Oliveira, L. & Watson, I. (1997). Case-Based Reasoning in Virtual Reality. In, Proceedings of the 3rd. United Kingdom Case-Based Reasoning Workshop. University of Manchester. Filer, N. & Watson, I (Eds.)

Case-based reasoning in virtual reality

Leonardo Oliveira[1] and Ian Watson
AI-CBR, University of Salford, Bridgewater Building, Salford, M5 4WT
www.ai-cbr.org
ian@ai-cbr.org

Abstract This paper presents a Computer-Based Training (CBT) tool that relies on an integration of Virtual Reality (VR) with Case-Based Reasoning (CBR). It is an application that handles past cases represented in VR to provide a training and learning environment. A prototype has been developed as part of this research. It holds past experiences of experts in the inspection of health and safety regulations of scaffold structures. Each case in the case-base contains a virtual scaffold structure along with the various tasks involved in its inspection. In order to encourage further applications of this approach, this paper presents several aspects of VR that can make this technology a powerful tool for case representation. Thus, the role of VR for case representation and memory recall are reviewed. Next, the methodology for development of the prototype is discussed, focusing on the process of case design in VR as a training tool. Then, a training session on the inspection of scaffold health & safety regulations is presented and conclusions are drawn.

1. introduction

CBR is a technology derived from artificial intelligence research which has its knowledge represented as cases used to solve past problems [10]. Thus, cases can be seen as a piece of memory representing a past experience, that is recorded for future reuse. CBR research has focused on several areas including:

- the storage and indexing for case retrieval; and
- media and structures for case representation.

The latter area represents the focus of this work, introducing VR and its characteristics as a means of case representation. The integration of CBR and VR plays its role in keeping records of past cases represented in a virtual environment that simulate a real situation. Thus, it allows users to have access to places and experiences in a computer environment that holds the representation of the memories and actions of human experts.

Kolodner [10] described cases as containing three major parts, which are:

1. the description of the case which allows its identification and retrieval;
2. the case itself, which contains information relevant to the domain of its application; and
3. the resulting state of the domain when the solution was carried out.

For example, one of the cases in the prototype deals with a scaffold structure involved in the construction of a residential house. The description for this case refers to the information that differentiates this case from the others contained in the repository, such as the type of scaffold, the type of work to be provided, the type of building, and the vicinity. The second part describes how the scaffold inspection has been performed, and the sequence of items checked. The third part presents information relating to the situation found on this site and recommendations for future similar inspections.

---

[1] L. Oliveira, is a Ph.D. candidate sponsored by the Brazilian Research Council (CNPq).

This research suggests the use of VR to improve the interface for CBR systems in these three parts of a case. VR is a technology that handles representations of the physical world [7] enabling the communication of complex ideas [16]. Its capacity to handle objects and their properties, to walk-through the virtual environment in real time, and to simulate real world situations in a 3D graphical display, makes this technology an ideal computer tool for describing real world models [3]. Bringing together VR and CBR, thus generating a standard association for these technologies, is the main objective of this research. The hypothesis behind this work is that this approach can help learning because it uses past cases to base its reasoning on, which is a natural process in human thinking. Moreover, it allows students to *learn by doing*, which is a recommended learning method, and it provides all the advantages of CBT [6 & 8] in an interactive environment that has the potential to stimulate learning.

2. the CBR interface

Dearden [5] stated that: *"the success of any interactive intelligent system, whether it is rule-based or case-based, is dependent not only on the quality or on the appropriateness of the knowledge encapsulated within the system but also on the quality of the interaction that the system supports"*. Apart from some academic demonstrators, the interface of a CBR system plays an important role in the quality of the support provided to users. Users have to at least interface with a CBR system to input a problem description and to receive the information contained in any retrieved cases.

Many current CBR interfaces accept textual description of problems (e.g., those based upon CBR3). Whilst many others allow problem descriptions to be made by selecting case features from menus or lists (e.g., those based upon ReMind). This research does not present any improvement in problem description, since problems are described by selecting case features on a menu within a virtual environment. However, VR can play a major role in presenting case information to users. Several CBR systems can be found using multimedia techniques, such as sounds, pictures, image animation and even digitised films. However, cases represented by these types of visualisation have some characteristics which are approached quite differently in this project. Firstly, such images are not *understood* or evaluated by the CBR system, since there is no computer language to access the internal contents of the files. Moreover, any case adaptation would require the adaptation or recording of new images and could not be based on the features of a previous case. An example of a learning application of CBR using digitised videos for case representation is the SPIEL (Story Producer for Interactive Learning) system [23]. Case features in SPIEL are textual descriptions of videos that are manually inputted into a database where those features are indexed to perform retrieval.

Apart from VR, where images are represented in an object-oriented architecture, current visualisation techniques present *static* information. Note that the term *static* refers to the information only, and has no relation with the way information is displayed to users. A movie is *static* because the content of each frame always remains the same. This definition also applies to animated images where the sequence of animation is. Conversely, VR is an *active* medium in the sense that users can interact with it and perform their own actions.

VR as an interface for CBR also allows access to case features which are dynamically displayed on the screen, and can be used to facilitate memory recall. Thus, VR can help bring cases closer to the natural process of memory recall. Increasing CBR's potential to provide CBT applications as close to real situations as possible is the main reason to bring VR and CBR together. Further information about the capabilities of VR and its role in the process of memory recall is discussed in the following section.

