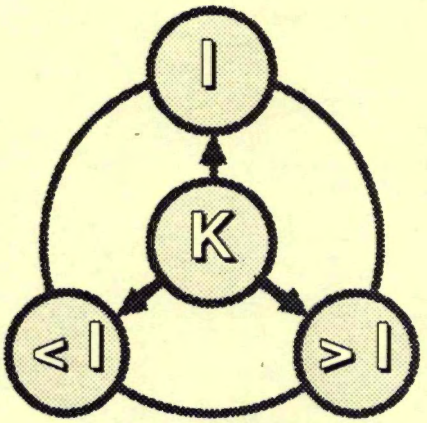


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INSTANTIATION OF KNOWLEDGE STRUCTURES IN BOOKS AND HYPERMEDIA

Technical Report KSI/NML-87-BHM
August 1987

Knowledge Science Institute
&
Neuro-Motor Laboratory

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ABSTRACT

Hypertext systems are often presented as advanced alternatives to books allowing material to be presented with its natural structure rather than forced into a linear sequential form. However, books may also be used to present highly structured material in a non-sequential form, particularly in reference works and in training manuals. While comparisons between books and hypermedia are widely made, there are very few examples of extensive material which is available in both book and hypermedia form. This paper presents a major example of a series of sports coaching handbooks and hypermedia presentations of the same material, where the use of both media has been optimized independently and where meaningful comparisons can be made.

INTRODUCTION

Advances in technology have made hypermedia systems feasible and they are attracting widespread interest for a variety of applications (Nelson 1980, Young 1986, Gassée 1987). However, the essential features of hypermedia systems are not well defined and there are danger that systems will not fulfil expectations and that the term will become over-used and lose its meaning (Gaines 1987c). In particular, although the flexibility in presentation and access of hypermedia systems is often contrasted with the rigid sequentiality of books, there are very few examples of extensive material which is available in both book and hypermedia form. This paper is based on practical experience in designing, implementing and applying a series of books and a range of hypermedia systems for sports coaching, each based on overt and detailed expression of the knowledge structures underlying coaching for specific sports.

There has been substantial progress in recent years in our understanding of the knowledge structures underlying the performance skills of athletes and the coaching skills of those involved in their selection and training. The abstract knowledge structures for sports coaching have been developed independently of specific sports (Vickers in press b). They have been shown to lead to significant analyses of a wide range of sports that guide the generation of coaching strategies and the individual acquisition of playing skills, and to be highly meaningful and comprehensible to both coaches and players (Vickers in press c). These knowledge structures are being applied through a variety of media. The new *Steps to Success* book series from Human Kinetics Publishers is based on the explicit use of the structures in handbooks for athletes and coaches. Initially ten sports are covered including archery, badminton, basket ball, golf, gymnastics, tennis and swimming. In the research laboratory we have developed a range of hypermedia systems based on the knowledge structures (Vickers 1987), including an expert system for ice hockey coaching (Vickers & Kingston 1987) which will be shown at the Winter Olympics in Calgary February 1987. This runs on a Macintosh using the expert system shell, Nexpert (Rappaport 1986), together with specialist knowledge acquisition, videodisc and CD-ROM control software. Film for the videodisc has been shot during a number of international games and associated training.

This paper is based on our experience in developing the knowledge structures, book series and hypermedia systems, and comparing and contrasting the resulting delivery systems for instructional material. It abstracts, discusses and illustrates the essential features of hypermedia systems, relating them to developments in conventional media and information technology. It develops specific guidelines for hypermedia design relating to the functionality and user interface, and illustrates these through our own experience. It summarizes the knowledge-based approach to instructional material design and illustrates this both in abstract and concrete forms. It describes the coaching material in book form and in hypermedia form, and develops theoretical and practical comparisons between the different instantiations of the knowledge and training structures.

HYPERMEDIA SYSTEMS

The concept of a hypermedium is very open-ended and a range of systems are being developed for a diversity of applications, from simple hypertext systems such as Learning Tool (Kozma & Roekel 1986) and Guide (Owl 1986), through electronic books (Weyer 1982) and encyclopedias (Weyer & Borning 1985), through programmable hypergraphic systems such as NoteCards (Halasz, Moran & Trigg 1987) and its extensions (VanLehn 1985, Sharp & Gaines 1987), through complex, multi-media systems for literary studies (Yankelovich, Landow & Cody 1987) to knowledge-based, multi-media systems for expert system development (Neuron 1986), computer-integrated manufacturing (Gaines 1986a) and sports coaching (Vickers 1986b, 1987, Vickers & Kingston 1987). The hypermedium concept is significant in capturing the computer-supported, open-ended access to a diversity of media that offers so many attractive possibilities for creative thinking, problem solving and networking by individuals and dispersed groups. It provides a basis for the integration of the very wide variety of resources offered by information technology within a coherent but non-restrictive framework. Data-processing, simulation, information retrieval, text processing, presentation graphics, databases, knowledge bases, expert systems, knowledge acquisition, and so on, may all be regarded in a significant sense as particular aspects of hypermedia systems.

However, the essential openness and generality of hypermedia should not lead to vagueness in the concept or system design In our developments of knowledge-based hypermedia systems we have found it necessary to develop a vocabulary to describe and design various features of these systems, and have also been involved in extensive discussions of what are the essential features of hypermedia. Many general questions have also arisen such as: what essential role does information technology play in hypermedia; what differentiates hypermedia from conventional information technology; what differentiates hypermedia from conventional media?

At the root of the terms, hypermedium and hypermedia, is the notion of a medium that goes beyond existing, pre-1980s, standard media, that is of new and advanced forms of intermediate systems mediating between people and their experience of the world, including other people. Hypermedia are often defined in terms of the technologies involved, such as computers and videodiscs, but these are local to our era and continually changing. Any definition must also take into account the intentions of the designers and users of such systems—to bring people into effective communication with sources of knowledge.

General Definition of Hypermedia

The following definition captures both the intentions and the technology: 'A hypermedia system is one that uses the most advanced technology practically available to facilitate those significant activities which result from increasing the effectiveness of interaction between people and materials relating to knowledge.' This is intended to be as timeless as possible; to subsume the wide variety of activities possible, such as problem-solving and creative thinking; and to leave open the question of what are materials relating to knowledge. At one time it would have been meaningful to regard a book as a highly innovative hypermedium system, and at later times radio and television could

have been similarly regarded. In our era, computing systems, knowledge bases and videodiscs exemplify the 'advanced technology' which can facilitate the 'significant activities' of education, training, decision-making, problem-solving, and so on.

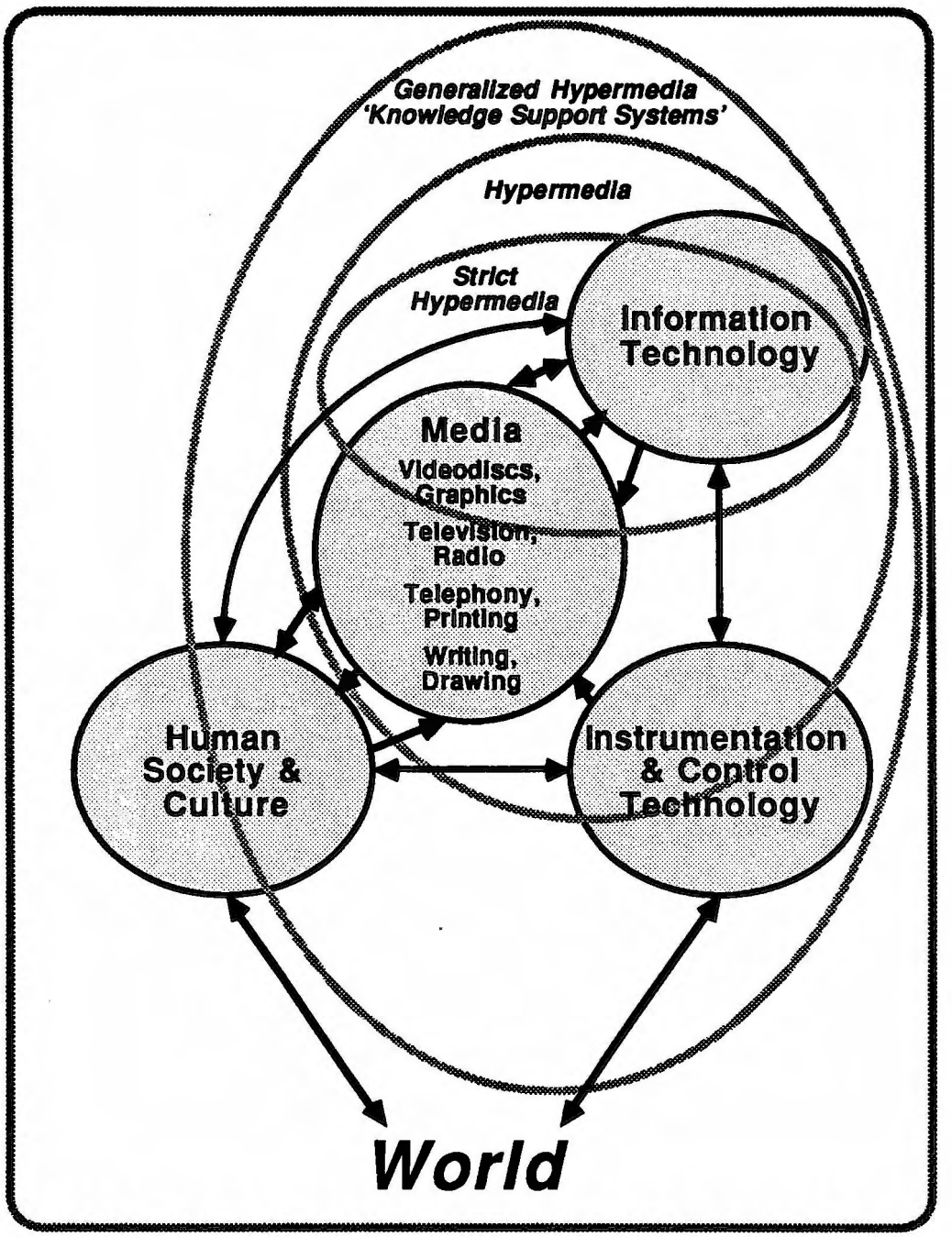


Fig.1 Features of various concepts of hypermedia

This definition still allows for various interpretations, and Figure 1 attempts to capture the key features of various concepts of hypermedia. Four major conceptual areas are involved: human society and culture, particularly its knowledge processes; instrumentation and control technology, particularly transducers that capture audio-visual events in the world; information technology, particularly databases and information retrieval; and media, ranging from basic drawing materials through to videodiscs.

The *strict hypermedia* definition sees hypermedia as integrating some components of information technology and modern graphic and videodisc media. The growing *hypermedia* concept is more general, seeing them as using information technology to extend all past media. The *generalized hypermedia* definition sees them as *knowledge support systems* (Gaines & Shaw 1987) that integrate existing human knowledge transfer processes with information technology, instrumentation and control technology, and the full range of media. There is no conflict between these interpretations—they differ only in their strictness and are usually differentiated by context.

