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ANALYSIS OF KNOWLEDGE SOURCES AND PROCESSING IN THE CONSTRUCTION AREA

ANALIZA ŹRÓDEŁ WIEDZY I JEJ PRZETWARZANIA W BUDOWNICTWIE

Abstract

A presentation of knowledge sources in the construction industry studied amounting to several years of experience. Knowledge is an indispensable element of engineering activity. Its characteristics, like the characteristics of the construction industry, require frequent updating of knowledge, and the knowledge itself is often hidden and not accessible directly. In a certain way, this justifies building knowledge-based support systems as tools for faster, more efficient and prompt functioning in the engineering business. Apart from characteristics of knowledge sources, the article presents the sometimes critical overview of methods for acquiring and further processing such knowledge. The usefulness of knowledge acquisition methods tested by the author largely depend on the source itself, as well as the form and content of this knowledge.

Keywords: knowledge acquisition, decision support system, data & text mining, CBR

Streszczenie

Zaprezentowano przeanalizowane na przestrzeni kilkuletnich doświadczeń źródła wiedzy w budownictwie. Wiedza jest niezbędnym elementem działalności inżynierskiej. Zarówno jej specyfika, jak i specyfika budownictwa wymaga częstych aktualizacji wiedzy, a ona sama jest częstokroć ukryta i niedostępna w formie bezpośredniej. Uzasadnia to budowę systemów wspomagających opartych na wiedzy, pozwalających na szybsze, efektywniejsze i sprawniejsze funkcjonowanie w działalności inżynierskiej. Oprócz charakterystyki źródeł wiedzy artykuł przedstawia krytyczne spojrzenie na metody pozyskiwania wiedzy oraz jej dalszego przetwarzania. Użyteczność przetestowanych przez autora metod pozyskiwania wiedzy w dużym stopniu zależy od samego jej źródła, a także od jej formy oraz zawartości.

Słowa kluczowe: akwizycja wiedzy, systemy wspomagania decyzji, data & text mining, CBR

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1. Introduction

Through an analysis of construction project management process, one can unequivocally conclude that this process is based on the process of continuous decision making. a characteristic feature of construction is its dynamic decision-making environment, defined by the uncertainty and risk factors. Furthermore, it has been observed that decisions – particularly those taken on an operating level – are characterized by extreme time pressure and the redundancy of information received. The excessive volume of information reaching the decision-maker will not facilitate the decision-making process while at the same time is not equivalent to having knowledge, as a basis of the reasoning process, at one's disposal.

In order to enhance the decision-making process, certain decision support solutions are being implemented (DSS). Their implementations are known, and the usefulness of such tools is without dispute [1, 5, 7, 9]. The vast majority of these are knowledge-based systems. Expert systems are the primary class of such systems. Other tools beyond these can be specified which by themselves constitute to knowledge media, such as artificial neural networks.

The process of developing such a tool, following a preliminary phase of identifying the needs, possibilities and relevance of development, are based on knowledge acquisition. The quality and sometimes complementarity acquired knowledge determines the quality and usefulness of decision-maker's support tool.

Analysis of all available knowledge acquisitions options for purposes related to the development of a DSS system in construction leads to the discovery of a vast diversity of available knowledge sources. The primary purpose of this article is the transfer the author's experience in the field of seeking knowledge acquisition methods according to knowledge source characteristics. Acquisition of knowledge is related to the extension and development of an advisory system created by the author into a complex technical management system [5]. This project is a strategic goal, the pursuit of which seems to inherently require the choice and adaptation of a knowledge acquisition method to available – sometimes unique – sources in the construction area.

2. Knowledge sources, acquisition and storage methods

During the process of building, any decision-making support tool based on knowledge cannot be completed correctly without a stage corresponding to knowledge acquisition. Several minor tasks can be distinguished within this stage:

1. Identification of knowledge sources, their usefulness and utilization options.
2. Choice of knowledge acquisition method according to source characteristics.
3. Preparation and implementation of the acquisition process.
4. Processing acquired knowledge.
5. Formalization and storage thereof in knowledge repository.

Prior analysis by the author came to the conclusion that there is a high diversification of available knowledge sources in the construction area. Figure 1 presents, inter alia, various forms of knowledge sources with corresponding examples.

