Interactive Video and Artificial Intelligence: A Convenient Marriage

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Abstract: This paper describes the theoretical framework of a research project aimed at exploring the new potentialities for instructional systems offered by videodisc technology and artificial intelligence methodologies and techniques. In the context of this project, ‘Earth’, a prototype of ITS, is being developed, which embodies the ideas presented. In an instructional system, interaction can be characterized by three properties: adaptivity, reactivity and flexibility. The existing interactive systems are adaptive and/or reactive. Flexibility is a new dimension of interaction allowed by videodiscs. In a flexible system the user explores a multi-media database of educational material and learning is a consequence of this exploration. In the paper, we briefly describe some of the major development problems and discuss how AI techniques provide a means to prevent the user from getting lost in the learning material.

Introduction

Educational technology and artificial intelligence (AI) have a small but seemingly increasing area of intersection.

The dramatic advances in computer, video and compact disc technology are making researchers and practitioners in the computer-based instruction (CBI) field re-evaluate the role of the computer in instructional systems. New possibilities are arising and becoming widely available; traditional approaches to computers in education appear poor and inadequate. Learning environments and intelligent tutoring systems (ITS) offer ideas and means to educational technologists to design effective learning systems which exploit the new media. The number of CBI packages dealing with procedural knowledge and reasoning strategies is increasing. Languages typically used in AI, and what is more important, the underlying philosophy, are increasingly used by CBI authors to develop learning environments.

The fact that the hardware used for AI applications is increasingly accessible to educational institutions, makes ITS potentially available to a large population. As a consequence, ITS developers are concerned with new problems, e.g. the lack of validation processes, the poor quality of the student/machine interface and, more generally, the lack of engineering in the development process. Some good solutions have been devised by educational technologists which could be transferred to the ITS field.

This paper describes the theoretical framework of a research project aimed at exploring and exploiting, for instructional purposes, AI techniques and methodologies and the great storage capacity of the videodisc. The details of the actual project will not be dealt with here.

The working hypothesis of this project is that learning can be a consequence of an exploration of the available learning material (audiovisuasals, texts, CBI products, learning environments, etc.).

The system we are developing is mainly intended to help users build up their own understanding of a theory. In a theory, both concepts and their relationships are relevant. Often these relationships are not univocally determined as they depend on the chosen point of view (Pask, 1979).

The problem of students wandering about in an environment which cannot guide them in the learning process is well known. To avoid this risk and also the risk of presenting a unilateral view of the subject a competent supervisor is needed which advises the users on how to explore the knowledge-base according to their learning objectives, role, prerequisites, and the learning material made available by the system.

So far we have developed a conceptual framework and designed the architecture of the system. A prototype is under development.

Interactive Video Potentialities

A typical interactive video (IV) station for education is composed of a videodisc player, a computer (often a PC) equipped with a graphic overlay device, a pointing device (mouse, touch screen, etc.) and a suitable monitor.

The components of the student station are changing as technology rapidly advances. As a result the potentialities of IV systems are continuously improving. Furthermore, in the near future it will
also be possible to interface IV systems with AI workstations for large scale applications. Hence, the importance of an effective integration of the two technologies grows continuously.

Two features characterize IV systems: multi-channel instructional communication and high storage capacity.

*Communication capacity*

Except for three-dimensional moving images, an IV system allows all kinds of known audiovisual stimuli typical of all known communication channels (Figure 1) (Sanna, 1982).

In this system the communication from the computer is superimposed upon the video images. Thus, the communication capabilities of an IV system are superior to those of television and computer combined. These capabilities can improve the effectiveness of instructional communication, but also pose new theoretical and practical problems. Therefore, the complexity of the production process of pedagogical material increases. For example, one of the theoretical problems concerns the criteria for defining suitable channels according to the nature of a given topic and of the student population. Furthermore, rules are needed to choose the most suitable channel at run-time, and the most effective strategy to achieve an objective according to the characteristics of a given student.

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Figure 1. Communication capabilities
Storage capacity

Currently available IV systems store audio, video, text and computer data. In the near future their capacity will increase using digital technology. For example, an interactive compact disc (CD-I) will contain a complete multi-media database totalling as many as 600 megabytes of data.

In the following section is a description of how increased storage capacity adds a new dimension to interactive systems.

