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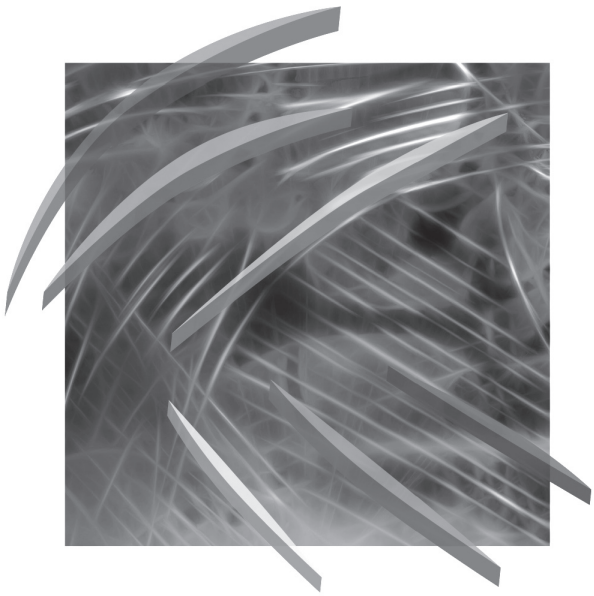

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BUSINESS DECISION SUPPORT USING HYBRID EXPERT SYSTEM

Abstract: The paper deals with the application of a hybrid expert system, Aitech DSS, which has been practically utilized for credit risk assessment and for decision support in financial analysis. The paper describes architecture of this hybrid DSS system. Additionally, it provides information about CAKE, a computer-aided knowledge engineering system, used for building Aitech DSS application.

Key words: decision support, expert system, hybrid expert system.

1. Introduction

Complex decision problems which often occur in business, especially in large firms and banking systems, require solutions which go beyond the traditional and well-established information technologies. For example, a full assessment of a firm's financial situation could benefit from connecting the diagnostic information with the prognostic information. Thus, the assessment uses a triplet: diagnosis – prognosis – decision. Moreover, a special case of a decision could be a specification of a repair process (e.g. a therapy). Expert systems address the above issues and provide valuable solutions in almost all disciplines – from medicine (e.g. among the latest applications see: [Kwiatkowska, Michalik 2008; Kwiatkowska, Kielan, Michalik 2009]), through geology, to engineering. Expert systems were utilized noticeably later in business than in the other disciplines, i.e. approximately in the mid-1980s. For example, the following early systems are well-described in the subject literature: FOLIO [Waterman 1985], TAXMAN, TAXADVISOR [Simons 1985], PlanPower [Stansfield, Greenfeld 1987], INVEST [Heuer 1988], Auditor [Dungan, Chandler 1985], Underwriting Advisor [Harmon, Maus, Morrissey 1988], FSA [Mui, McCarthy 1987] (see also: [Chandler, Liang 1990]). The early applications of expert systems in banking can be discussed separately, for example, early systems include

Lending Advisor, Letter of Credit Advisor [Harmon, Maus, Morrissey 1988], and Corporate evaluation [Barret, Beerel 1988]. In Poland, one of the first commercial-scale applications of expert systems was a project undertaken by the AITECH Artificial Intelligence Laboratory. This initiative started in 1990, and it has resulted in a completion of a specialized software system which has been intended primarily for business users. This system consists of an Artificial Intelligence (AI) software package, SPHINX, and an intelligent support system for economic and financial decisions, Aitech DSS. In both cases, the key components are a hybrid expert system, PC-Shell, and a simulator for artificial neural networks, Neuronix [Michalik 2002, 2004a]. Also, this system includes (1) a specialized tool to support the development and verification of hybrid expert applications, CAKE (Computer Aided Knowledge Engineering), and (2) an integrated environment to support the creation of analytical decision-support systems, HybRex.

2. A system for credit risk assessment and financial analysis

The presented system Aitech DSS is an intelligent decision support system (IDSS) for credit risk assessment and financial analysis. The overall structure of Aitech DSS is based on a tool system, HybRex, which in turn is a part of the SPHINX package. The Aitech DDS has been utilized in business applications by several companies such as banks, energy companies, and heating plants. The HybRex environment allows for the creation of an IDSS characterized by a hybrid architecture, which uses an expert system (ES) and neural networks (NN). Additionally, the HybRex allows for a full integration with the conventional technologies, for example, with built-in electronic spreadsheets for calculations and with the graphical library for graph presentations (Figure 1). The available information technologies, including ES and NN, are defined in the system dictionary as available methods in a method library. More specifically, a method is understood as a tool, an algorithm, a procedure, or an information technology provided for solving or visualization of a particular class of problems.

