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SYSTEMS AND MODELS OF ARTIFICIAL INTELLIGENCE IN THE MANAGEMENT OF MODERN ORGANISATIONS

MARIUSZ MALESZAK, PIOTR ZASKÓRSKI

Warsaw School of Computer Science (WWSI)

Modern organizations commonly use the strategy of a learning organization, and therefore operate with not only material resources, but also information resources. The collected data resources become the basis for generating business and management information. This database is maintained on various platforms using integrated BI (Business Intelligence) systems enabling knowledge to be generated through the data-mining mechanisms embedded in the artificial intelligence models. In this article, the authors focus on AI (Artificial Intelligence) models and systems based on ANN's (Artificial Neural Networks) and fuzzy set theory, which can be useful in solutions dedicated to supporting the complex management of modern organisations, and in particular the support of active functions (forecasting, planning and monitoring activities, as well as risk analysis and system effectiveness).

Keywords: *organization, management, operation system, MIS, BI, AI, artificial intelligence, risk, effectiveness, data mining, expert system*

1. Introduction

Globalization and widespread computerization and the creation of the information society has increased the demand for advanced systems that improve and support the management processes of organizations. Modern technologies allow for the creation of highly-specialised software, generally known as management information systems (MIS). Systems of this class allow for not only the maintenance of information “islands” organised according to specific domains into financial or logistic information databases, but also, first and foremost, they force the integration of information resources in such a way as to allow reporting of any cross-section and area of the business. The main objective of MIS is therefore to provide management authorities with actual and cross-sectional feedback of their own activities and those of other's in their field.

MIS solutions as a whole strengthen the positions of organisations and become a specific factor in strengthening the potential of modern enterprises. Systems for computer-aided design and manufacturing (CAD-CAM) as solutions supporting the supervision of industrial processes expose the opportunity and the need to integrate information resources created in different phases of the "life" of the product. This means, above all, the potential of the company is strengthened by utilizing the phenomenon of system synergy that is linked to the coherence and integrity of information resources in authorized places.

Ongoing monitoring of the company, as a whole and as a snapshot of the actual strategic and operational performance against the background of the action plans using historical data resources, is an inherent feature of modern organizations. Today, management information systems are the specific link between all parties involved in the business. In addition, the accumulated information resources can be a source of important strategic information and the basis for knowledge generation. Artificial intelligence systems and models can therefore create added value for companies that are able to extract this knowledge (e.g. Data Mining).

2. The modern organisation as a system of operation

A modern organisation (company, enterprise) should be viewed in terms of both its operation and its resources as a complex operational system integrating human, material, technical-technological, organisational, financial, intellectual and information resources (Fig. 1). This integration mainly involves the integration of implementation and management processes and functions/tasks, including the planning, forecasting, monitoring and evaluation of work processes [9].

The operational strategy of every organisation, as an operational system, should be to emphasise its purpose and the quality of its performance results. The institutional dimension always points to the pursuit of achieving the objectives within a specific configuration, determined by the choice of such methods, in order to achieve these goals within the prescribed time and place according to global quality criteria. The operational environment of the modern organization gives the situational context and determines the type of relationship based on shared knowledge resources and taking into account the criteria of reliability of operations [2, 5].

