DIGITAL INK AS A COLLABORATIVE LEARNING SUPPORT

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Abstract: Collaborative Learning is a technique used in problem or task resolution where learning occurs through the exchange of knowledge between students, and between students and teachers. In some situations communication between partners is better undertaken through the use of sketches or diagrams. The proposed environment introduces several tools into a computer supported learning environment using digital ink to facilitate expressiveness and creativity.

1 INTRODUCTION

The "Information Era" has brought changes to society that reflect in the teaching/learning environment. Institutions now need to be more than knowledge transmitters, becoming creators of stimulating environments, which must allow for partnership, exchange of experience and, above all, allow the development of critical and reflexive thinking (Basso 2000).

Furthermore, several researchers defend the use of technology as a pedagogical resource through the replacement of traditional expositive classes with classes offered with an alternative, more attractive, methodology, using computers, with interaction through websites, software and pedagogical games (Almeida 2008, Moran et al. 2004).

In this scenario, Collaborative Learning is a methodology that has gained importance. It is used in problem or task resolution where learning occurs through the exchange of knowledge between students, and between students and teachers (Verburgh and Mulder 2002).

Computer Supported Collaborative Learning offers a "collaborative environment" composed of several tools structured in the form of a groupware whose objective is to support communication, collaboration and coordination in group-based learning activities (Nitzke et al. 1999).

There are several collaborative content environments available for use on the Internet.

These include blogs, forums, discussion lists and wikis. In these systems, users express collaboration effectively through writing. However, there are many collaborative activities that are totally dependent on essentially visual content.

This type of content includes sketches, diagrams and technical designs, and is not well adapted to traditional environments, where information is basically presented in textual form. However, drawings/sketches can be used in the learning process to develop the habit of observation, the spirit of analysis, and the taste for precision. It would also be through drawings that purity of imagination is reactivated and the gift of invention enabled (Costa 2005).

The introduction of digital ink in the environment facilitates this type of activities, giving users greater freedom of expression, allowing them to exchange ideas in a more creative and natural way, enhancing communication, transforming some collaborative work difficulties in facilities.

Digital ink is a technology that represents drawings, sketches, and handwriting in its natural form. The use of digital ink is interesting because it allows for free expression, preserving the personality context of the person who writes. There is no restriction to a predefined structure, not even the need to write inside lines.

By exploring the digital environment, educators and students will be able to move on to a new, more powerful and more efficient paradigm of learning

(Tapscott 1998), making use of devices with native resources for digital ink, among them tablet PCs, smartphones, PDAs and others.

The drawing process associated with digital ink offers users benefits such as:

- It is fast, adequate to the short memory capacity.
- It is implicit and does not require sequential form or any special structure.
- It serves for analysis, verification and simulation.
- It is inexact and abstract, avoiding the need to include unnecessary details.

The main objective of this paper is to describe a set of tools for collaborative learning support that enhances the environment with digital ink. The tools present characteristics of interactivity and expressiveness by allowing the use of notes, sketches, diagrams and tracing as means for exchanging ideas, instead of limiting communication to writing. It extends the benefits of collaborative group work, giving users the possibility to create, edit and administrate visual content, in the same environment used for text.

The remaining of this paper is structured as follows. Section 2 presents an overview of the environment that results from the integration of the above-mentioned tools. Sections 3 to 6 describe each of these tools in more detail and Section 7 presents some conclusions from the work.

2 THE ENVIRONMENT

The proposed environment is a collaborative system whose goal is to provide advanced features to increase interactivity and expressiveness through the use of digital ink. As part of this system, a set of tools have been proposed and implemented:

- A **Digital Ink Wiki** that presents characteristics of interactivity and expressiveness by allowing the use of notes, sketches, diagrams and tracing as means for exchanging ideas, instead of limiting communication to text-based writing.
- A **Slide Annotator** that uses digital ink to integrate an electronic classroom environment based on slide presentations with a didactic knowledge. Through this tool, students have access to complementary material that will assist them in understanding and learning the subject being discussed in the classroom.

- A **Flowchart Designer** that integrates computer program flowcharts and digital ink to help first year students in the design of algorithms. The use of flowcharts has three main reasons: flowcharts have a minimal syntax; they are a universal representation; and they are easier than code structure for beginning students.
- A **Distributed Ink-based Whiteboard** that enables real-time interaction among a group of users by sharing a common, virtual, writing and drawing surface, which is presented to each user on its own device (typically a tablet PC). Users are allowed to ink on their local instance of the whiteboard while this ink is transmitted and rendered on other devices in the group via the classroom's wireless network.

