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Teresa Chambel
Nuno Guimarães

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Departamento de Informática
Faculdade de Ciências da Universidade de Lisboa
Campo Grande, 1749-016 Lisboa
Portugal

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Teresa Chambel, Nuno Guimarães

Departamento de Informática
Faculdade de Ciências da Universidade de Lisboa
Campo Grande, 1749-016 Lisboa, Portugal
{tc, nmg}@di.fc.ul.pt

Abstract: The potential for education of the motion picture was early recognized by many, but technological and use constraints have limited, or perhaps just postponed, the fulfilment of this vision. Significant technological advances and the new tendencies for media convergence and integration are transforming video into a dominant medium, suggesting new ways to support learning activities. The purpose of this paper is to contribute to the understanding of the effective use of video in education, in particular by discussing the role of hypervideo in learning environments. Our approach is based on human cognition concepts, the way media relates to learning, and hypervideo characteristics. These concepts and ideas are being developed and experimented in the context of the Unibase project on interactive and multimedia distance learning.

1. Introduction

"The theatre of education will be…where power can be found to project a motion picture on a screen"
W.Disney

The potential for education of the motion picture was early recognised by many, but technological and use constraints have limited, or perhaps just postponed, the fulfilment of this vision. Today, there is a social and economic need for education technology. Traditional education and training systems were shaped to meet the needs of an industrial society. The new information society needs people that learn and adapt quickly. Life-long learning will be a major requirement and a major change agent in the 21st century [Adam, et al. 1997, Boyle 1997, Dearing 1997]. Global access to information and technology changes the relationship between people and knowledge, and suggest new ways of supporting learning activities. A number of significant technological advances are making video more easy to access, store and transmit. Also, the new tendencies for media convergence and integration are transforming video into a dominant medium. In this context, it is becoming more relevant to understand how we can make an effective use of video to support learning.

The purpose of this paper is to contribute to the understanding of the effective use of video in education, in particular by discussing the role of hypervideo in learning environments. It describes and discusses the issues involved, and derives some requirements and guidelines for future developments in the field. First, it goes further into the potential and constraints of the educational use of video. Then it presents some human cognition concepts, and discusses the ways media affect learning. This is followed by the definition and discussion of hypermedia and hypervideo concepts and its use in education. The design of hypervideo for learning support is addressed. It briefly presents and discusses the hypervideo experiments we are doing in a project for distance learning on the Web, following the ideas, concepts and principles outlined in the paper. Finally, it draws some conclusions and puts forward perspectives for future work.

2. Envisioning Video as an Educational Medium

"I believe that the motion picture is destined to revolutionise our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks.", Thomas Edison, 1922 [Soloway and Pryor 96]

"Humans learned life's lessons by seeing real things or pictures with their eyes for ages, before they began learning through written or spoken words, so it is not strange that they still learn most readily that way"…"The animated cartoon can set forth anything from a world in evolution to the whirl of electrons invisible to human eyes; … can get inside a complex machine, slow down its action, explain its operation to apprentices with a clarity impossible in any other medium."…"The cartoon is a good medium to stimulate interest. It is an ideal medium for teaching."…"Educational films will never replace the teacher…but their advancement by means of the motion picture screen will give more people in this world an opportunity to learn. Pictures can make both teaching and learning a pleasure. And educators agree that when a student has begun to learn and like it, half their problem is solved." [Disney 1994].

Like Disney and Edison, others have foreseen the motion picture as a privileged educational medium, and there have been many expectations on the educational impact of TV and computers. However, they have not revolutionised or even had much impact on education. Some of the reasons are technological constraints, others relate to the way technology has yet been used to support learning.

