Partial Learning Model of Dyslexic Learner

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Abstract. According to the new definition of the learning components in the advanced adaptive learning in comparison with the basic adaptive learning, the process of learning is different and closely related to the human learner. In order to demonstrate the key improvements, we present the developed model reflecting the dyslexia state of a human and its behavior in the adaptive learning environment. Although not all dyslexia symptoms are covered, the model helps understanding the purpose of these learning environments for subjects with learning disabilities.

Keywords: basic adaptive learning - BAL, partial learning – PL, blank concept – BC, advanced adaptive learning – AAL, adaptive learning environment – ALE, adapted learning environment – IALE, learning mechanism – LM, in concept – IC, test set - TS

1 Introduction

After the development of several strategies for testing and instntiation using simulated learner models [7], we entered the phase where we can simulate a human learner on a way different than the one made in the basic adaptive learning conditions. During our previous research stages, we mostly used artificial learners typical for the machine learning methods [8] in order to prove the justification of the instantiation process. However those learners, although still suitable for experimenting within the advanced adaptive learning [2], can not show the improvements the partial learning brings over the traditional adaptive learning interpretation. This is the reason of the need for simulating different learner models closely related to the human behavior.

The first choice for a learner model was the one with the dyslexia syndrome and although we do not treat all of the symptoms, the simulation strives to show the potential usage and benefits of the advanced adaptive learning methods. Its success will be a huge step for our further research with other human related learner models which is a small part of our motivation for more efficient overall learning.

2 Key Facts About Dyslexia

Dyslexia [4], [5] is a syndrome of learning disability in the part of the information processing. The most frequent case of dyslexia is the visual processing impairment, especially affecting the reading, writing and calculating skills of an individual. Difficulties in reading, initially alter the learning process of a human, since textual expressions are very hard to recognize properly and thus their processing could result in totally wrong reasoning or conclusion.

Our analysis of the characteristics of dyslexia and effects it has on a learner, resulted in focusing only on the cases of acquiring information from textual expressions. The reason for this is the Awareness system [1] itself, since it is based on our research of the adaptive learning, so far using only string data types. In future research we expect this to change and to cover wider range of dyslexia effects with different input types layered in different stages of information processing cycle [14].

We derived two main questions to answer in order to successfully proceed with the development of a learner model with dyslexia:

- Which characteristics of the individual suffering from dyslexia can be represented with LM?
- Is it possible for the LM of a dyslexic learner to be recognized by the ALE? If yes, what TS has to be constructed for that purpose?

3 LM of Dyslexic Learner

The simulation of LM of dyslexic learner is intentional in its nature. Unlike the intentional simulations examined in [7], this one is not an easy task because of two reasons:

- difficulty in representing different types of dyslexia characteristics in PL conditions;
- difficulty in sustaining the PL process with the existing methods;

Most characteristics and effects of text processing impairment, such as inadequate phonological processing abilities [4] or visual discomfort [4], can not be described through the LM in PL because they are not related with the knowledge units.

For the following, however, it is possible to make a representation in the PL:

- short-term memory [4] – can not be directly expressed in LM but we propose an assumption that the concepts are learned by smaller number of ICs so that they can be easier to remember;
- lack of ability to associate individual words with their correct meanings [5] – the concept in LM can be learned by either non existing ICs or by ICs non related to it in ALE;

The short-term memory representation in LM can have a tolerance factor since the number of ICs for a concept in ALE can vary. Therefore in our simulation of the first dyslexia characteristic we can use a reference number so that the concepts which have IC set with equal number of ICs or less than its value are included in LM. We cannot forget the initial step of choosing a random number from 1 to $|V_{ALE}|$ as the total

number of LM's concepts - $|V_{LM}|$. Thus we have the following main strategies for LM simulation by including the concepts:

- having an IC set with the smallest possible number of ICs in the ALE (LM 1 on Fig. 1);
- which include an IC set with number of ICs equal to or less than a chosen number (LM 2 on Fig. 1);