The proposed environment has been developed inspired by the first year course on Algorithms and Computer Programming. This course has always presented a challenge for Computer Science Programs, probably because algorithmic reasoning is typically not part of the background students bring from high school.

Even though some of the tools have characteristics specific to this domain, most are generic and can be used for any domain where sketches and drawings are relevant.

3 DIGITAL INK WIKI

With the Digital Ink Wiki (DIWiki) (Almeida et al 2008), it is possible to share ideas in a more natural way, by allowing students to post drawings / sketches on the Wiki. These sketches can then be edited by other students using digital ink.

The tool also makes the correction activity easy. By using digital ink, users (teacher / students) will be able to use handwriting to annotate on content posted in the Wiki.

Furthermore, DIWiki (Figure 1) offers basic annotation features that allow users to mark, underline, emphasize or circle words in a sentence, as well as draw or make notations in the edges. These annotations or comments are reminders that we add to the documents to signal information or to highlight items of interest for subsequent reference.

Advanced features include sticky notes. This functionality offers flexibility in order to include several types of content in a document, for example, digital text, handwritten notes, "paint" aspects, or Web links.

The environment has two ink tool bars: *Drawing*, which can be used to draw and to write, and *Ink Annotations*. Both include a series of ballpoint pens, felt-tip pens and highlights to personalize the color and the width of the ink. It is possible to use the *Drawing* tool bar to insert diagrams, maps or images in the document being published.
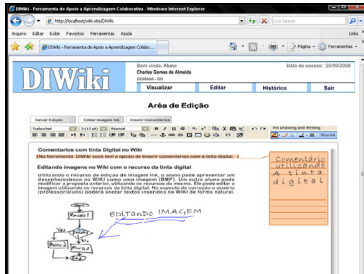

Figure 1: The DIWiki environment.

Data storage in the tool is done using the Ink Serialized Format (ISF), a file format specific for ink serialization that is compact, with high quality representation. Furthermore, the tool is able to recognize and export ink objects in different file formats, such as GIF and bitmap. This extensibility feature allows ink objects to be accessed through more than one interface (e.g., in devices with no native support for ink).

DIWiki offers a favorable environment for the knowledge construction process among students and among students and teachers, allowing collaborative learning through data sharing in several environments, such as wireless networks and mobile devices, guaranteeing users real-time access to the relevant information.

4 FLOWCHART DESIGNER

Sketches are handmade drawings with the goal of solving or clarifying a given problem or subject. As in handwriting, each person shows different characteristics when producing sketches. There are innumerable forms of drawing an object, and this can vary from person to person (Figure 2).
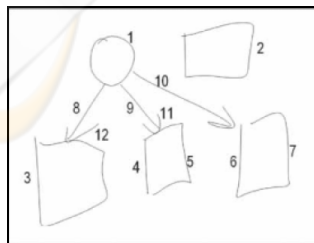

Figure 2: Different forms of sketching a rectangle.

To this, we can also add the inability of humans to draw curves and lines. This makes the recognition of sketches a difficult task (Davis 2007).

In Flowchart Designer, the process of sketcing is divided in two modules. First, the student freely sketches a flowchart with the aid of a digital pen. Second, the sketch is interpreted and converted into Java code. In the first module, the student creates the flowchart, using basic ink drawing functions such as erase, cut, paste, change color and select area for interpreting (i.e., execution of specific parts). At the end, the student selects the RUN button, and the flowchart is interpreted. If recognition is not satisfactory, the program offers a list of suggestions for the part of the sketch that was not recognized and the student can choose what the sketch really represents.

To implement the sketch recognition module, we use the LADDER system (Paulson et al 2007). It is based on the *Natural Interaction* system (or Magic Paper) (Davis 2007), which uses a hand scale that is in fact a constraint language of forms that describe the sketch, observing the direction, curvature and speed of sketching (Figure 3).

The sketch recognition language allows the description of more complex forms, based on more primitive ones and associated with a context. For example, Figure 4a shows the description of an arrow as the union of three connected lines with specific sizes (shaft, head 1 and head 2).
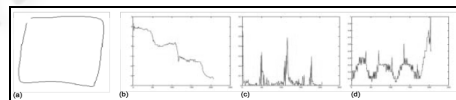

Figure 3: Features of a sketch. (a) sketch of a square and the direction of drawing (b), (c) curvature and (d) speed of drawing (Davis 2007).
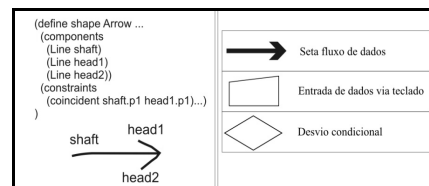

Figure 4: (A) Declaration of the arrow shape in LADDER (Paulson 2007). (B) Sample flowchart basic shapes.

