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# EDUCATIONAL SOFTWARE DEVELOPMENT USING HYPERTEXT AND EXPERT SYSTEM SOFTWARE CONCEPTS

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## ABSTRACT

This paper presents two computer software concepts: hypertext and expert systems; which are useful for educational software development. Good educational software enhances the learning process and offers opportunities for faculty to provide additional materials for independent studies, which would otherwise be impossible, due to the limited time and incredible growing rate of technological progress. The hypertext concept offers the students a non-linear learning style, while the expert system concept provides explanation facilities for students to probe the logic of the systems. Both approaches are extremely useful for educational software. With the proper tools, the courseware can be implemented easily and rapidly. Educational software packages in the area of concrete technology have been currently developed for use in the Department of Civil Engineering at Christian Brothers University. They are utilized as examples. Development tools, KnowledgePro and CBC-Xpert, are also discussed.

## INTRODUCTION

With the rate of technological progress, it is impossible to teach undergraduate engineering students all the latest technologies within a 4 year program. Besides being prepared for life-long learning, students must have enough basics and be aware of the latest technologies. New computer techniques can be used to develop educational software. With educational software, students can be introduced to various subject areas that are not taught in classes. The educational software can also be used to enhance the subject areas covered in classes. This paper describes 2 computer software techniques: hypertext and expert systems. The fundaments of the 2 techniques will be discussed. The hypertext software concept allows the students to select nonlinearly the sequence of his/her study. The expert system software concept allows the students to investigate the logic used by the system. Two educational software packages, developed for use in the Civil Engineering Department at Christian Brothers University, are utilized as examples. The software tools, KnowledgePro (Knowledge Garden, 1989) and CBC-Xpert (Baker *et al.*, 1990), are also discussed.

## WHAT IS HYPERTEXT?

Book style organization is a highly inefficient storage and retrieval technology. Very often it is too difficult to acquire information in a sequence, other than that created by the author, and that sequence may not be tailored to your needs or prior training. Some kinds of information simply do not fit well within a linear structure. Moreover, it is extremely difficult to integrate and update large bodies of frequently changing information drawn from a large number of different sources (Remde, 1989).

Computer generated text is nothing new, so any attempt to define hypertext should begin with an effort to establish what it is not. Hypertext is not Videotext. Videotext is text screens that are displayed on a television screen for 20 second periods. It is rigidly sequential and has no capability of reader involvement. Hypertext is not Computer Assisted Instruction, at least not in the usual sense of that word. A central feature of CAI is that the student must choose a "next screen" or "previous screen" sequence only. The materials are presented in a sequence chosen by the Instructional Designer, and are punctuated regularly by examinations and review sessions. Mastery of particular information and concepts is scored and evaluations secured. Hypertext is not full text database accessed by boolean searches. In the full text database the texts are called forth in a string according to requirements of the resident search engine. Once summoned, the texts may be scanned or read in linear sequence only.

Hypertext is an alternative information delivery system. Readers are able to find just the right information in the right sequence to serve their particular needs and support their particular learning paths, or problem solving needs (Remede, 1989).

Ted Nelson, who coined the word "hypertext," defines it as "a combination of natural language text with the computer's capacity for interactive branching or dynamic display of a nonlinear text which cannot be printed conveniently on a conventional page" (Conklin, 1987). Slatin (1988) has proposed that we think of a true hyperdocument as one "characterized by high-speed machine-supported linkages between nodes organized in a non-hierarchical data structure that exist and can exist only on-line, and only in the process of being constructed by a reader who chooses the available references to pursue and those to ignore". Conklin (1987) describes it as: "Windows on the screen which are associated with objects in a database, and links are provided between these objects, both graphically (as labeled tokens) and in the database (as pointers)."

In this completely interactive system, the hypertext is composed of chunks of text called 'nodes'. The size of nodes may be determined by several things, but it is usually constrained by the amount of screen territory inherent in the hardware. In a hypertext system all nodes are text chunks, but a node may also consist of data, graphics, video, sound or computer generated simulations. In such a case the system becomes a 'hypermedia' system.

Navigating among the nodes is accomplished by triggering 'anchors' in the nodes which may be shown on the screen in various ways. Specially created icons or buttons may appear in the text or portions of the text which may be highlighted. When the anchor is activated, it connects the reader to a destination node in the same document or in another document entirely. As navigation can sometimes become difficult in larger hypertext accumulations, special navigation aids have been created to assist the user. These include maps of the hypertext showing nodes and paths, hierarchies showing lists of node titles, traces that show the track the user has made through the hypertext during the session, and so forth.

