Application of the Theory of Multiple Intelligences to Digital Systems Teaching

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Abstract. *Transmission of knowledge is of extreme importance for the evolution of a society. For centuries, teaching processes have undergone considerable evolution to reach the current stage, creating new theories on the way. The Theory of Multiple Intelligences, by Howard Gardner, which has been chosen as the theoretic guideline of the work presented in this paper, states that the human intellect can be divided into areas of activity called intelligences. Stimulating other intelligences outside those naturally related to a discipline is a challenging task. To propose a solution to this challenge, this work presents three tools that are designed to help the teacher construct additional classes, along with a guideline for a course of Digital Systems.*

1. Introduction

Teaching is a process inherent to human evolution. Teaching methods and mechanisms can be found since the beginning of human societies, and have been evolving with them.

The first teaching methods were based on observation and trial. One simple example is the one of a blacksmith: by observing the master's techniques, the disciples tried to understand the forging methods and the best ways of using his master's tools.

Some progress was achieved during the Middle Ages, leaning towards the current stage of educational institutions and methods, while the final step was taken in modern age with the creation of educational institutions exclusively dedicated to conveying scientific knowledge in a structured and systematic way.

In current times, pedagogy researchers study how the human mind learns, how it can be taught to a good degree and ways to obtain better results when transmitting information.

In this paper we present a teaching method for digital systems, along with the theory on which it is based. In the next section we outline the Theory of Multiple Intelligences, the pedagogical theory we chose as a basis to our method. The following sections are dedicated to present details of the tools needed to implement the teaching method and, when appropriate, their relationship to specific theory chunks are highlighted. In the final section we present our conclusions and some possible extensions to the ideas developed here.

2. The Theory of Multiple Intelligences

Howard Gardner, a researcher and professor in the field of pedagogical theories, created a theory about the human intellect and reported it in his book "Frames of Mind" [Gardner 1983], in which he presented the basis of his theory.

The theory proposed by Gardner has been named "Theory of Multiple Intelligences", and states that the human mind can be divided into areas of activity.

Gardner based his theory on the studies of Jean Piaget [Archives Jean Piaget 2009] which were a starting point to the study of the human mind in the beginning of the twentieth century. One of the basis of Piaget's theory is the statement that the intelligence is composed of generic mental schemes embracing all possible intellectual areas. Such schemes could recombine through two basic processes: assimilation and accommodation [Pulaski 1971]. Piaget also defended that all human beings go through evolutionary mental stages that happen in a pre-established order, and with a known average duration.

Piaget's theory generalizes human intelligence in a way that some cases of handicapped individuals cannot be explained, such as *idiot savants* – which have a extremely developed mental capacity in one area but a very low level of development in all the others. For instance there are individuals that cannot read or write but that can draw extremely complex schemes or landscapes based entirely on their memories.

Such facts motivated Gardner to build his theory upon the concept that the human mind should be partitioned into areas of activity instead of being generic. As the result of his research, Gardner came out with a list of eight intelligences: linguistic, musical, logic-mathematical, spatial, corporal-kinesthetic, intrapersonal, interpersonal and naturalist.

The list resulting from Gardner's work became the basis of new studies and developments of his theories [Gardner 1993]. By recognizing different kinds of learning skills, his scientific contribution allowed new educational methods to reach a larger amount of students.

The choice of the Theory of Multiple Intelligences as theoretic basis for the tools was determined by it's capacity to separate the human mind into the eight areas of activity. The capacity of targeting each area separately, made it possible to create a systematic practical approach to the theory, facilitating the design of the software tools.

Some other pedagogic theories also have interesting concepts which are applied in more restrict ways. These limitations lowered their chances of becoming the theoretic basis for this project's implementation.

A very interesting teaching method is the Montessori [The International Montessori Index 2009] method, usually applied to children. This method manages to transmit the knowledge using real objects, with different textures, colors and shapes. With this approach, the Montessori method tries to reach the students trough several senses, not only through vision and listening as the usual methods. This characteristic would be very daunting to implement using computer software as almost all human interaction is virtual. Another known method is the Freinet [Fédération Internationale des Mouvements d'Ecole Moderne 2009] method which tries to deny the usual learning approach stimulating students to be more creative than exact.