, focusing on the main points of interest for this research work. An assumption of this work is that people remember things in the context of place, even where there is no significant connection between the thing remembered and the place where it is located. An example provided by Yate describes someone who was called upon to name unrecognisable victims of a vehicle accident. This person was able to name the victims by recalling the places where they had been seated. Space is a powerful trigger to recall memories and the information associated to them. Some other major issues that the Yate offers to support the use of VR for case representation are listed below.

- **Imaginary or real structures** - a scaffold structure is an example where a textual description would never provide the same level of remembrance as the visual representation of this structure. VR also has the advantage of helping people knowing how to find their way about a place using visual cues.
- **Concreteness and memorability** - recalling a view of a space is easier than recalling abstract symbols (such as abstract concepts or pieces of language). Concreteness produces memorability which is a key factor for learning.
- **Taxonomies for thought** - spaces have a coherence and logic which can be used to connect one idea to another, becoming a prominent tool to help user’s mnemonic thought.
- **Representing realities** - although some aspects of realities only exist inside the head of the individual, designs in relation to the single observer can always be used as a place of mediation between various individuals;
- **Detection of motion** - is a strong element in visual perception and users can gain much information from it. Moreover, motion can be the main source of understanding for many domains such as driving.

To conclude, virtual spaces have much to offer in terms of assisting learners to understand and memorise information. Although current VR technologies can help with various aspects of memory recall, there are still several aspects that cannot be supported by it, such as temperature, aroma and tactile textures. However, VR can work as a filter for space representation, allowing the display of information relevant to the domain. These and other relevant aspects concerning the design of past experiences in VR are the issues discussed in the following section.

4. designing virtual cases

> *“It may be that all human beings have the same perception of space at the biological level of perception. But certainly every society uses its space differently, both technologically and artistically”* Bolter, [2], p80

In addition to the usual issues of case representation in CBR, such as feature selection and indexing cases for retrieval, this research also involves the construction of the virtual worlds within which the cases are represented. This is a process of design with no universally accepted methodology to follow [4].

The development of this project has shown that the understanding of VR’s capabilities and their influences over the human process of perception and cognition can help in deciding whether VR is appropriate for case representation. Moreover, what can be represented in VR is not the only issue to consider. For instance, some factors such as the user's interaction with the virtual world, and the way it will be displayed should also be carefully evaluated [4].

In order to help those interested in representing cases in VR, a comparison of the representational ability of three VR packages has been undertaken, the results of which can be seen at the project's web site[2]. Thus, developers can match their needs to the VR package whose capabilities best suits their application. The VR packages compared were:

- Superscape VRT version 5 (http://www.superscape.com)
- Sense 8 WTK version 6; (http://www.sense8.com); and
- Integrated Data Systems Inc. IDS V*Realm Builder (http://www.ids-net.com)

We only considered built-in functions of the VR packages, avoiding the need for programmers to include those features in the applications. Currently, most VR packages contain a programming language and thus most of the features present can be programmed in. However, if the aspect requires programming, it has not been included as *supported* in the comparison.

Developers should also consider the following before choosing a VR tool for case representation:

- Even when a case representation involves some spatial attributes, developers should ask themselves whether a 3D graphics display would enhance understanding. For example, the influential CLAVIER system did not use any form of graphical display even though it was dealing with the spatial layout of components within an autoclave.
- The creation of virtual worlds is a time-consuming task, even though libraries of components can be built up to accelerate the process. Developers should be conscious of this factor. Most of the work involved in building virtual worlds is uninteresting, repetitive and requires long hours of debugging and optimising.
- There is a danger that the same virtual world when running on different hardware may appear differently from the developers original intention.

In addition, questions have been raised regarding the loss of abstraction that VR entails and its possible counter productive effect on understanding in certain domains [12 & 4]. For instance, Satalich [12] describes a study where the users of VR performed worse than a group who only worked on paper. The same author cited that there are several reasons supporting these results, such as: the amount of time users have been using VR, considering the novelty of the technology; the issues and the subject evaluated; and the deficiencies of the hardware used. The author suggests it is worth keeping these results in mind. However there is no reason to consider computer systems involving VR as necessarily inferior to traditional learning systems [12].

5. developing a prototype

A prototype has been developed as part of this research to explore the issues involving VR as a computer tool to represent CBR's cases and actions. The objectives of the prototype can be summarised as follow:

- identifying the suitability of the CBR paradigm as a training tool both for users and trainers,
- evaluating CBT development methodologies and their role in this application;
- examining performance of personal computers to handle VR CBR applications;

---

[2] Results can be seen at: http://www.surveying.salford.ac.uk/postgrad/Leo/vraspects.html and are constantly being updated and are open for comment. Another comparison, involving technical issues in VR packages, can be found at the http://www8.zdnet.com/pcmag/iu/features/1519/buildsum.htm.

- analysing the potential and weaknesses of this application as an intelligent training tool that keeps a corporate knowledge of the domain; and
- helping to get feedback from the experts involved in the research.

Three major reasons encouraged the task of prototyping, which were: the availability of experts committed to supplying the knowledge; a background knowledge in object-oriented languages and KBS development, and a CBR application developed within the same department dealing with case representation using an object-oriented architecture [11].