Technologies Within Hypermedia Systems

Generalized hypermedia systems can include conventional media as components and can also include non-mediated human activity and non-human activity. There are situations in interacting with a hypermedium system where it may be appropriate for the system to suggest to the user that he undertake activities quite apart from the system, possibly reporting back on the completion or consequences of the activity, for example, in sports coaching. There are also situations where it may be appropriate for the system itself to interact directly with the world rather than the user, for example, in process control.

There is a spectrum of components from those remote from the human-interactive and computer-comprehended central aspects of hypermedia to the diversity of peripheral ways of transmitting knowledge which may have to be included in a hypermedia system to achieve its overall functionality:

non-human activity, e.g. process control, robotics, computer communication;
human activity not monitored by the computer, e.g. reading, walking
computer-monitored human activity, e.g. typing, gesture, speech
computer-controlled activity, e.g. videodisc display
computer-communicated activity, e.g. pre-stored speech, graphic and text display
computer-generated activity, e.g. computed speech, graphic and text display

Distinctions may also be made about computer-generated activity in terms of the sophistication of the underlying algorithms, for example, that it is formula-based or knowledge-based.

Terminology for Hypermedia Systems

Within hypermedia technology, some important distinctions are worth making: between the hypermedium as a general carrier of information; a form of system using that hypermedium; a particular instance of such a system; and the the material that particular system carries. We use the terms: hypermedium shell, or *hypershell*, for a general system capable of carrying material in a particular hypermedium; hypermedium system, or *hypersystem*, for a particular instance of such a system loaded with material; and hypermedium base, or *hyperbase*, for the totality of material carried by a particular system. These neologisms are necessary to describe precisely the structure and contents of hypermedia systems, and are coined on a model of *expert system shell*, *data base*, *knowledge base*, and so on, so as to link with past referents. They remind us of the novelty and generality of the hypermedia concept which subsumes many aspects of previous media and information technology, but goes beyond them in essentially new features that cannot be subsumed by past concepts.

Two other important concepts in hypermedia are the linkage structure embedded in the material and the paths through the material generated by a user following parts of the linkage structure. We use the term *gateway* for a link within material to other material, and the term *perspective* for the viewpoint into the material that is built up through access to it. These have obvious spatial analogs and correspond to important features of hypermedia, that linkages are embedded in the material and that users build up new viewpoints to the material through their modes of access to it.

Relation to Knowledge Bases

The emphasis in the definitions above on access to knowledge raises the question of the relationship of hypermedia to knowledge bases (Brodie & Mylopoulos 1986). There is an interesting apposition between the two in that hypermedia research has focused on the anarchical nature of much knowledge in that it is unstructured and non-algorithmic, where knowledge base research has focused on the ordered nature of some knowledge in that it is well-structured and computer-processible. The term 'knowledge' has come to be used in a very narrow sense in the computing science literature, as 'those aspects of human knowledge that can be formally represented and processed.' This is a major restriction of the usual meaning of knowledge as 'acquaintance with ascertained truths facts or principles' (Oxford English Dictionary). The philosophical definition of knowledge as 'more than opinion, less than truth' (Runes 1972) captures the colloquial sense and is a useful concept for system development.

The problem is that much human knowledge is implicit in action and not formally represented and processed, possibly not formally representable and processable (Nisbett & Wilson 1977, Gaines 1986b, 1987b). Hypermedia go beyond knowledge bases in not requiring that the information system be able to represent and process the knowledge encoded in the media used. They subsume knowledge bases but extend knowledge representation to include any media whereby human knowledge can be transferred even if there is no means for analyzing that knowledge or its transfer. For example, a film of a skilled person performing a task which enables another person to perform that task better contains knowledge which can be accessed and transferred through a hypermedia system (Vickers & Kingston 1987).

HYPERMEDIA FUNCTIONALITY

As a technology hypermedia are defined by their *functionality*, the technical capabilities that they offer. It is useful to distinguish those aspects of functionality that are: *essential* in that systems without them would not be regarded as hypermedia; *expected* in that systems without them would be regarded as limited examples of hypermedia; and *desirable* in that systems with them would be regarded as particularly good examples of hypermedia. Figure 2 summarizes the definitions relating to hypermedia and the key features of their functionality discussed below.

Essential Functionality

The essential features of hypermedia come from the intention of bringing people into effective communication with sources of knowledge through as direct as possible access to the hyperbase.

Integration: An essential feature of a hypermedium is that the medium itself carries gateways linking materials in the medium. Standard media require external indexes or directories to carry such linkage information. In books, footnotes, sidenotes, literature citations and explicit references may be used to approximate such gateways.

Freedom: An essential feature of a hypermedium is the freedom to browse through the material along paths which are not predetermined, or determined by the system in response to user answers to its questions. A hypermedium is as *mode-free* as possible within a particular context and across contexts. Note that this freedom may sometimes conflict with usability, but this should be overcome through guidance not restriction. A book gives complete freedom to browse.

Hypermedia

Use advanced technology to facilitate interaction between people and knowledge-related materials

Terminology

Hypershell: system to carry material in a hypermedium
Hyperbase: collection of material in a hypermedium
Hypersystem: hypershell loaded with a hyperbase
Gateway: link between materials in a hyperbase
Perspective: structure built to access a hyperbase

Essential Functionality

Integration: provide for materials to carry gateways linking materials
Freedom: allow users to browse through non-predetermined paths
Flexibility: provide multiple perspectives on same material
Usability: provide natural user interfaces

Expected Functionality

Diversity: integrate a range of media and representations
Extensibility: allow users to add new data and new perspectives
Sociality: allow multiple users to access, update and communicate
Spatiality: provide extensive spatial metaphors

Desirable Functionality

Programmability: provide for the incorporation of other programs
Orientability: show users their paths through the hyperbase
Guidability: indicate suitable paths through the hyperbase
Recreatability: allow users to recreate past perspectives
Attributability: allow users to check sources of material
Communicability: aid users to check their understanding of material

Fig.2 Definitions of hypermedia and features of their functionality

Flexibility: An essential feature of a hypermedium is its flexibility in giving multiple perspectives upon the same data and in allowing new perspectives to be established which were not built in to the original hyperbase. Note that new perspectives will often be generated as the side-effect of action, by the user and by the system, such as search activity. There is an analogy to the way in which a traveller may come upon a significant but unexpected viewpoint by virtue of his attempt to get from one place to another rather than by specifically intending to find, or mentally create, that viewpoint as might a skilled artist. With books, perspectives are either inbuilt and fixed or have to be established using additional media such as pencil and paper. Multiple perspective building is common across books since many books contain, or are primarily, perspectives on other books.

Usability: An essential feature of a hypermedium is that the functionality provided is made as usable as possible. The functionality/usability distinction is a critical one in the human factors of computing (Shackel 1983). Ease of access to media has always been important—writing materials, books, phonographs, radio and television are extremely usable—and the incorporation of information technology should simplify access, not make it more complex.

Expected Functionality

The expected features of hypermedia are logical extensions of the intentions, and experience, of bringing people into effective communication with sources of knowledge.

Diversity: An expected feature of a hypermedium is its integration of diverse audio and visual media. Hypertext and hypergraphic systems without audio or videodisc capabilities can be examples of hypermedia, but many of the important design problems do not manifest until a diversity of media are considered. Books are often packaged with material on different media such as audio and video cassettes, particularly those concerned with training.

Extensibility: An expected feature of a hypermedium is its extensibility in allowing new material and new perspectives to be added to the hyperbase. Some components of current hypermedia systems, such as videodiscs, are not extensible at this stage of the technology. This is a significant limitation to their role in hypermedia and to the utility of particular hypermedium systems. A major design objective for a hypermedium system is to overcome this limitation, in the short term by providing remedial extensibility through the storage media of the computer, and in the long term by developing extensibility in components such as videodiscs. Some teaching books attempt extensibility by leaving blank pages for student notes, but books are generally not extensible.

Sociality: An expected feature of a hypermedium is its sociality in allowing multiple users to access and update a hyperbase. Nelson, in particular, has emphasized the communicative, social role of hypermedia (Nelson 1980). The designers have noted that, "One of the biggest limitations of NoteCards is the lack of support for collaborative work" (Halasz, Moran & Trigg 1987), and suggested extensions remedying this (Trigg, Suchman & Halasz 1986). Books allow for access sociality through widespread distribution of copies.

Spatiality: Existing hypermedia may be seen as making strong use of a spatial metaphor. Information is laid out in space and linkages are seen as paths accessed through gateways. This is so natural that it may not be seen as a metaphor, that is, knowledge in general has no intrinsic spatial representation, but we are so used to its presentation in books and through diagrams that we are conditioned to think of much knowledge in spatial terms. Other metaphors are possible and commonly used in our language: such as time, force, and human aggression (Lakoff and Johnson 1980). It would be interesting to see how these could enter into hypermedia. Smith (1977) suggested in his design for Pygmalion that led to the Xerox Star (Smith, Irby, Kimball, Verplank, & Harslem 1983) and Apple Macintosh user interface designs that visual thinking was at the heart of creativity. A high proportion of the human population uses the spatial metaphor and visual thinking for problem solving. However, there are many other bases for creative thinking and these

should be considered in the development of hypermedia. Books use spatial metaphors not only in diagrams but also in the typography of two-dimensional page layout. They also impose an often unwanted temporal metaphor in the serial progression of pages.

Desirable Functionality

The desirable features of hypermedia stem from the opportunities offered by hypermedia to subsume, and give effective end-user access to, many information technologies.

Programmability: A hypermedium shell provides an extraordinarily powerful end-user interface to a computing system, providing for intelligent help and presentation facilities to any depth required. To make use of this potential the shell must provide programming hooks into other programmed systems for dataprocessing, simulation, databases, and so on. A major limitation of simple hypergraphic systems is that they are not programmable in this way. NoteCards provides programming capabilities but only within the Lisp environment. Books lack programmability.

Orientability: One of the defects of current hypergraphic systems is that it is easy for the user to become disorientated, losing track of where he is in the hyperbase, along what path he has arrived there, and what further territory is open to exploration (Conklin 1986). It is desirable that some form of overview facilities be provided to map the hyperbase and show the user's path through it. Indexes and flow-charts attempt to aid orientability in books, and, for large works such as encyclopedias, great efforts may be made to provide access aids, for example the *Propaedia* of Encyclopaedia Britannica.

Guidability: It has already been noted that the requirement for *freedom* may conflict with that for *usability*. A mode-free system that makes every possible choice available to a user may be difficult to use because it places an excessive decision-making burden on the user. The hypersystem should make provision for a range of different forms of guidance which do not restrict choice but indicate the basis of choice, the most likely choices, and the reasons for these. Some of this can be embedded within the material which provides a local context, but other guidance is essentially global and needs to link with the orientability functionality, for example, highlighted suggestions for further exploration on the overview map of the hyperbase. Again, attempts may be made to provide access guidance for books, but they are restricted by the need to have the entire range of possibilities visibly present.

Recreatability: To optimize their perspectives users may take advantage of the freedom to browse through the system looking for relevant data. However, it is possible that they will regard the finishing perspective as less desirable than some earlier one, and it is important that they can checkpoint a perspective at any time and recreate it easily. Page markers are a simple aid to recreatability with books.

Attributability: A hyperbase contains a diversity of information of various origins, dates, and reliability. It is desirable that a user be able to check the attribution of material. Technically, this can be just another gateway, but it requires proper management of accessions to the hyperbase. In many book applications proper attribution of sources is regarded as very important.