According to [Soloway and Pryor 1996], one of the most important technological constraints for the design of learning support in computers has been its lack of enough horsepower. Technological constraints are specially important in the use of video. Until recently, equipment for the production and consumption of digital video was expensive and not readily available. A number of significant technological advances are making video more easy to access, store and transmit [Gibbs 1992, Chambel, et al. 1999]. These include advances in high-bandwidth networks and protocols, improvements in storage media, real-time compression and decompression hardware, greater availability of special-purpose audio and video processors, and faster rendering rates for graphics hardware. As for interactivity, early interactive video systems relied on analogue read-only videodisc technology, providing good video quality, but suffering from important limitations. On the other hand, digital video can be edited and modified, it can be processed and, like any other form of digital data, can be stored and retrieved from conventional storage systems [Gibbs 1992]. Along with technological advances, the new trends for media convergence and integration are transforming video into a dominant medium. Web support for multimedia object synchronised presentations is also being proposed and developed [SMIL 1998, HTML+Time 1998, SMIL 1999], providing new possibilities for the use of video in large scale and open environments.

For over 30 years, interface design was technology-centered. With the rise of computational power, from early 80s, user-centered design [Norman and Draper 1986] was afforded, and progressively since then, specially from late 90s, a learner-centered design is being made possible [Soloway and Pryor 1996]. As technological constraints are being reduced, the challenge of effective design and use of video to support learning becomes more relevant. So, the big issue here is: How can the perceived educational potential of video be fulfilled?

"The medium of the animated film is perhaps the most flexible, versatile and stimulating of all teaching facilities. The question now is where, how and with what means the educational film shall be included in the tool kit of the educators", Walt Disney.

3. The Cognitive Framework

There are many modes of cognition, many different ways by which thinking takes place. A view that is particularly relevant in our analysis defines two modes: experiential and reflective cognition [Norman 1993]. They do not capture all the thought, nor are they completely independent, but seem to be the extremes that technology forces us towards. Both modes are essential for human performance, although each of them requires very different technological support. Many tools fail by providing reflective support for experimental situations, or experimental support for reflective situations. In order to make technological products appropriate for people, we need a good understanding of the differences between these two modes and an understanding of human perception and cognition.

Experiential Cognition: The experiential mode leads to a state in which we perceive and react to events around us, efficiently and effortlessly. This is the mode of expert behaviour, and it is a key component of efficient performance. Experiential thought is essential to skilled performance: it comes rapidly, effortlessly, without the need for planning in problem solving. But the enjoyment of experiential mode is also its danger. It seduces the participant into confusing action for thought, like when one uses the technology of film, video, or even the printed page to watch others in experiential mode. It can be entertaining, but it cannot replace active participation. One can have new experiences in this manner, but no new ideas, new concepts, advances in human understanding. For this, we need the effort of reflection.

Reflective Cognition: While the experiential mode of cognition can be practiced simply by experiencing it, reflection is more difficult. The reflective mode is that of comparison and contrast, of thought, of decision making. This is the mode that leads to new ideas, novel responses. Reflection is a natural human state. But effective reflection requires some structure and organisation.

These concepts relate to cognitive psychology's *automatic* and *controlled* processes [Norman 1993]. Also related are Bruner's two modes of thought: *narrative* (stories, drama, experiences) and *paradigmatic* (scientific, logical); and the philosopher William James' kinds of thinking: *narrative thinking* (descriptive, contemplative) and *reasoning* [Bruner 1986]. The narrative mode, however, doesn't correspond exactly to Normans's experiential mode. Brenda Laurel also describes two modes of interacting with a computer in a different, but similar way: *experiential* and *productive* [Laurel 1993]. Her experiential mode is limited to receiving the experience, without activity on the part of the person. Norman's experiential mode combines both her experiential mode and aspects of her productive mode.

Along with the differentiation in modes of cognition, we all experience in different situations, some differentiation has been identified in Learning Styles: reflector, pragmatist, theorist and activist, the basic styles of which we are a mixture; and Learning Process Phases: conceptualisation, construction and dialogue, a "classic" learner centered pedagogy model. Different media, and the way they are used and integrated, can provide support for different learning modes, styles and phases.

4. Media and Learning

There are different media that can transmit the same information. But the medium is not a neutral carrier, it affects the way we interpret and use the message, and the impact it has on us [Norman 1993]. Each technological medium has affordances, properties that make it easier to do some things better than others. For a system to be capable of reflection, it must have a *compositional* representational medium that affords adding new representations, modifying and manipulating old ones, and perform comparisons. Human mind is such a medium. Reflection also requires the time and ability to elaborate upon and compare ideas. The medium must afford the *time for reflection*.

