Health and Safety Code Compliance Checking using an Integrated Hypertext and Knowledge-Based Expert System

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ABSTRACT

Several older buildings have been found to violate the building code requirements with respect to health and safety of occupants. In order to ensure compliance, building managers and inspectors require a thorough knowledge of code documents and expertise to assess the seriousness of violations. The present study aims at developing a computer tool integrating hyperlext and knowledge-based system techniques to facilitate code compliance checking and provide access to case studies of problem scenarios. The knowledge-base has been developed by extracting the relevant portions of the building code and these have been represented as rules. The case siudies information has been extracted from recent studies carried out by Public Works Canada. Typical interaction with the expert system will lead the user through a hierarchy of potential problems and identify the specific code requirement that is violated. Expert assistance in the form of explanations, reference to similar problem scenarios and interpretations to the code will be provided to the user. A framework to develop such a prototype system named HASES (Health and Safety Expert System) is presented. The ultimate objective of this system is to provide field inspectors with expert assistance, reference material and report writing using IBM-PC notepad/portable computers.

INTRODUCTION

In order to ensure the health and safety of occupants, buildings must be inspected to check their compliance to current regulatory requirements prompted by building code changes or other standards. A recent study undertaken by the Public Works Canada shows that several Agriculture Canada buildings have code violations affecting the occupants in terms of air quality, water quality, fire safety and other occupancy hazards. It is often difficult for building managers and inspectors to identify these problems, because of the lack of expertise in compliance checking.

Research in computer aided conformance checking has resulted in the development of several prototype expert systems for design assistance (1,2) and hypertext systems to provide the electronic versions of the code (3). Though these technologies have wide application in the industry, the development of commercial tools have not been successful yet. Further, many development efforts have fallen short of the industry expectations with respect to functionality and practicality. It is recognized that expert assistance to interpret code requirements, to identify solutions to potential problems and to prepare report are essential in any automated code compliance checking system.

The knowledge required in compliance checking expert system is directly obtained from the building code documents. But this information is not sufficient to assist inspectors in identifying and resolving code violations. Recent building inspection studies carried out by Public Works Canada shows that a database of problem scenarios would be extremely valuable to the user. Several case study documents produced by PWC contain this practical knowledge which can be made available by integrating a textual database with a building code knowledge base.

OBJECTIVES

Public Works Canada have recently completed a study of 19 Agriculture Canada buildings, and compiled the results in three volumes reporting a total of about 1700 occurrences of code violations and recommendations to overcome these problems (4). There is a dearth of information that can be extracted from the above study

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to implement a knowledge-based expert system to assist in future building inspections. Figure 1 shows the classification of problem categories relating to health and safety of occupants. A typical frequency of problem occurrence for one of the buildings is shown in Table 1. It can be observed that fire, occupancy and other building hazards are most often encountered. In addition, air quality problems have been very significant.

Many of these problems are a result of the change in building code requirements over the past thirty years. Technological developments and occupancy changes have also contributed to such situations. Buildings must be inspected periodically to check compliance to current building code requirements with respect to health and safety. The objective of the present study is to develop an expert system incorporating both the building code requirements and the case study information. Such a system should assist building inspectors to navigate through the relevant portions of the code, identify any possible violations and propose strategies to resolve them. In addition, automatic report generation of the inspection is needed to maintain consistency and save time.

Based on the review of the Agriculture Canada building inspection studies, it has been found that most violations correspond to the requirements in Part III of the National Building Code of Canada (5). Some of the important ones include the requirements for exits, fire separations, fire alarms, sprinklers, barrier free access and service facilities. The case study information relating to these requirements are extracted for three buildings. Each case study is stored in a database with the following information: problem type, description, causes, recommendations and the code reference. The user will be able to access both the code text and case study information during any consultation. Three types of users, namely advanced, novice and expert are expected to access the knowledge base. Based on the level of user expertise, explanations and reasoning will be provided.

