VIRTUAL REALITY CASE-BASED REASONING:
A FRAMEWORK FOR COMPUTER-BASED INSTRUCTION

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Abstract

This paper presents a Computer-Based Training (CBT) tool that relies on an integration of Virtual Reality (VR) and Case-Based Reasoning (CBR). It is an application that handles past cases represented in Virtual Reality (VR) and aims at providing a framework for the development of computer-based instructional applications. A prototype has been developed as part of this research and is used to provide examples on the issues discussed. The application holds past experiences of experts in the inspection of health & safety regulations of scaffold structures. Each case in the prototype contains a virtual scaffold structure and tasks involved for its inspection. The instructional activity happens by reviewing tasks on scaffold inspection to either increase or evaluate users' skills. The prototype development methodology is presented explaining the process of case design in VR. A training session on the inspection of scaffold health & safety regulations is presented and conclusions are drawn.

Keywords: Case-based reasoning, computer-based training, case-based teaching, intelligent tutoring systems, virtual reality.

1 - Introduction

CBR is derived from Artificial Intelligence (AI) research and has its knowledge represented as cases that are similar to experiences in human memory (WATSON, 1997). Cases can be retrieved and used to clarify a present situation (KOLODNER, 1993).

Cases should be seen as a piece of memory representing a past experience, which is recorded and can be accessed for further examination. Current CBR research has been focusing attention mostly on two areas: storage and indexing for case retrieval; and media and structures for case representation. The latter represents the focus of this work, which introduces VR as an interface for case representation.

Case representation was pointed out by KOLODNER, (1993) as containing three major structural parts:

(i) the description of the case allowing its identification and retrieval;

(ii) the case itself, or the information that is relevant to the application domain; and

(iii) the solution, or resulting state of the domain when the solution was carried out.

This research uses VR to improve the interface for CBR in these three parts of a case. VR is a technology that handles representations of the physical world enabling the communication of ideas (SHERMAN, CRAIG, 1995). 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 interface for describing real world models (BROOKS, 1994).

The integration of CBR and VR plays its role in keeping records of past cases represented in a virtual environment simulating real situations. This approach can prove useful and help learning for such reasons as: it uses past cases to base its reasoning on, which is a natural process in human thinking, it allows students to learn by doing, which is one of the most recommended learning methods; and it provides all the advantages of CBT (DEAN, WHITLOCK, 1992; SHLECHTER, 1991) in an interactive environment that has the potential to stimulate learning (DAVIS, LANSDOWN, HUXOR, 1996).

2 - The CBR interface

DEARDEN, (1995) cited 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.

CBR is a system that gathers information about a problem; interprets that information; searches in a store of previous cases to find the ones that best match the inputted problem; and presents the cases matched, allowing users to get the information contained in those cases. Thus, users have to at least interface with the CBR system: to input the problem's description; and to receive the information contained in the case retrieved.

In the first situation, current CBR interfaces operate on a level of inputting textual description of cases. Depending on the CBR shell and the structure used for case representation, case description can also be made by selecting case features from menus.

The second situation deals with providing the information contained in a case, and this is where VR can play a major role. CBR applications are using multimedia techniques, such as sounds, pictures, image animation and digitised films, to better communicate the information contained in the cases. However, apart from VR, 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 for users. This definition also comprises animated images where the sequence of animation is predefined and the contents of the files can not be accessed.

VR representing past cases allows an "active" interface, in the sense that users can interact with it and perform their own experiences. The VR interface also allows access to case features that are dynamically displayed on the screen and can be used to facilitate memory recall. Overall, increasing CBR's potential to provide CBT applications as close to real situations as computers can provide is the main reason to bring VR and CBR together.

3 - The "art of memory" recall

> *"Images must be lively, active, striking, charged with emotional affects so that they may pass through the door of the storehouse of memory… however, we need to ask ourselves what would constitute the lively, active, striking and emotionally charged equivalents for our own time.*
>
> (YATES, 1966, p286)

YATES, (1966) cited that people remember things in the context of the reality found where the case happened, even if there is no significant connection between the thing remembered and the local where it is located. Space representation is a powerful trigger to recall memories and the information associated to them. Other issues that the "Art of Memory" offer to support the use of VR for case representation are:

(i) Imaginary or real structures - a scaffold is an example where a textual description would never provide the same level of remembrance as the visual representation of this structure, which can also include the advantage of people finding their way about the representation in VR.