Types of interaction

Existing interactive instructional systems can be characterized according to their degree of adaptivity, reactivity and flexibility.

Adaptivity

Roughly speaking, adaptivity is the ability of an instructional system to 'adapt' its behaviour according to the user’s behaviour.

Purely adaptive systems embody teaching/learning strategies such as drill and practice, testing, CAI tutorials, socratic dialogues and so on. The major features of this class are:

- the teaching procedure is predetermined and embodied in the system;
- the information from the student to the system is in the form of either an answer to a question posed by the system, or a question posed to the system;
- the information from the system is a teaching sequence selected (or synthesized) on the basis of information coming from the student.

Using a geometrical metaphor, purely adaptive systems could be thought of as lying on an axis according to their degree of adaptivity (Figure 2).

Reactivity

Reactivity is the capability of evaluating a set of functions available to the user: the system ‘reacts’ to the student’s inputs by performing the related computational activities and making available their results.

The major features of purely reactive systems are:

- the learning procedures (or the learning actions) are defined by the student on the basis of the available functions of the system;
- the information from the student comprises commands, instructions or procedures which activate the available functions;
- the information from the system is the result of the computation activated by the student input.

Simulation, microworlds, games and programming environments are typical applications belonging to this class.

Using the geometrical metaphor, reactive systems could be thought of as lying on an axis, according to their degree of reactivity.

Systems having both a component of adaptivity and a component of reactivity lie on the plane of these coordinate axes (Figure 3, see over page).

Such concepts as adaptivity or reactivity are too complex and imprecise to be quantified. They could be defined in terms of fuzzy sets (Ghislandi, Midoro and Olimpo, 1986). However, a more accurate definition of these terms is beyond the scope of this paper.

Flexibility

The storage capacity of IV systems allows the development of multi-media databases of pedagogical material in which users retrieve the information they require. We will call this property of interaction flexibility, the capability of answering
a set of queries available to the user, by retrieving the proper material from a database. The following features characterize purely flexible instructional systems:

- the learning procedure is defined by the user who can choose different topics and levels of depth of the subject;
- the input from the student is a set of commands for retrieving information;
- the output is the display of information stored in the database. This is the main difference between reactivity and flexibility. In fact, while the output of reactive systems is the result of a computation, the output of flexible systems is the display of stored multi-media information retrieved by the user.

Flexibility could be represented as the third dimension of the interaction space. A generic interactive system can be represented by means of a point in this space, with the kind of interaction characterized by the value of adaptivity, reactivity and flexibility (see Figure 4 opposite).

Flexibility is the new dimension of interaction allowed by IV technology which provides both high storage capacity and multi-channel communication.

Future flexible systems could embody the whole knowledge of a given domain, similar to a section of a library. They should also be able to cope with different kinds of instructional objectives and user populations.

**Developing Flexible Instructional Systems**

In a flexible system on a given domain, users explore a multi-media database of learning material. In complex systems this material may be adaptive (tutorials, diagnostic tests etc.), reactive (learning environments, games etc.), or non-interactive (audiovisual sequences, texts, etc.). During the learning process the learning objectives, the level of depth, the channel of communication and the kind of activity may change.

As flexible systems have structures and operation modes different from other CBI systems, new development methodologies and instructional processes must be defined. In particular, the variety and amount of material require criteria, methods and techniques to select and organize it.

This section briefly describes an approach to cope with some of the major development problems. In the following section, we show how artificial
intelligent techniques provide a means to prevent the user from getting lost in the learning material.

A given subject domain can be characterized by two elements:

- the structure of the knowledge of the domain; thought of as the set of facts, concepts, methods, techniques, skills and their relationships, shared by specialists of the field;
- the whole material embodying this structure, i.e. books, journals, reports, conference proceedings, existing educational material, ad hoc instructional material and so on.

An *ideal* flexible instructional system should embody the entire structure and all the material of the subject domain. For practical purposes, the complexity of the structure must be reduced and the associated material must be selected and organized.

Defining educational aims reduces the number of topics and selecting only the entailment relationship among concepts simplifies the structure. At Istituto Tecnologie Didattiche we are developing ‘Earth’, a prototype of a flexible system whose theme is plate tectonics (Midoro, Persico and Sarti, 1987). In this project we use top down expansions of Petri nets for knowledge structuring (Ferraris et al., 1984). Figure 5 shows an example of expansion of a particular activity.