REPRESENTATION ISSUES

A review of existing software development techniques show that hypertext representations are efficient for automating code references and problem descriptions. Rule-based representations are suitable to identify code violations by defining the code requirements. A recent technique known as expertext has also been demonstrated to achieve the above objectives of code compliance checking (6). The present implementation will integrate hypertext and knowledge-based techniques to provide a framework for incremental development and easy updating. The following knowledge sources have been identified for the six major problem categories:

i. *Air quality*
   ASHRAE Standards
ii. *Water quality*
   Canadian Plumbing Code 1990
iii. *Environmental detriments*
   Canadian Environmental Protection Act
iv. *Fire hazards*
   National Fire Protection Code 1990

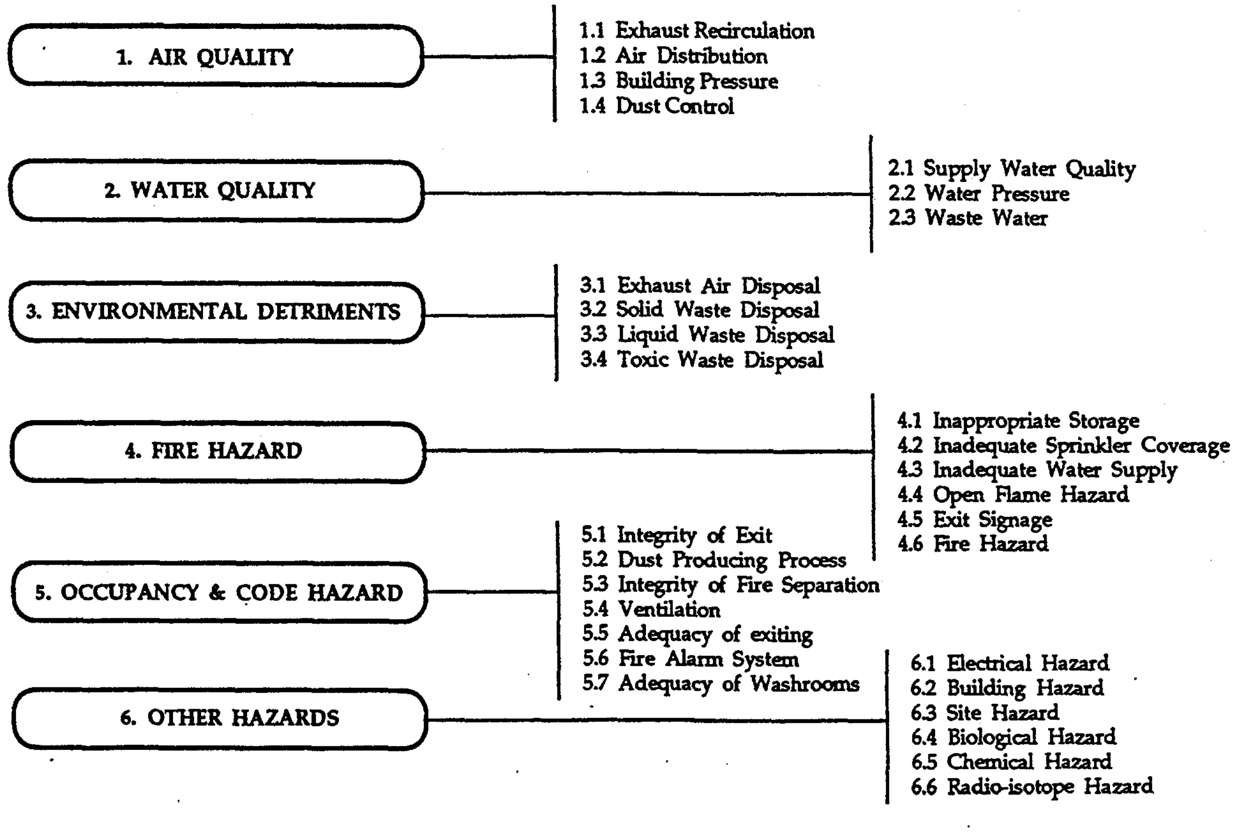

Figure 1: Classification of Problem Categories

#	Problem type	freq.	#	Category	freq.
1	**Air Quality**	17	1.1	Exhaust Recirculation	8
			1.2	Air Distribution	9
			1.3	Building Pressure	0
			1.4	Dust Control	0
2	**Water Quality**	4	2.1	Supply Water Quality	2
			2.2	Water Pressure	1
			2.3	Waste Water	1
3	**Environmental Detriments**	0	3.1	Exhaust Air Disposal	0
			3.2	Solid Waste Disposal	0
			3.3	Liquid Waste Disposal	0
			3.4	Toxic Waste Disposal	0
4	**Fire Hazard**	29	4.1	Inappropriate Storage	3
			4.2	Inadequate Sprinkler Coverage	1
			4.3	Inadequate Water Supply	2
			4.4	Open Flame Hazard	0
			4.5	Exit Signage	0
			4.6	Fuel Dispensing	0
			4.7	***Fire Hazard***	***23***
5	**Occup. & Code Hazard**	26	5.1	Integrity of Exit	4
			5.2	Dust Producing Process	0
			5.3	Integrity of Fire Separation	9
			5.4	Ventilation	4
			5.5	Adequacy of Exiting	6
			5.6	Fire Alarm	1
			5.7	Adequacy of Washrooms	0
6	**Other Hazards**	50	6.1	Electrical Hazard	6
			6.2	***Building Hazard***	***40***
			6.3	Site Hazard	2
			6.4	Biological Hazard	0
			6.5	Chemical Hazard	2
			6.6	Radio-isotope Hazard	0

Table 1: Typical Frequencies of Problems

v. *Occupancy and code hazards*
National Building Code 1990

vi. *Other hazards*
Occupational Health & Safety Handbook

The current implementation focuses first on the occupancy and code hazards which are caused by violating the current National Building Code (NBC). Part III of the NBC addresses the Use and Occupancy requirements including fire safety and service facilities. The first step in knowledge extraction is to identify the relevant clauses of the building code that correspond to medium and high rise office buildings. NBC refers to these buildings as occupancies D