Communicability: It is never clear to either user or system wether material presented to a user has been understood. At times this can be very important, and it is desirable that explicit gateways are established to material which checks the understanding of other material. In educational applications, hypermerdia can provide an open-textured, rich, supportive environment corresponding to the modern *ecological* paradigm (Gaines 1987a). However, it is important to make provision for both system and student to ascertain the extent to which knowledge has been communicated. Pask (1976, 1980) in his *conversation theory* has discussed the significance and difficulty of establishing an "agreement over an understanding," and developed techniques very

applicable to hypermedia. The explanation facilities of expert systems may be seen as an attempt to provide the rudiments of this type of communicability (Hughes 1986, Swartout 1986), but are currently restricted to output of more detailed computer reasoning rather than input and validation of the user's understanding. Educational books, in particular, attempt to provide exercises and commentaries that aid the students in checking their understanding.

Designing Hypermedia Shells

The list of functionality required, expected and desired in hypermedia systems may seem extensive but there is nothing within it that is not already available, or readily built, in commercially available computing systems. It is straightforward to design and implement systems with the functionality specified above if these design requirements are specified at the outset. A hypermedium shell is a logical extension of existing human-computer interaction shells on workstations, intelligent terminals and personal computers. All of the functionality specified is highly desirable to users of modern advanced computer systems where even simple personal computers may offer extremely complex facilities. Much of the functionality is already available through window/mouse graphic interfaces but not necessarily incorporated appropriately in applications.

The IRIS INTERMEDIA system at Brown University (Yankelovich 1986) is an oustanding example of the clean architecture and powerful extensible functionality that can be achieved using modern hardware and software technology, particularly an object-oriented design (Garrett & Smith 1986, Haan, Drucker & Yankelovich 1986, Meyrowitz 1986). The weaknesses of most existing hypergraphic systems stem largely from the operating environments in which they have been developed. Notecards lack of sociality, and its programmability only in Lisp, are due to limitations of the Xerox Lisp machine environment. The lack of a multi-tasking operating system on the Apple Macintosh has limited the programmability of products such as Guide and Learning Tools. Workstations with programmable window systems such as X-Windows integrated with multi-tasking operating systems having good inter-process communications such as Unix can readily provide most of the functionality specified. Recent developments such as the open architecture version of the object-orientated expert system shell, Nexpert (Rappaport 1986), on the MicroVax and Mac II make possible knowledge-based orientability, guidability, and communicability. The multiple screen capability of the Mac II makes it feasible to use a level IV interactive videodisc (Lambert & Sallis 1987) driving a fully-integrated display.

SOME HYPERMEDIA SHELLS AND SYSTEMS

In comparing books and hpermedia, it is appropriate to outline some of our experience in unusual hypermedia developments. Whereas many hypermedia systems are designed primarily for passive information retrieval from large multi-media hyperbases, we have also been concerned to integrate knowledge elicitation, expert systems and intelligent computer-assisted learning into hypermedia systems.

Knowledge Support System Zero

KSS0 (Knowledge Support System Zero) is a hypermedium shell designed to support the knowledge acquisition and transfer processes involved in the rapid prototyping of expert systems (Gaines 1987b). It operates on networked Macintosh computers and videodisc players, integrating a wide range of knowledge acquisition tools within a hypergraphic framework. In particular, the attribute elicitation techniques used by KSS0 to elicit the conceptual structures of experts are very natural ways of determining linkage structures for hypermedia. An attribute is one pole of a bipolar distinction applying to a class of objects and particular attributes provide natural links in a hyperbase, for example *refutes—supports* (Trigg 1983). Figure 3 shows entities being rated on elicited attributes in an interaction with KSS0 in the *InSport* system. The videodisc is used to illustrate entities, attributes and case histories in the domain under discussion. The knowledge

elicitation and analysis modules within KSS0 have been incorporated in other hypermedia systems as tools to elicit user models, generate advice, and indicate appropriate individualized perspectives on the hyperbase.

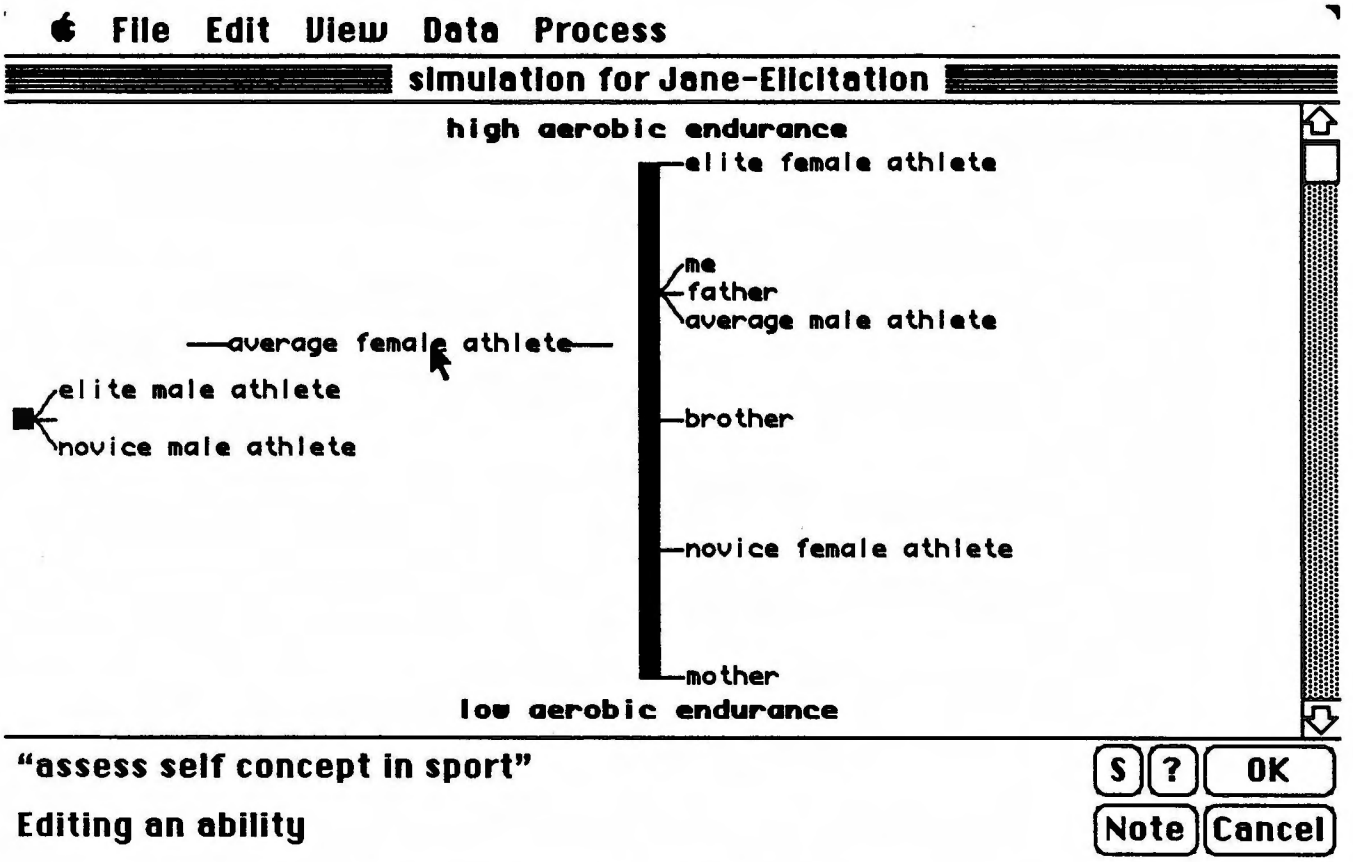


Fig.3 Rating entities on attributes in KSS0

InSport

InSport is a hypermedium system designed to aid those wishing to improve their involvement with sporting activities. It combines five sub-systems: a videodisc containing information on sports particularly relevant to a novice; an iconic interface to the videodisc representing spatially the knowledge structures underlying sporting activities; a personal knowledge elicitation system interviewing users on their perceived status in sports relative to various relations and role models; a cluster analysis mapping the user's relation to the role models; and a knowledge-based advisor highlighting a perspective within the iconic interface to suggest useful material for the user to review from the videodisc.

Figure 4 shows a FOCUS (Shaw 1980) cluster analysis of entity-attribute relationships generated by KSS0 and used in *InSport* to provide feedback and advice to the user. For example, Jane can see that she views herself and her brother as clustered with elite athletes, her father with average athletes, and her mother with novices. The uniform clustering of males and females shows that she is making no sexist distinctions. Her high estimates of her aerobic endurance and anaerobic power lead to training advice different from that if they had been low. If she had not understood these technical terms she could have asked for explanations through material on the videodisc. *InSport* operates on a Macintosh computer and videodisc player to generate a highly supportive environment for those desiring to participate fully in sporting activities but finding perceived, or actual, impediments to doing so.