(ii) 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 learning factor.

(iii) Taxonomies for thought - spaces have a coherence and logic that can be used to connect one idea to another, becoming a prominent tool to help user's mnemonic thought.

(iv) Representing realities - although some aspects of realities only exist inside the head of the individual, design in relation to the single observer can be used as mediation between individuals;

(v) Detection of motion - it is a strong element in visual perception and users can gain much information from it. Moreover, motion can be a main source of understanding for certain domains.

The aspects reviewed show that the place where the case happened is important for recalling and VR has much to offer assisting learners to understand and memorise information. VR can work as a filter for visual representation, allowing the display of information relevant to the domain. Aspects concerning the design of past experiences in VR are discussed in the following session.

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, 1986, p80)

Apart from the usual issues involving case representation in CBR (see KOLODNER, 1993; WATSON, 1997 for further details), this research also involves the construction of the virtual worlds where the cases are held. This is a process of design and, as such, there is no standard or common-sense operation or methodology to be followed (BROOKS, 1994).

The development of this project has shown that the understanding of VR capabilities and their influences over the human process of perception and cognition can help decide whether VR is appropriate for case representation. Moreover, what can be built in VR is not the only issue to consider in VR case design. For instance, aspects such as the user interaction with the virtual world, and the way it will be displayed should also be evaluated (DAVIS, LANSDOWN, HUXOR, 1996).

In order to help those interested in representing cases in VR, Table 1 shows aspects of reality and draws a comparison between three VR packages. Developers can match their needs to the VR package which capabilities best suits their application. The VR packages compared in this table are:

- 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)

Table 1 considers only built-in functions of the VR packages, avoiding need for skilful programmers to include those aspects of reality in the applications. Currently, most VR packages contain a programming language and thus, in a way, most of the aspects present in this table can be achieved. However, if the aspect requires programming, it has not been included "as supported" in this table.

Aspects of Reality	**VRT**	**WTK**	**IDS**
Extent and scaling			
Height	yes	yes	Yes
Depth	yes	yes	Yes
Breadth	yes	yes	Yes
Object's position and movement in 3D			
linear velocities	yes	yes	Yes
Translation	yes	yes	Yes
rotation	yes	yes	Yes
non-linear velocities	yes	yes	Yes
Lighting			
light source	yes	yes	Yes
Distancing	yes	yes	Yes
Direction	yes	yes	Yes
Spread	yes	no	No
different colours	yes	yes	Yes
Active colour properties			
Hue	yes	yes	Yes
Saturation	yes	yes	Yes
Passive colour properties			
Transparency	yes	no	No
Translucency	no	no	No
Reflectivity	no	no	No
Texture	yes	yes	Yes

Aspects of Reality	**VRT**	**WTK**	**IDS**
Viewpoint dynamics			
3D free movement	yes	yes	yes
variable degrees of freedom	yes	yes	yes
fixing to objects	yes	no	no
not to penetrate some objects	yes	yes	no
Dependable object Constraints	no	no	no
Hierarchical object constraints	yes	yes	yes
Object properties			
Mass	yes	yes	no
Volume	yes	no	no
Hardness	no	no	no
Brittleness	no	yes	no
Flexibility	no	no	no
Object behaviour			
Gravity	yes	no	no
change colour	yes	yes	yes
expand or contract	yes	yes	yes
reference to the viewpoint	yes	yes	yes
responsive sounds	yes	yes	no

Tab. 1 - aspects of reality supported by VR tools

Table 1 can also be seen as critical success factors that can be used to evaluate VR packages suitability for case representation and project development. At the time this paper was written those listed were top PC packages. They all are VRML compatible, although VRT and WTK claim that their own standards for delivering applications through the Internet are currently more comprehensive and powerful than VRML (which is actually true). However, ongoing developments in new VR tools and technology related applications are expected to improve representation of reality aspects, even for delivering VR applications through the Internet. Below are listed some more issues that developers should consider prior to choosing VR as CBR interface:

- even when the case representation involves some sort of spatial attributes, developers should ask themselves whether a 3D graphics display would enhance understanding;

- the creation of virtual worlds is a time-consuming task (though libraries of objects can be built up and accelerate the process) and developers should be conscious of this factor;

- most of the work involved in building VR worlds is uninteresting, repetitive and requires long hours of debugging, optimising, and setting up;

- there is a danger that virtual worlds when running on different hardware may appear differently from developers original intention.