The following sub-sections provide further details on the methodology for the development of this application, as well as information about the several stages involved in the prototyping task.

5.1. development methodology

A major issue in this work was the development of a methodology combining CBT requirements with the CBR approach. CBR is focussed on similarity and case retrieval. On the other hand, CBT applications rely on methodologies to guide users' understanding. Thus, developing an application of CBT implies providing guidelines for similarity assessment and case retrieval to assist users' learning.

A literature review was performed to identify methodologies for the development of such computer systems as knowledge-based systems, CBR, CBT, and computer-aided learning applications. The recommendations taken from this literature review have been cross-checked and the resulting methodology is summarised in Figure 1. It presents the three main stages of the development of the prototype and aims at answering the following questions:

- Are the computer training sessions, based on past experiences, able to provide the requirements of my organisation in terms of training?
- Is CBR the right medium to provide the training?
- How should the training sessions, be organised?

Answers to these questions are briefly tackled on Figure 1. Full details on the methodology adopted for the development of the prototype will be presented further in future publications by the authors of this work.

The VR package used for the development of this application was Superscape VRT version 4.0. It incorporates an environment for building VR worlds and a programming language that allowed the development of the CBR engine and the structure of guidelines for the training sessions. Further details about these issues are discussed in the following sections.

5.2. case representation

Some of the issues concerning the application of VR to represent past experiences, which have been particularly important for the development of this work, are:

- presenting the cases in the way they were visualised by the experts;
- making cases useful in transmitting experts' experiences;
- displaying objects in an adequate level of detail required to properly evaluate the knowledge present in the virtual case;
- ordering and interconnecting the information to be displayed;
- providing descriptions for the cases in VR that allow proper matching and retrieval; and
- handling the objects that belong to each of the cases already in the repository to perform case adaptation.

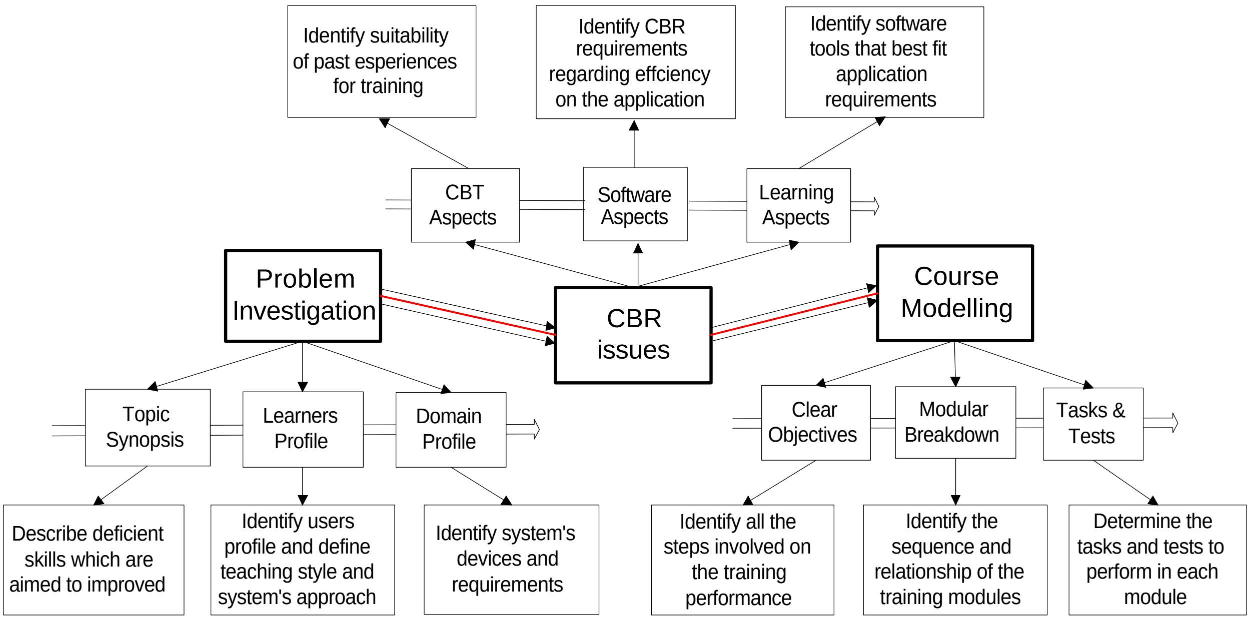

Figure 1 Methodology for the development of the prototype

VR provides an interface that users can interact with, experiencing simulations of the real world. However, the creation of these virtual worlds, as discussed in section 4, is not an easy task. One of the main lessons taken from the implementation stage was the importance of using modelling techniques prior to the representation of the cases in the VR environment. Modelling techniques were also used for such tasks as: understanding the statements provided by the experts; helping to establish the sequence of the training sessions; and representing the cases in VR.

Modelling the information embodied in each case and the relationships between the pieces of this information, prior to the implementation in the computer, has also proven to be very helpful in saving time to build the virtual environments. The modelling technique used in this work was Express G and Figure 2 shows one of the models used to implement a case in VR, i.e. building a scaffold structure in accordance to British Standard BS 5973-1990.