The methods are closely connected with their implementations. The present version of Aitech DSS provides the following methods [Michalik 2004b]:

– expert system,
– neural network,
– calculation spreadsheet,
– timesheet,
– dialog (GUI),
– access to databases,
– external interface (among others, to databases via ODBC),
– cube (using OLAP terminology),
– prognosis,
– report,

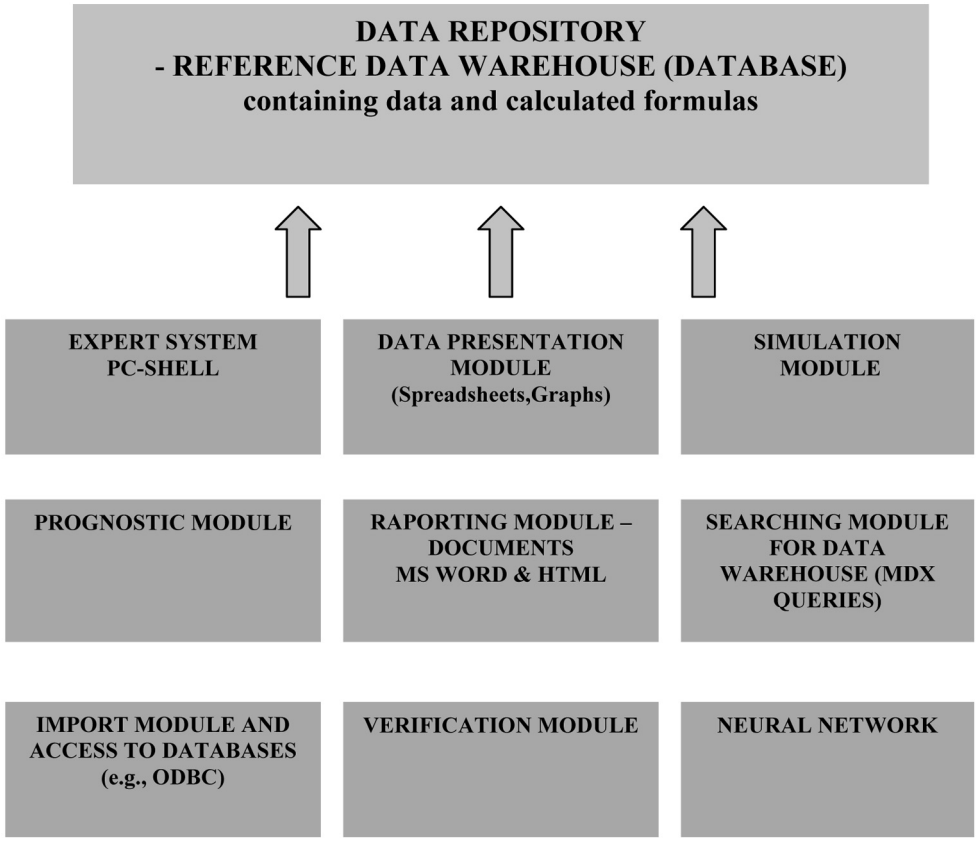

Figure 1. Overall structure of the hybrid system Aitech DSS

Source: own elaboration.

– simulation,
– graph,
– verification.

The available conventional information techniques allow the user of the expert system to solve a problem (even a narrowly defined problem) in its complexity. This "complex" approach to problem solving is necessary since, in many practical situations, the users will not accept an expert system which solely generates conclusions based on a solution for a given analytical problem. For example, a financial analyst or credit inspector want to see the basic data or aggregated data (e.g., financial indicators), as well as they want to visualize graphically the characteristics of some economic factors. Thus, a successful application of an ES in a company or bank requires that an ES is open and interactive. The ES systems which operate in an autonomic way (i.e. without interactive communication with the users) are generally unsuccessful in

business applications. Therefore, the user interfaces and an access to databases are crucial components of the presented environment.

