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# Adaptive Reading Assistance for Dyslexic Students: Closing the Loop

**Andreas Schmidt** and **Michael Schneider**
FZI Research Center for Information Technologies
Haid-und-Neu-Str. 10-14, 76131 Karlsruhe, GERMANY
{andreas.schmidt | michael.schneider}@fzi.de

## Abstract

Adaptive reading assistance can improve the reading performance of students, but current dyslexia pedagogical theories do not yet provide sound results on a micro-level. We want to provide a reading assistance solution that both helps the learner and the dyslexia researcher. In order to archive this, we encode adaptation knowledge in a descriptive way by making use of state-of-the-art ontology-based techniques. This enables a closed-loop approach of continuous improvement. In this paper, we want to present the overall approach as well as initial results of our work within the EU project AGENT-DYSL.

## 1 Introduction

Dyslexia affects a significant number of students (it is estimated that one in ten children is dyslexic) and leads to a considerably slower development of readings skills. As reading skills are key for success at school and later in the job, dyslexic people are turned into low achievers in education and learning, excluding them from several aspects of social living. Dyslexia, however, does not mean that these students do not learn to read well at all, but rather it takes them significantly longer and requires more practice than for non-dyslexic learners.

The most promising approach to help dyslexic learners is to assist their reading skills development while they remain within their normal peer group. As direct teacher support is limited, this needs to be complemented by eLearning solutions. Especially for dyslexic students, such a solution needs to be sensitive to the learner's capabilities and current emotional state. This demands for a highly adaptive reading assistance system (in contrast to current software products for that purpose).

However, research on dyslexia is in many respects not yet able to provide the knowledge for adaptation rules, e.g., how to intervene into the reading process of a dyslexic child with a certain error profile. Thus the adaptation rules themselves will have to be subject of research; we need a closed-loop approach as illustrated in fig. 1. In a first step, adaptation knowledge is encoded based on state-of-the-art dyslexia theories. The effect of applying adaptation knowledge in providing learning assistance to students is then assessed in a subsequent step by dyslexia experts. Based on that assessment, dyslexia theories are modified, which in turn form the basis for an improvement for the learning assistance system. For such evaluation loops, we need to represent the adaptive behavior in a way that is easy to understand and changeable by non-technical dyslexia experts.

Within the EU project AGENT-DYSL[1] [Athanasaki *et al.*, 2007] we have taken an approach that is based on state of the art semantic technologies to represent such adaptation knowledge in a descriptive way, which shall be presented in the remaining part of the paper. In section 2, we give a brief overview of related work and the AGENT-DYSL project as a whole, before we present the adaptation approach in more detail in section 3. Finally, we conclude the paper in section 4.

## 2 General Overview

### 2.1 Related Work

Regarding reading assistance, there are relatively few software application that are specifically targeted towards dyslexia and its specific problems. As a consequence, state of the art commercial software applications like Kurzweil 3000[2] or ReadOn[3] hardly have any form of user adaptivity beyond simple preferences. Recent research approaches like [Amiri, 2006] concentrate particularly on dyslexia and makes use of speech recognition and eye tracking to adapt to readers' progress.

However, all of these approaches do not allow for deep adaptation by, e.g., considering user-specific error types. That way, pedagogical intervention is very limited.

### 2.2 The project

AGENT-DYSL wants to go beyond that. It aims at providing a truly user adaptive reading assistance system for dyslexic students which allows them for reading arbitrary text documents (e.g., text books). The system will present

[1] http://www.agentdysl.eu
[2] http://www.kurzweiledu.com
[3] http://www.readonsoftware.com

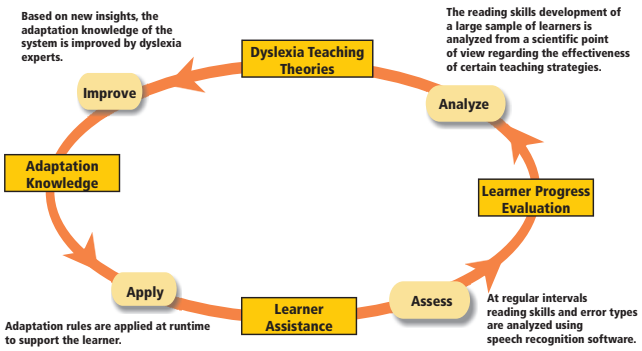


Figure 1: Closed Loop Approach

the text in an augmented way by using techniques such as text highlighting, segmenting words into its syllables, emphasis on certain characters, or preemptively reading words aloud by the usage of text-to-speech techniques. The key innovative feature of AGENT-DYSL is the adaptivity of the presentation to the individual student and her context such as estimated subjective difficulty of a word, or the current mental and emotional state (e.g., if she is more or less concentrated, or if she gets tired). The system can also suggest individual learning resources for further training, which is useful for a teacher of a dyslexic child.