Questions have been raised regarding the loss of abstraction that VR entails and its possible counter productive effect on understanding certain domains (DAVIS, LANSDOWN, HUXOR, 1996). For instance, SATALICH, (1995) describes a study where the users of VR performed worse than a group who only worked on paper. The same author cited that the reasons supporting these results could have been: the amount of time users have been using VR, considering the novelty of the technology; the issue and the way it has been developed, the learning evaluation methodology; 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 (SATALICH, 1995).

5 - Developing a prototype

A prototype has been developed as part of this research so as to explore the issues involving VR as an interface to represent CBR's cases and actions. The objectives of the prototyping stage were:

- helping to get feedback from the experts involved in this research;

- identifying 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 applications; and

- analysing the potential and weaknesses of this application as an intelligent training tool that keeps a corporate knowledge of the domain.

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. The following sub-sections provide further details on the development of this application.

5.1 - Case representation

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 the section 4, is not an easy task. Issues concerning the application of VR for representation of past experiences, which have been particularly important for the development of this work, are:

- presenting the cases in the way they have been visualised by the eyes of the experts;

- making cases useful in transmitting experts' experiences;

- displaying objects with the level of detail that is 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.

The structure for case representation in the prototype was implemented using the concept of Memory Organisation Packets (MOPs) and Scripts", which has been described in SCHANK, (1982) and SCHANK, (1996). This concept says, for instance, that a construction site with a scaffold structure serves as a MOP for an expert, and that the several activities involved in its inspection constitute what the concept calls a Script. Thus, each examination of a scaffold is represented as a series of Scripts (or tasks) that can be common for other scaffold structures.

For instance, one of the cases present in the prototype describes a site in which repairs will be done on the rooftop of a three-storey building. In order to identify whether the scaffold complies with British Standards regulations, some 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 that is common for several MOPs.

Objects in a virtual world are usually seen as buildings, rooms, walls, pieces of furniture, etc. However, VR files can also contain objects that are invisible for the environment and hold attributes responsible for interfaces, animation, and traditional computer algorithms such as functions, rules and procedures. Thus, case representation by VR involves tasks that go beyond the 3D modelling, such as the case description for future retrieval, which is discussed next.

5.2 - Featuring cases for retrieval

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

CBR guidelines for case retrieval prescribe that case features should be useful in describing the case and allowing its proper recognition and retrieval (KOLODNER 1993; WATSON, 1997). CBT requirements indicate that there is no a unique way to provide training neither a methodology leading to best learning. Moreover, the process of designing the lessons can be one of the most problematic aspects of CBT development (DEAN, WHITLOCK, 1992). The usual approach goes from fairly general knowledge (e.g. general implications of health & safety on scaffolding) to more specific tasks (e.g. how to properly inspect the scaffold foundations) (SHLECHTER, 1991).

REDMOND (1992) stated that CBR applications for training should also include two aspects: 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. The same author indicates that one of the greatest challenges in building such systems regards the ability to provide features capable of proper case retrieval as well as helping users to access cases' knowledge.

In the light of this work, case featuring has been approached in terms of describing scaffold structures and the tasks involved in performing inspection of health & safety regulations. Thus, features have been provided at two levels: (i) at the top level describing the cases, and (ii) at a lower level describing the Scripts each case contains. Case features have been chosen in terms of descriptions that differentiate the cases 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 levels of featuring have been carried out in close contact with experts, who also provided guidelines for the task sequence to be followed performing scaffold inspection.

The object-oriented hierarchy used for the VR case representation held an important role in this work. For instance, there are several CBR applications using various graphic media, such digitised images and video. An example of a learning application of CBR using digitised videos for case representation is the SPIEL (Story Producer for Interactive Learning) system (BURKE, KASS, 1996). Case features in SPIEL are textual descriptions of videos that are manually inputted into a database where those features are indexed to perform the retrieval.