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**Figure 4. Interaction space**
Figure 5. Expansion of activity 1.1
In Figure 5 ovals pointing at a rectangle represent concepts or topics from which other concepts or topics (emanating from the rectangle) can be derived; a rectangle represents a relationship of entailment. Both concepts and relationships can be expanded into a more detailed net. In this way the complexity of the knowledge structure is reduced at the expense of a decrease in generality.

Learning material can be associated with each node of the net. Typically, the material allows different learning strategies, activities and levels of depth to fit the specific characteristics of the individual student. In Figure 5 activities comprise an audiovisual sequence, a set of examples used in educational literature, a diagnostic test, some excerpts from scientists' original papers and a simple learning environment. These are associated with each node of the net.

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(1) Activity type: [formulate, confirm, deduce, explain, consider]

Figure 6a. Database model (knowledge)
In our system the organization of the material and its integration into the knowledge structure have been achieved by means of the database methodology. In the conceptual model of our databases (Ullman, 1982), shown in Figure 6, the topics (circles in Petri nets), the entailment relations (rectangles) and the material are three main entities, connected by means of suitable relationships. Each entity is characterized by attributes which are used for retrieving the material according to specified criteria.

A suitable interface is available for users to retrieve information; to choose a topic they can use a table of contents. Once the topic has been selected, the learning material characterized by given attributes can be chosen through a menu or a set of key words. As an alternative, the user can also explore the structure by means of a graphic map of the contents and retrieve the proper material. Moreover the system can be browsed through by means of a control pad allowing access to meaningful chunks of material. Finally, the user can access the material through a suitable query language.

Figure 6b. Database model (material)
So far, the user can explore the learning material without a guide. Many educationalists have proven that while this complete freedom can be productive for experienced able learners, the lack of guidance can result in useless wandering for weak or inexperienced students. To help users reach given educational objectives on the basis of their learning characteristics and needs, a competent supervisor is needed (Burton and Brown, 1982; Clancey, 1987). (The term ‘coach’ used by Burton and Brown is not adopted here; we prefer ‘supervisor’ to stress guidance while exploring a database, as opposed to training in procedural knowledge.) The next section discusses some of the main characteristics of such a supervisor.

**AI Techniques for Flexible Systems**

In a flexible system, the supervisor should embody the experience of a good teacher. A high degree of adaptivity can be reached by adopting AI techniques. In particular, the supervisor should recognize the educational needs and learning characteristics of the user and consequently choose the content and form of the learning process. In ‘Earth’ the learning process resulting from the guided exploration of the database is dynamically shaped on the basis of the user’s state of knowledge, aims and behaviour.

Let us consider the supervisor’s role in more detail. The supervisor performs five main tasks:

- Evaluating whether the user’s educational needs can be satisfied by the system.
  
  To this extent, the supervisor must know the user’s objectives and motivations in order to compare them with the characteristics of the system and to evaluate if the system can allow users to reach their objectives. This also implies that the system evaluates whether the user has enough knowledge and motivation to reach these objectives. In ‘Earth’ we assume that different user populations can pursue different objectives. In Figure 7 the table relates each population (identified by their roles) to the class of possible aims. The supervisor must be able to cope with changes in users’ needs and objectives during the interaction.

- Choosing topics.
  
  The system decides which topics are consistent with the user’s needs and dynamically plans the presentation. For instance in ‘Earth’ the user can approach plate tectonics from a historical point of view or from a descriptive one. Furthermore, details of the theory, such as an explanation of the St. Andreas fault or the Mediterranean area could be explored. Different topics correspond to different approaches. The system

<table>
<thead>
<tr>
<th>AIMS</th>
<th>overview</th>
<th>study</th>
<th>teacher training</th>
<th>source analysis</th>
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<tr>
<td>humanities teacher</td>
<td>X</td>
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*Figure 7. Roles versus aims*
selects the set of possible topics and dynamically constructs and tunes the presentation of teaching material.

- Deciding the level of depth, the strategy and the communication channel for a given topic.

