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CLLIS - A Lessons Learned System for Knowledge Management in Construction Organizations

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Abstract
Knowledge Management (KM) is a concept that is gaining wide acceptance and is being implemented in various industries as an enabler of better decision-making. KM can be defined as the management of knowledge-related activities involving knowledge-workers in an organisation to achieve the specified organisational goals and objectives. KM concepts can be implemented to capture and reuse the construction knowledge derived from this information for improving the construction business processes in terms of time, cost, safety, and quality. This paper addresses the issues involved in the design and development of a Lessons Learned System (LLS) on the conceptual basis of Case-based Reasoning (CBR) for effective & efficient KM in construction organisations. An Internet-based prototype tool, CLLIS (Construction Lessons Learned Information System) has been developed to collect, document, store, retrieve, and reuse the construction lessons learned.

Keywords
Lessons Learned System, Knowledge Management, Construction Management, Case-based Reasoning

1. Introduction

Construction projects require effective collaboration, coordination, and communication with data and information exchange among a large number of organisations that will be responsible for various phases of the project life cycle. With the construction industry becoming more information and knowledge intensive, it has become essential for construction organisations to manage the knowledge embedded in the construction business processes to remain competitive. 'Knowledge Management' (KM) is an emerging concept that is gaining wide acceptance and is being implemented in many industries to achieve improved level of performance and competence. KM can be defined as the management of knowledge-related activities involving knowledge-workers in an organisation to achieve the specified organisational goals and objectives.

Traditional methods of gathering and using lessons learned have enjoyed limited success due to various reasons (Kartam, 1996). Some of them are: (i) lack of meaningful classification system, (ii) unmanageable format that limit access, retrieval, and updating of the potentially enormous volume of lessons, and (iii) difficulty in integrating new systems into existing operations & procedures. With the advancements in Information and Communication Technologies (ICT) it is possible to overcome some of the shortcomings in the traditional Lessons Learned Systems (LLS). An ICT-enabled LLS can facilitate learning in a construction organisation. Case-Based Reasoning (CBR) is an Artificial Intelligence (AI) technique, which is capable of utilising the specific knowledge of previously experienced problem

situations (cases). It is also an approach to incremental and sustained learning. Since it is very difficult to formulate rules based on the ill-defined construction cases, this methodology of reusing cases to solve similar problems in future is definitely a better option for a construction LLS. The objective of this paper is to present the design and development of CLLIS (Construction Lessons Learned Information System) - a LLS prototype. CLLIS was developed based on the conceptual basis of CBR.

2. Literature Review

The most common formalised feedback system presently used by construction organisations is "close-out" or "postconstruction" conferences at the conclusion of projects (Kartam, 1996). While they are beneficial to some participants, they have many shortcomings. The most serious shortcoming is the failure to uniformly document lessons learned in a manner useful to others in the future. Application of lessons learned has been attempted to some extent in the field of aerospace engineering (NASA Lessons Learned, 2000, RECALL Lessons Learned, 2000), health and safety (Department of Energy Lessons Learned, 2000), design (East et al., 1995, Architect Lessons Learned, 2000) and general project management (Saad and Hancher, 1998). AI technologies like rule-based Expert Systems (ESs) and Neural Networks (NNs) have been extensively used for some applications in these domains. However, these techniques have various drawbacks in applications: ESs lack the capability to learn themselves, and NNs deal primarily with problems that could be presented in numerical figures (Yau and Yang, 1998).

2.1 CBR in Construction

Several CBR systems have been proposed for the construction domain in recent years. CBR is useful for a wide variety of problem solving tasks, including planning, diagnosis and design (Kolodner and Jona, 1991). The Reviewer's Assistant is a system developed at the U.S. Army Corps of Engineers, Construction Engineering Research Laboratories (CERL) to assist design reviewers in capturing and appropriately reusing their design review experience (East et al., 1995). ARCHIE is an architectural design system, CADSYN and DDIS are structural design systems developed using CBR (Kolodner, 1993). Yau and Yang (1998) recommended that in the experience oriented construction industry, CBR adapts well for computer applications, as long as information from previous projects is available. Yau and Yang (1998) also developed a CBR application, CBR-CURE, to estimate construction duration and costs of building construction projects at the preliminary design stage. Arditi and Tokdemir (1999) developed a CBR based model to predict the outcome of construction litigation.

Some of the systems described above (Reviewer's Assistant, RECALL, CADSYN, ARCHIE, and CBR-CURE) have been developed on the conceptual basis of CBR with limited implementation. There is a need in the construction industry for the standard methodology for documentation and reuse of lessons learned. These lessons learned should also be readily available to the construction personnel at various construction sites, which may be geographically widespread.