3. Digital Systems

The discipline chosen for the application of Gardner's theory was Digital Systems, as it includes a great number of aspects of logical and physical implementation of computer systems. Only the basic topics where covered, ranging from boolean logic, through truth tables and finishing with Karnaugh maps and combinatorial vs. sequential circuits.

These topics constitute the theoretical basis of Digital Systems courses and are strongly bent towards using logic and mathematical concepts. Usually, this didactic content privileges students that have a highly developed logic-mathematical intelligence, while the other individuals are likely to face larger obstacles to understand it.

4. The Transmission Media

The transmission media is as important to the educational process as the content to be conveyed. To reach a significant amount of the target population, and to allow the inclusion of interactive multimedia content, the World Wide Web has been chosen to fulfill this role.

The college students population have high levels of access to the Internet [DeBell and Chapman 2009], making it a transmission media through which a professor can easily reach his or her students. Online tools that are easy to use may help the teacher to create high quality complementary lectures and distribute them through the World Wide Web, reaching distracted students and those who need extra-class support.

The typical transmission media in a classroom are the voice that can be associated to musical intelligence, the gesture that can be associated to visual intelligence, and the writing either on a blackboard or on a slide that can be associated both to visual and linguistic intelligences. On the Internet, regarding usual text pages, only visual and linguistic intelligences are privileged.

We aim at using the internet as a means of facilitating access and reaching the greatest possible amount of students. To that intent, it is needed to provide the students with several communication means: videos, images, interactive state diagrams, and exercises with immediate answers.

5. The Tools

In this paper, some tools are proposed to ease the teachers' burden in creating online lectures, either by facilitating the drawing of logic state diagrams or by consistently showing the contents as the teacher created.

The system is based on a virtual representation of a real classroom. There are blackboards for each classroom, and a classroom for each course. The professor can thus present didactic contents in a modular and sequential way, defining the velocity in which the course is to be covered.

This approach aims at making the adaptation process easier both to the professor and the students. In one hand, the professor can make use of his or her previous experiences in a real classroom to display the subjects and develop the course to his or her liking, and on the other, the students can use these tools to learn in similar ways they would in a regular classroom.

5.1. The Backend

The backend provides a simple interface for the professor to create the lectures without the need to use several different, and sometimes expensive, tools. It is developed with the PHP language [The PHP Group 2009] and comprises two modules:

- A manager that contains a list of lectures for each course, stored in directories of a web server and links to managing them.
- A blackboard editor which consists of a text field for editing and saving the contents of the blackboards.

Blackboard creation is accomplished using only plain text to facilitate the system operation and avoid dependencies from external visual tools. The professor may format some portion of a blackboard text, or even add links and logic state diagrams using a predefined custom syntax, which is later interpreted and converted to HTML by the mini text-processor.

5.2. The Mini Text-Processor

The mini text-processor is also constructed with the PHP language and is responsible for loading the text written on the blackboards, interpreting its markup tags and reformatting it to HTML.

The custom syntax interpreted by the text-processor has been designed according to a markup style called lightweight markup language [NationMaster.com 2009], which creates simple and nonintrusive formatting tags. This approach avoids moving the reader's focus to the formatting tags instead of the text itself. That means that even being filled with tags, the original text should be easy to read.

Some lightweight markup languages already implemented concepts like those cited above and are usually applied in discussion forums, blogs, and personal home pages. Textile [Allen 2009], Markdown [Gruber 2009], and Almost Free Text [Coram 2009] are three of these languages. Two characteristics are common to these languages: they have simple rules, and are easy to learn. The main difference among these languages is their ability to represent basic HTML components such as links, images, tables, and so on.