During interpretation, if there is a syntactic or lexical error, the user is pointed to the part of the flowchart where the error occurred. The user can then edit the sketch to carry out the correction. When the flowchart is ready, the user can convert it into programming language code (Figure 5).
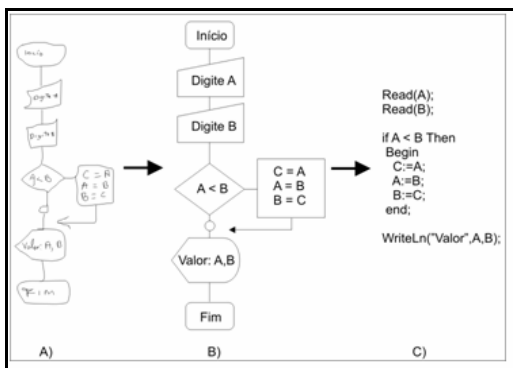
Figure 5: Sample flowchart sketch (A), recognized shapes (B), and result of conversion into code (C).

The sketch can be published and modified by other users (students). Modifications can be tested in the same way as the original sketch. Versions of the flowchart are kept, representing the modification sequence.
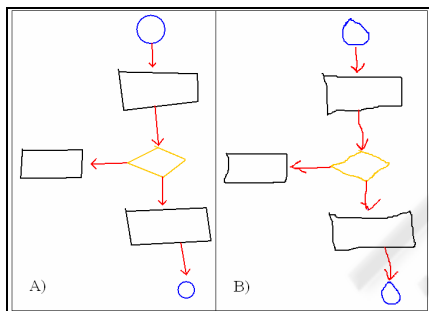

Figure 6: Shapes recognized by LADDER (A), and the original sketch without smoothing the lines (B).

5 SLIDE ANNOTATOR

The use of adequate and easily accessible didactic material (scientific articles, e-books, Web pages, among others) is essential to establish a permanent dialogue in a learning environment. For instance, this is important in order to give advice to students, to motivate learning and increase knowledge on the worked subjects, to promote critical understanding of contents, to instigate the student for research, and to make possible the supervision and evaluation of the learning process (Neder 2001).

In this sense, the Internet is ever increasing its presence in the daily life of students. However, one of the most important challenges is the retrieval of relevant documents. Depending on how the query is made, the selection of relevant material may be very time consuming.

The identification of relevant information is carried out by human beings in a natural way by analyzing the document's context. The simple reading of a heading or a summary, for example, can elucidate the content of the material at hand. When carried out by an automated system, this task is no longer trivial.

The Slide Annotator tool allows students to retrieve relevant didactic material associated to the subject being presented by the teacher. This can be done in class, while the teacher is explaining the subject, or later, when the student is reviewing or studying the subject.

The electronic classroom environment in consideration here assumes that lessons are delivered in synchronous form, with teacher and students co-located in the same environment at the same time. The tool was inspired by Classroom Presenter (CP), a presentation tool developed by the University of Washington that allows the sharing of digital ink in slides between teacher and students (Anderson et al. 2007).

With CP, all students receive, in real-time, working copies of the teacher's slides. CP allows teachers to interact with students through digital ink annotations on the screen, used to clarify questions and propose exercises, among others. Students can also send questions to the teacher and receive feedback.

Slide Annotator builds upon CP by allowing students to select words contained in the presentation and access a set of documents related to the context being shown in the slide display area.

For example, take the slide presented in Figure 7. If the student marks the word "alphabet", the tool analyzes the slide's context and verifies that the subject being treated in this lesson is related to "state diagrams" and selects documents that deal with alphabets in this specific context and not just any alphabet. It is worth noting that documents are not limited to text, but can include drawings, demonstrations, exercises, simulations etc.