Digitised videos have some characteristics differently approached in this project. Access to the contents of these images is performed on pixels and requires complex algorithms that do not provide precision to understand file contents (BIMBO, 1996). Moreover, case adaptation requires recording of new videos as well as the creation, input and indexing of new features. Thus, apart from the advantages supported by VR regarding its visual interactive environment (see section 2) this visualisation technique also provides access to the contents of the files. Advantages that can be taken from this access are:

- the possibility to create new cases by extracting and combining the virtual cases;

- the possibility to create libraries containing objects and hierarchies that can be shared between users and developers to speed up the process of case representation; and

- the possibility to develop computer algorithms to automatically perform the creation and featuring of new cases by adapting from the objects-hierarchies, thus avoiding the usual difficulties associated to these time-consuming tasks.

5.3 – Approach for retrieval

The retrieval mechanism adopted in this prototype works by accessing the contents of the VR cases through the object-oriented architecture used to represent the virtual worlds. The interface for retrieval in the prototype allows users to search either only for MOPs, only for Scripts or both together. It has been achieved by the featuring of cases and Scripts independently. The framework for featuring and retrieval of cases and Scripts follows an object-oriented hierarchy as displayed in Fig. 1. Features for cases have been stored as properties attached to a child of the object at the top of the cases' hierarchies (Global 1 to N) and to a child of the object at the top of the Scripts' hierarchies (Global S1 to SN).

At the very top of the hierarchy is a file called "Index" and it 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 the cases with their Scripts. Thus, the cases and Scripts contained in the prototype repository have their features stored into the case files as well as into the Index file. The reason behind this redundancy is to avoid the need to open the various VR files searching for their contents.

The retrieval mechanism performs a search using a weighted-nearest-neighbour approach (KOLODNER, 1993; WATSON, 1997) and the *core* of the retrieval algorithm is shown in Fig. 2.

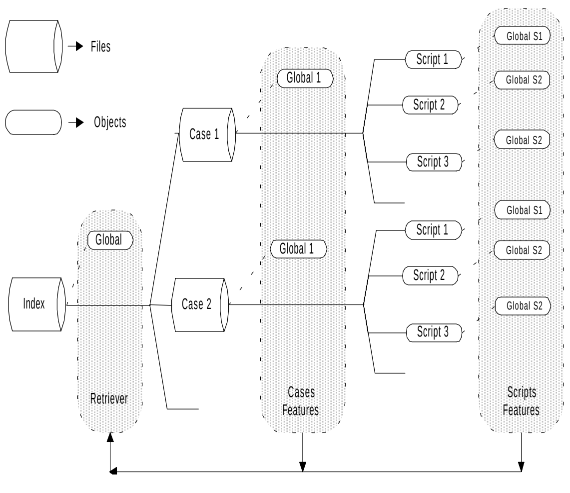

Fig. 1 - Architecture for the VR case featuring

```
/*  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 match > than 50% of the input
  Loop for X from 1 to Total_Number_of_Cases
      If Total_Match_Case (X) > 50%
      display Total_Match_Case (X)
```

Fig. 2 - Retrieval Mechanism

5.4 - training performance

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

This freedom to choose the sequence of the tasks inspecting scaffolds is quite in accordance with the CBR paradigm. CBR allows users the freedom to retrieve the case they want, according to the input describing the case. The same approach has been included in this prototype, which has also been designed to cater different levels of users, such as (i) beginners blindly following systems guidelines for the case retrieval sequence, (ii) users experienced with the domain retrieving the script they want to reinforce knowledge, and (iii) trainers illustrating their lessons with a virtual representation of past occurrences on site.

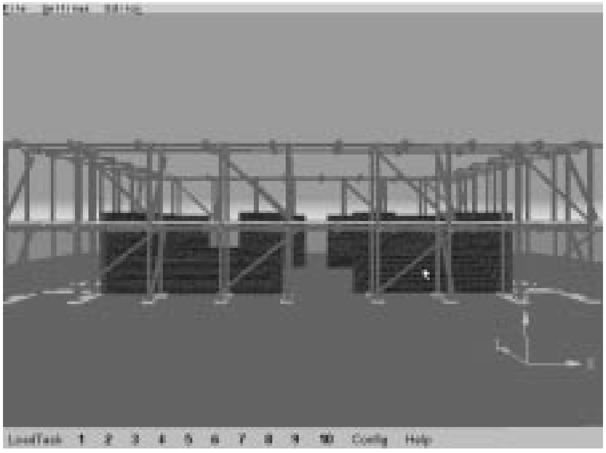

Fig. 3 - interface for case representation

Fig. 3 shows one of the cases present in the repository. The menu bar at the bottom prescribes a sequence of scripts associated to the inspection on this structure. When clicking the mouse over the script number, the system presents guidelines on how to properly perform the task associated to the number. Thus, the number will change its colour on the menu bar, indicating that the task has been performed.