For example, let us compare printed text with television. Reading affords control of pace and reflection, but is relatively slow and difficult, and it takes considerable training and practice to learn to read. It takes mental effort, even for the most skilled reader. Printed text, alone, has some limitations as a tool for reflective thought. It is only a display medium. By itself, it does not afford composition, but with a pencil, you can cover words up or expand upon them, through written annotations in the margin, augmenting human reflection. Furthermore, reading affords reflection by coupling the self-paced nature of the act with the compositional powers of the mind. In this sense, broadcast television cannot augment human reflection. It does not afford composition or the time to reflect. Watching television is relatively easy, one does not need previous training or practice, and it does not take much mental effort. However, it is event-paced, materials flow continually, there is no time for reflection, no time to ponder or reconsider. The nature of the experience makes you passive to its process, in body and mind [Mander 1991]. Taken in this way, it is the worst excess of an experimental medium. Mander focuses upon the extreme, upon the excesses of shallow material, presented so as to exploit the seductive powers of the experiential mode. But television, properly constructed, can be a powerful tool for reflection [Norman 1993].

Furthermore, television and printed text do not afford the same kind of prolonged debate and argument that is possible with an interactive medium, as those that support our communication with another person [Norman 1993]. Eco argues that this is an important drawback in television teaching capabilities [Eco 1979]. His main argument is that it is essentially a medium that transmits a message to a wide and heterogeneous audience, without any feedback, and that between the sender and the receiver there are many filters sensitised by psychological and social or cultural screens, affecting the way the message is understood. He defends that learning should take place in a broader context, where discussion could happen, and an expert on the subject could be consulted or mediate discussion. Anyway, television could have a very interesting role in supporting this process, and he acknowledges the merits educational television has had in some cases, as with the Sesame Street program. The Web, for instance, with its ability to accommodate different media, can present high-level of interactivity through e-mail, news, a virtually ilimited number of interactive applications and, as its main feature, can provide us with hypermedia information, navigation and information discovery support.

The former suggests we need different media to support different learning modes. However, some media can be designed in different ways, in order to augment its traditional capabilities. In particular, television and video, when properly constructed, can be a powerful tool for reflection. If the user can select what is to be seen and control the pace of the material, and it is easy to go back and forth, to stop, to make annotations, to compare and to relate to other materials; then we will have an audiovisual technology that can add understanding and

affords reflection in a manner often superior, for its richness, to that possible with the written word alone.

5. Hypermedia and Hypervideo

Effective reflection requires some structure and organization [Norman 1993]. Structuring and organizing information is the main issue in hypermedia. Hypermedia, or multimedia hypertext, is the widely known term used to refer to hypertext, interlinking nodes that may contain different media, such as text, graphics, video and sound [Nielsen 1995, Hardman, et al. 1995]. Hypermedia has proven to be a powerful way to structure and interact with multimedia information. However, being multimedia is not enough for a system to be *truly* hypermedia. Different media can be used purely as illustration in a system where links are restricted to text, or they can be more actively involved in the "hyper" structuring aspects, by also participating in links.

Compared to other media, video has some unique characteristics that make it more rich and interesting, and yet more complex to handle [Elmagarmid, et al. 1997]. While its richness suggests the use of a powerful structuring paradigm, its complexity makes the task more challenging. Hypervideo refers to the integration of video in *truly* hypermedia documents. So far, on the Web and on almost every hypermedia system, when supported, video could only be manipulated in a way similar to a VCR, with controls to run, stop and pause, and links could only be made to or from video as a whole. Video must have the ability to contain link anchors, and not be regarded as a "dead-end node". True integration of video requires a more powerful hypermedia model. This should be done by taking into account its spatial and temporal dimensions, and by defining the semantic and mechanisms for linking video. Also, new concepts of navigational support should be defined, taking into account the aesthetic and rhetoric aspects of integrating several media in hypermedia [Chambel, et al. 1999, Gessler 1995, LiestØl 1994, Sawhney, et al. 1996].