Moreover, when opening a slide using the tool, information recovery techniques, applied automatically to the document, identify words considered relevant in a slide and convert them into hyperlinks, allowing students prompt access to complementary didactic material, either previously selected by the teacher and stored in a repository, or retrieved from the Internet.
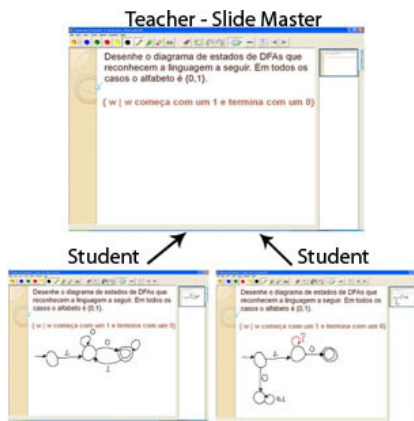
Figure 7: Example of interaction between teachers and students on Classroom Presenter.
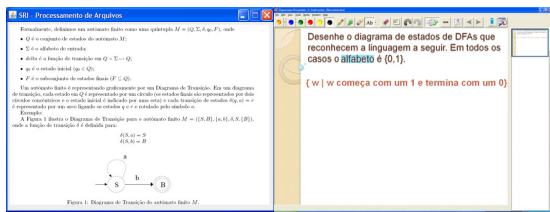

Figure 8: Example of recovery of contextualized teaching material.

The retrieval of relevant material is done using query expansion to better contextualize the original user query. The technique consists in the addition of related terms to those originally defined in the query. To enable query expansion, an analysis of the presentation and the slide content is undertaken to identify related terms, such as synonyms, stemming variations, or terms that are physically close to the query terms in the slide.

Original query: **computer programming**

Query expansion: **computer** **programming** **program** **data** **language** **algorithm** **programmer** …

Figure 9: Example of query expansion.

6 DIGITAL INK WHITEBOARD

It is widely known that the ability to share and exchange content is vital in the learning process. This is especially true about content that students produce during lectures and other classroom activities as part of the cognitive processes that take place while learning a new subject. In particular, we are interested in group-based learning, whereby students gather around a virtual shared space where they can express their ideas in a natural way using digital ink. Drawings, annotations, sketches and other forms of graphical representation drawn by a student are immediately transferred and rendered on the screen of the other students in the group. Problem-solving activities are a natural fit for this kind of collaboration tool.

While a number of tools exist that allow this kind of interaction in the classroom, among them Jarnal (Levine and Teege, 2008) and Group Scribles (Roschelle et al. 2007), we observe that they typically suffer from poor quality of interaction due to networking problems that are common in a congested local wireless network such as in a busy classroom where each student has his own wireless device. Typical problems include packet loss and delay, which may cause, respectively, the loss of vital ink strokes or their late reception by some users. In most situations, besides being a nuisance to users (as interaction through digital ink becomes out of sync with face-to-face interaction), may cause misunderstandings as, e.g., parts of a sketch or formula may be missing on some users' screens.

To tackle this problem, we designed and implemented an adaptive middleware platform that is able to autonomically reconfigure the underlying communications mechanisms in order to alleviate or eliminate packet loss and delay (Provensi et al 2008). Such adaptations are performed on behalf of users in a transparent way, requiring no user interaction with the middleware and, in the typical case, enabling user-to-user interaction to proceed without any noticeable change. Typical adaptations include compression and/or reduction of the quality of ink representation (without noticeably compromising its rendering), as well as configuration of network packet sizes.

The ink-based whiteboard was then implemented on top of this adaptive middleware platform, resulting in an interaction environment that guarantees the quality of service that is required for a meaningful real-time collaborative application. We plan to implement other collaborative applications on top of this middleware platform, such as ones that use rich multimedia content at real-time. We also plan to experiment with this platform to build applications aiming at distance-based collaboration.

7 CONCLUSIONS

The goal of this work was to describe a collaborative learning support environment that integrates digital

ink into the learning environment. This allows for more freedom and creativity in the environment, adapted to situations that require visual interaction by means of drawing and sketches.

In this context, the paper presented concepts, forms of interaction, main features, aim and functionalities of the proposed tools. These tools form a rich classroom environment, especially for teaching and learning activities that involve group-based problem solving.

We have begun to use these tools in a number of courses on Introductory Computer Science, both for major and non-major students. These courses are offered in a tablet PC laboratory, where students have access to digital ink technology in a one tablet per student basis. The PBL methodology (Schmidt 1983) is used to introduce the course syllabus, complemented with lessons using ink-annotated lecture notes. Students are encouraged to seek the solution collaboratively and independently of the teacher that acts only as a guide. The proposed tools are used to facilitate communication and enhance discussions within and between groups.

One of the main outcomes has been a substantial increase in student engagement, evidenced by higher class attendance levels and lively discussions among the students, both during and after class.

As future work, we plan to integrate the four tools described in this paper, in order to ease the process of switching from one tool to another and also to enable the meaningful exchange of ink data among them.

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