3. Solution Methodology

The broad solution concept adopted to arrive at a solution for the above mentioned problem is to use an Internet-based CBR system, which facilitates some of the KM needs of the construction organisations. A basic structure of the construction case was designed based on the literature available. A combination of semi-structured interviews and questionnaire survey had been conducted to acquire the cases to seed the case-base and to refine the proposed case structure. An Internet-based prototype tool (CLLIS) has been developed to demonstrate the concept.

3.1 Issues to be addressed in the Development of CBR Solution Methodology

At the highest level of generality, a general CBR cycle may be described by the following four processes (Watson and Marir, 1994): (i) RETRIEVE the most similar case or cases from the case-base, (ii) REUSE the information and knowledge in that case to solve the problem, (iii) REVISE the proposed solution, and (iv) RETAIN the parts of this experience likely to be useful for future problem solving. The following issues should be addressed while developing a CBR system: *Case representation, Case indexing, Case storage, Case retrieval, and Case adaptation*.

3.2 Collection of Construction Cases

One of the key elements of a KM endeavor is the capture of both explicit and tacit knowledge from "knowledge workers" (experts who have knowledge). A basic questionnaire that has been developed based on the structure of the construction case was used in the semi-structured interviews with construction managers and engineers of three major construction firms in India, to collect the initial cases. It has been found during the discussions that most of the problems faced in the construction sites are related to general project management rather than technical problems. The authors were able to collect around 20 cases from projects involving the pre-cast construction of flyovers, bridges and viaducts.

4. Design of Framework for CLLIS

Developing a CBR system involves several typical processes as shown in the Figure 1.

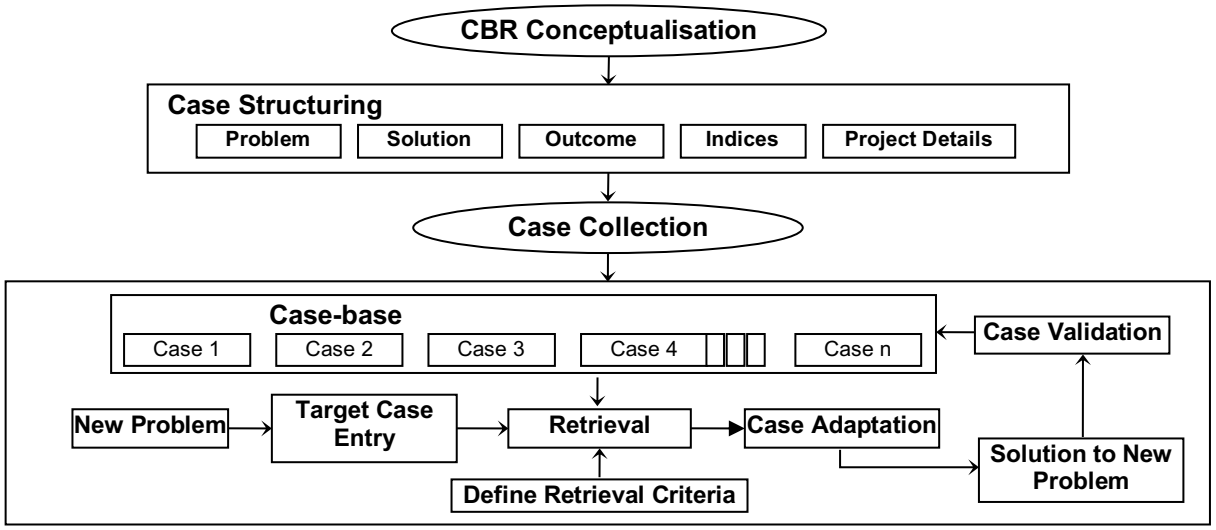

Figure 1: General CBR Development Methodology
(Adapted from Yau and Yang, 1998)

4.1 Case Structuring / Knowledge Representation and Case Retrieval

Knowledge representation is a key element of any knowledge management initiative. A construction case basically consists of three entities namely, (1) Lesson, (2) Index, and (3) Project Details. Further, lesson is a composition of (a) Problem description, (b) Solution description, and (c) Outcome description, as presented in Figure 2. Each entity in the case is represented by a set of fields. Three sets of indices have been used to organise the construction lessons. One is based on the MASTERSPEC specifications (to represent the activity codes), the second is based on keywords and the third is based on the structure. MASTERSPEC is a comprehensive, efficient, and easy-to-use master specification system (ARCOM, 2000). Another major constituent of a construction case is the details pertaining to the project from which