AGENT-DYSL is a three-year project funded by the European Commission under the eInclusion call and is carried out by a consortium of nine partners from different European countries, consisting of dyslexia researchers, educational experts and teachers, and several technological partners. The evaluation of AGENT-DYSL will take place in three testbeds for the languages English, Greek and Danish. The system will be evaluated directly in classrooms, executed by the different evaluation partners in the project's consortium, and in cooperation with schools and their teachers from England, Greece and Denmark.

### 2.3 Project Vision

The AGENT-DYSL approach can be divided into three conceptual parts:

- **User Context Acquisition & Management.** Basis for the adaptive system behavior is a thorough acquisition and management of the student's context. This includes individual preferences, but also individual error profiles. In order to detect these typical errors automatically, the student can read the text aloud, and speech recognition will be used to identify reading problems in the text. Also the current mental state will be detected by using image recognition to track and evaluate the face of the child with a simple webcam. At least, one will be able to detect reduced awareness of the child, which can then be used to temporarily pause the text presentation and the word recognition process.
- **Adaptive Annotation of Text.** Based on this context information, upcoming sentences are analyzed with respect to words likely to cause problems for the student. For these words, appropriate changes to the presentation are determined, taking also into account, e.g., the current emotional state of the student.
- **Presentation.** Finally, the text is presented augmented with specific highlighting, word segmentation, etc.

The key challenge in a closed loop approach is now to encode the knowledge that is used for implementing the system behavior in a descriptive way. In the following section, we will present our ontology-based approach to meet this challenge.

## 3 Descriptive Adaptation Knowledge

### 3.1 Overview of the Approach

Key idea of the adaptive core of the AGENT-DYSL system is to enable *deep* adaptation to the reader's individual characteristics. This requires (a) a much higher degree of pedagogical knowledge encoded into the system and (b) a wider range of contextual features that allow for a reasonable application of this pedagogical knowledge to provide reading assistance. More specifically (see fig. 2), the

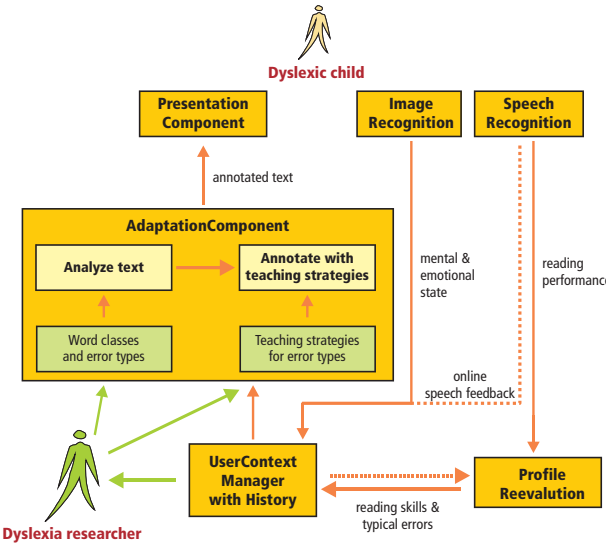


Figure 2: AGENT-DYSL Adaptation Component

adaptation component of the AGENT-DYSL system needs to detect parts of the text (usually words, but also phrases or even sentences) likely to cause problems for the reader. This depends on a classification of error types (like semantic and morphological, visual, or phonological errors) and the words or phrases they typically occur in and an error profile of the learner, indicating the frequency of errors. As soon as we have problematic words, we can apply teaching strategies to adapt the presentation. This includes slowing down reading speed, emphasis on specific letters, or preemptive reading aloud of the word, e.g., when the reader is getting frustrated. Already this example shows that the appropriateness of a teaching strategy does not only depend on the learner characteristics, but also on the situation. This also includes the concentration level of the learner.

### 3.2 Role of the ontologies

In order to realize the sketched behavior, we use an ontology-based representation for user contexts and adaptation knowledge. There is an upper-level ontology, specifying the relevant concepts and the relations between them, and all user contexts can be regarded as instance knowledge bases. The ontology itself was derived as the result of a conceptual analysis of the regarded domain together with dyslexia experts in the project. It captures different aspects which are of interest for AGENT-DYSL (see fig. 3).

The ontology contains concepts for a **Learner** together with her **Context**. The context is described by a set of **ContextFeature**s, like the learner's age, or his preferred font size. There are highly dynamic features, like recent reading errors made, or the current mental state of the learner. There is also a special group of subfeatures, called **ProfileFeature**s, which build up the **LearnerProfile**. The profile features describe more stable aspects, like the general reading speed, or the typical reading errors, the learner is expected to produce. These profile features are generally the result of aggregating the dynamic features like *current reading error* into a *typical reading error* and eventually into a *reading level*.