6. Video in Hypermedia Learning Environments

Hypermedia is particularly well suited for open learning applications, where the student is allowed freedom of action and encouraged to take the initiative [Nielsen 1995]. According to [Boyle 1997], there has been a switch of emphasis from tutor systems, that emulate a human tutor, to a hypermedia and learner centered approach, which emphasises the learning as the central phenomenon. Intermediate approaches provide assistance, as a resource, rather then to direct the learner. Different hypermedia designs provide for different levels of freedom, allowing the accommodation of different learning situations and styles. There have been many hypermedia systems produced specially for educational use, in many areas, for different levels, and adopting different strategies. Several examples and benefits of hypermedia use in learning support have been reported and discussed in the literature [Nielsen 1995, Ess 1991, Thüring, et al. 1995, Kommers, et al. 1996].

Constructivists have argued strongly for the need of authentic learning experiences. Video clips can greatly enhance the authenticity of a computer based learning environment [Boyle 1997]. A study [Christel 1994], comparing the use of two versions of a course on code inspection, one version using full motion video (30 frames per second) and the other presenting the same audio, but over a slide show design (one image over 4 seconds), indicates

that higher quality visuals may indeed help instructional hypermedia perform better. Video has been used in different ways in hypermedia learning environments: for motivation, illustration of concepts or experiences, as the main vehicle of information, as a tool for experiments, etc; and, as mentioned before, different control over the video display has been given to the user. For the sake of illustration, we will mention some examples of the use of video in hypermedia learning environments. Video Linguist shows clips of television broadcasts from a country speaking the language being taught. The advantages of this approach are that TV shows are fun and motivating and that they teach the culture of the country, in addition to the language. À la Recontre de Philippe, from MIT's Project Athena [Hodges, et al. 1989], teaches French by means of a role-playing simulation, also using video. Links to a dictionary, and to different versions of subtitles in the foreign language, or as a translation, originally provided or added by the student, help with the structuring and use of the contents to be learned. The Shakespeare Project [Friedlander 1988], aimed at university level students in drama theory, makes use of video in a way students can compare different performances of the same play, and confront their interpretations with the ones directors and actors had made about that performance. An example of use of hyperlinking in video is the 'focus pull' facility developed in the Cytofocus system, by Roy Stringer [Boyle 1997]. As the user moves a lever on the screen, she can adjust the focus on the slide, by playing a video sequence taken by pointing the camera down a microscope as the focus was adjusted. Many users may not even realise that they are manipulating a video sequence.

On the Web, video has been mostly used in small segments, as illustration. Video streaming technology, with its ability to present the video while it is being received from the server and not requiring much local storage capacity, is making easier and faster the access to larger videos. One of the most popular uses, for educational purposes, has been the synchronized presentation of video recorded in live classes with the slides presented in the class. The main uses of educational videos on the Web are presented and discussed in [Collis and Peters 2000].

7. Design of Hypervideo for Learning Support

There is no folk design for cognitive artifacts as there is for many hand tools. Cognitive tools are simply harder to get right. But there are some principles that can guide our way in making learning technology a human technology that inform and enrich our lives [Norman 1993]. Traditional *Instructional Design* provides a systematic and formal set of guidelines for producing computer aided instruction systems. However, its approach has been strongly criticised. The theoretical basis of its propositions was considered weak or outdated for the computer technology they addressed. But Instructional Design offers challenges to the multimedia designer, with its emphasis on a clear statement of objectives, clear thinking about choices of method, and rigorous assessment. And frameworks have been developed or adapted, to capture some of the characteristics of new technologies and media available for the design of learning environments [Boyle 1997, Reeves and Harmon 1994, Reeves and Reeves 1997, Sumner and Taylor 1998, Taylor, et al. 1997].

