Enriching Online Learning Resources with "Explanograms"

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Abstract

This paper introduces a new learning resource for traditional and distance education. Explanograms are explanatory text and diagrams captured and stored as they are developed over time. Explanograms offer a new twist on an ancient means of communication by preserving the chronology of their creation. Teachers can develop explanograms as easily as capturing an explanation offered during lecture or office hours. We invented the explanogram as a learning aid for students, and as a means for improving our productivity as teachers. In this paper we describe the technology behind explanograms, how we plan to use them, and our approach to evaluating their effectiveness. A demonstration of the technology will be presented at the conference, where we hope to engage a broad spectrum of experts for suggestions and perspectives on the use of explanograms.

1 Introduction

An explanogram is a sketch or diagram that a student can play. The chronological development of the explanogram is captured along with an optional audio and/or video track. Explanograms differ from normal sketches or diagrams by letting students see how the diagram evolved to reach its final state. Using an explanogam makes it possible to rewind, skip forward, and examine specific areas of an explanation. Since the intermediate states are available and the visual representation is linked to other media sources it is possible to review an element of explanation drawing on all the available sources. In addition the explanogram can be reviewed and explored as often or for as long as desired.

Explanograms differ from hypermedia or multimedia presentations in the effort required to produce them. Authoring multimedia courseware is a challenging and time consuming task. Creating an explanogram is as simple as giving an explanation to a student during office hours. A special pen and paper are all that are required. An explanogram server provides the support for indexing the media forms to create links between the animated sketches and associated sound or video recordings. The server also generates animations of the written component for presentation on a viewing device, such as a web browser.

Experience with geographically distributed student teams and the tools they found effective for collaboration have informed the development of explanograms. The Runestone project [2, 6] involves teams of six students, three Swedish, three American, working together on a software development project. Email, IRC, and to a smaller extent IM are the preferred means of communication and collaboration. The characteristics of these technologies that make them popular are platform independence, location independence, and weak synchronicity.

Compared to telephone or network audio/video channels, IRC and IM are only weakly synchronous. At the message level, pauses between exchanges were not considered rude or disruptive to communication. Students reported that time to think during an online conference was a valuable characteristic of IRC[3]. The conclusion we drew is that de-coupled synchronous media such as IRC and IM provide the best of two worlds - the flexibility and adaptability of a conversation, combined with some of the opportunities to reflect and consider that a book (or written document) offers.

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Explanograms are designed for platform and location independence. Once captured, explanograms may be displayed on a variety of devices, including web browsers, telephones, and PDAs. A searchable archive of explanograms serves as a learning resource to complement textbooks, class notes, and faculty office hours. The explanogram is an innovative extension of a classical pedagogical device, but because it can be examined and used from any device with a web browser it has the essential properties of location and platform independence so crucial to student adoption.

The other lesson we drew upon when creating explanograms was the benefit of weakly synchronous communication. Unlike a traditional diagram, or a textual explanation, the explanogram can be examined to determine how it came to be in its final state. We speculate that the ability to capture the chronological development of a graphical explanation will improve a student's understanding of the concept being explained. We expect this to be the case for several reasons. First, a diagram that evolves over time is inherently more interesting and dynamic than one that does not. Second, suitable annotations can draw out the most interesting aspects of the phenomenon being explained. Third, compared to a live explanation from a teacher, a student controls the pace of the explanation, and may readily bring other resources into the learning process.

The benefits of an explanogram are similar to those for algorithmic visualization[4, 7] and multimedia courseware[5]. The major difference between these technologies and ours is that explanograms may be developed very easily, for almost no additional cost in faculty time. This is in rather dramatic contrast to carefully built multimedia artifacts or educational supplements (such as lecture recordings[9]) which are typically created with special purpose tools.

Our intent is to capture something which we already spend time doing, namely explaining difficult concepts to students in person, and turning these otherwise transient efforts into something that can benefit not only the student who initially requested the explanation, but her peers and our future students. Seen in this light, explanograms are a means of increasing utilization of faculty expertise and adding a continuous process improvement aspect to teaching.

The more time a teacher spends with students the larger the collection of explanograms he would collect. We hope that having a high quality and broad collection of explanograms to your credit becomes a point of pride and a means of demonstrating what is otherwise a largely invisible and under-appreciated activity.