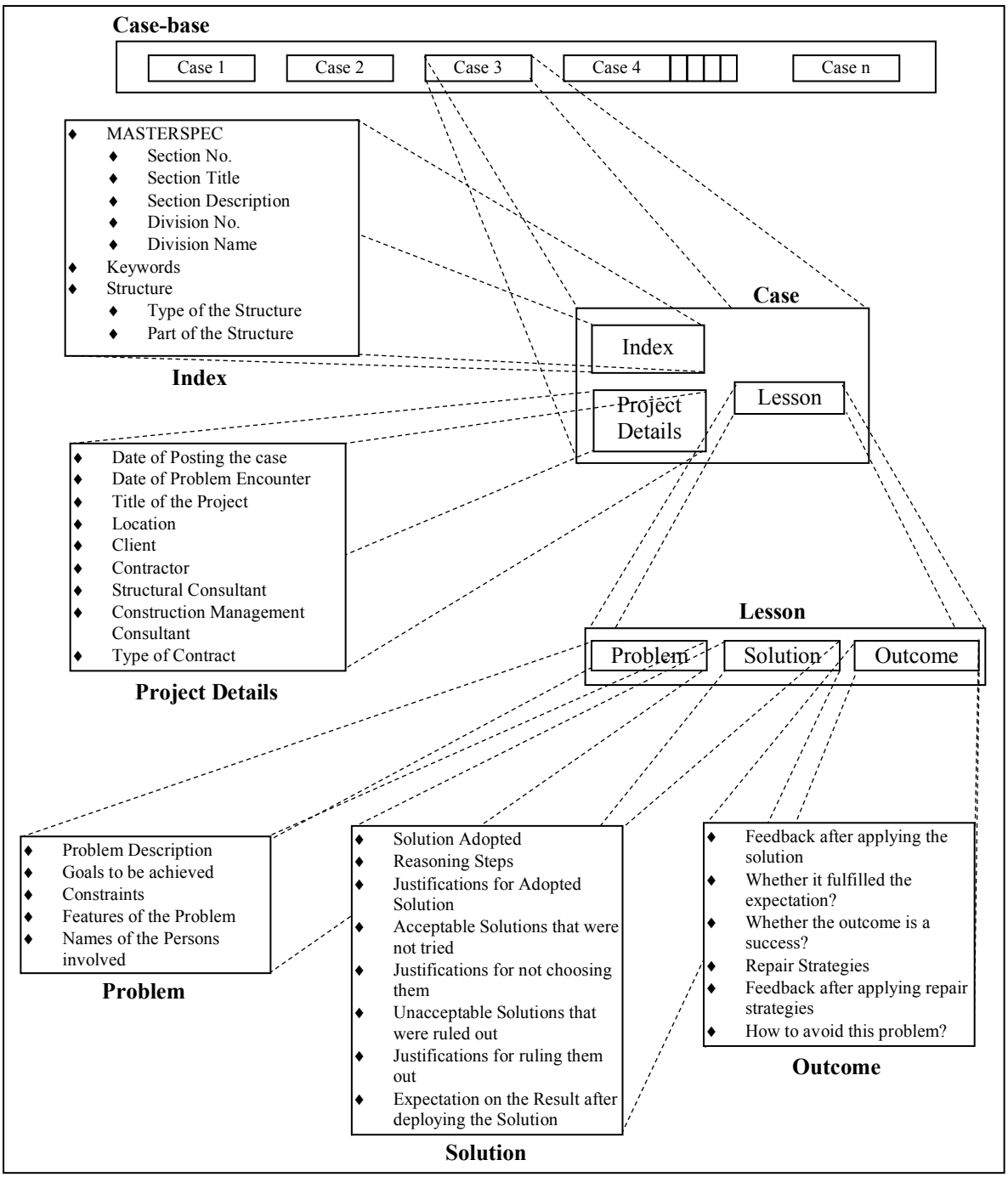

Figure 2: Organisation of Case-base

the case is recorded. This is to present the general description of the case. Case retrieval based on MASTERSPEC specifications and keywords were considered desirable for implementation.

4.2 Case Adaptation

The partially matching cases for the present problem are to be manipulated to propose a ballpark solution. Since the construction cases are ill defined, it is very difficult to frame rules. Hence, it has been proposed to refine the search methodology. The case-base was searched with multiple fields viz. Type of Structure,

Part of Structure, Keywords, Type of Contract, MASTERSPEC Division Number, and Project Location along with weights (to specify the importance of a field). User can select weight for a field from a range of 1 to 10. *Degree of match* (*DoM)* is calculated based on the matching fields of the above input variables, with the corresponding fields of the cases in the case-base and their weights. *DoM* is basically a weighted mean of the matching fields (Charlesraj, 2001).