The applications of particular methods comprise the so-called analysis scenario, which describes a typical execution of an analytical process in a specific discipline. It should be emphasized that one application of a system may contain several different analytical scenarios with their own specific reports. This feature is paramount for the flexibility of the final system. Moreover, this feature allows the end users to build their own analytical scenarios which meet their particular requirements. Furthermore, in business practice, different levels of management may require different reports (analytical scenarios). For example, a financial analyst, who works day-to-day with the system, has different information requirements than a financial director, a manager or a board of directors. The flexible, interactive and open system architecture provides for the appropriate matching between the content of the reports and the particular needs of their receivers (addressees of the reports). The created scenarios become later a part of a common bank of scenarios. It is crucial for the end users that the creation of new scenarios does not require tedious programming. The new scenarios are created using simple creation tools (wizards). This allows the end users to create their own scenarios without assistance from the software providers. In some applications, for example, in banking, this "self-sufficient" creation of scenarios is crucial for the end users. This situation has been experienced by the authors: since the credit methods are critical know-how for banks, banking organizations want to have this knowledge under their exclusive control. A typical scenario is composed of an import of elementary data, specifically from external systems such as financial and bookkeeping systems, which generate periodical financial reports. The subsequent steps of a scenario include in most cases lists of the financial factors, which are converted and sent to an ES as facts. The final step of the typical scenario is the automatic generation of an MS Word report using an OLE mechanism. This process can be schematically represented as follows [Michalik et al. 1995]:

Elementary Data → *Aggregates/Indicators* → *Facts* → *ES* → *Conclusions.*

3. Computer support for the creation, verification and validation of the knowledge bases

The complex nature of the decision-making process in the discussed application requires special considerations for the application testing (evaluation, verification, and validation). Although the subject literature on the methodology of building expert systems is relatively rich, the number of publications discussing the construction of hybrid methods is very limited. Even more limited is the number of publications on the computer support for the creation of hybrid expert systems. Therefore, the first step in the SPHINX project was the creation of the tools and the environments to support the knowledge engineers in their creation of new ES and NN applications.

The tools for the knowledge engineers include, among others, editors for knowledge base, panels for the management of the NN learning process, a system supporting the creation of dialog interfaces, etc. The next step was the creation of the dbMaker system, which supports the creation of a base of explanations such as "what is it?" and so-called metaphors for the expert system, which can be viewed as a management system for a textual database. The SPHINX project was the first step towards integration of diverse components of an expert system and the creation of tools to support the knowledge engineering process.

The expert system PC-Shell, which is the central part of the Aitech DSS application, is equipped with a knowledge base editor with an additional option of formal translation (i.e. without a generation of the resulting code), which speeds up the verification process of a knowledge base at the initial phase of source code writing. For many applications, this tool is sufficient for a construction of a valid knowledge base. In many disciplines, including the discussed business applications, the large size of the knowledge base cause that the application is difficult to verify, validate, and maintain. Moreover, in many cases the knowledge acquisition process requires collaboration with multiple domain experts. Additionally, the large scope of the knowledge base may require a complex structure with several sub-areas (sub-problems). This particular problem was solved in the Aitech DSS by an application of blackboard architecture. The system architecture is complex since some of the knowledge sources could be heterogenic, and they could include (in addition to a knowledge base) applications of neural networks, metaphors, full-text explanations "what is it?" and multimedia files. An additional issue in the design and implementation of an expert system is the linguistic representation for the knowledge. The complex nature of representational language and its syntax could create some barriers in the initial phase for an inexperienced knowledge engineer. However, on the other hand, the rich functionality of the system and the availability of many tools and environments provide an opportunity for the creation of high-quality application systems.

To simplify the work of a knowledge engineer, the developers of the Aitech DSS added a specialized tool called CAKE (Computer Aided Knowledge Engineering, using an analogy of a CASE tool). The developers assumed that the user does not have to know the details of the syntax of the language, which is used for the description of a knowledge base. The user can work with the system using dialog windows and creators. As a result, the CAKE tool supports the following knowledge-engineering activities:

- project management for the application,
- creation, expansion, and maintenance of knowledge bases,
- creation of the heterogeneous knowledge sources,
- verification and validation of the acquired knowledge,
- security for the application using a system of authorizations and passwords,
- creation of binary knowledge bases,
- group work.

The authorization and password system is controlled by the system administrator. This approach limits unauthorized access to application during its development and implementation.

One of the crucial issues in the ES creation is validation of a knowledge base. The issues related to testing, verification, evaluation and validation have been discussed since the very early publications on the subject of expert systems, for example: [Hayes--Roth, Waterman, Lenat 1983; Harmon, King 1985; Waterman 1985; Barret, Beerel 1988]. The discussions about the evaluation and validation of the expert systems in business applications can be found in the following publications: [Chandler, Liang 1990; Thierauf 1990]. These two publications discuss the knowledge engineering process from a traditional perspective – without computer support. This approach can be illustrated by the following quotation [Waterman 1985]: "The knowledge engineer presents the cases solved by the expert and the prototype system to other experts. This provides a way to compare strategies of different experts and find essential points of disagreement." On the other hand, the SPHINX project (starting from 1990) has gradually introduced new environments, which support a knowledge engineer, and automate several knowledge creation processes. In context of evaluation and validation, the CAKE system provides automatic detection of the following problems [Michalik 2011]:

1. redundant rules,
2. subsuming rules,
3. contradictory rules,
4. inconsistent rules,
5. missing rules,
6. unused attributes,
7. unused values for the attributes.