The important characteristics about hypertext that makes it an excellent learning environment is the ability of the student to move through a large body of textual information composed of multiple texts by following pre-planned sequences of links set into the text by the instructor. Research at Brown University at the Institute for Research in Information and Scholarship (IRIS) has indicated that links "condition the user to anticipate important and purposeful relationships between linked materials ... to stimulate and encourage habits of relational thinking in the user. This inherent emphasis upon interconnectedness provides a powerful means of teaching sophisticated critical "thinking" (Landow, 1989).

Hypertext applications include dictionaries (Raymond and Tompa, 1988), medical handbooks (Frisse, 1988), technical documents (Walker, 1987), and student advising (Malasri, 1990).

## A HYPERTEXT EXAMPLE: WC-MIX

WC-MIX is a concrete mix design program using the water-cement-ratio method. The step-by-step explanation takes the students to six major steps in determining the concrete proportion, as shown in Figure 1. This can be used simply as a checklist for students who already know

```
..WC-MIX..................................................
:                                                        :
: WATER-CEMENT-RATIO METHOD                              :
: ------------------------                               :
:   STEP-BY-STEP PROCEDURES:                             :
:                                                        :
:   <STEP 1> Determine air content (if needed)           :
:   <STEP 2> Determine w/c ratio                         :
:   <STEP 3> Determine slump                             :
:   <STEP 4> Perform trial mix                           :
:   <STEP 5> Determine unit weight of concrete           :
:   <STEP 6> Calculates mix proportion per cu.yd of concrete :
:                                                        :
:                                                        :
:                                                        :
:........................................................:
:........................................................:
: F1 Help        F3 Select                    Pg 1 of 1:
: Space Cont.    F4 View              F8 DOS   F10 Quit :
:........................................................:
```

Figure 1. Six major steps in determining a concrete mix.

how to determine the concrete proportion using this method. The symbol '< >' used in Figures are hypertext nodes, which imply that more information on those nodes is available upon request. In the actual system, these nodes are highlighted.

If the students would like to explore further, they can simply select a node of interest using function keys, F3 and F4, or using a pointing device, such as a mouse. For example, if the user selects the '**<STEP 2>**' node in Figure 1, more information is displayed in a window, as shown in Figure 2. Two more nodes, i.e., '**<exposure condition>**' and

```
..WC-MIX..................................................
:                                                        :
: WATER-CEMENT-RATIO-METHOD                              :
: --..........................................           :
:   : The water-cement ratio (w/c) is determined:        :
:   : from the <exposure condition> and the    :         :
:   : <strength> of the concrete.              :         :
:   :                                          :         :
:   :                                          :         :
:   :                                          :         :
:   :                                          :         :
:   :..........................................:of concrete :
:                                                        :
:                                                        :
:                                                        :
:........................................................:
:........................................................:
: F1 Help        F3 Select                    Pg 1 of 1:
: Space Cont.    F4 View              F8 DOS   F10 Quit :
:........................................................:
```

Figure 2. Window of deeper information.

'**<strength>**', appear for deeper information. If deeper information is requested, the system will overlay a new window over the existing ones, as shown in Figure 3. The system is also capable of displaying standard PCX graphics files. Figure 4 is displayed as a result of selecting the '**<typical graph>**' node on Figure 3.

The development of WC-MIX is facilitated by a software tool, KnowledgePro. The 'say' commmand is used to display messages. Windows are created using 'window()' and 'close_window()' commands. Hypertext links are marked with the '#m' command and nodes are provided through the 'topic' command. Graphics files are displayed with the 'picture' command. A partial list of WC-MIX source file is shown in Figure 5.

```
..WC-MIX..................................................
:                                                        :
: WATER-CEMENT-RATIO-METHOD                              :
: --..........................................           :
:   : The water-cement ratio (w/c) is determined:        :
:   : f.........................................         :
:   : <:Water-cement ratio based on strength can  :      :
:   :  :be determined by:                         :      :
:   :  :  ....................................... :      :
:   :  :  :Established lab data can be obtained by :     :
:   :  :  :several trial mixes with various w/c    :     :
:   :..:  :ratios. The 28-day strength of cylinder :oncrete :
:      :  :from each mix is plotted versus w/c ratio:    :
:      :..:                                        :     :
:         :   * select here to see                 :     :
:         :     a <typical graph> *                :     :
:         :........................................:     :
:........................................................:
:........................................................:
: F1 Help        F3 Select                    Pg 1 of 1:
: Space Cont.    F4 View              F8 DOS   F10 Quit :
:........................................................:
```

Figure 3. Layers of windows for more depth information.