and F-3. The minimum floor area of buildings is assumed to be 600 sq.m., thereby excluding the requirements of Part IX. All buildings will be checked for the 1990 edition of the code requirements as if they were built new or undergoing renovations. Some buildings might not have been modified for many years, at which time they comply with the then required codes, but changes in occupancies over time might cause occupancy hazards.

Once all the relevant code articles are identified, the next step is to develop a hierarchy of objects and attributes which can be used in IF-THEN rules to represent the code requirements. All construction elements and building components are identified as objects, i.e.: door, exit, corridor, room, etc. Any property associated with an object is defined as an attribute. The major issue in knowledge representation here is to identify the relationship between objects and attributes. A sample hierarchy of objects, attributes and their relationships for representing exit requirements is shown in Figure 2. There are three levels of attribute relationships used in implementation. The first level provides the relationship between building parameters such as building height, number of floors, etc. and specific building components such as an exit. The second level links the various attributes of building components, for example, the number of exits, exit width and distance between exits. The bottom most level will relate the attributes of the different building components.

Figure 3 shows the software architecture of HASES implementation. The knowledge base consists of the following components:

(i) Building database
(ii) Objects database
(iii) Code requirements
(iv) Case studies database

The building database consists of generic data of all buildings that are under investigation. This database will contain information about the building name, location, number of floors, area, construction type, occupancy classification and other global data required to extract the portion of building code that is to be used in compliance checking.

The objects database will consist of all the attributes and values for building objects to represent factual information contained in the building code. In addition, the user input values are retained in the objects database during a consultation. The rule base operates on this information and contains all conditional requirements of the code. This inference mechanism is primarily forward chaining, supplemented by "when changed" methods. This combination of inference techniques will ensure consistency and constraint evaluation in a dynamic manner.