In addition to broadening the positive impact of time spent directly with a teacher, we hope that explanograms help individual teachers improve their productivity by making a valuable explanation reusable. Eventually we anticipate that some means of editing explanograms will be valuable. This would allow a teacher to improve an existing explanogram, or to polish and prepare explanograms to accompany a lecture or assignment. The preparation of explanograms in anticipation of student needs could be particularly beneficial for distance education courses.

The remainder of this paper is structured as follows. Section 2 gives an overview of the explanogram technology and system architecture. A sample explanogram is presented as a series of image snapshots in section 3 in an attempt to give the reader a feel for the nature of an explanogram. We conclude the paper with a discussion of the outcomes of the explanogram initiative so far, and present our future plans for studying the educational impact of explanograms.

2 Explanogram Technology

Explanograms are made possible by the commercial release of a pen which is capable of sensing and recording pen strokes made on a normal sheet of paper upon which a barely visible background pattern has been printed. The pattern on the paper provides coordinate information in a very large pattern space, and the pen associates a time stamp and coordinates associated with the path of the pen on the pattern space between each "start" and "stop" action of the pen. A "start" action occurs when the pen is pressed onto the paper (whereupon timestamps and coordinates start to be recorded) and the "stop" action occurs as the pen leaves the paper (terminating coordinate/timestamp recording) for the current "pen stroke". Pen location is sampled at 50 Hz.

Automated storage and presentation of explanograms is possible since the pen automatically uploads the penstrokes to a designated computer where we then store them in a database. This database of timestamp and penstroke information is then processed and indexed with the other media forms available in order to present explanogram visualizations with associated sound and visual media to the user.

2.1 Related Technologies

The Anoto pen is not the first handwriting input device developed for interaction with computers. The Xpad and other related products have been on the market for some years.

While these devices provide flexible input of hadwritten data on computers, they are limited in sophistication, and typically cannot be used independently of the computer. Another limitation of these devices is that they do not provide the combination of pen stroke data and time stamps necessary to create the cross indexing between the multiple media forms that characterizes an explanogram.

2.2 The Pen

The Anoto Technology permits the generation and recording of highly accurate pen stroke data from writing on ordinary paper upon which the Anoto pattern has been printed (see 2.3). The digital pen allows a user to store and easily transmit what is written on a sheet of paper. The digital pen contains a camera, embeded processor, Bluetooth radio transceiver and an ink cartridge.

Commands to the digital pen are all implemented through interactions with the paper. There is neither display nor buttons on the digital pen, only light diodes and a vibration device which indicate operational modes and provide feedback to the user. Since the digital pen can communicate using the Bluetooth transceiver, it can also give feedback to the user through mobile phones and computers.

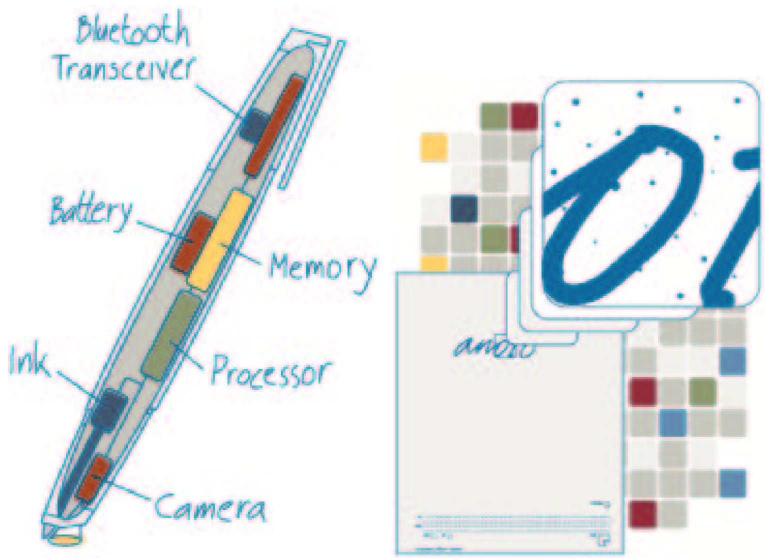

Figure 1: The Anoto Pen and the Anoto Pattern

The pen's functionality is based on the Anoto pattern printed on the paper. Different areas of the paper are assigned different functions. Some special purpose areas are defined to handle special actions. A key example is the "Magic box", which must be on the paper according to the Anoto human interface guidelines[8]. When a Magic box is ticked, a set of predefined actions are carried out which are the pen equivalent of pressing the Enter key on a computer. The hardware in the digital pen allows for direct streaming transmission of data, though this is not currently implemented.