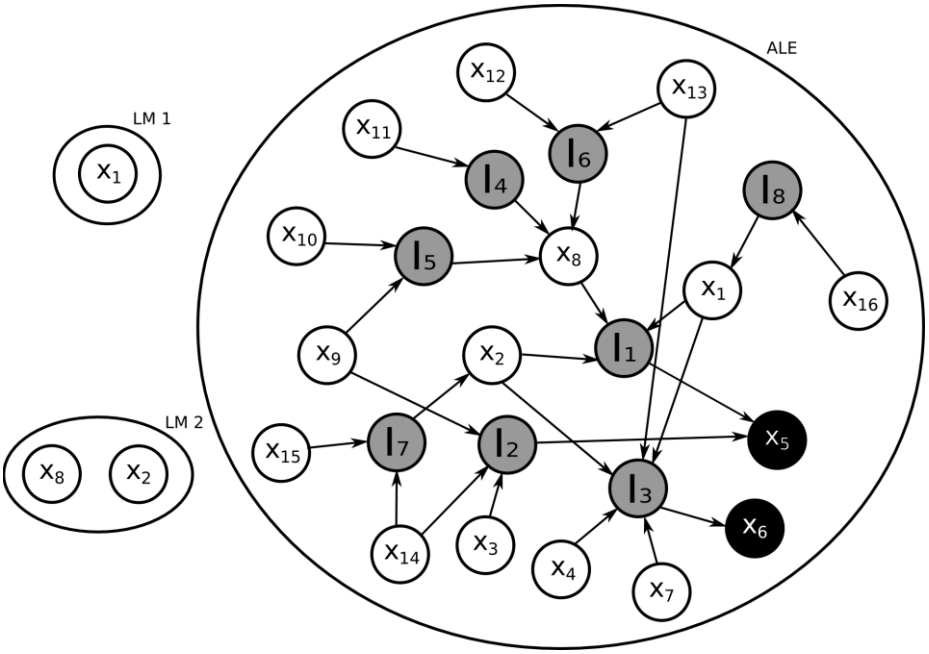

Fig. 1. LM simulation of short-term memory

In order to explain the example on Fig. 1, we state that LM 1 is simulated by choosing the concepts with IC set consisting of only one IC since 1 is the smallest possible number of ICs of all the IC sets in ALE. Only the concepts x_1 and x_8 satisfy this condition, but x_1 is included since the chosen random number of $|V_{LM}|$ is 1.

On the other hand, LM 2 is simulated by choosing the concepts with IC set consisting of 2 or less ICs. Besides the previously mentioned concepts, the concept x_2 satisfies this condition too, but x_1 is omitted because the chosen random number of $|V_{LM}|$ is 2, and the concepts x_2 and x_8 are chosen instead.

The second characteristic of dyslexic learner (not being able to associate some words with their correct meanings), is even harder to simulate because it occurs less frequent and a right choice has to be made among the incorrectly described concepts.