The design of multimedia learning environments has two main components: *Conceptual Design*: dealing with the issues of the structuring of content (curriculum) and the structuring of interactions (pedagogy); and *Presentation Design*: dealing with giving life to the previous concepts, as fully realised multimedia systems. It is grounded in conceptual design, but has its own problem space. A crucial issue here is the holistic design of the presentation.

Presentation design should exploit human perception features, such as expectancy and pattern recognition, to achieve the powerful effects of perceptual clarity and simplicity. Unity and harmony emphasise the wholeness of the experience. The design of the individual media components should fit into this harmonious framework. Principles from the traditional disciplines dealing with text, graphics and video can help inform design decisions, but need to be re-examined in the new multimedia context, as new issues of media integration and complementarity emerge.

Multimedia involves a balanced integration of many kinds of media objects. Being a multimedia experience in its own right, video poses a significant challenge to multimedia design, not yet fully addressed [Boyle 1997, Sawhney, et al. 1996, LiestØl 1994]. The use of video needs to be functionally integrated into the overall learning context, considering the aspects of the integration with other media [Boyle 1997]. Video has to be reshaped to become a balanced component in interactive multimedia learning environments. The learner should be given the maximum amount of control, consistent with the learning goals of the context, and the adequate support for cognition modes that promote learning. Hypervideo provides the mechanisms to enter video at a number of points, to traverse it in a number of ways and reach, from it, any other related point in the hypermedia space. Technology can provide this, but a conceptual framework must be devised to make this a sensible and useful thing to do. The ability hypervideo provides for the integration of video as an active resource has immense possibilities. We need adequate tools and frameworks to explore these possibilities.

8. Hypervideo Experiments in a Distance Learning Web Environment

The ideas presented and discussed in this paper are being tested and validated in the context of the Unibase Project on interactive multimedia for open and distance learning [Chambel, et al. 1998], where video plays a central role. The main goal of the project is to transform the distance learning processes at Universidade Aberta (Portuguese Open University), in order to make it more effective. We want to provide students with a long distance multimedia interactive environment that keeps them motivated and help them learn more, in a better way, making the task more flexible and with reduced costs. Universidade Aberta is primarily concerned with open and distance learning, covering a wide variety of knowledge domains. Its current educational system is aimed towards the production of videos, that are broadcasted on TV at pre-fixed schedules, also made available in videotapes that can be purchased by the students, or watched in the regional support centers; textbooks; and tutor support, usually by phone. As separate media, these have the problems we described before. The materials only have a macro relation, as they cover the same subjects, but students do not have an easy way to interact, relate and study them when they want and at their own pace, nor to participate in discussions with their colleagues.

In the educational process carried out, students follow subjects laid out in the textbooks and watch television programs related with each subject. A fundamental problem is the decoupling that exists between the two types of information, and the monolithical format of the video material, leading to a less effective exploitation of these sources. Integration leads to an increased effectiveness through mutual reinforcement of both textbook and video program. The design rationale we adopt for the educational artifacts being developed is based on the notion that the integration of basic elements of information must explore the cognitive bias of the different materials and create added value through adequate bridges between those elements. Effective integration must be sought by allowing the learner to exercise the

"natural" cognitive attitude, while inducing proactive "breakdowns" [Winograd and Flores 1986] that trigger reflective processes [Norman 1993]. On a video-centered material, such as the one we are proposing, this means letting the user enjoy and absorb the video information in very much the same way as it is currently "consumed" in the television type of interaction. On the other hand, as this type of information processing is essentially experiential, the hypervideo environment must be designed to involve the user in such a way that he is led to "stop, think, and correlate" different types of information. A related mechanism or approach is used very successfully in simulation games such as SimCity.

Hypervideo mechanisms are therefore the basic tools for the purposeful and directed integration of video information. In this context, we developed a model and some tools for hypervideo support on the Web [Chambel, et al. 1999], as extensions to HTML and existing Web tools. We are also exploring new forms of integration and navigation of video in hypermedia [Chambel and Guimarães 1999], with a special emphasis on learning support, developing video annotation tools [Correia and Chambel 1999], and creating course material, following these concepts and using these tools.