When reviewing the available knowledge sources in the construction area, one can notice their characteristics, consisting of diverse ways of storing knowledge and various forms of knowledge*. For an expert, a knowledge source is an expert's mental model; in a text document, knowledge is encoded as a verbal transcription in a specific language, according to the applicable spelling and grammar rules; analyzing and acquiring knowledge requires observation, registration and formalization. This leads to a general conclusion that the knowledge acquisition method depends on the characteristics of the source of such knowledge. Therefore, a single method cannot be unequivocally and arbitrarily adopted for such acquisition; individual methods need to be matched with the source, often involving simultaneous acquisition, which allows bridging knowledge gaps.

Available knowledge acquisition methods can be generally divided into traditional "manual" methods and automated methods (Fig. 1). Based on further conclusions, it seems reasonable to establish a third class of hybrid methods, constituting a coherent combination of elements of traditional and automated acquisition methods, alternatively a combination of their simultaneous use in the case of acquiring knowledge from one and the same source. Remarks about the foregoing will be presented in the final section of the article; still, this phenomenon is mentioned at this point.

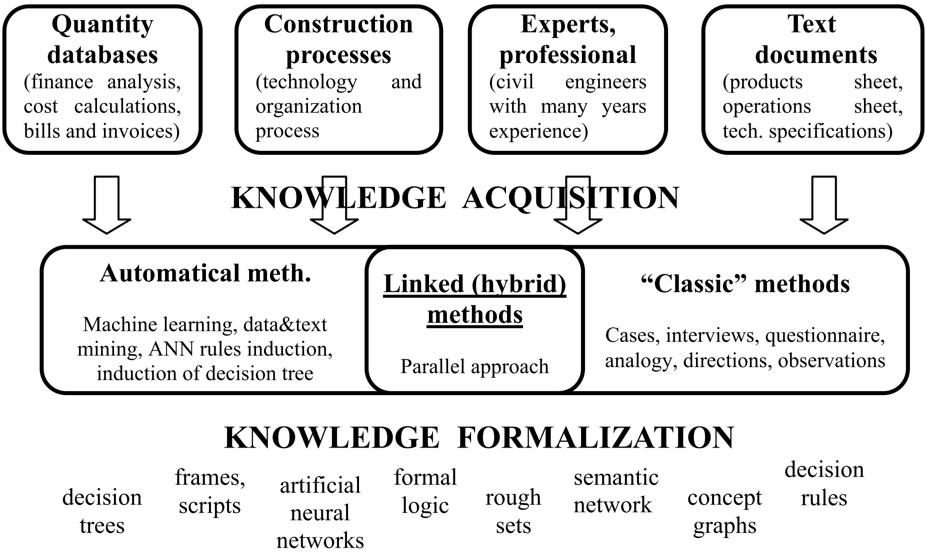

Fig. 1. Knowledge in construction – possible sources, acquisition and formalizations methods

* Knowledge in the industry also comes in the form of skill, which can take months or years to acquire. In some cases this skill is simply lost due to the person with that skill leaving the industry, having never properly passed it on.

The final primary element related to the phase of acquiring knowledge for the purposes of building a DSS system is the method of processing and formalization acquired knowledge. In this aspect, one may point to consequence of executing prior tasks. The choice of knowledge formalization method is complex because, as it was already noticed earlier, it is a consequence of the initiated knowledge acquisition process but at the same time refers to the subsequent stage, i.e. building a DSS system as a tool. With regard to knowledge formalization methods, there are universal and dedicated methods to retain knowledge either openly or in a hidden form. Fig. 1 gives an approximate classification of knowledge formalization methods, and more comments about the selected methods will be presented further in the article.

3. Acquisition processes – case analysis

With regard to an effort to pursue a task constituting development of an intelligent large-size warehousing facilities management system, the author used various knowledge acquisition methods, allowing him to share his observations and to state his conclusions.