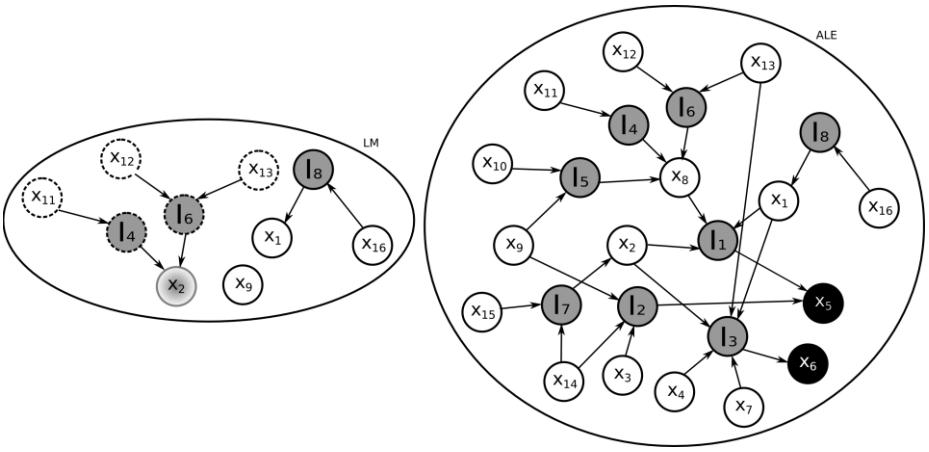

Fig. 2. LM simulation of the occurrence of concept with incorrect meanings

Associating a word with incorrect meanings can be represented as having a concept with incorrect IC sets and ICs, which provide knowledge for different concept in the ALE. Usage of this representation will result in LM which breaks the rule of BAL – in order to achieve AL, the LM must be structured as a subgraph of ALE's knowledge graph. However, in PL conditions we will treat the "confused" concepts only to recognize the LM as the one belonging to a dyslexic learner. These concepts will not take part in the further learning process.

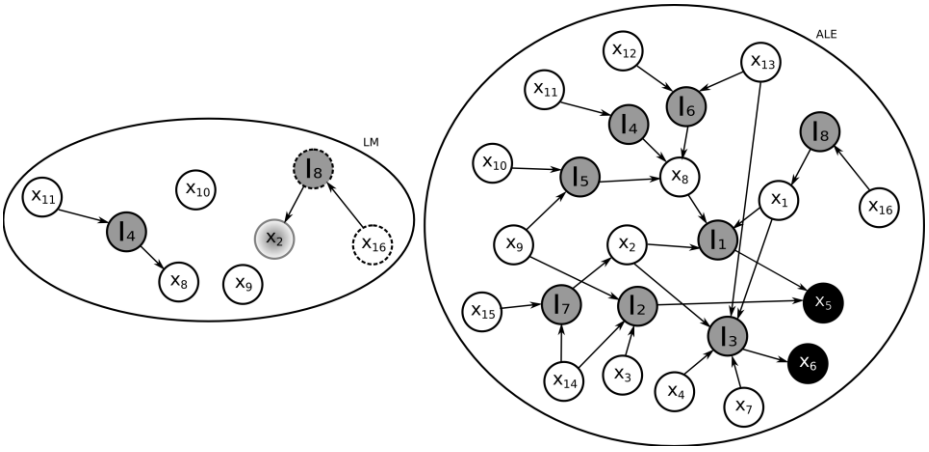

Fig. 3. LM simulation of both dyslexia symptoms

The simulation is done by random choosing of one or more pairs of concepts with the existing IC sets. Then for each of the pairs, a single concept is chosen to be

included in the LM. We choose one subset of the set of IC sets of the concept that is not included in the LM, to provide the knowledge to the chosen concept in the LM. The LM can also include concepts with correct relations.

As shown in Fig. 2, the LM contains one concept (x_2) with knowledge passed from the IC sets determined by the BCs I_4 and I_6. However these two BCs pass knowledge for the concept x_8 in ALE. This means that the learner's LM does not provide knowledge properly i.e. the learner is falsely aware of the concept x_2 (learned through BC I_7 in ALE). The advantage in this situation is that the ICs providing knowledge for I_4 and I_6 can be used as a base for easier learning of other concepts, in this case the correct concept x_8.

The whole picture of LM representing the dyslexic learner with both characteristics can be given by combining the two simulations into one. Fig 3. shows the LM containing concept x_8 as the concept learned by only one IC and concept x_2 incorrectly learned by concept x_{16}, besides the root concepts x_9 and x_{10}.

4 Detection of the LM of Dyslexic Learner

Important task in the AAL when experimenting with dyslexic symptoms is to be certain that the LM belongs to a learner suffering from dyslexia. This is very hard to determine because some learners can show the short-term memory and/or incorrect meanings effects, but they might not suffer from dyslexia. This kind of miss chiefs are rare but possible especially when it comes to relatively small ALEs. That is why our model so far can detect the LM as dyslexic only with certain probability.