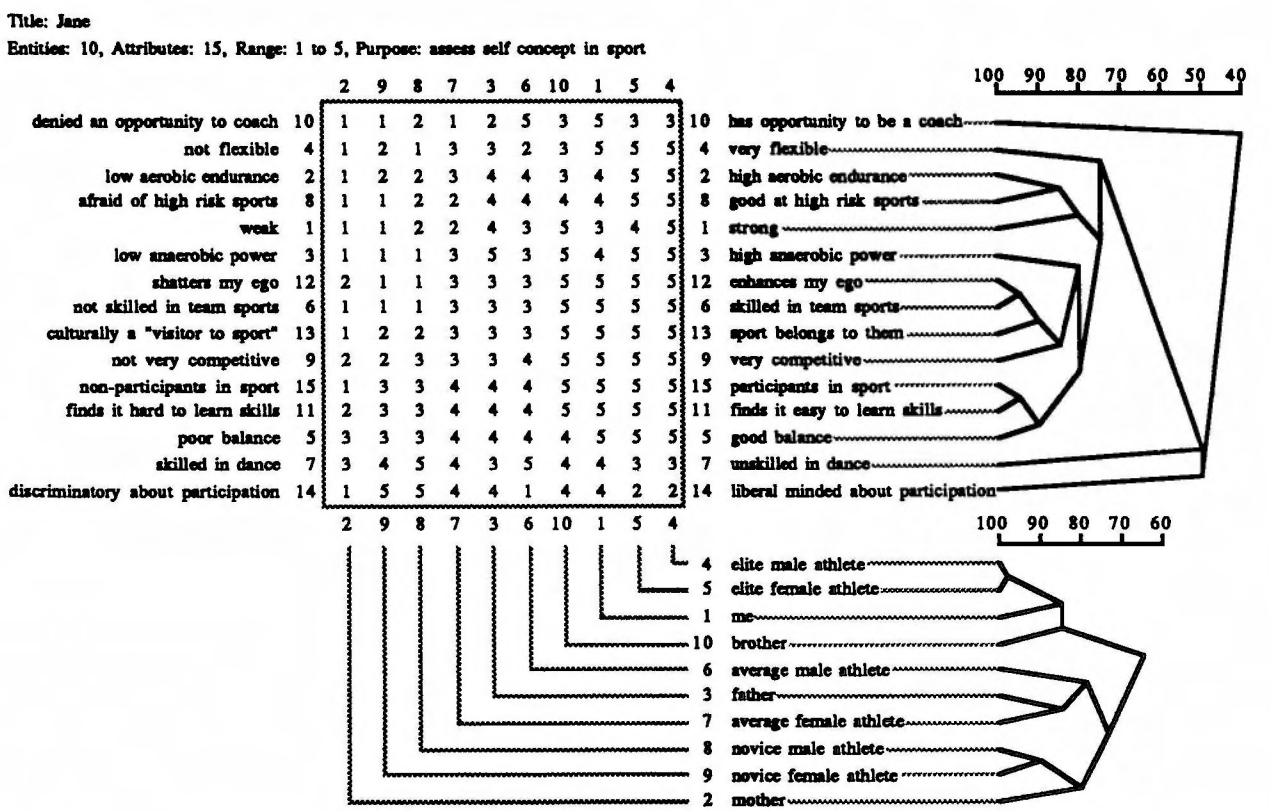


Fig.4 Cluster analysis used to give advice and feedback from KSS0 in *InSport*

Knowledge-Based Coach System

KBCS (Knowledge-Based Coach System) is a hypermedium system designed to aid coaches in the development of their skills and those of their players and teams. It subsumes the technology used in InSport but places greater demands on it because of the much greater range of detailed knowledge structures required in a professional context. It is based on research concerned with the modeling the cognitive processes of athletes through monitoring their eye movements when watching the performance of other athletes (Vickers 1986a, in press a). Previous to this the knowledge structures of master coaches and teachers were developed using other techniques (Vickers 1983)—namely, content analyses of sport specific technical and film sources, followed by the development of hierarchies in consultation with the expert coach or teacher. The development of knowledge structures then leads to new teaching techniques based on structured knowledge acquisition. Structures have been developed for a wide range of individual sports, team sports, dance activities and outdoor pursuits, including archery, backpacking, badminton, basket ball, bowling, jazz dance, golf, gymnastics, ice hockey, racquet ball, softball, swimming tennis, and volleyball. Figure 5 shows the top level of a knowledge structure developed as a declarative schema for badminton (Vickers & Brecht 1987, in press a,b).

Technology Management System

We have a number of related hypermedia developments including TMS (Technology Management System) to aid the design and management of flexible manufacturing systems, incorporating a videodisc catalog of robots and machine tools, an expert system advisor, machine grouping optimization and animated simulation (Gaines 1986a). Figure 6 shows how each specialist area of manufacturing knowledge is represented as a *knowledge island* that has within it the datasets and procedures specific to that knowledge. Data from external sources triggers off processing within

an island that eventually results in processed data being passed from one island to another. This is in turn triggers further data processing in the other knowledge island which eventually propagates to other islands. Some islands have external connections that pass conclusions, recommendations for action, out to the external world. Islands are distinguished by the relative homogeneity of the data and processing within them. Connections between them represent data which is relevant to more than one island, but probably relevant in very different ways. The structure is fully recursive in that islands generally have sub-islands within them and group naturally into areas.

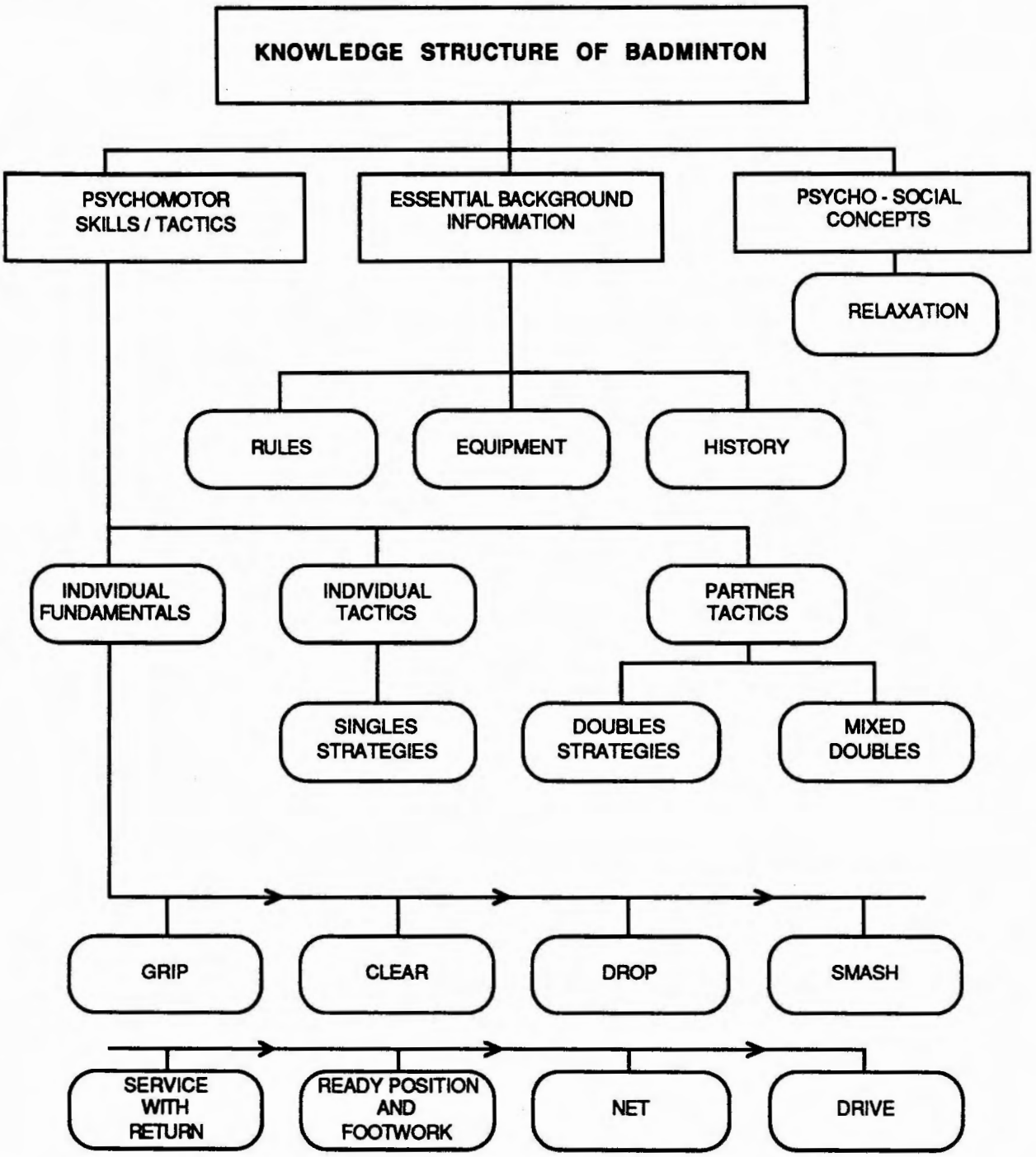


Fig.5 Top level of declarative knowledge structure for badminton

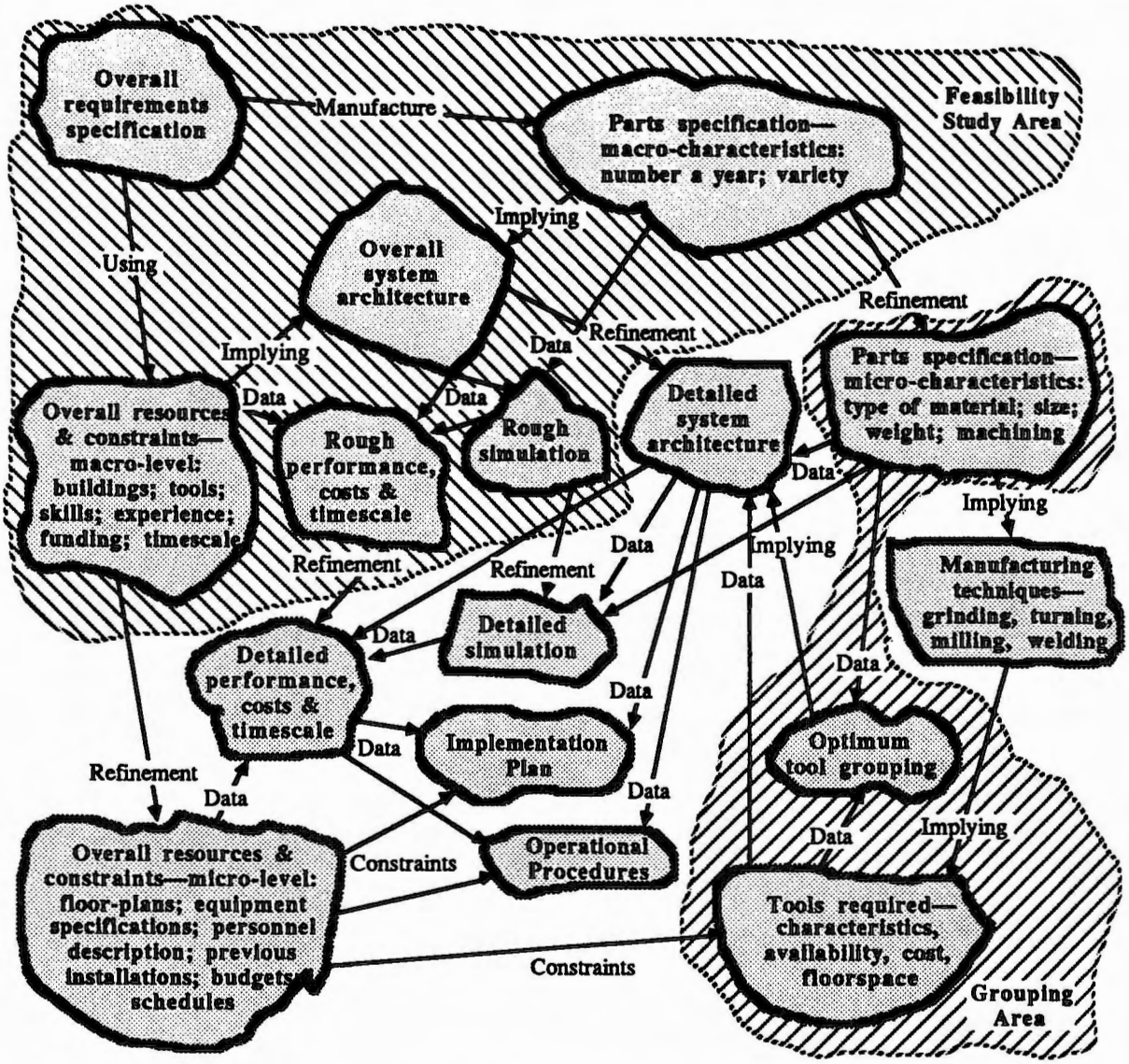


Fig.6 Knowledge islands for integrated manufacturing systems

User Interface Problems

In all the systems developed a number of common problems have arisen with the user interface, particularly user disorientation and problems of lack of modality. A very open-ended, multi-functional, multi-media, multi-window, multi-activity system may seem very attractive in the functionality, flexibility and freedom it offers the user, but it can feel like attempting to drive a supersonic fighter with experience of domestic automobiles! The following sections describes our approaches to overcoming these problems, first, in the hyperbase, through the use of detailed knowledge structures as the basis of overall system design, and second in the hypershell, through the modular design adopted for the more complex systems.