The pen can operate in conjunction with a local computer or in a more complex mobile configuration. The difference between these two modes of operation is illustrated below. The ability to use the pen in mobile configuration means that explanograms can be created anywere. Thus one can imagine creating an explanogram during a teaching break in a classroom, or recording a text only explanogram at a hotel while at a conference in response to an email question.

Certainly an email reply to a question is also possible, but creating electronic pictures and diagrams is time consuming. The explanogram captures the speed of handwritten explanations and makes it rapidly available electronically, thus significantly increasing the effectiveness of the teacher.

2.2.1 Local functionality

In the local mode of operation the digital pen is used in conjunction with a desktop or notebook computer in the immediate surroundings. For example this can be used to synchronize notes taken in a traditional organizer with an application, such as Microsoft Outlook, on a computer. But most importantly it is possible to create a direct low latency communication channel to a local computer.

When operating in this mode the interaction between the pen and a computer is as follows.

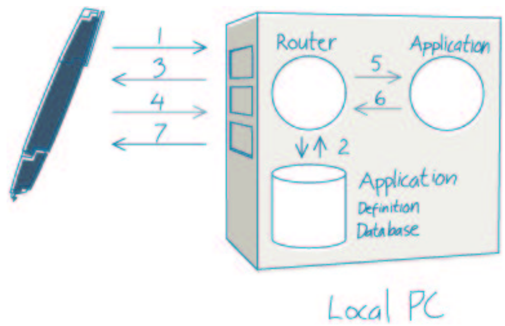

Figure 2: Local functionality - when the pen is used directly with a computer

1 Data (Pen ID, x,y-coordinates) from the digital pen are sent to the local computer.

2-3 The software together with the Application Definition Database gives instructions to the pen on what data to send, how to format and tag the data, and to which local application the data should be sent.

4-5 Pen-stroke information, together with information about the local application, is sent to the local application which then handles the request.

6-7 "OK" is sent back to the pen, clearing the pen's local storage.

2.2.2 Internet functionality

Internet functionality is equivalent to mobile functionality since the digital pen can use a GSM/GPRS enabled phone as well as an internet connected pc as the medium for accessing the Internet. Services could be, for example, ordering products by ticking an order box in an advertisement or sending written content as sms, email or other messaging formats.

2.3 The Paper

The paper pattern consists of a fine mesh of dots displaced from vertically crossed lines in a grid pattern. The digital pen uses only a small portion of the grid (6x6 dots) to locate its position on the pattern. The possible combinations of dot displacements from the grid defines a unique area exceeding 60 million km^2 in area. This corresponds to a writing surface area equivalent to the land area of Asia and Europe combined.

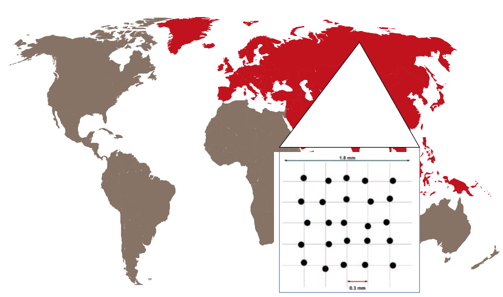

Figure 3: The pattern grid and its coverage. Every square 2 x 2 mm is unique

The camera in the digital pen operates in the infrared spectrum and the pattern has to be printed with carbon-ink. Due to the absorption of infrared light by the carbon ink the pattern is visible to the pen, even through drawn or printed material created using non carbon ink. Thus, when drawing with the digital pen the camera only sees the pattern on the paper and not the written ink or other material printed in non-carbon ink.

The pattern is printed in a high resolution which makes it barely visible to the naked eye on ordinary white paper. High resolution is vitally important in achieving a high fidelity copy of the pattern, thus preventing the dots from being printed on top of each other. With a requirement of 0.1 mm accuracy and a resolution of 0.3 mm the pattern must be printed in at least 1000 dpi resolution. Dividing the pattern into domains of varying size and functionality allows the digital pen to react differently depending on where it is positioned. Pattern templates are stored in the digital pen which map to the most common functions. Positioned in an area on a paper which corresponds to one of the pattern templates, the digital pen will immediately perform the function mapped to the pattern template.