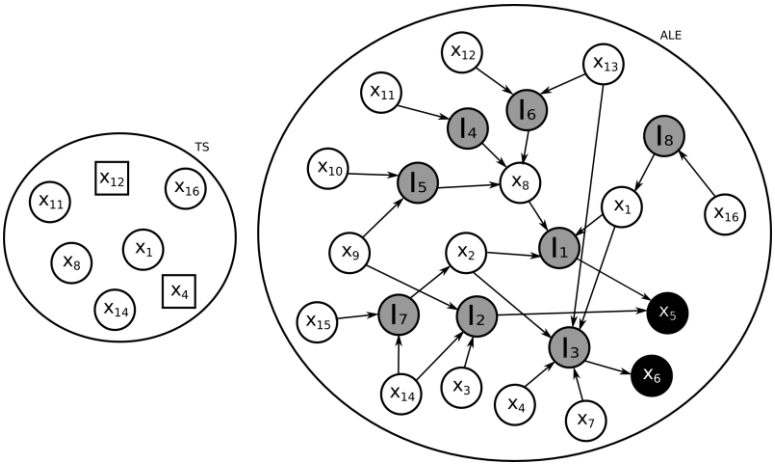

Fig. 4. TS for detection of the short-term memory symptom

In order to make the prediction of the LM as correct as possible, special TSs must be constructed. We will consider the prediction as correct if the LM shows at least one of the two previously mentioned symptoms.

For the purpose of detecting the short-term memory symptom, the TSs will be filled dynamically – if the learner states that the concept is known and the concept is related with the smallest number of ICs, then the ICs as well will be included in the TS.

Suitable example is shown on Fig. 4. The key concepts are x_1 and x_6 because they can be learned by the smallest number of ICs possible – 1, and most of them (in this example both) must be included in the TS in order to make the test relevant. If they are positively confirmed1 by the learner, their ICs are included in the TS as well, until one of them has negative confirmation. For the root concepts x_{14} and x_4 there are no proper conclusions to be made besides the fact that the learner is aware of the first one, and has not previously learned the second one, because there are not any BCs in the TS whose knowledge is provided by them in the ALE.

The dynamic filling of the TS occurs also when it comes to detecting the symptoms of incorrect meanings. Obviously the difference from the previous symptom is the more clear impact of the confirmation results. The best choices for initial concepts to be included in the TS are those with more IC sets and/or ICs. When asked about the confirmation, if positive, then some of the concept's ICs will be included as well until it is confirmed they are truly known by the learner. Otherwise, if the concept is not known by the learner, then the filling continues with other initial concepts.

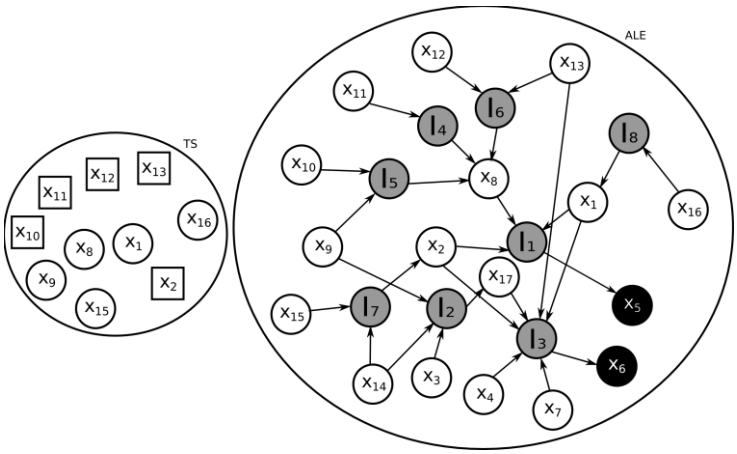

Fig. 5. TS for detection of the incorrect meanings symptom

The example on Fig. 5 shows the key concepts x_1, x_2 and x_8 as the ones that will make the decision whether the learner shows signs of dyslexia. The root concept x_{15} is irrelevant in the final conclusion because its concept x_2 is not positively confirmed by the learner. Let x_1 be the first to fill the TS. Since it is confirmed positively, the next to go will not be x_2 but x_1's IC x_{16}. Because x_{16} is confirmed positively and there is no other concept for it in the ALE, we conclude that the learner has learned the concept

1 The circles denote the positive confirmation and the squares negative

x_1 by previously learning x_{16}. Thus there is no dyslexic problem with the learner here, so far.