5.3. case memory structure

The structure for the case memory in the prototype has been implemented using the concept of Memory Organisation Packets (MOPs) and Scripts, described in [13] and [15]. This concept says, for instance, that a construction site with a scaffold structure serves as a MOP for an expert, and that the activities involved in its inspection constitute Scripts. Thus, each examination of a scaffold is represented as a series of Scripts (or tasks) which may be common for other types of scaffold structures.

For example, one of the cases present in the prototype describes a site in which repairs will be done on the roof of a three-storey building. In order to identify whether the scaffold complies with British Standard BS 5973-1990, certain tasks have to be performed. One of these tasks is to check whether the vertical bars (technically called *standards*) are well centred on top of soil plates. Any scaffold structure (which is not suspended), must have its bases well centred on top of soil plates. Thus, the task of inspecting if standards are properly supported by the soil plates is an example of a Script which is common for several MOPs.

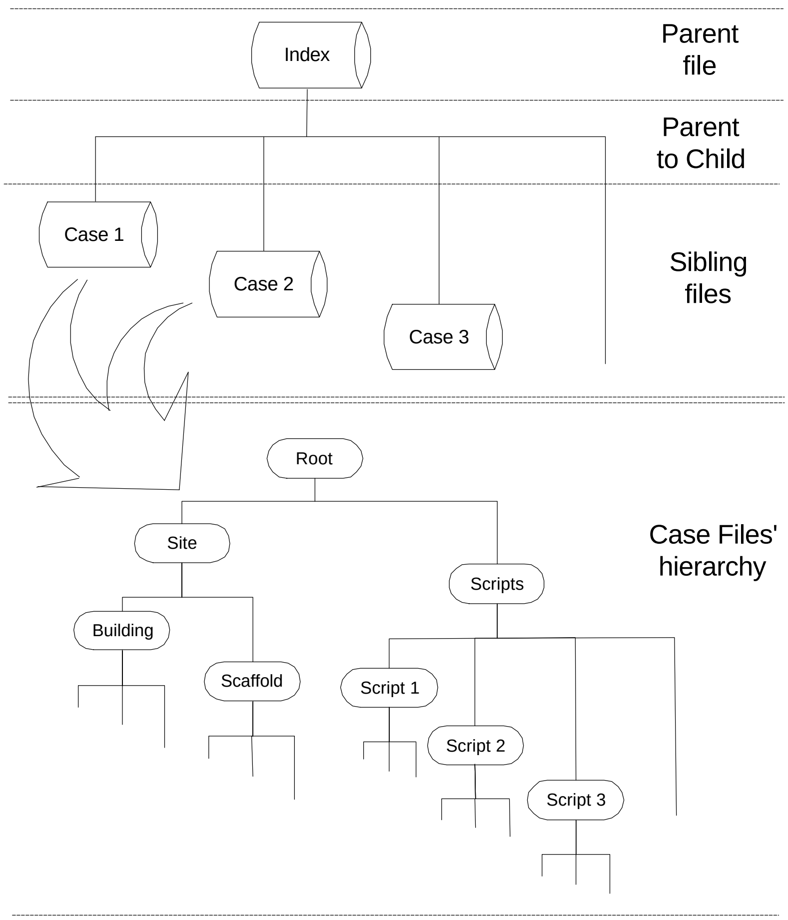

Figure 2 prototype hierarchical framework

Each case (or MOP) in the prototype has been represented in a different VR file which also contains the Scripts belonging to each case. This approach was adopted because of the very large number of objects involved in the representation of scaffold structures and it does slow down the interaction process. The internal structure of the case files follows an object-oriented hierarchy built upon a “Root” object in a “tree” structure as illustrated in Figure 3. Further details regarding the reasons for adopting this framework are discussed in the following section.

This hierarchical structure serves as an organisational foundation upon which to build virtual worlds. It supports the inheritance of features down the hierarchy. Inheritance is useful for several reasons. For instance, when an object is child of another object, its position within the virtual world will them be defined in terms of the position relative to the parent, rather than in terms of its world co-ordinates position. This characteristic of inheriting properties is specially important in this work, because it allows case adaptation, where full hierarchies of objects can be used to create new cases by case substitution.

Objects in a virtual world are usually seen as buildings, rooms, walls, pieces of furniture, etc. However, VR files can also contain objects which are invisible in the environment and hold attributes responsible for interfaces, animation, and traditional computer algorithms such as functions, rules and procedures. Thus, at one level VR case representation becomes a programming task that does not differ from any other object-oriented language (i.e., identifying case features and assessing similarity). Further details about the framework adopted in this work for identifying case features for retrieval is discussed in the following section.