For instance, one script deals with the inspection on the overhang at the end of the boards. The system's guidelines move the viewpoint around the structure, replicating the views that an expert would have on a real site (see Fig. 4). Theoretical information about this task is also provided by reading the menus or listening to an expert's advice.

Independently from the system's guidelines, users can freely walk-through the virtual case searching for irregularities on the structure. Once a irregularity is found, users can click on the object and the system will fix it. This approach is specially important for trainers, who can use the system as a tool to illustrate site occurrences. For instance, viewpoints such as presented on Fig. 5, could be difficult or dangerous to access even on real structures. Moreover, trainees would need to physically go to a site where this structure is present, and special supervision would be required.

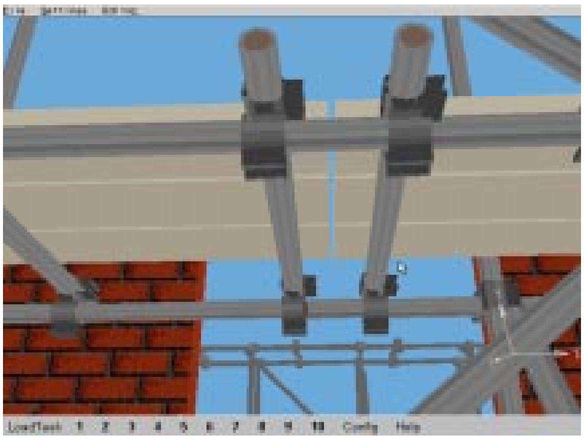

Fig. 4 - overhang of the scaffold's boards

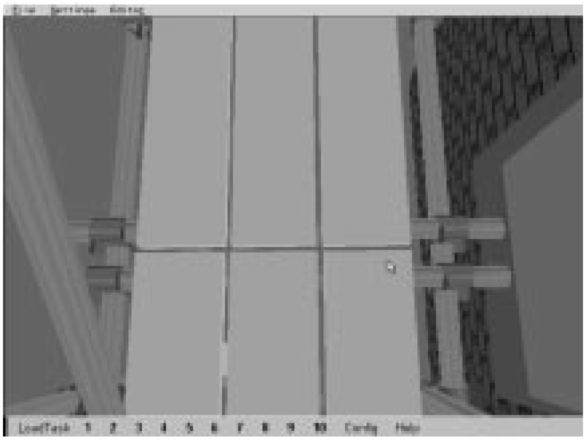

Fig. 5 - view from the scaffold's platform.

Most of the objects of the scaffold structure hold 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.

6 - Conclusions

Experiencing is a keyword related to VR and a dominant characteristic of this application. In fact, VR allows training by-doing or by-experiencing which is a recommended form of learning (SHERMAN, CRAIG, 1995). The physical world simulation, achieved by VR, which has an special meaning for several domains, provides an interactive environment that facilitates understanding of the performances displayed.

The process of designing virtual worlds can be difficult and time-consuming. However software for virtual world building are becoming more powerful day-by-day. Moreover, third-party objects are becoming increasingly available and it will ease the process of virtual world design. Modelling techniques to previously evaluate objects' behaviour, dimensions, positions, dependencies and links with other objects may help easing and speeding up world creation.

VRML is in a state of rapid development. Along with the Internet it can bring a number of attractive features for education, such as; it is compatible with several computer-platforms and browsers; there is a great number of software and libraries that can be downloaded for free; and it relies on existing WWW tools that are currently part of students knowledge, easing its use and accelerating its spread.

CBR enables retrieval of past cases which can make users learn by: (i) having the opportunity to access the structure and the contents of a past experience; (ii) understanding the content of a case and its relevance to the domain, (iii) accessing the actions and recommendations taken from the past case; (iv) reasoning to solve new situations by establishing comparisons with similar cases in the repository, and (v) creating new cases by adapting from 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 advantage learning (SHERMAN, CRAIG, 1995). One of the main reasons to choose CBT relies on providing good courseware at low cost. The experience taken from this project express that though it shall not be seen as a minimum cost option, subsequent updates and revisions should be possible at relatively low cost. Therefore, CBT may not be seen as an approach to bring best results in a short period of time.

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