The implementation is being carried out using LEVEL 5, an object oriented development tool available in the MS-Windows environment. LEVEL 5 facilitates the integration of multiple representation techniques including frame-based, rule-based and hypertext, and provides tools to rapidly develop end-user interfaces. Several display screens and rules have been implemented along with the case studies database for three buildings.

Example scenario

A typical consultation session with HASES will have the following steps:

Step 1:
The user begins a consultation specifying the level of his/her expertise to be either expert, advanced or beginner. Based on the level of expertise, the system will provide an appropriate level of guidance.

Step 2:
The user will then select a building from a database of buildings to obtain the basic parameters. If the building to be investigated is new, it can be added to the database and the following parameters have to be defined: building name, address, occupancy classification, area, height, number of storey below grade, number of facing streets, type of construction and presence of sprinklers.

Step 3:
The user selects a problem category and from hereon the problem definition begins. Menus of items will be presented to obtain specific information required to check compliance.

As an example, if the user chooses Occupancy and Code Hazards, then a subsequent menu containing the following items will be provided: exits, fire alarm system, floor safety, adequacy of washrooms, fire separation and barrier-free access. Assuming that the user selects exits, another menu of relevant items such as integrity of exits, number of exits, exit headroom clearance, exit width, etc. Each item here corresponds to specific code requirements. If the exit width is selected, then the system will request the type of exit and the area of floor that this exit serves. Knowing the area, the system will calculate the number of persons using the exit, and then calculate the required exit width based on the exit type. Comparing the required exit width to the actual, the system will provide the result of compliance check.

Step 4:
The result will be displayed in an output screen with options to obtain explanation and reasoning. Access to the text of building code clauses will be provided. Also there will be options to prepare a report and save it in files.