The system must choose which material associated with the topic best fits the characteristics and the learning objectives of the student. In 'Earth' the subject matter is represented at different levels of depth. Suitable material is associated with each level. Furthermore, material which allows different learning strategies is associated with each node of the knowledge structure. For each strategy, learning material is available which can be audiovisual, textual and interactive. The supervisor narrows the set of learning material and eventually chooses the material to be presented, according to the user's learning objectives and characteristics.

- Generating a 'connective tissue' among topics to make the interaction smooth.

In 'Earth', a repertory of connective material is associated with each relation in the database from which the supervisor chooses the most suitable. This is analogous to the dissolve between two video scenes and is required to give a continuity to the presentation.

- Explaining, upon request, why a teaching/learning strategy has been adopted for a given user.

The explanation takes into account the user's characteristics. In particular it is of interest for teacher training applications. This task is analogous to the explanation functions existing in many expert systems.

All these activities only make sense if the available material is so rich as to require great experience to select it.

To perform the tasks stated above, a sophisticated model of the user is required (Self, 1987). At the beginning of the interaction the system initiates such a model-making hypotheses about the user. During the learning process the student model is updated according to the user's behaviour and the initial approximations are refined. The model describes the role of the user (student, teacher, layman, etc.), objectives, knowledge of specific prerequisites and possible misconceptions, background, learning style and the history of his/her interaction with the system. In other words, this model attempts to capture all those features of the student that may help a teacher to devise a proper learning strategy.

Summary and Conclusions

We have attempted to show how videodisc technology and the increasing mass memory of computers allow a new dimension of interaction, namely flexibility. We have argued that a flexible system requires skilled learners able to fully exploit its capabilities. A competent supervisor adds to this system the dimension of adaptivity, which not only makes the system effective for weak learners, but also optimizes the learning process of expert learners.

A flexible and adaptive system is effective in learning facts, theories and taxonomies using different approaches, assuming different points of view, choosing a desired level of detail, focusing on selected aspects of the theory.

In 'Earth', plate tectonics can be approached from the historical point of view, examining the mechanisms of the birth of a scientific theory. Alternatively, the user can choose to learn the basic concepts of this theory ignoring the historical dimension, or can be interested in understanding the tectonics of a given area.

Flexible/adaptive systems seem to be inadequate for acquiring problem-solving skills. 'Reactive' educational systems are more suitable for dealing with operational skill. Consequently, an interactive system, able to encompass the knowledge of a given domain, should be characterized by flexibility, adaptivity and reactivity.

We have been using the 'Earth' project to explore the problems related to this kind of system. We are aware of the difficulty of deciding an effective treatment for a student on the basis of a student's aptitudes (Sleeman, 1987) and at this stage we have more questions to ask than answers to give. More research on basic aspects of learning and teaching is needed to develop an effective supervisor. On the other hand, the development of adaptive/flexible systems gives the opportunity of obtaining a deeper insight into the learning mechanism in an operational way.

References


**Biographical notes**

Researcher at the Istituto Tecnologie Didattiche (ITD) of the Italian National Research Council, Dr. Midoro has been working in the field of educational technology since 1974, his major interest being methodologies for the advancement of educational systems development. Dr. Midoro is presently in charge of the Earth project, aimed at developing a learning system that integrates artificial intelligence and interactive video technology.

Dr. Chioccariello worked at the Educational Technology Center of the University of California, Irvine, from 1981 to 1986. He presently works for ITD and is involved in the Earth project on a full-time basis.

Professor Olimpo has been teaching software engineering at the University of Genoa since 1977 and has been Director of the ITD since 1982. Most of his research activity has been devoted to defining an engineering approach to the design of educational systems and to creating suitable paradigms for computer education.

Researcher at the ITD, Dr. Persico has been active in the field of educational technology – theory and applications – since 1981. Presently, she is involved both in the Earth project and in the development of courseware for the teaching of formal logic and is a member of the PLET Editorial Board.

Researcher at the ITD, Dr. Sarti has been active in the field of educational technology – theory and applications – since 1977. Presently, he is involved in the Earth project and is interested in the application of AI tools for the development of educational software.

Researcher at the ITD, Dr. Tavella has been interested in educational technology applications since 1979. Presently, he is involved in the Earth project and in the development of several educational packages.

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