THE KNOWLEDGE STRUCTURES APPROACH TO BOOK AND HYPERMEDIA DEVELOPMENT

The flexibility of hypermedia is often contrasted with the rigid seriality of books. However, as we have already noted, a well-designed book is not necessarily rigid or serial in its organization, and it

can achieve many of those things claimed for hypermedia. Yankelovich, Meyrowitz and van Dam (1985) have given a well-balanced survey of the relative advantages and disadvantages of books and hypermedia. The new technology does have significant advantages, but it also has disadvantages also such as comparitively high cost, lack of portability and problems in 'flipping through' in a browsing mode. The comparison of hypermedia of books needs to be taken to a level of detail where the significant differences can be analyzed. We shall argue that the technologies of books and hypermedia have many features in common, are complementary in their applications, and that a knowledge-based design approach can generate materials in both media that can be complement, rather than compete, with one another.

Perceptual-motor skills are notoriously difficult domains within which to elicit underlying knowledge structures (Nisbett & Wilson 1977, Bainbridge) and most developments of expert systems have been concerned with cognitive skills such as decision-making where the expert can verbalize the activity, although even then the experts' explanations may not fit their behaviors (Michalski & Chilausky 1980). However, the development of *knowledge structures* for *action* has been found to be possible for many significant sports activities, and to lead to a model for instructional design that can be applied to the generation of material for both coaches and individual athletes (Vickers 1983, in press b). This model, and the knowledge structures involved in a particular sport, applies to the development of both books and hypermedia. The following sections outline the model, exemplify the knowledge structures, and show how they are used in different media.

Knowledge-based Instructional Design Model

Figure 7 shows the knowledge-based instructional design model (Vickers 1983) used in the development of books and hypermedia. It has eight modules in three phases:-

- The analysis phase is concerned with the knowledge structures underlying:
  - —1 the activities to be taught;
  - —2 the learners;
  - —3 the learning environment.
- The decision making phase is concerned with the use of the knowledge structures to generate actual training material involving decisions about:
  - —4 the scope and sequence of activities, particuarly the use of a top-down or bottom-up approach;
  - —5 the objectives to be achieved;
  - —6 the evaluation of whether these objectives have been achieved
  - —7 the actual teaching and training progressions.
- The applications phase is concerned with the realization of the material in a particular form for a particular purpose, such as:
  - —8.1 lesson and practise plans;
  - —8.2 unit and season plans;
  - —8.3 school curricular and sport development programs;
  - —8.4 individualized programs for teaching and coaching;
  - —8.5 Computer-based learning systems.

The term *knowledge structure* at the top of Figure 7 originates from Glaser's (1984) work on competence models and Winograd's (1975) on declarative and procedural structures. Knowledge structures are a convenient encapsulation of information relating to a skill for purposes of communication, capturing the "cognitive economy" (Rosch 1978) of an expert. They are best thought of like maps to a territory, useful as ways of discussing location even if the divisions are arbitrary, but even more useful if some of the divisions are contours of significant features like rivers and mountains.

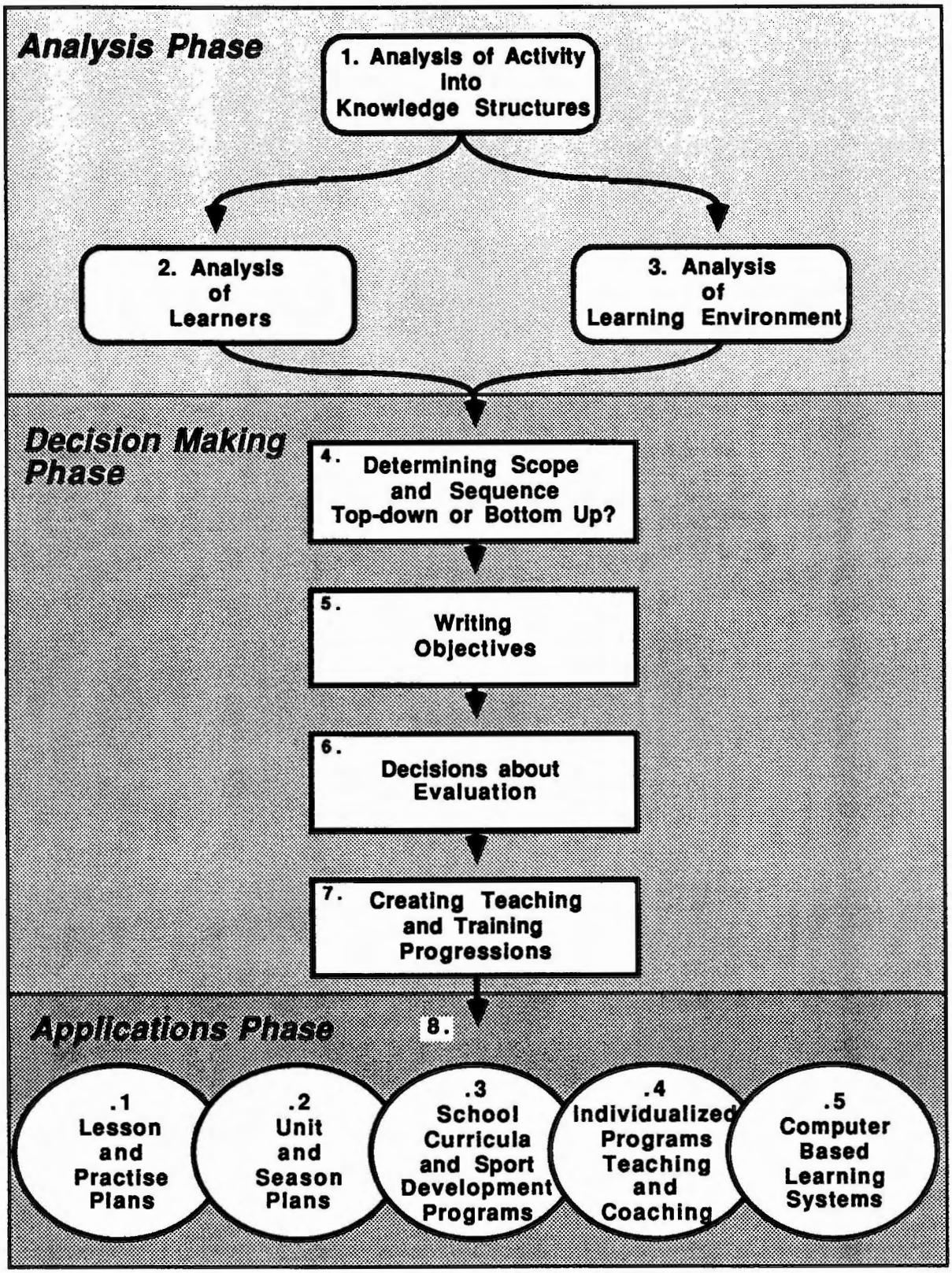


Fig.7 Instructional design model utilizing expert knowledge structures

A knowledge structure for action, such as that shown in Figure 5, names all the *skills* in an activity and for each skill, their subskills. For each *subskill,* selected biomechanical, motor learning and other technical points are represented. This information is ordered hierarchically based upon transfer of training principles, ease of learning, and the expert opinion of master teachers and coaches in the field. Also identified are *the strategies and tactics* of the activity placed in a hierarchical arrangement beginning with individual tactics and leading to partner, three plus, full game and special situations. In addition to skills and tactics, a knowledge structure also identifies categories of *background information* for teaching or coaching such as safety, rules, equipment, historical or other areas as selected by the analyst. A third analysis centres upon the *physiological/training area* and includes warm-up, conditioning, training and medical information. Finally, a knowledge structure can present selected *psychological/sociological concepts* such as relaxation techniques, motivation, leadership, and professional roles.

The extent to which each of these areas is emphasized determines, to an extent, the philosophy of the resultant sport and physical education curricula. If a skills training program is desired then the *psychomotor skills and tactics* categories will be developed more so than the other areas. If demonstrated *knowledge about physical activity* is considered an important outcome, then selected concepts in the *physiological/training* and *psychological/sociological* areas will be emphasized. If an *affective* or *humanistic curriculum* is sought then the *psychological/sociological* analyses will take precedence. A major strength of a knowledge structures approach is that the analysis can be tailored to emphasize the type of curricular content required.

Module two in Figure 7 analyzes the learners in terms of, given what we know about the skills and strategies of an activity, what do we know about how people with different age and ability levels learn the sport? The types of information provided here are: what are some strategies for finding out about learners; how can you determine entry level skills and understandings; are there unique safety concerns in this sport; what do we know about skill acquisition in this sport, the novice to expert transition?

Module three analyzes the learners in terms of the basic requirements needed in order to teach the sport or activity. Five areas are covered: safety; facilities; equipment; cost; time factors; and game modifications.

Module four makes decisions about the scope, the types of content selected from the structures, and the sequence, the order in which content is to be presented. Decisions about two strategies are particularly important: a bottom-up strategy means that content is selected from the bottom of the structures upward and from the beginning of the structure, flowing to the end; a top-down strategy means that material is selected from the top of the structures first, such as concepts, full game tactics, holistic ideas, and then bottom content is then selected to develop these concepts.

Module five makes decisions about the objectives to be accomplished. For each skill or concept, novice to expert objectives are written, either for each item identified in the knowledge structures, or following the scope and sequence charts devised for specific classes. Objectives are stated in terms of:

a) psychomotor technique (this material has already been identified in the structures)
b) psychomotor performance—the quantification of skill (accuracy, time, consistency)
c) background knowledge—about rules, technique, tactics, physiological, psychological, and sociological concepts
d) psycho-social areas—emotional growth, values.

Module six makes decisions about a formal evaluation system, as a vehicle for providing feedback, as a formative evaluation and motivational aid. In some contexts, evaluation may be required in order to assess students relative to established criteria or to one another and to assign a final grade.

Module seven makes decisions about the selection and design of learning activities based on the knowledge structures to help the students achieve the objectives.
Module eight has multiple branches because the information identified in modules one through seven can be used in different settings, such as: a) Lesson or practice planning; b) Unit or season planning; c) School curricula or sport development programs; d) Individualized programs; e) Computer based learning systems.

Implementation of the Instructional Design in Books and Hypermedia

Knowledge-based instructional designs can be implented very simply and naturally in book form, demonstrating that books are capable of carrying the highly structured mixture of text, hierarchical structures and photographic material associated with hypermedia. Figure 8 shows a page from a badminton instruction book (Vickers & Brecht 1987) showing the detailed biomechanical sequences in variants of the forehand clear in badminton. The small reproduction of the overall structure of Figure 5 at the top left places the material in context for the student. Figure 9 shows the facing page in the book containing the time lapse photograph of an expert performing the overhand forehand clear, numbered according to the knowledge structure in Figure 8. Thus the student is able to focus of a particular complete activity which forms a major component of badminton play, see it analyzed as an activity sequence, and see that sequence played out by an expert. Detailed scope and sequence tables, teaching progressions and learning activities, and performance objectives, are given based on these knowledge structures.