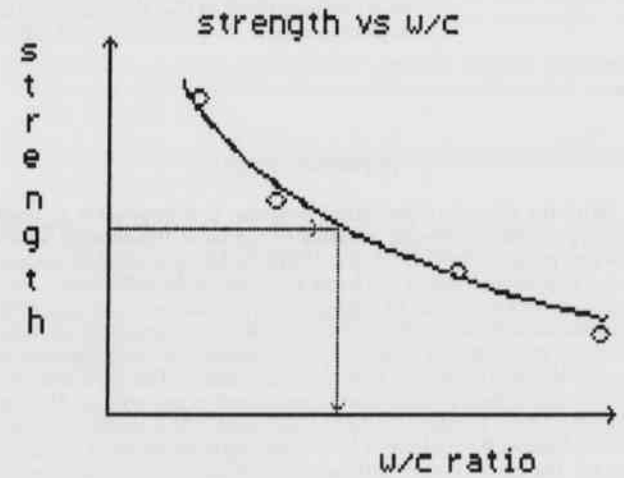


Figure 4. Capability of displaying PCX graphics files.

```
say(
' WATER-CEMENT-RATIO METHOD',
' -------------------------',
'   STEP-BY-STEP PROCEDURES:',
' ',
'   #mSTEP 1#m  Determine air content (if needed)',
'   #mSTEP 2#m  Determine w/c ratio ',
...
...
...
   topic 'STEP 2'.
   window().
   say(
   'The water-cement ratio (w/c) is determined',
   'from the #mexposure condition#m and the',
   '#mstrength#m of the concrete').
   close_window().
   end.
   ...
   ...
   ...
     topic 'typical graph'.
     picture (wc).
     end.
   ...
   ...
   ...
```

Figure 5. A partial list of WC-MIX source file.

## WHAT IS EXPERT SYSTEM?

Expert systems are computer programs that use Artificial Intelligence (AI) techniques to make computer programs easier and more effective, and normally go beyond numerical programming into symbolic programming (Harmon and Sawyer, 1990). Expert systems are computer systems that employ human knowledge to solve problems that ordinarily require human intelligence (Hayes-Roth, 1990).

There are several ways human expertise can be represented in expert systems, such as rules, frames, objects. The IF-THEN rule is one of popular representations. Systems employ the IF-THEN rule representation known as 'Rule-Based Systems'. Since the example used in this work use the IF-THEN rules, discussion is therefore limited to rule-based systems.

Most rule-based systems have 3 separated components; the inference engine, knowledge bases, and explanation facilities. The inference engine is the part that solves problems by applying the knowledge in the knowledge bases. It determines which rules applied and in which sequence. Knowledge bases contain the domain knowledge. Due to the separation of knowledge bases from the inference engine, knowledge is transparent to the end-user. The student can clearly understand the knowledge in the system without having to understand a computer programming language. Knowledge bases are also easily debugged, modified and updated. The explanation facilities allow the student to probe the logic of the system, such as why the question is being asked or how the system reaches a conclusion. These educational benefits of rule-based systems will be demonstrated with a sample system, WCMXINFO, in the next section.

In recent years, the expert system development has been facilitated by the availability of development tools, known as 'shells'. A shell is simply an expert system with the inference engine, explanation facilities, and empty knowledge bases. The developer, using a shell, simply implements the knowledge bases. CBC-Xpert, one such shell, was developed at Christian Brothers University for educational purposes. Students can learn how to use the system quickly, due to its simplicity.

There have been several expert systems developed for uses in engineering education and several schools have offered courses on the subject as recently documented (Malasri *et al.*, 1990, Mohan and Maher, 1989).

Similar AI techniques used in expert systems have been used in more advanced systems known as Intelligent Tutoring Systems (ITS) or Intelligent Computer Assisted Instruction (ICAI). These systems try to find the misconception of the student and try to customize the tutoring material to the student (Barr and Feigenbaum, 1982). More recent research on ITS or ICAI is reported by Mandl and Lesgold (1988) and Wenger (1990).

## AN EXPERT SYSTEM EXAMPLE: WCMXINFO

WCMXINFO contains information needed for the mix design calculation using the water-cement-ratio method. It addresses the same problem of WC-MIX, but with a different approach. The consultation begins with a menu from a main program written in BASIC, as shown in Figure 6. If the user selects the third option, the EXPOS.KBS knowledge base is used and the query starts, as shown in Figure 7. At this point, the user can ask WHY by typing "w". The system will respond by displaying the current rule, as shown in Figure 8. The system asks more questions until it reaches a conclusion as shown in Figure 9. The user can trace to see HOW the system reaches this conclusion. The system responds to the HOW question by displaying rules used in that particular consultation.

```
In the water-cement-ratio method of mix design,
you would need the information on the following
topics:

 1. air content
 2. average strength required
 3. w/c ratio based on exposure condition
 4. w/c ratio based on strength
 5. minimum cement for flatwork
 6. slump

 7. EXIT

Select an option ? _
```

Figure 6. Menu screen of WCMXINFO.

```
                         expos.kbs


What is the exposure condition?
     1    freeze-thaw cycles
     2    watertight
     3    frost-resistant
     4    sulfate attack
     5    placing concrete under water
     6    floors on grade
Enter the index of your response (1-6)> _
```

Figure 7. Consultation with EXPOS.KBS knowledge base.

```
                         expos.kbs


Why? Because "exposure_condition" is needed to evaluate
     rule 1.

Rule 1

IF     exposure_condition = "freeze-thaw cycles"
THEN   wc = "Select w/c ratio based on strength"
```

Figure 8. WHY question.

```
                         expos.kbs

                Results of database query

The maximum w/c ratio is ---> "0.50"
```

Figure 9. Conclusion screen.