More detailed information about the Anoto technology, pre-preprogrammed template functionality and the paper pattern is available from the Anoto website[1].

3 Sample Explanograms

Congestion control in IP networks is a difficult but important subject in a computer networking class. TCP protocol implementations use a strategy known as "slow start". The in-aptly named slow start algorithm uses an exponential increase of transmission rate in it's first phase. The second phase of the algorithm involves a linear increase of capacity. When congestion of the network is detected, the sender "backs off' dramatically, halving the rate at which data is sent, and beginning the phase cycle anew. Examining the behavior over time of the slow start algorithm is very helpful to understanding it.

The sketches below are three snapshots from an explanogram which illustrates the TCP slow start algorithm. This explanogram was developed "live" in front of a student upon their request for clarification of the phase behavior of the algorithm. The first image shows the exponential increase of phase one, with a note indicating the goal of working up to an initial guess of network capacity. The second image shows how the increase goes to a linear increase until a packet times out when not acknowledged. The final image indicates the aggressive back off of the algorithm and a return to phase one.

Compared to a diagram prepared with a drawing tool, the explanogram is more informal (some might say sloppy), but was created with very little effort. The most important aspect of the explanogram (difficult to capture in the static medium of paper) is the way in which it preserves the time dimension of it's creation. Bookmarks and a simple navigation interface allow a student to explore important elements of the concept being described, while synchronized audio can supplement the diagrammatic explanation.

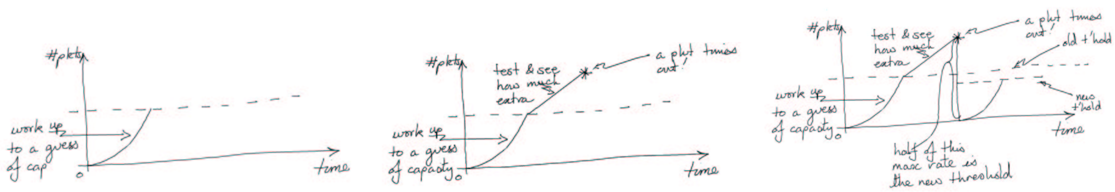

Figure 4: Three frames from an explanogram illustrating TCP slow start algorithm.

4 Conclusions

We have described explanograms, a new type of learning resource. We expect that the technological innovation upon which explanograms are based will soon be widely available. We believe explanograms can improve teaching efficiency by capturing and preserving value that is currently being lost. Explanograms are a highly efficient way to capture and present multi-media learning resources, saving teacher time and effort while at the same time enriching the educational experience.

The development of explanograms is founded on our observation of the tools used by students for remote collaboration. Platform and location independence together with a weakly synchronous medium offer the best chance for widespread adoption and use. Flexible presentation on a wide range of device types also makes explanograms readily accessable. The simple nature of the text animation element of explanograms means that they become a time saving feedback device for teachers on the move, and this is enhanced by the ability to upload an explanogram via a GSM or GPRS connected mobile telephone.

Results from our evaluation and the collection of explanograms developed for a course on computer networking will be presented online during the conference presentation. The explanogram repository, and the current explanogram services offered at Uppsala University can be found at `http://handwritten.it.uu.se/`.

4.1 Future Work

The first use of explanograms will be for a course on computer networks taught in the spring of 2003. We plan to evaluate some of the teaching and learning issues associated with determining the effectiveness of explanograms during this course with the following studies:

Study 1 Select a non-essential concept or algorithm in computer networking. Divide the course randomly into two groups. Present one group with a traditional textual and visual explanation of the concept, and the other with an explanogram for the same concept. Test and compare each group's understanding of the concept.

Study 2 Selected students will be interviewed in depth about their use of and experiences with explanograms. The objective is to try to identify a range of categories in which explanograms can be experienced. Once categories of experiencing explanograms have been identified we can focus on examining the effect of these manners of experiencing the explanogram phenomenon on concept understanding in the areas covered by the explanograms.

Study 3 Create a set of pre-defined explanograms to accompany a course on computer networking. Make them available via the web. Measure access volume and patterns through the webserver. Perform small numbers of interviews with students concerning their use of particular explanograms.

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