What does hypermedia realization of such material add to the book form? First, the knowledge structures involved, while generally far simpler than students expect, are fairly large in book form, taking tup to fifty pages of detailed charts. They are daunting at first although the serious student rapidly becomes fascinated by them. The hypergraphic presentation of the hierarchical knowledge structures on a computer screen is less daunting, and clicking on them with the mouse to access different levels is simple and natural. The computer is particularly useful in keeping track of objectives and their achievement, and presenting this dynamically in attractive graphical form. Figure 10 shows screens from ActionMark (Vickers 1987), a program using the knowledge structures to: present the skills being taught in order of presentation; describe how improvement in each skill can be attained; keep track of improvement in each skill; test on knowledge of rules, technique, tactics and so on; provide a total score for each student at any point in time; let each student know how they are progessing on each skill relative to others in the class; and provide students and instructors with a variety of records and printouts.

The ActionView component of ActionMark gives access to a videodisk containing relevant information to each skill. It replaces the time lapse photograph of Figure 9 with a video sequence of the expert in action, allowing each stage in the biomechanical sequence to be shown stopped, and then linked into context by forwards and backwards slow and normal motion under the control of the student. This particularly important in terms of *cognitive biomechanics*, how we cognitively understand what is observed, read, heard or kinesthetically sensed in a physical movement. It is a term that can be applied to both performers and observers of performers, such as teachers, coaches and judges. A person proficient in cognitive biomechanics knows the function, the purpose of the movement and the biomechanical qualities that must be perceived in order to provide optimal feedback and assistance. For teachers and coaches, this type of information must ultimately be determined perceptually/cognitively, and is dependent upon their ability to observe a performance and judge the skill against some internal template or knowledge structure. The videodisc provides a means for transmitting this template that cannot be emulated verbally and provides capabilities that watching athletes directly cannot. Slow motion, repetition, and overlayed graphics can provide an attention-directing analysis of key features of the activity that train the students' perception in a way that is very difficult in real time.

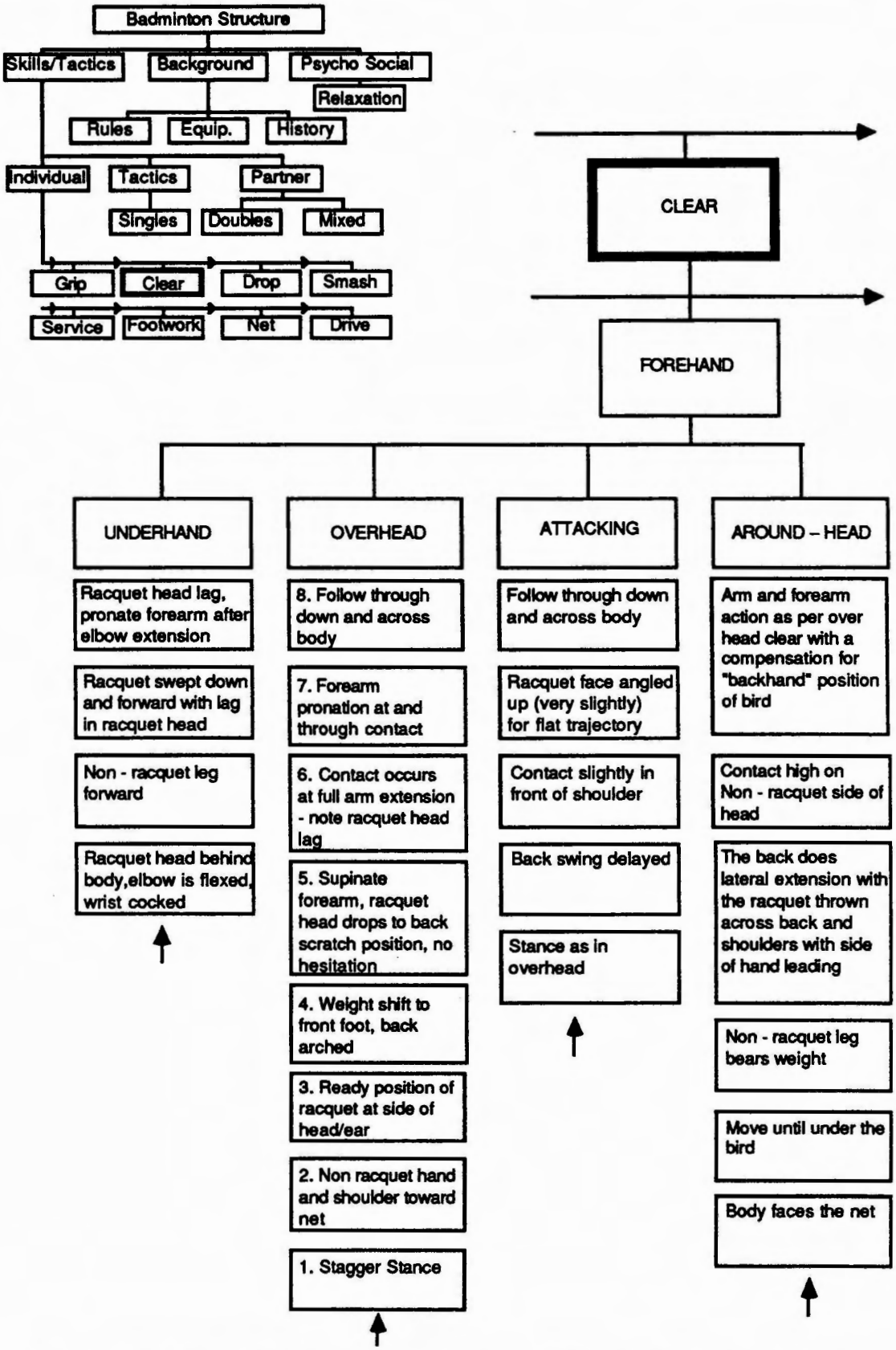


Fig.8 Knowledge structures for action—forehand clear in badminton

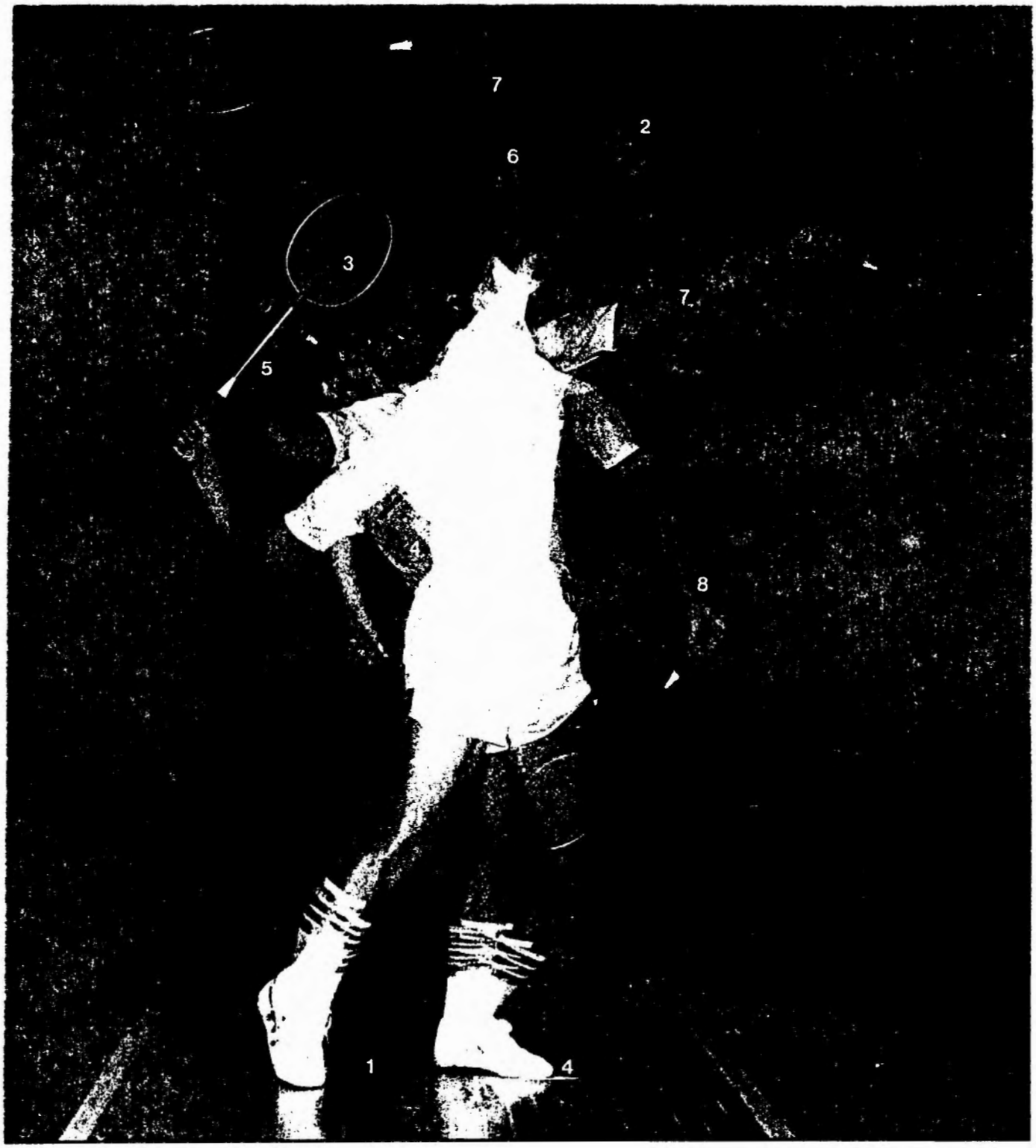
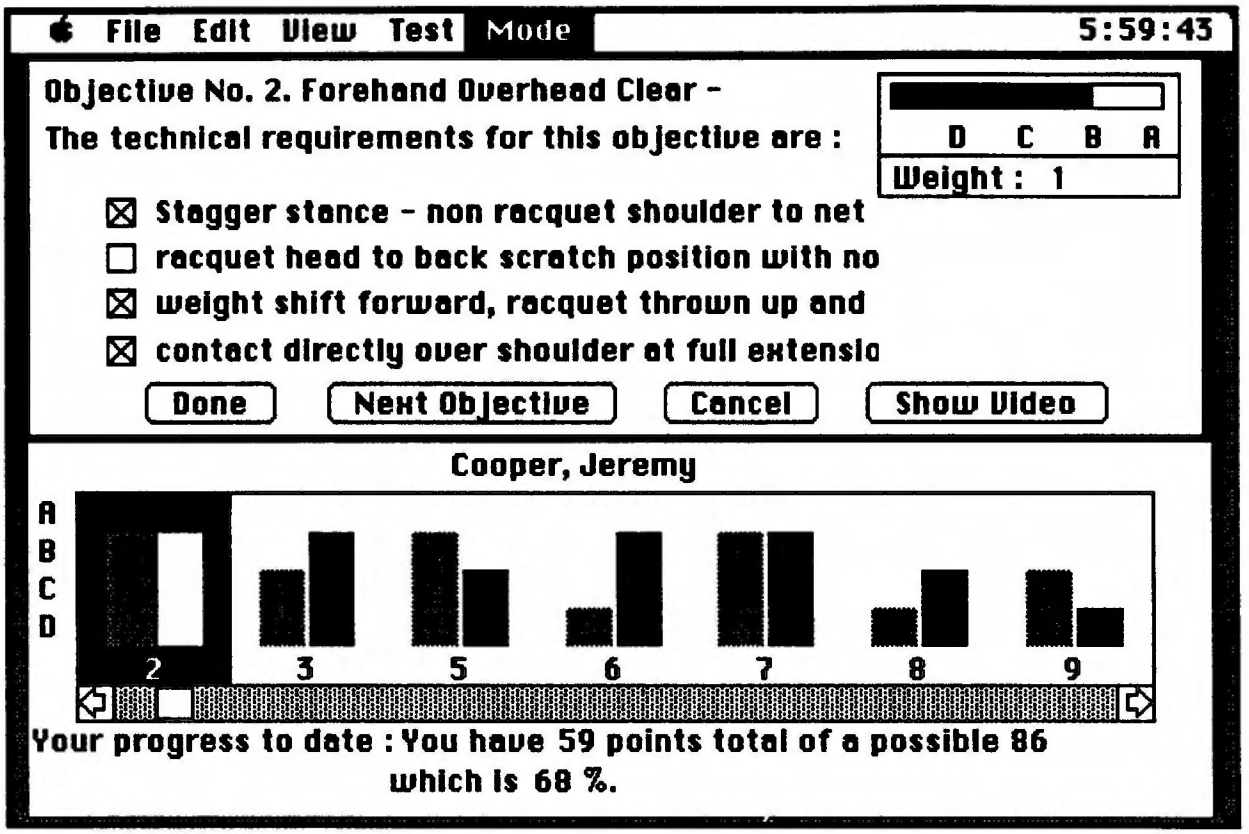