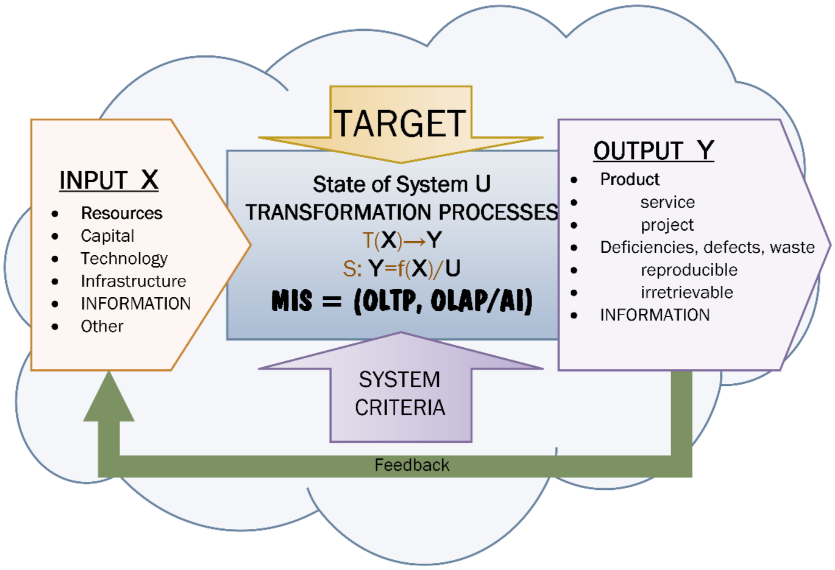

Figure 1. Systemic perception of modern organisations

In modern business organizations, globalization and the opening up to external suppliers and customers should be taken into account. Computer systems therefore allow for the implementation of business projects based on standardized operating procedures. The important prerequisites for the effective operation of modern organizations are a knowledge of the business environment and up-to-date information about the processes, objectives and common benchmarks of business processes. Modern organizations, accordingly, as a set of ordered elements **(E)** and associated with each other by respective relationships **(R)** – have the corresponding structure, strengthened by the effect of synergy [2, 5]:

$$S = \{E, R\} \tag{1}$$

Every organization, as a complex system, is a dynamic structure defined by Cartesian product sets; input **(X)** and output **(Y)** and the states of the system **(U)**:

$$S = X \cdot Y \cdot U \tag{2}$$

A modern organization is focused on quality assurance with regard to the efficiency and reliability of the whole and of every part of this system. The role and significance of information flows and decision-making mechanisms in the relationship between the operational (working) and management (control) subsystems is important in this.

Systemic observation of a modern organization imposes unambiguous valuation and assessment of its elements/components. An important part of this are information resources held in integrated systems (MIS), both in operational

(On-Line Transaction Processing – OLTP) and decision-analysis type (On-Line Analytical Processing – OLAP), including Artificial Intelligence systems (AI). The quality of the relationship with the operational environment is determined by the precise and unambiguous definition of inputs and outputs, as well as the flow of information, ensuring effective cooperation within and outside the organization. Being the basis for generating and managing knowledge, information therefore is a specific type of resource for organisations. Evaluation of the level of implementation of the objectives of the organization vector requires the use of objectivised systemic criteria for the types of functionality, usability, reliability (regarded as a function of time, determining the feasibility of the processes under ambient and system conditions, wherein $F(t) = 1 – R(t)$ is a measure of disability / failure of the system or its component), efficiency (defined as the ratio of value and cost of achieving), risk, safety, and systemic quality, which takes into account a variety of systemic attributes, including furthermore reliability and functionality. Consequently, the level of implementation of the objectives of an organization requires a comprehensive evaluation from the perspective of the systemic attribute vector, which requires the use of advanced information technology.

3. The place and role of information systems in the management of organisations

As previously mentioned, information technology binds organisations both internally and externally (Fig. 1). Not all organizations are aware of the economic importance of management support systems. This is often due to limitations in infrastructure and limited trust in external services (e.g. Cloud Computing). In conditions where motivation to change comes from disturbances in the functioning of the organization - the modernization of the information management system usually starts with an immediate search for a solution. In the process of reorganization, external personnel and/or entities possessing relevant, mostly interdisciplinary expertise, are often involved. However, this requires mutual understanding and trust. It is worth noting the fact that most systems can be scaled and adapted to the needs of the organization. This means that an organization can gradually restructure their operating models and implement various subsystems and integrate resources. In response to market demand, highly specialized MIS systems initially evolved into modular solutions, offering ever-greater levels of functionality and often becoming general purpose applications.

