has an internet access or from a USB stick (in which profile and preferences were stored from the learner in a previous usage of the application). The learner profile and preferences contains information about the reading performance of the user and the severity of reading difficulty, as well as types of errors that a learner with dyslexia more likely to make, usual reading speed of the learner, learner preferences (font colors, line spacing, highlighting color).

Then, the learner could load a desirable PDF file which will automatically be reformatted based on current learner profile. The reformation will include adjusted presentation (font size, line spacing) as well as word highlighting which follows the learner reading speech. The learner can reformate the text using appropriate buttons that GUI provides (Figure 4). Changes to learner's preferences are saved directed to AGENT-DYSL server or saved to USB stick and immediately synchronized with the remote server when the learner has internet access. The application provides a re-evaluation mode that helps learners to achieve a profile that will be characterized for their reading ability. According to learner's profile, a personalized reading environment is set. In this direction, the Profile re-evaluation mode is set updating learners' profiles.

In order to achieve a profile using the *Profile re-evaluation* mode, the learner has to take a test: a series of pre-selected texts is displayed to learner asking from him/her to read while the camera and microphone is activated. These texts include words which are connected to all known error types that a learners with dyslexia may do. Therefore, the learner starts to read the system records and on-line analyze and recognize the input of camera and microphone.

**Figure 4**: User Interface for Learners with Dyslexia

Then, according to the results of the analysis, the adaptive reading assistance can determine and store the learner's profile in the AGENT-DYSL server. The learner's profile is updated in short period of time using the profile re-evaluation mode in order to respond to the current learner's needs. The updated learner's profile is uploaded to the AGENT-DYSL server if the learner has an internet access or in a USB stick which the stored data will be synchronized with the data of the server as soon as an internet access is set up.

In addition, the proposed system provides a teacher tool. Using this tool a teacher can write down his/her assessment for the learner, see a description of the current learner profile or print a report with recommendations associated with the profile of the learner. Also a teacher can change the learner account settings such as password, learner preferences and learner profile.

The evaluation of the social and educational acceptability of the software involves teachers and student from schools of Greece, UK, and Denmark using questionnaires. The learning scenarios produced by the teachers is collected and transcribed after the in-service teacher education.

## 6. Conclusions

In this paper, we have presented the AGENT-DYSL approach to inclusive learning support for children with dyslexia. The main innovation of this approach is to combine speech recognition, affective state recognition via image recognition, and error type profiling via an adaptive, ontology-driven knowledge core to provide personalized support for the learner. The approach is complemented by a user interface that is specifically geared towards children with dyslexia.

Instead of providing a special educational environment for children with dyslexia, the AGENT-DYSL system allows for an inclusive educational setting. The AGENT-DYSL system supports the usage of any teaching material used in classroom education, provides the required additional reading assistance and thus supports teachers and enables children with dyslexia to participate in ordinary classroom education. The system is being evaluated at schools of three countries (UK, Greece, and Denmark).

## 7. Acknowledgement

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