Photo By Dac Dang

Fig.9 Associated photograph illustrating action in the forehand clear



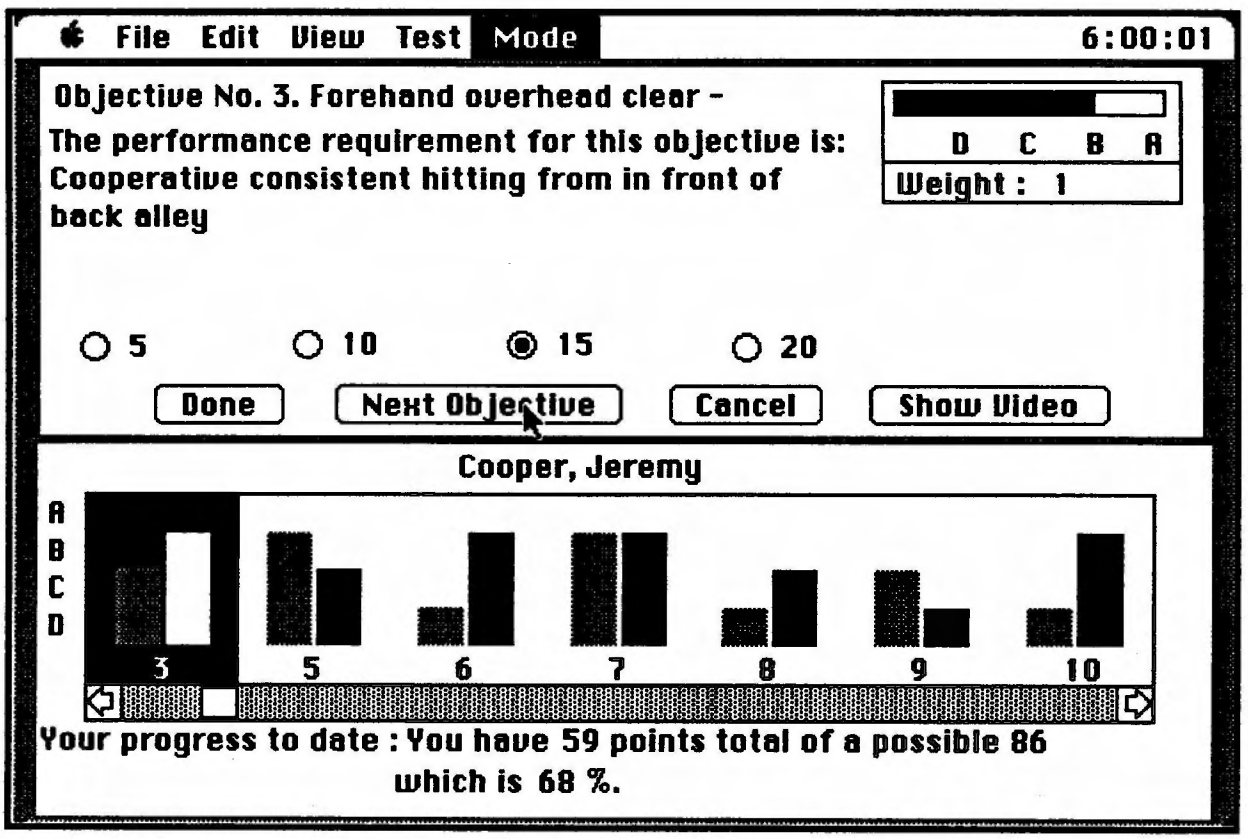


Fig.10 ActionMark screens showing technical and performance objectives

Thus, books can be used in a highly structured fashion to impart skills, but some aspects can be significantly improved through hypermedia. The combination of the low-cost, portable book as a study aid to the student, and a hypermedium system as a supportive learning environment will be the most effective approach in the short- and medium-term. It is particularly attractive to develop both systems together since the hypersystem provides a very productive development and validation environment for the knowledge structures, and desktop publishing extensions can be used to produce the book from the hyperbase.

HYPERMEDIA SHELL DESIGN

Usability and orientability requirements coupled with the problems of embedding gateways in videodisc material (we are currently using non-interactive level 3 systems under computer control without integrated graphics) have placed special emphasis on designing effective maps to the hyperbase. Figure 11 shows two approaches that we have found effective and mutually compatible in giving a user understanding of, and control over, access to our hypergraphic and videodisc sub-systems, and the building of perspectives on both.

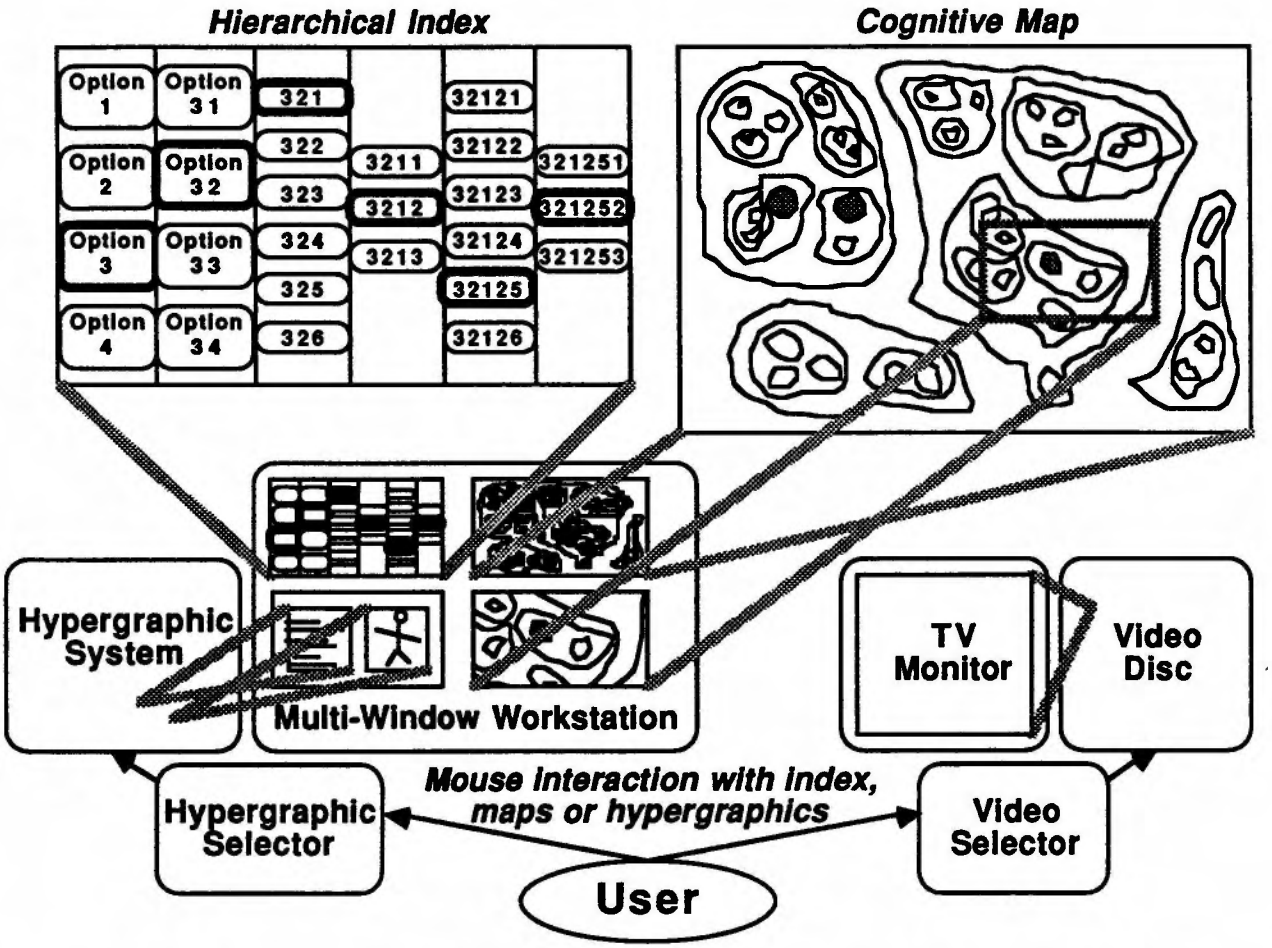


Fig.11 Hypermedia access through a hierarchical index and a cognitive map

The *hierarchical index* is a straightforward representation of the knowledge structure of Figure 5. Each level is represented by a set of buttons in columns from left to right. Initially only the leftmost buttons are visible, corresponding to the four knowledge domains at the top of the hierarchy. Clicking on one of these buttons selects the relevant domain and makes visible a second

set of buttons, specific to the first-level selection, for second-level selection. By successive clicks the user can descend to the lowest levels of the hierarchy and select a specific topic. Double clicking on any button gives access to the hypergraphic system or video disc as appropriate and causes content material to be displayed. The buttons in the Figure are numbered to show the selection sequence but normally have meaningful textual labels.

This hierarchical index gives rapid access to the hyperbase and has the advantage that a large amount of material can be accessed through a small window. It goes some way to orientability by showing the path taken through the hyperbase. However, it cannot show: the relation of the path to alternatives; which material is recommended for access; which material has already been accessed; and what relations exist between materials. The *cognitive map* is a second representation of the knowledge structure which gives these additional features at the expense of compactness. The map shown represents the hierarchical structure of Figure 5 through enclosed knowledge islands which are again clickable and double-clickable for selection and hyperbase access. Multiple windows may be opened on the map and zoomed as required, usually one showing the overall map on a smale scale and others showing specific areas of interest in greater detail.

