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Knowledge-based navigation system for building health diagnosis

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ABSTRACT

Medical records are important diagnostic tools designed to assist doctors in the management of their patients' health. Maintenance records are vital for on-site building managers in a comparable sense when planning the operational life cycle of the buildings housing health facilities. Unlike their medical counterparts though, these records are compromised by a lack of systematization and empirical verification. With a view to redressing these shortcomings, this paper introduces a knowledge extraction method that combines semantic indexing and clustering analysis, referred to as the Building Diagnosis Navigation System (BDN System).

1. Introduction

The building life cycle consists of several stages: proposal, planning, design, construction, operation, renovation, and demolition. In terms of the cost of the building life cycle (LCC) or long-term management, the managerial emphasis has shifted from planning, design, and construction, to the operational stage [1]. The duties of on-site building managers at the operational stage typically involve community affairs, security, planning and cleaning services. They also perform facility management on a regular and casual basis. Difficulties often emerge during diagnosis owing to the lack of real-time referential materials. Although the Building Management System (BMS) is commonly used in enterprises, asset value management or scheduling management is usually the major focus. Consequently, the maintenance record section only offers brief details about repairs in relation to time, cost, location, and so forth. However, the absence of a maintenance knowledge base would result in a cognitive error – a misdiagnosis – on the part of whoever was maintaining it [2]. This information is of limited value when making maintenance decisions. When on-site managers search the Internet, they are confronted by an overwhelming amount of data. Consider the case of a leaking roof, for example. Performing a Google search on "roof leaking what to do" returns approximately 4,160,000 results. The absence of consistent criteria makes it difficult to choose effectively. It follows that on-site managers face three interrelated problems during the implementation of a maintenance strategy. Firstly, internal building maintenance records and knowledge lack structure because they have not been tested in practice. Secondly, most companies do not share internal knowledge with the public [3]. Consequently, the public resorts to the Internet to satisfy their information needs. However, Internet sources are commonly regarded as unreliable [4]. Some can even be misleading to such an extent that they create risks for users [5], The problem with the quality of information on the Internet is not that there is too little of it available, but rather that there is too much; vast chunks of it are incomplete, misleading, or inaccurate, and this is not only the case in the medical arena [6]. However, recent studies show that while novices can easily find information for questions that have specific answers, they have difficulty in finding answers for questions requiring a comprehensive understanding of a topic (e.g. identifying risks and preventive measures) [7]. Incomplete information can easily lead to incorrect maintenance operations. Maintenance deficiencies are usually associated with building deterioration that was overlooked and treated in an improper fashion [8]. In summary; information on the Internet is often inadequately tested and examined due to its incompleteness. Therefore, users cannot be assured of its credibility for practical purposes. The published reports of research institutes can be acceptable alternatives in certain respects, but considerations of time effectiveness and cost have rendered them beyond the scope of this paper. Third, and finally, the manager cannot avail themselves of the reference materials at their disposal.

Concerning the first two problems, it has been noted [9] that maintenance records are kept in a structured storage system. This enables the on-site managers to retrieve precedents from case his-

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tories when deciding on an appropriate course of action. In addition to test reports and construction layout, the details of maintenance contractors or experts with comparable experience can be accessed. Ideally, consistent monitoring of the Building Medical Record (BMR) workflow would improve the reliability of the references. In practice, however, the sharing of knowledge may be restricted by the decentralization of electronic files (BMR files in MS Word or Excel format). Therefore, information acquisition and reuse remain problematic. When addressing the third problem from a network perspective, it becomes obvious that information overload is a significant problem for Internet users. In recognition of this fact, Google released its "Wonder Wheel" in 2009. This tool enables users to construct search strings through keyword-based clusters, thereby refining information retrieval. The Building Diagnosis Navigation System (BDN System) has in turn incorporated these principles of the "Wonder Wheel". It is anticipated that the Web-based application of the BDN System can resolve any problems associated with BMR file retrieval.

This study proposes a concept of Building Medicine that is analogous to the design logic of human medical records. BMR facilitates the diagnosis of facilities so maintenance can be performed as required. Human medicine has certainly progressed rapidly, so it appears likely that digital medical records will eventually act as real-time references during diagnostic procedures. The BDN System is an extension of BMR with the capacity to streamline the BMR (database and workflow) structure. Information access and the on-site facility management can be coordinated via a wireless Internet connection. This model develops a technique to extract the BMR so knowledge can be reused. An ontology-like dynamic building disease classification is developed by combining semantic indexing and clustering analysis.