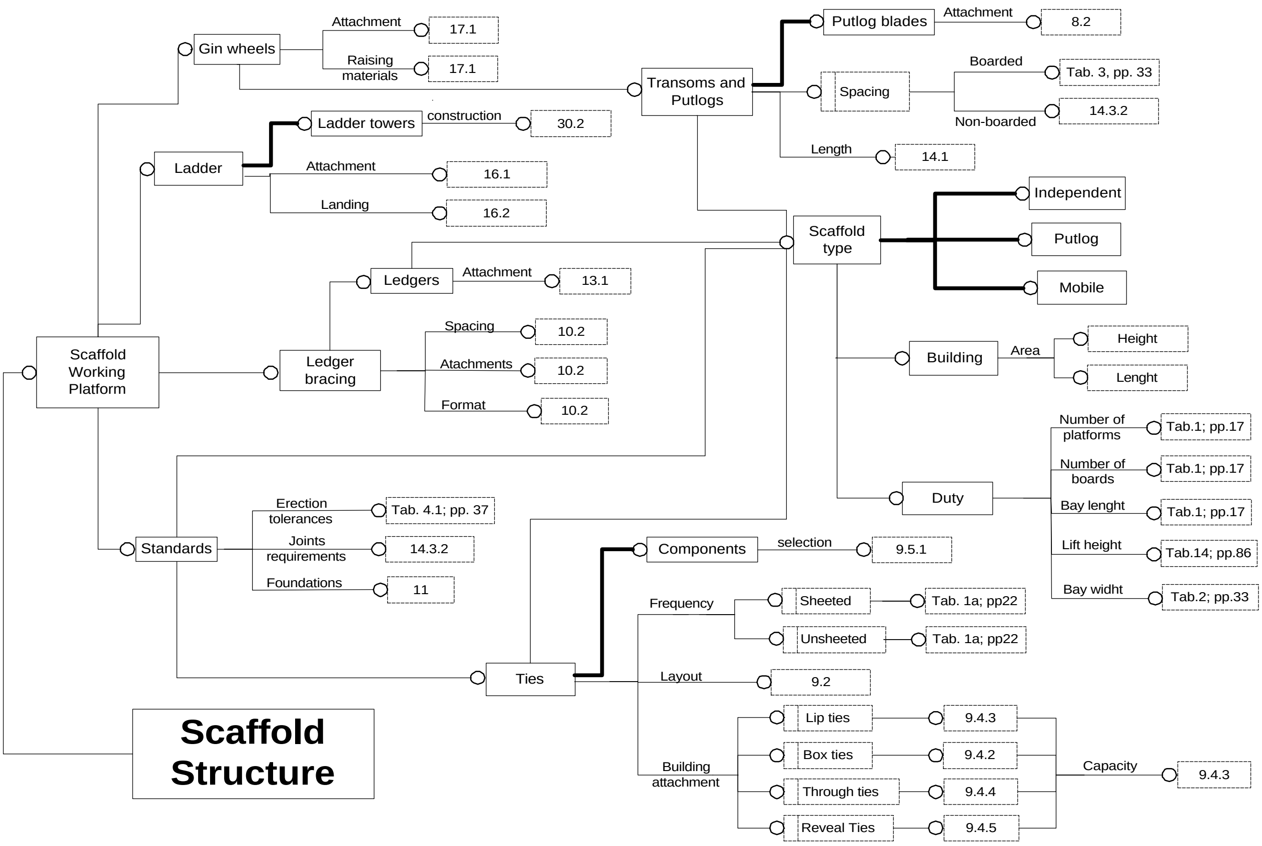

Figure 3. Express G case model

5.4. identifying case features

Feature identification in the prototype results from the combination of three main issues: (i) from the CBR paradigm in terms of adopting features that differentiate the cases in the repository and properly address them for retrieval; (ii) the requirements of CBT applications in terms of methodologies to help training and learning; and (iii) the capabilities of the object-oriented hierarchy used to represent the cases in VR.

Guidelines for case retrieval prescribe that case features should be useful in describing the case and allowing its proper recognition and retrieval [10 & 21]. CBT requirements indicate that there is no a unique way to provide training nor a single methodology which leads to best learning. Moreover, the process of designing the lessons can be one of the most problematic aspects of CBT development [6]. A common approach goes from presenting fairly general knowledge (e.g. general implications of Health & Safety on scaffolding) to describing more specific tasks (e.g. how to properly inspect scaffold foundations).

Redmond (1992) stated that CBR applications for training should also include two aspects; namely: presenting the same kind of situations users encounter on the job, as well as carrying a presentation that will be properly kept in the users memory [22]. The same author indicates that one of the greatest challenges in building such systems is the ability to provide features capable of proper case retrieval as well as helping users to access case knowledge in real situations.

In the light of this work, feature identification was approached in terms of describing scaffold structures and the tasks involved in performing inspections for health & safety regulations. Thus, features were provided at two levels: at the top level describing the cases, and at a lower level describing the Scripts each case contains. Case features have been chosen in terms of features that differentiate the cases contained in the repository, such as the type of scaffold, the type of work to be provided, type of building, scaffold dimensions and site characteristics. Script features concern the description of the items and tasks to perform inspecting the scaffold structure. Both descriptions were carried out in close contact with experts, who also provided guidelines for the task sequence to be followed performing scaffold inspection.

As discussed before, VR provides direct access to the contents of the visualisations. Some advantages that can be taken from accessing the contents of the files are:

- new cases can be automatically created or existing ones adapted by combining objects from other virtual cases; and
- libraries containing hierarchies and objects can be shared between users and developers to speed up the process of case representation.

Currently the prototype does not performing automatic adaptation or creation. The main reasons for these limitations are the restricted time for the development of this research as well as the complexity that training applications require, specially forbidding inexperienced users to insert inappropriate cases in the repository. The following section describes the architecture used for identifying case features as well as the retrieval approach.