The mini text-processor uses a custom syntax which is based on some aspects of other lightweight markup languages. Table 1 presents some of the formatting tags used by the mini text-processor custom syntax. The first column shows how the professor would type the text when creating the virtual blackboard, and the second column indicates the corresponding meaning, i. e., the HTML format applied to the text.

Table 1. Syntax for the mini-processor lightweight markup language

Text in Chalkboard	Meaning
Text	Text in bold
Text ####	Lecture title
Text ===	Lecture topic
* Text A * Text B	Bulleted list
{LNK:Text|http://addrees.com}	A link to the Web page at http://address.com and named Text
{IMG:Text|http://address.com}	An image located at http://address.com and labeled Text
{MOV:Text|http://address.com}	A movie located at http://address.com and labeled Text
{LSD:Text|A:0010|B:1110}	A logic state diagram entitled Text, with two logic signals A and B

The first six lines of Table 1 indicate aesthetic formatting, generally used to change the font type, size, or even style (bold, italics, etc). The following three lines correspond to the insertion of lists, and the last four lines show how to insert objects in the virtual blackboard such as images, links, videos, and the logic states diagrams.

Among the four objects just mentioned only the logic states diagrams don't have direct HTML representations and need to be implemented through other means.

5.3. The Applet

To provide the insertion of logic states diagrams as those presented in Figure 1 our mini text-processor would have to generate them on the fly, while loading the virtual blackboard to the student's web browser. To do that, a Java applet has been implemented so that the professor does not need to draw the diagram by hand: he or she only types a textual representation of the logic signals and the applet does the rest.

In Figure 1 three example signals are presented by the applet: A, B, and A·B (the Boolean operation A "and" B). The corresponding text written by the professor to generate this diagram is "{LSD:|A:010101|B:110011|A.B:FT0001}", without the quotation marks.

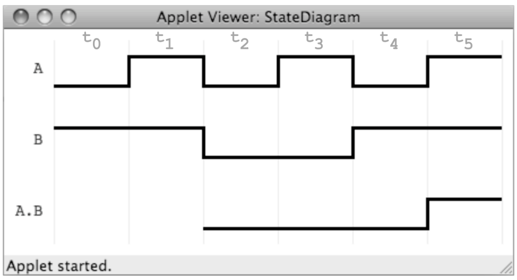

Figure 1. Logic state diagram example.

Each logic signal is created by writing its name, followed by a colon and the logic levels that comprise the signal. Each signal is separated by a "|" – vertical bar – character. If the logic levels are typed using the numbers "0" and "1", the signal is simply drawn on the screen by the applet and no interaction is provided. However, if the logic levels are typed using the letters "F" – for false – and "T" – for true – it means that the applet should leave gaps on those signals, allowing the students to fill them as an exercise. The system can afterwards indicate the correct answers by associating each "F" to a "0", and each "T" to a "1" and displaying accordingly which gap was correctly filled and which wasn't.

In the example of Figure 1, the first two columns (t_0 and t_1) of the A·B signal are left blank for the students to fill. To answer the exercise, the student can click on the upper half of a gap (setting its values to "T" or true) or on the lower half of the gap (setting its value to "F" or false). Let's assume that the answers given by the student taking this lecture is shown by the dashed line in Figure 2.

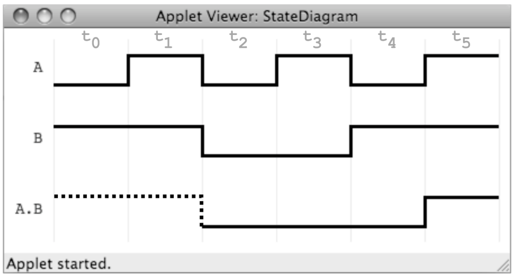

Figure 2. The diagram from Figure 1 with the gaps filled by the student.

To fill his or her answers in Figure 2, the student clicked the upper half of both gaps, answering the exercise as "TT", i. e., true logic signals for both gaps. Note that, while the answer filled by the student is presented as a dotted black line in Figure 2, in the actual screen it is shown as a blue continuous line.