All the partially matching cases were ranked based on the *DoM*. The solution of the case with the highest *DoM* is assumed as the initial solution for the present problem. It is the responsibility of the user to judge whether this solution can be directly applied or needs some modification or the solution needs to be derived right from the scratch. Though CBR was used as the conceptual basis for the design and development of CLLIS, only limited capabilities have been implemented. The case evaluation and adaptation functions were not fully implemented in this application. Experts in both CBR research (Kolodner, 1991) and applications (Mark et al., 1996, Haque et al., 1999) agree that the best use of CBR is as advisory systems that rely on the user to perform evaluation and adaptation.

5. Implementation Details of CLLIS

The system architecture of the CLLIS is shown in the Figure 3. HTML programming has been used to create the Graphical User Interfaces (GUI) for entering new cases, case querying and query results. Server-side processing has been done using Active Server Pages (ASP) with VBScript. Construction cases that were collected to seed the case-base were stored in Microsoft Access database. Microsoft Access database tables have been designed based on the evolved case structure. Tables that were created in Microsoft Access are: Problem, Solution, Feedback, Project_Details, and Index. All these tables were connected using the CaseID as the primary key. Queries have been designed using Structured Query Language (SQL) to search through the case-base. Microsoft ODBC (Object DataBase Connectivity) was utilised to connect to the database. Pictures/Drawings relating to cases were stored separately and linked dynamically to the cases.

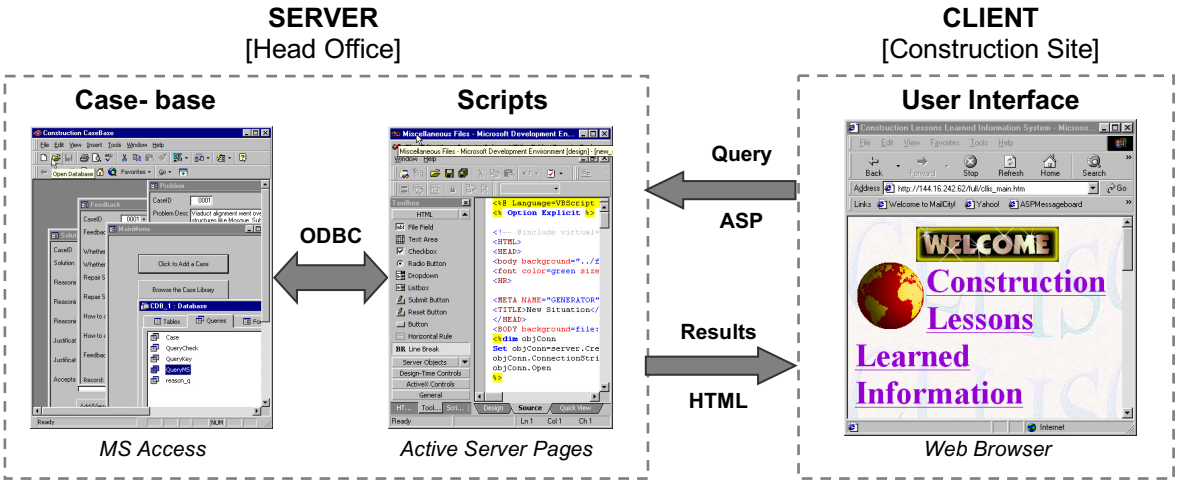

Figure 3: System Architecture of CLLIS

The following functions are provided by the CLLIS: (i) Users can search the case-base based on the MASTERSPEC Section Number, (ii) Users can search the case-base based on keywords, (iii) Users can browse through all the cases in the case-base, (iv) Users can submit a new lesson, (v) Users can search the case-base based on multiple fields, and (vi) Help and Error Handling.

6. Summary and Conclusions

A framework has been developed to collect, document, store, retrieve, and reuse the construction lessons learned. An Internet-based prototype tool, CLLIS has been developed. Implementation of a tool like CLLIS in a construction organisation will improve the management of construction knowledge within and/or across the construction organisations. Periodical review and addition/deletion of the construction cases ensures the knowledge update. Instant access to the knowledge can be ensured in this system with state-of-the-art methods in ICT. CBR can be used to develop LLS, to assist the construction engineers/managers. Development of an automated CBR system for a construction organisation is very difficult to implement considering the wide variety of problems faced in a construction organisation.

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