5.5. retrieval framework

The method for retrieval used in the prototype allows users to search only for MOPs, only for Scripts or for both together. This is possible because cases and Scripts are independent (see section 5.3). Case features are stored as properties attached to a child of the object at the top of the cases' hierarchy (Global 1 to N). Script features are stored as properties attached to a child of the object at the top of the Scripts' hierarchy (Global S1 to SN).

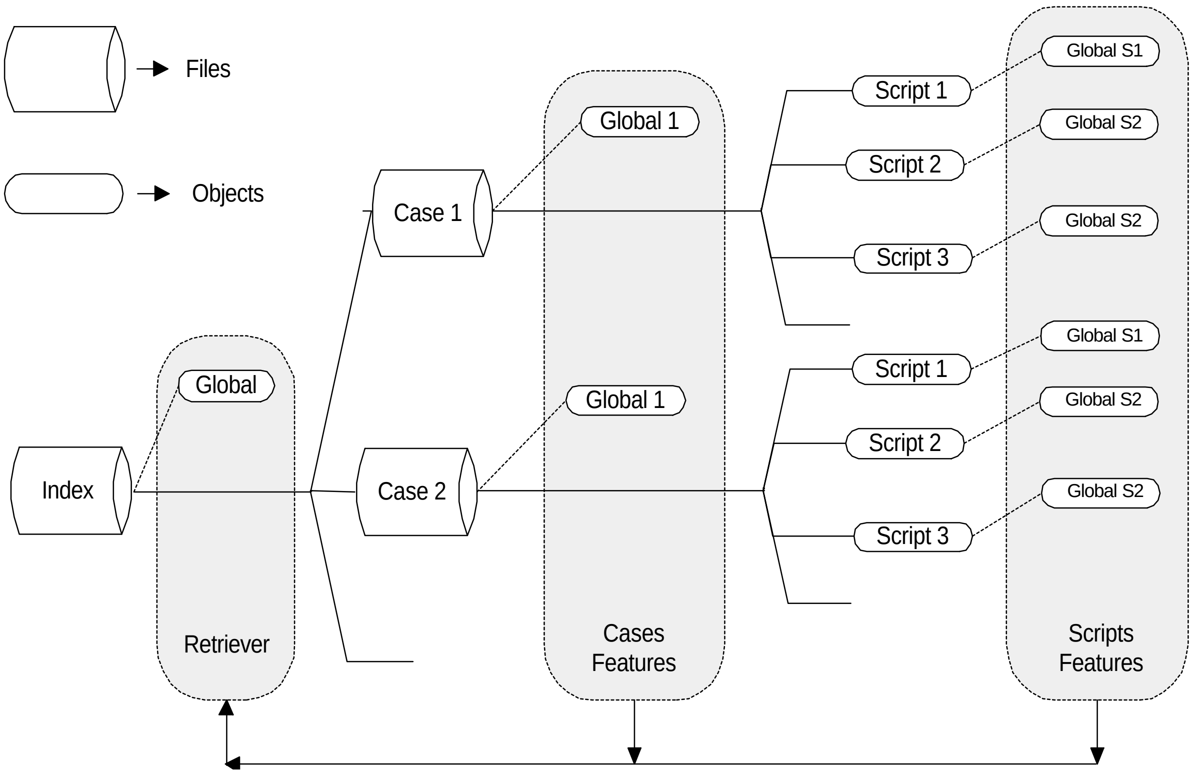

Figure 4 the object oriented case memory

At the very top of the hierarchy is an object called "*Index*" which holds the retrieval mechanism and all the information required for case retrieval, such as the names of the VR case files and the features describing all cases with their Scripts. Thus, cases and Scripts contained in the prototype repository have their features stored in the case files as well as in the Index file. The reason behind this redundancy is to avoid the need to open the various VR files searching for their contents, and thus slowing down the retrieval process.

The retrieval mechanism performs a search based on a weighted-nearest-neighbour approach [10 & 21], and the core of the retrieval algorithm is shown on Figure 5. The code of the algorithm has been written in SCL (Superscape Control Language) which is a language that though similar to C, is exclusive for VRT users.

```
•   Case Retrieval
    /*  identifying total weight for features in each case */

     Loop for X from 1 to Total_Number_of_Cases
          Loop for Y from 1 to Total_Number_of_Features
                    Total_Weight_Case (X) = Total_Weight_Case (X) +
    Feature_Weight (Y)

    /* matching inputted case features */

          Loop for X from 1 to Total_Number_of_Cases
                    Loop for Y from 1 to Total_Number_of_Features
                              If Feature (Y) = True
                                        Total_Match_Case (X) =
    Total_Match_Case (X) + Feature_Weight (Y)

    /* stabilising weight for each case    */

    Loop for X from 1 to Total_Number_of_Cases
          Total_Match_Case (X) = (100 * Total_Match_Case (X) /
    Total_Weight_Case(X)

    /* allow retrieval for cases matching more than 50% of the input
          Loop for X from 1 to Total_Number_of_Cases
                    If Total_Match_Case (X) > 50%
                              Them "display Total_Match_Case (X)and allow
    retrieval for Case (X)"
```

Figure 5 the retrieval algorithm

5.6. training performance

On real construction sites, experts do not follow a pre-established sequence to inspect health & safety regulations on scaffold structures (although some prescriptions do exist). The usual approach is based on checking key parts of the structure, which allows experts to identify whether the structure has been properly erected, will be safe to work on, and safe for anyone in the vicinity of the structure.