3.1. Expert knowledge

An expert turned out to be the first and natural source of knowledge. An approach involving acquisition of expert knowledge has been presented in [6]. An expert is a person specializing in a narrow field, with extensive knowledge and experience, who resolves complex problems requiring such knowledge and experience. Expert knowledge resources are gathered in the expert's mind through a so-called mental model. This model is often extensive and its complementarity depends directly on the expert's knowledge and experience. Transferring such a model directly into a knowledge base tool offers the chance of obtaining a complete base, often exhaustively describing the relationships governing the given phenomenon. Unfortunately, a mental model also involves one of the major weaknesses of this source. a mental model is not tangible; it is an abstract repository. In order to acquire knowledge contained in a mental model, due to its format (intangible), one may apply traditional/ manual knowledge acquisition methods. The most commonly chosen form of acquisition is to conduct a personal interview. When this approach is used, one should take account the gradual loss of knowledge during the acquisition process and further during formalization. This is a natural occurrence, due to the fact that all forms of communication with an expert (whether verbal or non-verbal) involve certain limitations in transferring knowledge (such as language limitations, encoding). Another item that adversely affects the ability to acquire a complete model is the noise occurring in the acquisition process, followed by the knowledge formalization process itself, which also leads to further depletion of knowledge. In order to eliminate the knowledge depletion process, repeated knowledge acquisition sessions concerning the same phenomenon should be applied, as well as simultaneous knowledge acquisition using different techniques as far as possible. This generates added costs related to the need to verify knowledge obtained through various methods and during subsequent acquisition sessions, rendering the acquisition process time-consuming and requiring engagement of an expert each time.

Knowledge obtained from an expert is usually available in natural (linguistic) format; therefore, it is easy to interpret but difficult to process. If we intend to use it as a support system module, it needs to be adapted accordingly to the characteristics of the reasoning apparatus. This requires the choice of an appropriate method of encoding knowledge contained in the database. According to the author's experience, the most common and "friendly" format for recording expert knowledge is the rule-based "if... then" format, i.e. simple or complex rules. Using relatively simple methods (scaling, fuzzy sets, binary encoding), knowledge can be transformed and its format can be adapted to the majority of reasoning mechanisms. An example diagram of expert knowledge acquisition is presented on Fig. 2.

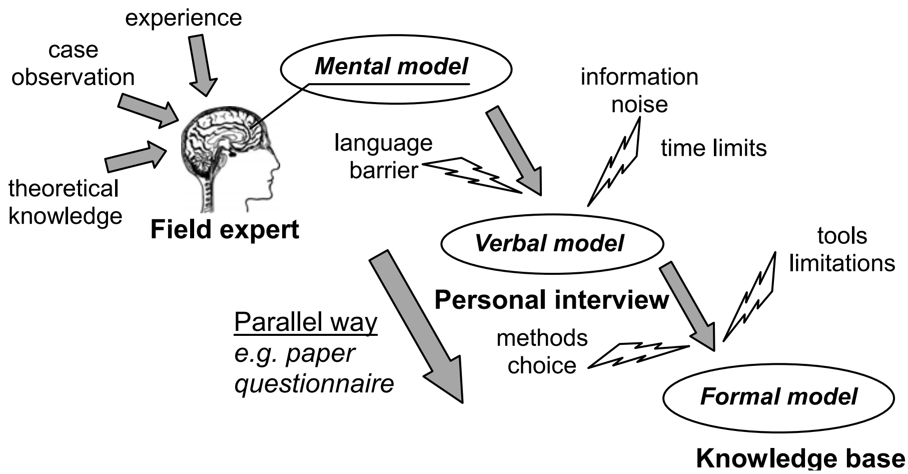

Fig. 2. Example of expert knowledge acquisition process with possible environmental specific factors

3.2. Data and text documents

Currently, there is a major source of various papers related to economic reviews, concept designs, design dossier elements, technical opinions, material data sheets, etc. available to the construction industry. These papers are available both on hard copy and in electronic format, and the data and further the knowledge contained therein is based on quantitative and qualitative format, i.e. text. In order to acquire and use knowledge from this kind of source, one may use various knowledge acquisition and formalization techniques. The first group of acquisition techniques refers to "traditional" methods where the acquisition approach will be based on thorough analysis of source (text, numerical specification, design) by a party specializing in the given field; this will be followed by a procedure similar to the approach presented earlier (section 3.1) Execution of the processes has been identified on Fig. 2. This approach is time-consuming and costly but, as it will turn out, it allows for acquiring precise, pure (with minimum proportion of noise) and easy to interpret knowledge.