As an illustration, we present some examples from the hypervideo document being developed for the "Introduction to Literary Studies" course at Universidade Aberta. Figure 8.1 presents a text page referring to the "The Aesthetical Dimension of Literature" chapter in the textbook.

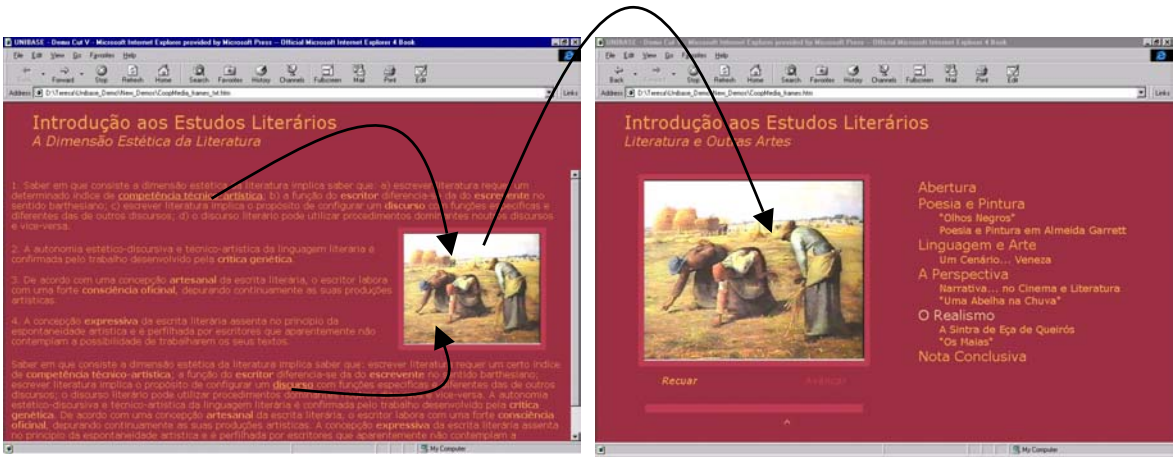

Fig. 8.1 – a) Text centered page; b) Video centered page.

Text integrates illustrative figures. In some points along the text, links are established to video excerpts that are presented in these figures. Two of these links are exemplified. In these situations, only the video excerpt illustrating the issue discussed in the text is presented. The student has an augmented version of the textbook. She may read it, and additionally watch video references come to life, as illustrations in the text. If the student wants to explore the video further, she may follow the link established from the video illustration to the corresponding video centered page. In the example, "Literature and Other Arts", one of the fifteen episodes of "Introduction to Literary Studies", the student is lead to the environment of an augmented television experience. She can passively watch the whole video, having additional information in the video index that, being synchronized with the video, highlights and calls the attention to the topic being presented. This way, the concepts and structure of the information conveyed in the video are made explicit and stressed. The student can also play a more active role, by following the links defined from the index to the video, or from the video to other materials. This way, she may, for instance, go back to review a concept, move forward to other topics, relate and compare information.

Fig. 8.2 – Navigation examples in a hypervideo document.

Figure 8.2 illustrates navigation in this hypervideo document. Exemplified links can be followed from text to video, from video to text and from video to video, in different points in space and time. In N1, the teacher talks about Almeida Garrett's Olhos Negros poem. In this moment, two spatio-temporal links are defined. On the girl's face, a link (L2) to the moment in the video when the poem is read out, and on the rest of the image, a link (L1) to the written poem page. L3 exemplifies a link from the index to the video. L4 and L5 exemplify navigation in history, which records all the moments in the video where the user has navigated across. L6 exemplifies a link from the video timeline to the video. This timeline provides video navigation assistance. Some of its functionality include: the presentation of the video current position, around midway in N4; and direct access to the video, in a continuum, while the index provides discrete access to the most relevant topics. There are other mechanisms to assist navigation, among which we highlight those relating to link awareness [Chambel, et al. 1999]: How to provide information about the spatial and temporal location of links?, their duration?, their destination? More relevant and complex issues when a dynamic medium is involved, since links may change in time. As an illustration, we mention one mechanism developed to provide information on *when*, and *for how long*, there are links on the video: The existence of links causes video border color change (N1 and N3), that will fade to the original color (N4), reflecting the time left before the links are gone.