After the negative confirmation of x_2 the next in the queue is the concept x_8. It is positively confirmed and we start to check each of its ICs by IC set (first x_9 and x_{10}, then x_{11} and finally x_{12} and x_{13}). Because only x_9 is confirmed positively, the conclusion is that there is no way for the learner to be aware of the concept x_8 by having learned only x_9 from all of its ICs. The case would be different if only x_{11} was positively confirmed but in this situation besides x_9, the IC x_{10} must be learned along in order to complete the knowledge passed from the BC I_5 to the concept x_8.

5 Instantiation for the LM of Dyslexic Learner

Having simulated or detected the LM of the dyslexic learner, the final step before the start of the learning process is the creation of the IALE. The purpose of IALE, as in every learner model scenario, is to provide the required concepts prior to the learning of the terminal concepts.

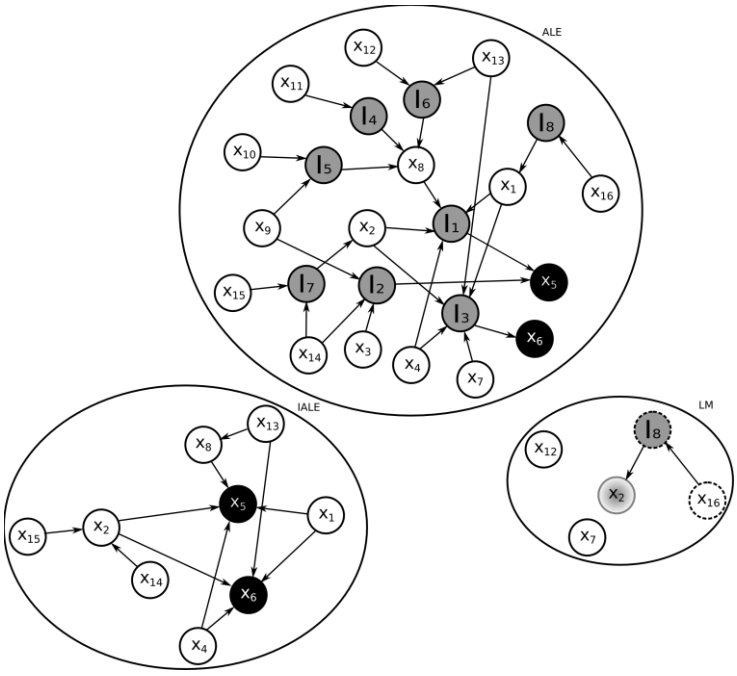

Fig. 6. IALE with smallest possible set of concepts for dyslexic learner

However there are two possible interpretations of the best IALE for dyslexic learners, as a consequence of the interpretations of the short-term memory symptom:

- IALE contains the smallest possible set of ALE's concepts required to reach the terminal concepts;

- IALE contains only the concepts representing the smallest set to complete a required IC set in order to reach the terminals;

The first interpretation is generic and such instantiation can be applied for every learner model as shown in Fig. 14. It can be noticed that a total of 8 concepts are required in order to learn the terminals.