In order to see the correct answer for the exercise, the student double clicks the mouse on the signal's name, which tells the applet to display the correct answer (provided by the professor) for that signal. The expected answers are shown either by a green line, when the student correctly fill the gap, or by a red line, when the student makes a mistake. As for the example of Figure 2, after double clicking on the name of the signal A·B, the applet would display the equivalent to Figure 3. Note that in Figure 3 the green line is shown as a dotted black line, and the red line is shown as a dotted grey line.

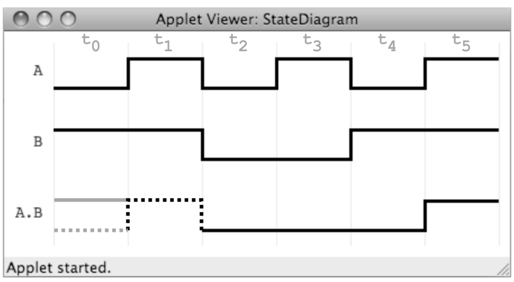

Figure 3. The applet showing the results expected by the professor.

For this exercise, the professor expected the student to fill the gaps with the values “FT”. Since the student incorrectly filled the first gap with the value “T” instead of “F”, the applet shows a continuous grey line on the upper half of the first gap with his or her original (and incorrect) answer.

Another important feature of the applet is the association of a high frequency sound (a beep with soft decay) to true logic levels and a low frequency sound to false logic levels. This association aims at establishing a mental binding between the frequency of the beep and the value of the logic level. The reason for the choice of the frequencies is that true logic levels are also said to be high logic levels while false logic levels are also said to be low logic levels.

The student can listen to the sounds of the logic signals shown by the applet (only those that the professor described as “0” or “1”). To that intent, he or she can double-click on the title of one of the columns (t_0, t_1 and so on), triggering a sequential presentation of the logic levels as follows:

- The first logic level on the double-clicked column flashes in a different (yellow) color and the corresponding beep (high frequency for high levels and low frequency for low level) is played for one second; and
- The previous step is repeated for each logic level defined by “1” or “0” in the chosen column, starting at the top most signal and descending to the bottom.

This binding of sounds to the visual representation of logic signals aim at reaching students with ease at learning by listening (musical intelligence), and some difficulty in learning by watching (visual intelligence).

In example, if the student double-clicked the title of the fourth column (t_3), the applet would play one high frequency beep followed by two low frequency ones, while flashing each logic level, starting at signal A and stopping at signal A·B.

6. Relationships Between the Intelligences and the Teaching Method

The main goal of our teaching method is to properly approach students that are more developed in those intelligences that are not naturally approached by the didactic contents. As such, it’s necessary to consider two factors, related to the Theory of Multiple Intelligences:

- Understanding the contents of the lecture requires some specific intelligences to be naturally approached; and
- The transmission media may stress the use of some intelligences while diminishing others. This is naturally accomplished by the symbols that encode each intelligence, i.e., the sounds of spoken words for the musical intelligence and the letters of written words for the linguistic and visual intelligences.

For the method proposed here and the cases under consideration the target intelligences are the logic-mathematical, linguistic, visual, and musical. In this case the use of several transmission media would ease the approach of the linguistic, visual, and musical intelligences, and would not affect the logic-mathematical intelligence as it is inherently tackled by the contents of the discipline itself.

The main reason to choose these four intelligences is that they should either be present in one of the transmission media or be part of the subject of the course. The other four – corporal-kinesthetic, intrapersonal, interpersonal and naturalist – are either too unrelated to the tools and the course, as the naturalist, or could only be applied in a much more complex system then the one we planned for this project.

While all the three tools – the backend, the mini text-processor and the applet – have significant importance to the project, only the later implies the direct use of three intelligences at the same time: musical, logic-mathematical and spatial. The applet provides a primary way of interaction for the student and does it through several means: the sounds that are related to the logic levels intend to correlate two different stimulus – the logical and the musical. This is the main way for the applet to reach the musical intelligence, using it as an information transmission channel.