Ad 1. Redundant rules

The rules are redundant if for two rules R_i and R_j:
$R_i \Leftarrow W_{i1} \wedge ... \wedge W_{in}$ and
$R_j \Leftarrow W_{j1} \wedge ... \wedge W_{jn}$, where R is conclusion, W are conditions and $i \neq j$,
holds: $\{W_{i1}, ..., W_{in}\} = \{W_{j1}, ..., W_{jn}\}$.

Ad 2. Subsuming rules

If for two different rules:
$R_i \Leftarrow W_{i1} \wedge ... \wedge W_{im}$ and
$R_j \Leftarrow W_{i1} \wedge ... \wedge W_{in}$
holds $\{W_{i1}, ..., W_{im}\} \subseteq \{W_{i1}, ..., W_{in}\}$, then we can say that rule R_j subsumes rule R_j.

Ad 3. Contradictory rules

Two rules
$R_i \Leftarrow W_1 \wedge ... \wedge W_n$ and
$\neg R_j \Leftarrow W_1 \wedge ... \wedge W_n$, where $i \neq j$
are contradictory.

Ad 4. Inconsistent rules

Two rules

$R_i \Leftarrow W_1 \wedge ... \wedge W_n$ and

$R_j \Leftarrow W_1 \wedge ... \wedge W_n$, where $i \neq j$ and $R_i \neq R_j$

are inconsistent.

Ad 5. Incompleteness of rules

It is assumed that a knowledge base is complete when the rules include all possible combinations of the attributes and their allowable values in the rule antecedents (conditions) and the rule consequents (conclusions). Otherwise a knowledge base is incomplete. It is important to notice that in practice most knowledge bases are incomplete, which is a normal situation. In Aitech DSS, the knowledge base is incomplete if there exists a combination of attributes and values for which there is no rule including this combination in its conclusion.

Ad 6. Missing rules

We define missing rules as a situation in which there are no rules for specific attributes.

4. Summary

The special architecture of the Aitech DSS system and the knowledge engineering tools (PC-Shell, CAKE, HybRex, Neuronix) provided an intelligent decision support system characterized by:

- a high level of transparency of the available technologies for the information processing (an application is created using a form of a "block building" for the final solution of a problem),
- easy modification of the projects (analytical scenarios) by the end users, without the necessity of re-programming and involvement of the software provider,
- ability of evolutionary (gradual) expansion of an application.

The hybrid character of the system allows, among others, for effective problem solving using a system of interconnected wide-ranging sub-problems. As a result of the hybrid approach, the Aitech DSS provides a rich environment for the creation of applications based on the triplet: ⟨diagnosis, prognosis, therapy⟩ using ES, NN, as well as the conventional information techniques. The system and the hybrid model were extensively verified in business practice in many applications (see for example [Marcinek 2003]).

The system CAKE has demonstrated its usefulness, efficiency, and effectiveness in the knowledge engineering process. One of the indicators of this fact is the information that most of the students' projects in the course "Expert Systems" are implemented using the CAKE system, even though the utilization of this particular system is not mandatory. In this paper, we had to omit some details of a hybrid implementation within the language layer for knowledge representation; however, this information can be found in: [Michalik et al. 1994a, b, 2010]. More details about the other layers can be found in: [Michalik 2004].

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WSPOMAGANIE DECYZJI BIZNESOWYCH Z WYKORZYSTANIEM HYBRYDOWEGO SYSTEMU EKSPERTOWEGO

Streszczenie: Artykuł dotyczy zastosowania hybrydowego system ekspertowego Aitech DSS, który został w praktyce wykorzystany do oceny ryzyka kredytowego i wspomagania decyzji w analizie finansowej. W artykule przedstawiono architekturę takiego systemu. Dodatkowo przedstawiono informacje o CAKE, systemu wspomagającego inżynierię wiedzy i wykorzystanego do utworzenia aplikacji Aitech DSS.

Słowa kluczowe: wspomaganie decyzji, system ekspertowy, hybrydowy system ekspertowy.