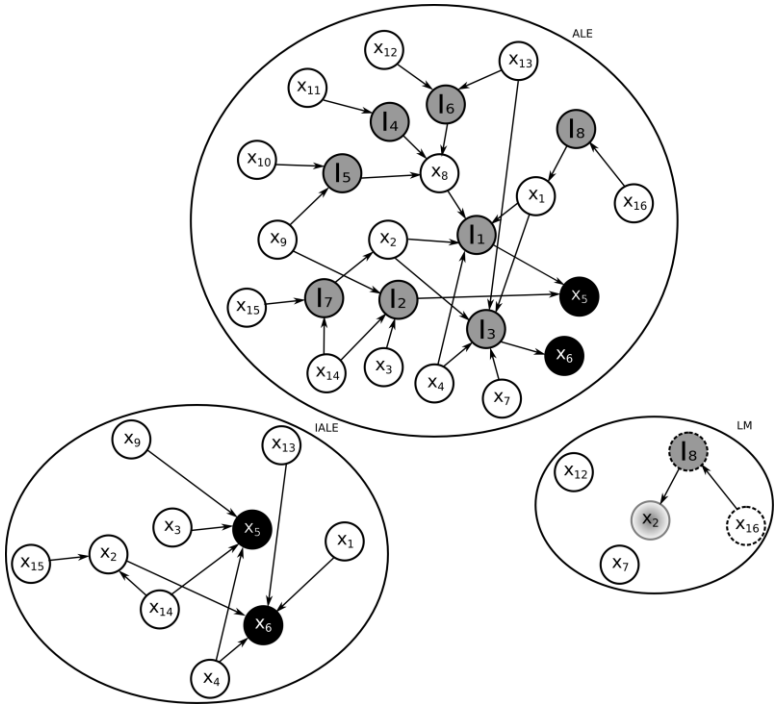

Fig. 7. IALE with smallest number of required ICs for dyslexic learner

The second interpretation is adapted for usage in case of dyslexic learners only. It takes advantage of the short-term memory explanation when it is always better to learn each concept by the smallest number of ICs possible even if it results in a greater total number of concepts required to learn the terminals. To easily construct the IALE we prefer to move backwards starting from the terminal concepts and then choose the IC set which needs smaller number of ICs in order to be complete. Fig. 15 shows an example of such IALE where the BC I_2 is chosen over I_1. Although this improves the chances of learning the concept x_5 with only 3 ICs, it increases the total number of concepts needed to learn both terminals (8 instead of 7).

6 Conclusion

In this paper we managed to simulate some of the behaviors of an individual suffering from dyslexia. In order to achieve the communication with the LE, we succeeded in simulating a learner model reflecting two dyslexia symptoms. Our previous research and conclusions [7] of the PL, was used to make a bridge with the learning process in reality, expressing the short-term memory and incorrect meanings symptoms as if they were features of the PL's components. In addition we showed the possible interactions between the ALE and the LM of a dyslexic learner, explaining the detection of the dyslexia symptoms and the generation of IALE for an LM detected as dyslexic. However, we did not cover the final learning process and the order of the concepts to be learned by the dyslexic individual. The process is the same as with every other learner model and the delivery order strategies are applied as well.

When comparing the two IALE it is obvious that the second representation is faster and easier to implement. The reason for this is the avoidance of the calculation of every possible combination of IC sets in order to reach the terminals. And the increasing of the total number of learned concepts is often insignificant. Therefore our conclusion will prefer using the second type of IALE when the dyslexia learner is using our AAL system and the first type in general cases of learners.

With our research, development and upgrade of the AAL model, we want to show the possibilities laying behind the knowledge representation of learners with disabilities considering the information processing. The existing adaptive assistants for dyslexia learners like AGENT-DYSL [6], [9] try to solve only the surface consequences of dyslexia by using adaptive text annotation techniques or making a choice between different multimedia presentations, but are unable to manipulate with the knowledge units on lower level like we do with our learner model in PL. Also our research focuses on detecting and working with dyslexic learners in real time, unlike the long term examination and following of the development of the learners during certain time periods, as given in [11] or workaround the syndrome by learning games [13]. The practical results of our learning system will follow after our research in PL is completed, because of the difficulties in dividing the learning material as optimal as possible. The main obstacle still remains in the form of detecting a dyslexic state of the student, which has its roots in the identification problems explained in [10].

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