The effective accumulation and reuse of repair records can provide feedback during the planning and design stage of a building's life cycle. Taiwanese construction companies can offer service commission experts in response to maintenance and management problems. Architects can have recourse to these services as a form of quality assurance. Arditi and Nawakorawit [10] view the direct participation of a property company in a favorable light, arguing that it contributes to the assessment of facility construction. Chew and De Silva [11] argued that early feedback on poor building maintenance and construction could prevent any recurrence. Research by Shen et al. [12] shows that information technology will play a key role in the construction industry over the next decade. The BDN System is the key to the effective accumulation, extraction, and reuse of maintenance records. Property management and construction companies stand to gain from its incorporation into their workflows.

The largest property management company in Taiwan, the Tokyo Property Management Group (TPMG), assisted the testing of the BDN System. In addition to their provision of maintenance data, TPMG invited twenty on-site managers to participate in a survey. The principle objective was to determine if the BDN System reduced the amount of time required to reach decisions, along with any associated operational costs. The enhancement of competitiveness hinges on the retrieval of case histories and experts relevant to the problem at hand.

2. Background research

2.1. BMR implement

This study uses the SOAP progress note as the design reference for the diagnostics of the BDN System. Chang et al. [9] developed Building Medical Records (BMRs) based on human medical records. The BMR structure includes basic information, a problem list, the SOAP progress note, and attached reports. The S in the SOAP progress denotes any subjective statements made by maintenance personnel or users. O stands for objective finding. In this step, past test reports, inspections and related layouts are examined. If there is a construction document germane to the diagnosis, it is carefully noted for future reference. A involves Assessment. This extends to function evaluation, the building's family history, and the cause of disease. Preventive measures are also recorded. P refers to a Plan, whereby a treatment method, non-hazardous/green renovation material, and Health Counsel of Building Management (similar to Health Counsel of Human Medicine) are recorded. An example of the application of SOAP progress can be found in Table 1, where maintenance and management records in BMR are incorporated into TPMG.

2.2. Traditional maintenance records and future trend versus BMR

Maintenance records are usually comprised of checklists, handbooks, or building management systems. BMR differs by focusing on preventive measures rather than post-factum diagnosis. Liska and Liska [13] developed diagnostic forms suited to routine inspections. However, the fixed checklist format makes little allowance for the recording of new kinds of problems or future long-term maintenance strategies. The Building Long Life Meeting of the Japanese Building [14] makes specific reference to The Building Construction Handbook, as a source of information regarding the diagnosis of building diseases. It consists of 29 chapters, which cover topics such as structure, waterproofing, exterior walls, facilities, the environment, and earthquake proofing. The illustrations explain diagnosis, method, and standards. Although the book may be exhaustive with respect to its featured items, it is difficult to generalize such findings to all building diseases. Their growing number and sheer variety can only be addressed on an ongoing case-by-case basis. It is certainly difficult to collate relevant maintenance data, images, medical records, and test reports, so an innovative methodology is clearly required.

ARCHIBUS/FM is a brand of internationally renowned property management software. Its condition assessment function predicts and evaluates the future repair and cost efficiency of the maintenance activities. It is also designed to track the execution progress of maintenance activities [15]. Such a computerized maintenance management system (CMMS) can facilitate functions such as work orders, trouble calls, equipment cribs, storage inventories and preventive maintenance schedules [16]. However, it is reliant on the knowledge and experience of in-house craftspeople and contractors. The evaluations are recorded in the work description, while the craftspeople enter data in the note field. The simplicity of this content does not compare to the comprehensiveness of a doctor's records. Therefore, the comprehensive maintenance support of domain specific knowledge that on-site maintenance staff require in order to reduce human error becomes more problematic [2].

The application of the facility management system is also problematic. Howard and Björk [3] note that clients who successfully use Building Information Modeling (BIM) may not wish to share their knowledge. For example, several of the leading property owners using BIM are public bodies and are therefore obligated to publish their experience. Property management companies can use BMR to assist their diagnosis of a facility and expedite their decisions about treatment prior to the sharing of property knowledge. In terms of the application of BMR, Shen et al. [17] integrated the lifecycle of a construction project (including design, procurement, construction, operation, and maintenance) to support the effective maintenance of built structures, facilities, and infrastructures. The integration of BIM and RFID is an example of this approach. Ergen et al. [18] also proposed that information could be recorded by RFID during the operation and maintenance stages. In the foreseeable future, these records could be integrated with the manage-