The knowledge base can be easily developed using any wordprocessor capable of creating ASCII files. The listing of the EXPOS.KB knowledge base is shown in Figure 10. The 'title' command provides an identification for the knowledge base. The 'goal' command tells the system what to look for during the consultation. Once a value is found for the goal variable, the consultation terminates. The 'rules' section provides domain knowledge in the IF-THEN format. Rules can be in any order. Input data is obtained from messages specified in the 'prompts' section. The result of the consultation is displayed using the 'conclusion' command. There are only 5 commands used in the system with English-like syntax. Anyone, with or without the background on expert systems, can understand the knowledge which is explicitly built into the knowledge base.

In a typical expert system, the problem solving part or the inference engine is separated from the knowledge part. This makes the domain knowledge easy to check, to update, and to maintain. CBC-Xpert provides the develper with an inference engine (INFER.EXE). Knowledge bases are ASCII files created using any wordprocessor following a simple

```
title "expos.kbs"
goal wc
rules
1
if    exposure_condition = "freeze-thaw cycles"
then wc = "Select w/c ratio based on strength"
2
if    exposure_condition = "watertight"
and   water = "fresh water"
then wc = "0.50"
3
if    exposure_condition = "watertight"
and   water = "sea water"
then wc = "0.45"
4
if    exposure_condition = "frost-resistant"
and   member = "thin sections"
then wc = "0.45"
5
if    exposure_condition = "frost-resistant"
and   member = "all other sections"
then wc = "0.50"
6
if    exposure_condition = "sulfate attack"
and   sulfate = "moderate"
then wc = "0.50"
7
if    exposure_condition = "sulfate attack"
and   sulfate = "severe"
then wc = "0.45"
8
if    exposure_condition = "placing concrete under water"
then wc = "not less than 650 lb of cement per cu.yd."
9
if    exposure_condition = "floors on grade"
then wc = "select based on strength and minimum cement
          requirement"
prompts
exposure_condition
  "What is the exposure condition ?"
     "freeze-thaw cycles" "watertight" "frost-resistant"
     "sulfate attack" "placing concrete under water"
     "floors on grade" /
water
  "What is the type of water ?"
     "fresh water"  "sea water" /
member
  "What is the type of member ?"
     "thin sections"  "all other sections" /
sulfate
  "What is the level of sulfate attack ?"
     "moderate" "severe" /
conclusion
"The maximum w/c ratio is ---> " wc
```

Figure 10. The listing of the EXPOS.KB knowledge base.

syntax. The consultation is made by executing the inference engine with proper knowledge base, such as:

> INFER AIR.KBS

In WCMXINFO, a main program was written in BASIC to provide a menu, as shown in Figure 6, and bring up the appropriate knowledge base, as shown in Figures 7-9. The CBC-Xpert's inference engine is called with an appropriate knowledge base using the 'SHELL' command in BASIC, as shown in Figure 11.

```
...
...
390  INPUT "         Select an option ";N
400  IF N=1 THEN  SHELL "infer.exe  air.kbs"
410  IF N=2 THEN  SHELL "infer.exe  avgstr.kbs"
420  IF N=3 THEN  SHELL "infer.exe  expos.kbs"
430  IF N=4 THEN  SHELL "infer.exe  wc.kbs"
440  IF N=5 THEN  SHELL "infer.exe  flatwk.kbs"
450  IF N=6 THEN  SHELL "infer.exe  slump.kbs"
460  IF N=7 THEN  SYSTEM
...
...
```

Figure 11. The SHELL command in the main program.

## CONCLUSION

Hypertext is an alternative information system that offers the students a completely interactive encounter with the topics of study, permitting them to stretch their growth potential by providing multiple levels of increasing technicality. When combined with Expert Systems, a "glass box" feature is provided to the structure of the knowledge and logic contained in the system. With tools such as KnowledgePro and CBC-Xpert, the creation of such alternative information systems and updating of materials can be easily accomplished by non-programmers. We are tempted to say that this alternative system renders traditional textbooks obsolete as complex knowledge can be packaged and delivered electronically, as well as easily revised, delivered and stored. Besides learning the course contents, students are given increased skill with relational and critical thinking, as well as exposed to new training technologies that they will see with increasing frequency.

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