In order to shorten the acquisition process, one may use a group of automated methods. Data & text mining techniques which may serve as a good example here. Detailed descriptions of these techniques and attempts at applying them in the construction industry are presented in [2, 4]. These methods, albeit seemingly efficient and quick in theory, will not always yield the anticipated results with reference to the characteristics of sources in the construction area. This remark refers mainly to the text mining method. The method, consisting of acquiring formalized knowledge from text documents, would not always lead to complete and adequate interpretation of source. In the construction area, practically any text document contains a certain portion of information identified with a numerical value and associated measurement unit. These elements, often without context in the mining industry, were interpreted as noise and subject to reduction. Consequently, the acquisition process would be depleted by this portion, very important in reality. The analyzed cases of text mining implementation showed a certain consistency of acquired knowledge with the actual situation (acquired through the traditional approach); however, for this method only an approximate state of knowledge can be referenced. Where such a state is sufficient for reasoning, use of text mining method seems reasonable, which is even more the case considering that the final product of the acquisition process is often formalized (neural network, decision tree). It should, however, be noted that the data mining method shows up fewer weak points than text mining. On the basis of the reviewed cases [4], we may conclude that this approach works to a satisfactory extent with regard to quantitative data. The approach requires certain "manual" control over the analyzed data groups, but enables quick learning of the relationships between the factors under review, and acquired knowledge – as in the case of text mining – it is recorded in formal media.

Incidentally when describing this source, it would be reasonable to mention the options of further processing knowledge contained in universal media, such as artificial neural networks or decision trees. With reference to Fig. 1, one may notice that the media mentioned above is recognized as a knowledge source. This is partially due to the format, format which – for example in case of a neural network – are equated with a "black box", and on the other hand the fact that in reality, the popularity and versatility of this media has led to encoding knowledge originally in that format, as in the case of language encoding for text sources. The paper [3] presents a concept for expanding such knowledge through complemented automation and clarification involving a relatively simple Bio-Re algorithm. The reason behind the use of this algorithm is to achieve a complete representation of knowledge and not only input-output sets. This approach facilitates learning and understanding the relationships governing the input-output system. At the moment, work is being carried out with the purpose of effectively implementing such an approach in translating various cases of knowledge contained in neural networks.

3.3. Case observation

The observation of various processes and occurrences constitutes a third group of knowledge sources in the construction area. The author believes this is the most valuable source of knowledge, as in-depth analysis provides grounds for observing a spectrum of factors affecting achievement of the goal, observing the importance of these factors, possible problems, and at the same time quickly confronting the results in real-life system. This method is reasoning, called CBR (case-based reasoning), is acknowledged and described [8] and applied, however it would be useful to focus on two specific fields. The first of these is related to the tooling base, the other – to placement of a baseline in the "knowledge-phenomena-result" and aiming at the optimum value. When focusing on the tooling base, one will notice a certain trend for implementation of visual and automated techniques in observation and registration of processes and occurrences. Employing an expert in observation of processes/phenomena, followed by acquisition of knowledge from his mental model, can be taken into consideration, by analogy to the above described procedures, but it is in such complex approach an expensive arrangement (cost of expert employment), often not practically feasible (expert's time limitation,). a simpler solution would be to prepare such resources as special forms for observers (even without specialized knowledge). It is important to prepare such forms so as to make them fit for use in an automated knowledge acquisition process. This is the approach followed by the author in researching operational damage in large-sized warehouse buildings, for the purpose of developing a technical management system. This approach involves the special adaptation of a form – “event notification sheet” – adjusted to the requirements of the mining text process in which efforts are taken to minimize the certain negative phenomena identified above, consisting of a significant loss of quantitative data. The study covered more than ten warehouses storing automotive spares as part of a distribution network, and has not yet been completed due to the lengthy event observation process (events are occasional in nature).