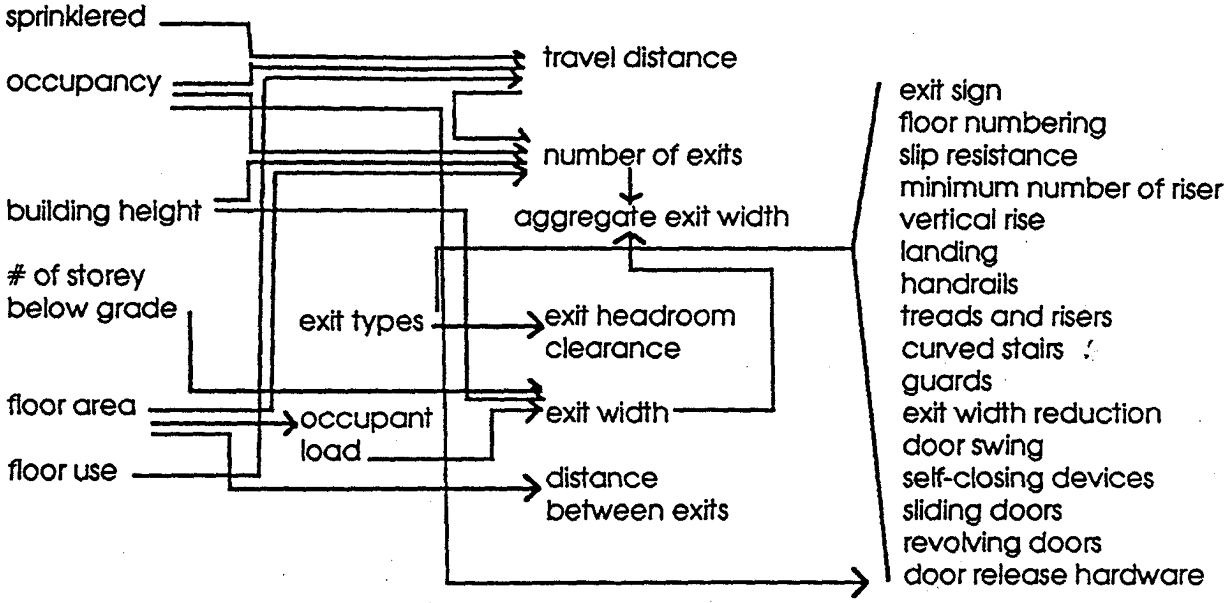

Figure 2: Three Levels of Relationships Between Attributes

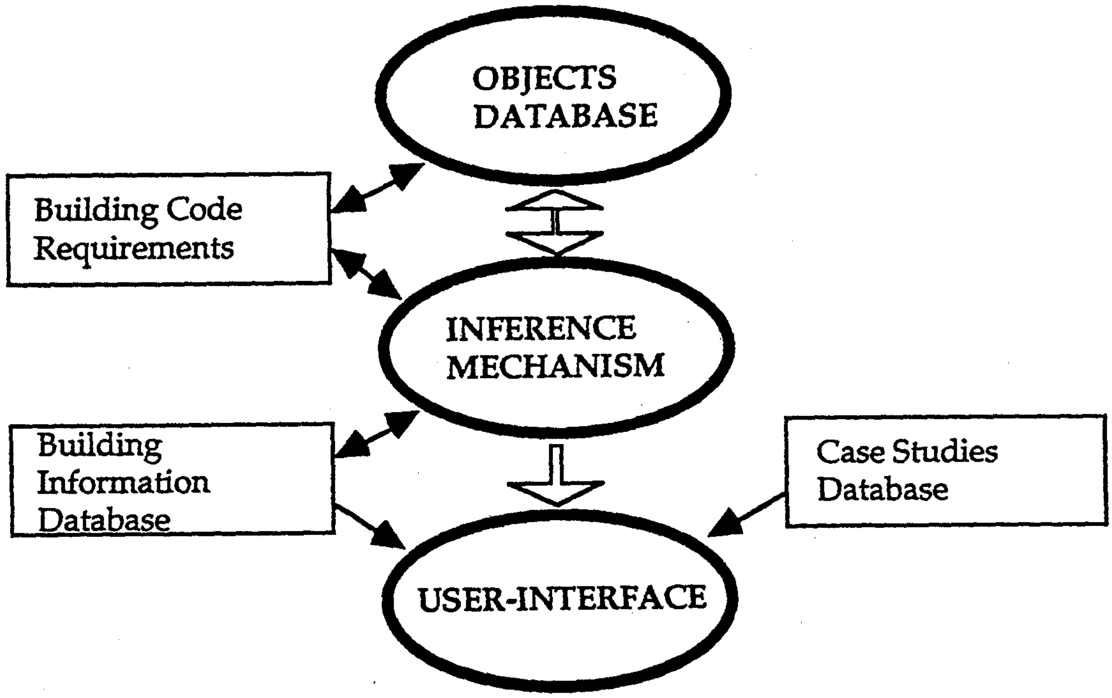

Figure 3 : HASES Software Architecture

Step 5:
Once a compliance check is completed, the results can be added to the case histories database. Subsequently, the user can cyclically continue to evaluate other requirements by repeating steps 2 through 5.

In addition to the above, the user could access the case studies database at any time during a consultation and retrieve information and access the building code text as required.

CONCLUSIONS

The present work demonstrates the development of an integrated hypertext and knowledge-based environment for code compliance checking. The HASES system will improve productivity and provide built-in expertise to field inspectors who may need instant help. The hypertext database will provide case studies information which is often useful to establish the seriousness and magnitude of problems. Also the reference to specific buildings would enable the building managers to identify the people whom to contact for further assistance. The expert system approach to compliance checking would lead to consistent and thorough verification of building code requirements and selective access to code documents would enhance the consulting session. Field testing of the HASES system will soon be carried out to obtain feedback from building inspectors. The HASES knowledge base and scope should further be extended to address the other issues relating to indoor air quality and environmental hazards.

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