This freedom to choose the sequence of the tasks for inspecting scaffolds is quite in accordance with the CBR paradigm. CBR allows users the freedom to retrieve the case they want, according to the inputted description of a problem. The same approach has been included in this prototype which has also been designed to cater for different levels of users, such as: beginners blindly following the system's guidelines for the case retrieval sequence, users experienced with the domain retrieving the script they want to reinforce their knowledge, and trainers illustrating their lessons with a virtual representation of

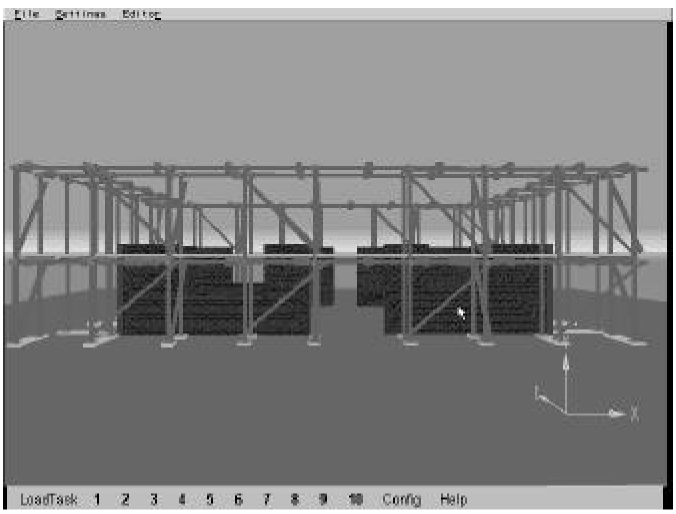

Figure 6 interface to the training environment past occurrences on site.

Figure 6 shows one of the cases present in the case library. The menu bar at the bottom prescribes a sequence of scripts associated with the inspection of health & safety regulations on this structure. When clicking the mouse over the script number, the system presents guidelines on how to properly perform the task associated with the script. The number will change its colour on the menu bar, indicating that the task has been performed.

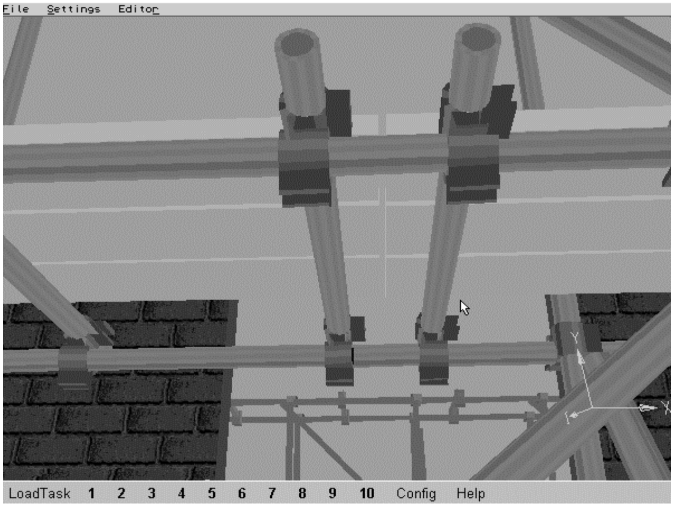

Figure 7 overhang of scaffolding boards

For example, one of the scripts performs inspection of the overhang at the end of scaffolding boards. The system moves the viewpoint around the structure, replicating the views that an expert would have on a real site (see Figure 7). Theoretical information about this task is also provided by reading the menus or listening to an expert's recorded advice. Most of the objects of the scaffold structure hold some additional information regarding dimensions, material nomenclature, etc. This information can be accessed by clicking on the right mouse button on top of the virtual object. Thus, each case works as a repository of information concerning the domain of inspection of health & safety regulations on scaffold structures.

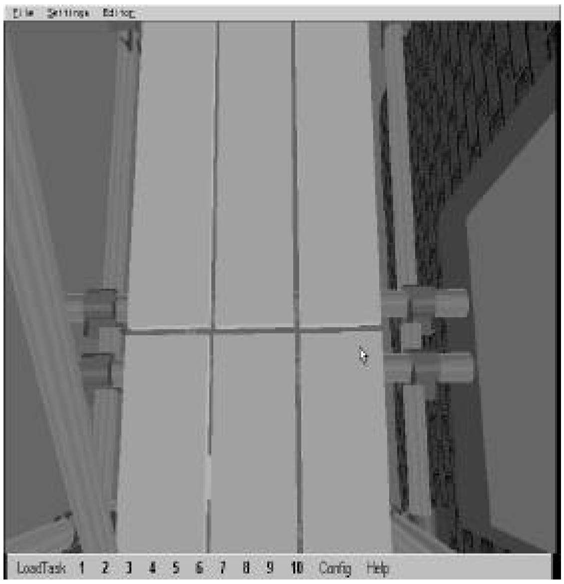

Figure 8 view from the scaffold's platform

Users can also freely walk-through the virtual case searching for irregularities on the structure independently from the system's guidelines. Once an irregularity is found, users can click on the object and the system will fix the irregularity. This approach is specially important for trainers, who can use the system as a tool to illustrate site occurrences. For instance, viewpoints, such as that presented in Figure 8, could be difficult or dangerous to access on real structures. Moreover, trainees would need to physically go to a site where this structure is present, and special supervision would be required.