**ErrorType**s, which build an abstraction for the concrete reading errors, need to be associated with three concepts:

- **Word**s these ErrorTypes may occur in. In order to keep this manageable, we will usually cre-

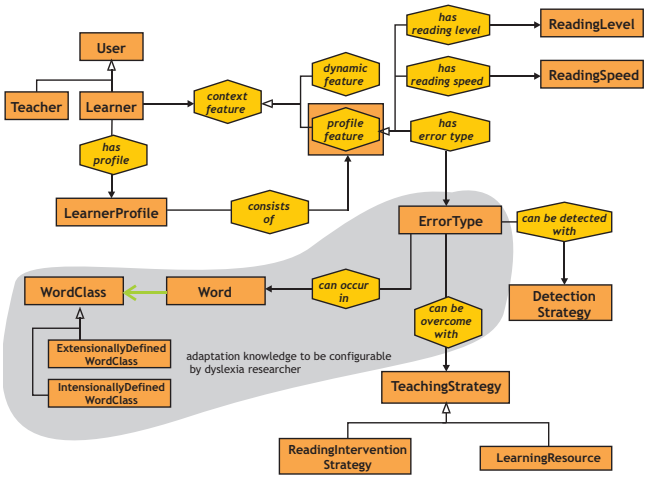


Figure 3: AGENT-DYSL Upper-Level Ontology

ate **WordClass**es. These can be defined extensionally (**ExtensionallyDefinedWorldClass**) by simply listing individual words, or intensionally (**IntensionallyDefinedWorldClass**) by defining a pattern at individual letter, on syllable or other level). Examples for such patterns could be *words containing more than 5 syllables*, word with certain letter combinations or the like.

- **TeachingStrategy** is a pedagogical measure that tries to help the learner to overcome this ErrorType. We can divide these strategies into **ReadingInterventionStrategy** (i.e., an intervention into the reading process of the learner). Examples for such interventions are different forms of highlighting (color, font size), word segmentation or preemptive reading of difficult words. The other type of strategy is to recommend a **LearningResource** (Exercises, other texts, etc.).
- **DetectionStrategies** are important for deriving ErrorTypes from speech recognition: It answers the question on how we can distinguish one error type from another when the learner mispronounces a word.

### 3.3 Involving the Dyslexia Expert

As we want to build a system in which a dyslexia expert is able to configure the system behavior, we need to specify which parts of the ontology are expected to be changed by the dyslexia experts and which parts need changes by the software developers. It is clear that DetectionStrategies and TeachingStrategies as well as the acquisition of ContextFeatures needs to be predefined as we need complex software components to apply them. But the dyslexia expert can provide input on two aspects: (1) classification of Words and the association with ErrorTypes on the one hand, and on the other hand (2) the association of ErrorTypes with TeachingStrategies, which has to be contextually dependent.

For the first case, there is currently no classification of words and/or error types we can make use of. We are currently starting with a very basic approach with a few error types and extensionally defined word classes. This has its clear limitations especially with respect to unknown texts. But what we expect to gain also from error statistics of the students is a more general knowledge about intensionally defined word classes (by using patterns). We are currently exploring different alternatives for pattern languages that are easy to understand and still expressive enough.

For the second case, AGENT-DYSL will use a rule-based mechanism with sets of rules of the form:

> "If the word/phrase/sentence $W$ is contained in one of the child's typical errors $E$, and the child is currently in emotional state $S$, then choose the following teaching strategy $T$"

With this approach, we do not encode the way AGENT-DYSL operates on the user context in a procedural programming language, but instead encode it in terms of more descriptive *rule sets*. By making these rule sets accessible and modifiable from outside the system, dyslexia experts will become able to experiment with the way AGENT-DYSL works.

The dyslexia expert is expected to adjust these rules easily via a specific GUI, by which he is able to build new rules, delete old ones, and modify existing ones. She can do this for each rule by selecting word classes, error types and contextual features together with a set of teaching strategies. She can then let proband children use this modified version of AGENT-DYSL, and see whether the modified system has better effects on reading performance of students (using log data information as well as standardized reading performance assessments). If the system's and the child's reaction do not meet the expert's expectation, she can re-adjust the rules step by step to improve the system.

## 4 Conclusions and Outlook

We have presented our approach of a closed-loop approach to an adaptive educational system. Ontology-based techniques as employed in AGENT-DYSL allow for a descriptive representation of the adaptation knowledge. We are currently in the process of implementing the system and evaluating it with dyslexia experts.

Future work will investigate into more complex error types that are not triggered by individual words, but rather by a specific phrase or semantic context. This will also lead to considering different scopes for applying teaching strategies (like word, phrase, sentence).

## References

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