The map is marked to indicate material recommended for access and material already accessed. It can be used to display a variety of forms of auxiliary information through dynamic overlays, for example relations between one topic and other topics on the map. This allows for multiple hierarchies corresponding to different relations in the same hyperbase, for example, the declarative structure of a sport is shown as an *instance-of* hierarchy whereas the components of a tactic in terms of individual skills is a *part-of* hierarchy. Such maps can represent non-hierarchical and mixed relations equally well. The index and the map are mutually compatible systems which complement one another in operation and can be used together since they mutually update one another, for example, the index provides a labeled access path when a low level topic is selected in the map.

The problems which counterbalance the advantages of a freely-accessible, nearly modeless, system have also been major design considerations. We have introduced the concept of a *recommendation for access* as a way of highlighting appropriate paths and perspectives for the user without forcing him to follow them. The recommendations may come from a wide range of sources but it is usually convenient to think of them as generated by an expert system acting in an advisory role based on a user model. For example, in InSport we use the knowledge elicitation process of KSS0 shown in Figure 4 to generate a simple user model, feed it back directly as generated hypergraphics as shown in Figure 5, and use the model to recommend access to the hyperbase through highlighting a cognitive map as shown in Figure 6. Figure 12 shows how these activities interact to give individualized advice generation as a front-end to a generalized hyperbase access through a cognitive map.

KBCS, the sports coaching system, is similar to *InSport* in its basic structure but involves multiple complex knowledge structures and processing as shown in Figure 13 where they are organized to bring out the general architecture. In the top layer: the *user model* and *domain model* have already been discussed; the *action model* contains coaching sequences; the *performance model* contains evaluative criteria; and the *conversation model* contains procedures for checking that material is understood. In the next layer: the *specific user* data and *advice* generation have already been discussed; the *in-system activity* keeps track of users' accesses to the hyperbase; the *out-system activity* allows actual training to be recorded; the *evaluation* data keeps track of performance levels; and the *understanding* data keeps track of what material has been checked as understood. The next two layers contain procedures for processing the knowledge and giving access to the hyperbase.

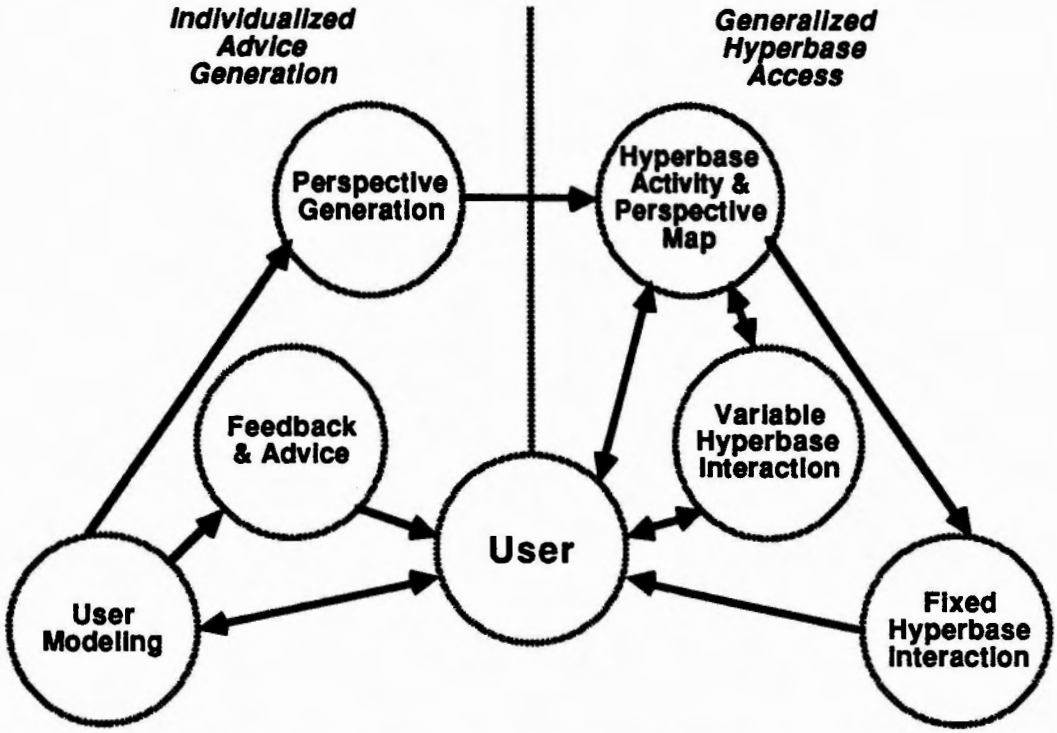


Fig.12 Advice generation front-end to hyperbase access through a cognitive map

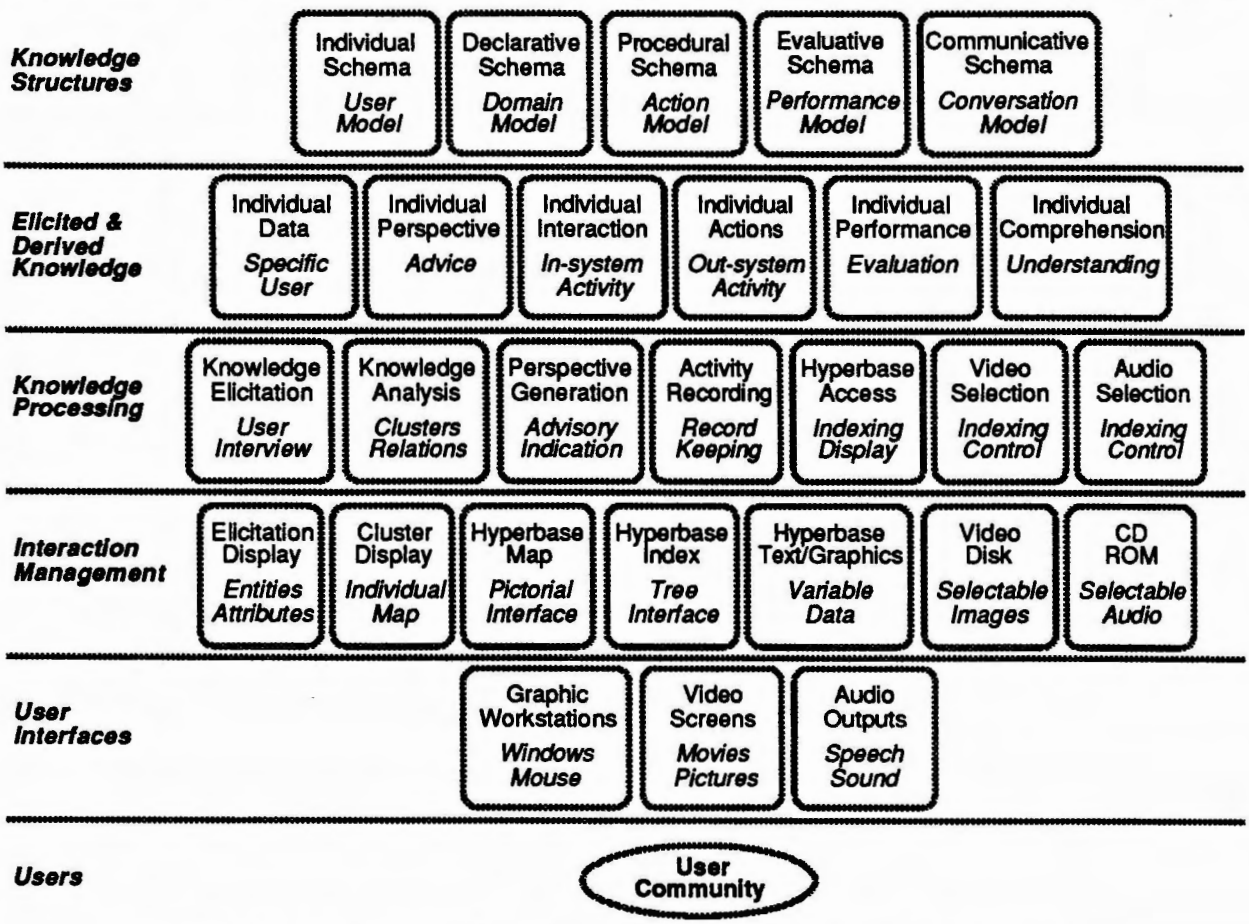


Fig.13 Architecture of a knowledge-based hypermedium system

Currently all the systems are implemented in Pascal and the knowledge structures are used through fairly simple table-driven logic. The next implementation is being developed as an integral part of the open architecture version of the object-oriented expert system shell, Nexpert, and will offer much greater power and flexibility in the use of the knowledge structures and in their dynamic updating. The combination of expert system shell, knowledge acquisition system and hypermedia system is expected to give a very powerul knowledge-based hypermedia shell that can be used in a wide range of applications. In particular, knowledge-based hypermedia systems are a major advance in our capabilities to develop intelligent computer-assisted learning systems based on the *ecological paradigm* which educates by providing the student with a supportive experiental environment (Gaines 1987a).

CONCLUSIONS

Hypermedia may be seen as a very significant stage in the evolution of media in general, and in that of information technology as a medium for human knowledge in particular. The new possibilities for interactive communication with passive and active stores of knowledge provided by new generation computing systems create opportunities for further enhancement of human intelligent activity through new media. The hypermedia concept provides a basis for the integration of the very wide variety of resources offered by information technology within a coherent but non-restrictive framework. Data-processing, simulation, information retrieval, text processing, presentation graphics, databases, knowledge bases, expert systems, knowledge acquisition, and so on, may all be regarded in a significant sense as particular aspects of hypermedia systems.

This paper has analyzed the essential, expected and desirable features of hypermedia systems in order to give a basis for system specification, design and evaluation, and to attempt to avoid the trivialization of the term hypermedia through its loose application. Examples have been given of knowledge-based hypermedium systems from our own developmental experience, and specific techniques for improving usability and orientability, and overcoming problems of mode-free operation, have been described.

Books and hypermedia are complementary, rather than competetive, technologies. Much of what is claimed for hypermedia can be achieved through well-designed books, and, in the large-scale, by well-structured libraries. It is particularly attractive to use a hypermedium system to develop knowledge structures for material that is published in both book and hypermedia form. The overall conceptual model that is most useful in the development of hypermedia, and the management of their applications, is to take the generalized definition of Figure 1 and think of them as another stage in the development of *knowledge support systems*. Ultimately, it their impact on the knowledge processes of people and society which is significant, not the underlying technology. Understanding these knowledge processes, and the role of technologies in supporting them, is the most significant step we can take in the development and application of new systems.

ACKNOWLEDGEMENTS

Financial assistance for this work has been made available by the National Sciences and Engineering Research Council of Canada, the Social Sciences and Humanities Research Council of Canada and Employment and Immigration Canada. The *Steps to Success* book series is being supported and published by Human Kinetics Publishers, and involves a number of master coaches in North America. We are grateful to our colleagues Eric Gullichsen for stimulating discussions relating to hypertext systems, Larry Katz for access to his research on interactive videodisc applications, Alain Rappaport for access to Neuron Data's developments of knowledge-based hypermedia, Kathleen Robertson for access to her notes on Jean-Louis Gassée's presentation and Mildred Shaw for access to her research on knowledge acquisition systems. The detailed knowledge structures for ice hockey and badminton have been developed in collaboration with

George Kingston and David Brecht respectively. David Johnson jointly designed the hyperbase hierarchical index, and he and Maurice Sharp programmed the.prototype ActionMark system.

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