6. conclusions

Experiencing is central to using VR as a visualisation tool and is a dominant characteristic of this application. VR supports *learning by doi*ng, a recommended form of learning. The physical world simulations achieved by VR provide an interactive environment that facilitates understanding of the lessons displayed. The process of designing virtual worlds can be difficult and time-consuming. However software for virtual world building is becoming more powerful day-by-day. Moreover, third-party objects are increasingly becoming available and this will ease the process of virtual world design. Modelling techniques to make explicit objects' behaviour, dimensions, positions, dependencies, and links with other objects will help speed up world creation.

One of the benefits resulting from the use of CBR that presents special interest for this research, is learning [1, 10, 13, 14 & 15]. CBR supports the retrieval of past cases that can help users learn by:

- having the opportunity to access the structure and the contents of a past experience;
- understanding the content of a case and its relevance within the domain;
- accessing the actions and recommendations taken from the past case;
- reasoning to solve new situations by establishing comparisons with similar cases in the repository; and
- creating new cases by adapting the cases contained in the repository.

Researchers have stated that there are very few, if any, domains in which CBT could not be used to assist learning [18]. We understand that one of the main reason to choose CBT relies on providing good courseware at low cost. The experience taken from this project indicates that though it cannot be seen as a low cost option, subsequent updates and revisions should be possible at relatively low cost. However, CBT may not be the approach that bring best results in a short period of time.

7. references

[1] Aha, D.W., (1997). Artificial Intelligence Review (special issue on Lazy learning). Norwell, Mass.: Kluver. Forthcoming.

[2] Bolter, J.D. (1986). The Turing's man: western culture in the computer age. Penguin Publishers.

[3] Brooks, M.R. (1994). Virtual reality interfaces for complex environments. M.Sc. thesis, University of Manchester.

[4] Davis, S.B., Lansdown, J. and Huxor, A. (1996). The design of virtual environments. SIMA Report Series No. 27, AGOCG - Advisory Group On Computer Graphics, ISSN 1356-5370.

[5] Dearden, A.M. (1995). Improving the interfaces to interactive case memories. Proc. of the First United Kingdom Case-Based Reasoning Workshop. Eds. Watson, I., Marir, F. and Perera, S. University of Salford.

[6] Dean, C. and Whitlock, Q., (1992). A handbook of computer-based training. London: Kogan Page.

[7] Earnshaw, R.A.; Gigante, M.A. and Jones, H., (1993). Virtual Reality Systems. Academic Press.

[8] Gery, G.J., (1995). Making CBT happen. Gery Performance Press, Tolland, MA, USA.

[9] Hayward, T., (1993). Adventures in virtual reality. Prentice Hall Computer Publishing.

[10] Kolodner, J.L., (1993). Case-based reasoning. San Francisco, California: Morgan Kaufmann.

[11] Perera, R.S., (1997). A case-based approach for collaborative estimating and design. Ph.D. dissertation, University of Salford, Dept. of Surveying.

[12] Satalich, G.A. (1995). Navigating and wayfinding in virtual reality: finding proper tools and cues to enhance navigation awareness. Masters Thesis, Human Interface Technology Lab, University of Washington, http://www.hitl.washington.edu/publications/satalich/ (last visited 05/97).

[13] Schank, R.C., (1982). Dynamic memory: a theory of reminding and learning in computer and people. Cambridge University Press.

[14] Schank, R.D., Kass, A. & Riesbeck, C.K., 1994. Inside case-based explanation. Lawrence Erlbaum Associated, Inc., Publishers. Hillsdale, New Jersey.

[15] Schank, R. D., (1996). Goal-based scenarios: case-based reasoning meets learning by doing. In: Leake, D.B. (editor) Case-based reasoning: experiences, lessons and future directions. AAAI Press/MIT Press, pp. 295-347.

[16] Sherman, W.R. and Craig, A.B. (1995). Literacy in Virtual Reality: a New Medium. Computer Graphics, VOL 29 (4), pp. 37-41.

[17] Shlechter, T.M., (1991). Problems and promises of computer-based training. Norwood, N.J.:Ablex Pub. Corp.

[18] Sloan, B. and Schofield, N.D. (Eds.) (1992). Computer-based training in property and construction. University of Salford, Department of Surveying.

[19] Sycara, K., (1992). CADET: a case-based synthesis tool for engineering design. International Journal for Expert Systems. 4 (2), pp. 157-188.

[20] Yates, F.A, (1966). The art of memory. London: Routledge & Kegan Paul.

[21] Watson, I., (1997). Applying case-based reasoning. Morgan Kaufmann Publishers.

[22] Redmond M.A. 1992 - Learning by observing and understanding expert problem solving. Georgia Institute of Technology, College of Computing. Technical Report No . GIT-CC-92/43, Atlanta.

[23] Burke, R. and Kass, A. (1996) - Retrieving stories for case-based teaching. In: Leake, D.B. (ed.) - Case-based reasoning: experiences, lessons and future directions. AAAI Press/MIT Press, pp. 93-109.