Figure 8.3 exemplifies indexes synchronized with video. Besides from being links to the video, indexes change their appearance when active, i.e., when the video is playing the topic they relate to. In the first example, textual topics change their color. In the second, images are highlighted by a colored border. In the document authoring, these images may be selected among the most representative in the video, or they may correspond to all the scenes in the video, and become its visual summary. In this situation, video processing techniques are applied for scene cut detection [Correia and Guimarães 1996].

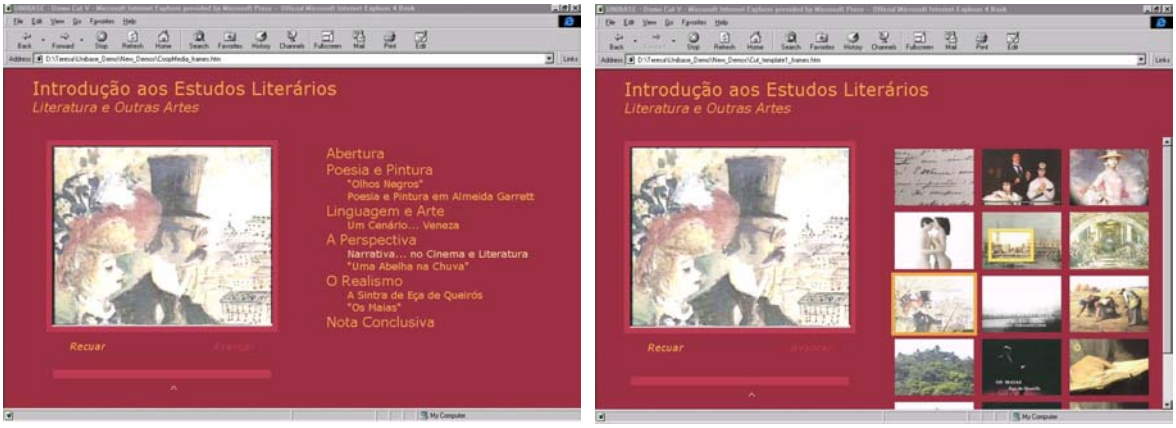

Fig. 8.3 – Indexes synchronized with video. Visual summary of the video.

Being developed for the Web, course materials are complemented, when appropriate, with external references, defined as links. Using these hypermedia and hypervideo mechanisms, students can also make their own enriched versions of the available materials and possibly share them with their colleagues, or present work illustrated with integrated references to the available materials. Through email and newsgroups, students can also communicate among them and with teachers, and they can participate in discussion forums related with the subject at hand.

Main issues for future work concern the usability of the tools; the support for the authoring of hypervideo documents, including the application of other video processing techniques [Blake and Isard 1998, Correia and Guimarães 1996, Elmagarmid, et al. 1997] in order to help and find the anchors for which to establish links, and the automatic creation and maintenance of links along time; and full support for the functionality found useful and adequate for the integration of different media and interaction modes, to accommodate different styles of learning.

9. Conclusions and Perspectives

This paper has identified and discussed the role of hypervideo in learning environments, to achieve effective learning with video, by itself or integrated with other media. The discussion was based on human cognition concepts, on the way media relates to learning and on hypermedia and hypervideo characteristics. Important features include the ability to integrate video with other media, in a richer way, taking into account its spatial and temporal dimensions; to let the user select what is to be seen and control the pace of the material; to make it is easy to go back and forth, to stop, to make annotations, to compare and to relate to other materials; and to communicate and cooperate with other students and experts on the

subject. The paper also described how this concepts and ideas are being experimented and shaped in our work in the Unibase project on distance learning. There are still some technical and methodological challenges facing the effective design and use of hypervideo in learning environments. Technology will provide the tools; methodologies will guide the design for its effective use. As this process progresses, video will become more and more flexibly accessed and used in many ways that can better support learning processes.

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