The applet also reaches the visual-spatial intelligence through the colors of the signal when the student fills a right (green color) or wrong (red color) answer, since these colors are commonly used for the purposed of presenting correctness. It also relates the musical and spatial intelligences using the demonstration sequence that is triggered when the student double-clicks the title of the columns (t0, t1 and so on). This sequential demonstration forces the binding of sounds and logic level which are represented by the position of the signals lines.

To provide the didactic contents in a rational way the following guidelines could be used when designing the course:

- Explanations of the fundamental theory should be done by plain text and static images, without the presence of elaborate schemes. We approach the subjects "Boolean logic", "Truth tables", and "Karnaugh maps" in this way. The text presents the topics from a formal perspective, with the logic-mathematical rules exposed during the explanation.
- For those topics that are more dependent on visual representations like "Logic gates", "Combinatorial circuits", and "Sequential circuits", explanatory videos should explain their main aspects, directly approaching the visual and musical intelligences. Figures and logic state diagrams should be used as a complement to the explanation, and in the proposition of exercises to assure that the content has been properly understood.
- The course introduction should be recorded and presented as a video. Plain text and static images should be used for the longer parts that usually require figures for explanation.

Using this guideline, the professor should be able to approach all intelligences indicated in the beginning of this section. The logic state diagrams and its associated sounds, the speech of the professor in the videos of the lectures, and the figures and the text in the virtual blackboards are delivered in a way to surpass certain students' difficulties that may arise on a regular classroom. In an obvious example, if a student has difficulties in learning only through observation, the interactive logic state diagram may help him or her connect the concepts of logic levels and logic gates and better understand the whole course. On other side, if reading is the best way for another student to learn, the theoretic explanations through plain text and figure may allow him or her to absorb the lectures informations.

7. Conclusion

The professor of a discipline must not approach one or two intelligences and exclude the others in his or her lectures, for this may result in learning difficulties and lack of attention of those students inclined to learn through one of the excluded intelligences. The greater is the number of intelligences the professor uses in his or her lectures, the greater is the probability that the students will properly understand the concepts being exposed.

We presented tools to ease the composition of interactive lectures and to make them available full time on the World Wide Web. These tools aim at stimulating teachers to implement complementary online lectures may help them reach greater amounts of students. By adopting the educational principles presented here, complements to regular digital systems courses may be designed and implemented in a way that we believe would please both students and teachers. The later would have access to a set of tools designed to help them in creating their lectures' contents, while the former would be granted with multimedia contents, exposed through different views and formats, increasing their chances of understanding the discipline's topics.

Preliminary laboratory tests – reviews by teachers of our department – indicate that the use of interaction through the logic states diagram stimulate the learning process of logic operations and simplify the creation of exercises, allowing the professor to focus on the content to be displayed instead of the drawing of the diagrams itself. The "plain text" approach for composing the lectures, besides being simple is also straightforward to use and have been resulting in good reviews on the preliminary tests. These characteristics help in the lectures creation, speeding up reasonably the whole process.

Methods for formally testing the whole method (tools and content) will be applied in the next weeks, generating more specific reviews. The final results will be based on reviews by Computer Science students and instructors who will have the entire system at their disposal. The students will be able to study the Digital Systems course having no access to the back-end functionality. The instructors will test a version of the system, including the back-end functionality. The tools the instructors need to make on-line lessons and assess the user's experience will be thus provided.

As a suggestion to extend this work, one could implement additional applets to further facilitate the generation of lectures, automatically composing graphical elements such as Karnaugh maps and digital electronic schemes in the same way the logic states diagram are constructed: using plain text.

Another suggestion to extend this learning method is to provide interactivity among an instructor (or even the professor) and the students. Usually the use of chat rooms, forums, blogs and instant messages satisfy the interests of both sides and allow the correction of wrongly understood terms, theories and lectures.

Finally, some kind of online test could be provided to complement the idea of an entire digital systems course taught through the Internet.

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