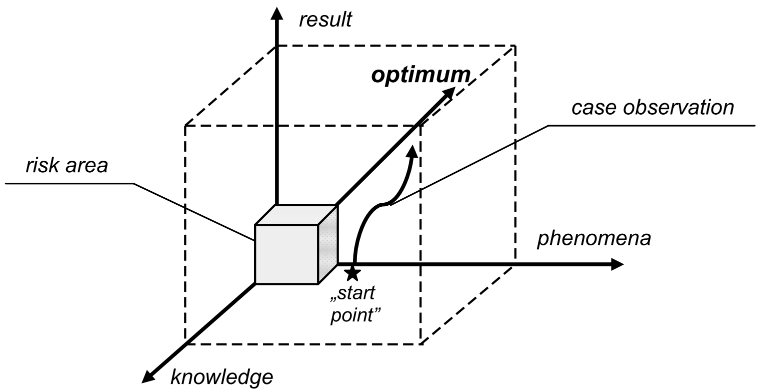

Fig. 3. Placement of “start point” in the “knowledge-phenomena-result” space

Another significant field for this knowledge source is the baseline point in the “knowledge-phenomena-result” space. Its location determines the accuracy and speed in achieving a certain optimum in knowledge availability, awareness of the given phenomenon in a real system, and achievement of the anticipated result. An example of such system is presented on Fig. 3. It seems extremely important that the baseline point placement can be derived from a certain level of original knowledge, which may be obtained on the basis of operations of an initial decision system, engineering experience, or theoretical background. a situation in which the baseline point location is purely accidental and intuitive constitutes a major risk area for correct interpretation of observations, and at the same time this presents serious uncertainty regarding optimum and accurate decision making.

4. Conclusions

The groups of knowledge sources presented in the construction industry lead to a conclusion about their diversity in terms of formats and representatives, as well as characteristics of simultaneous occurrence of quantitative and qualitative descriptions, being mutual in terms of content and meaning. Analysis of these sources as well as experience in the acquisition process authorize a statement that expert knowledge, which he already has, constitutes the most extensive knowledge source, and the knowledge acquisition process itself is relatively simple and temperately sensitive to loss of knowledge contained. For other sources, represented in great numbers, the acquisition process can be automated; however, considering the characteristics of these sources and resultant knowledge losses, only an approximate representation of knowledge can be obtained. The author's current work on knowledge acquisition is aimed at implementing parallel approaches in knowledge acquisition (where internal consistency of acquired knowledge is an issue) and the application of controlled mining techniques, where a preliminary acquisition template would eliminate the phenomenon of loss of a certain portion of knowledge described in quantitative format.

References

[1] Anderson T., *Knowledge types: Practical approach to guide knowledge engineering in domains of building design*, Expert Systems, Vol. 13, No. 2, 1996, 143-149.

[2] Gajzler M., *Text and data mining techniques in aspect of knowledge acquisition for decision support system in construction industry*, Technological and Economic Development of Economy, Vol. 2, 2010, 219-232.

[3] Gajzler M., *The Idea of Knowledge Supplementation and Explanation Using Neural Networks to Support Decisions in Construction Engineering*, Procedia Engineering, Vol. 57, 2013, 302-309.

[4] Gajzler M., *Zagadnienie wyboru lokalizacji z wykorzystaniem metodyk data mining*, Budownictwo i Inżynieria Środowiska, Vol. 2, No. 3, 2011, 253-261.

[5] Gajzler M., *The Support of Building Management in the Aspect of Technical Maintenance,* Procedia Engineering, Vol. 54, 2013, 615-624.

[6] Gajzler M., *Neural networks in the advisory system for repairs of industrial concrete floors*, Computer Assisted Mechanics and Engineering Sciences, Vol. 18, No. 4, 2011, 51-54.

[7] Hajdasz M., *Flexible management of repetitive construction processes by an intelligent support system*, Expert Systems with Applications, Vol. 41, No. 4, 2014, 962-973.

[8] Kończak A., Pasławski J., *Abductive and Deductive Approach in Learning from Examples Method for Technological Decisions Making*, Procedia Engineering, Vol. 57, 2013, 583-588.

[9] McCowan A., Mohamed S., *Decision support system to evaluate and compare concessions options*, Journal of Engineering and Management, Vol. 133, No. 2. 2007, 114-123.