The evolution of software dedicated to supporting the management of processes in the organization led to the development of ERP systems (Enterprise Resource Planning). These systems bring many additional features not available in the previously used domain-specific solutions offered by MIS systems. Most ERP solutions are modular framework systems, allowing for flexible adaptation to the requirements and developed standards functioning in organizations. A characteristic feature of these systems is the so-called single point of data entry into the system and the ability to reuse this information. For example, information about the new contractor can be entered into the system by a mobile trader during the first presentation. These data will be used in subsequent dealings with the customer through CRM module, during shipment in store module, while processing of settlements with the counterparty in financial accounting module, as well as in the processes related to reporting, monitoring and forecasting analytical modules, or controlling.

Particularly noteworthy are the analytical capabilities offered by ERP systems. Although their diversity makes it difficult to uniquely identify a set of features offered by this class of systems, however, due to the similarity of platforms on which they are embedded, you can point to a few areas of typical analytical modules. The main feature is the mode of storage and organization of data. The vast majority of analytical systems use the multidimensional data model (Online Analytical Processing – OLAP) for this purpose. In addition to supporting decision-making processes, the processing of multidimensional data structures, performing trend analysis, financial analysis and general statistical functions, one should point out the ability of these systems to uncover knowledge and associate facts gained using data mining algorithms (Data Mining – DM). Among the wide range of algorithms used in data mining processes, algorithms embedded in artificial intelligence models deserve special acknowledgement.

4. Identification of artificial intelligence systems and models

There are a number of solutions providing advanced analytical models embedded in artificial intelligence systems currently on the market [10]. The most commonly used techniques are artificial neural networks, methods based on fuzzy set theory and evolutionary algorithms.

An example of a solution using artificial neural networks is that, for instance, based on a multilayer neural network, or as a specific case, the perceptron algorithm of the Microsoft Neural Network Algorithm (MNNA). This algorithm has the ability to dynamically create a network of three layers of depth and complexity, depending on the category of the analysed problem. It is worth noting that dual layer implementations, and those therefore devoid of hidden layers, bring about a specific case of the use of the network used in the calculation by logistic regression for dichotomous variables. Consequently, in the process of learning, the algorithm utilizes the mechanism of backward propagation of errors. However, the learning of the network is an operation with a significant degree of complexity and is closely related to the values of the parameters initiating and controlling the operation of the algorithm. The algorithm starts with an evaluation of the tested data set and the extraction of the training data. At each iteration, a measurement of the result value is taken until a state is achieved where the accuracy of the network no longer increases. In the next stage, decisions are made regarding the complexity of the network itself. For data models dedicated exclusively to forecasting, a single network that represents a complete set of attributes is created mapping the set to be tested. If, however, the data model has mined the attributes used in both the input and the forecasting networks, the algorithm defines a dedicated network for each of the attributes.

In various types of measurements and calculations, values from a set of real numbers are normally used. Contrastingly, people reason and communicate with each other using linguistic terms, in other words, descriptive language. Incongruence in the description of reality can be solved using fuzzy logic. Values in the range [0,1] form the basis of calculations in the theory of fuzzy sets. Processing of real data is done by fuzzy models after a blurring operation, while the transposition of the results into real form is achieved through the reverse operation; so-called, defuzzification [4]. The freedom of the description of the variable is used as the most faithful description of reality. Trying to compare the values of such variables is based on the calculations of the distance of the vectors of these variables, in other words, the extent of similarity of the values.

Another category is evolutionary algorithms. This term refers to optimization algorithms inspired by the biological processes of evolution (crossover, reproduction, mutation, and selection). Mimicking biogenetic processes, algorithms of this class gradually form better and better solutions with each new population [1].

The algorithms embedded in artificial neural network models play an important role in data mining processes. These can be particularly useful in the analysis of complex input data, the source of which can be various ERP system modules or aggregated data in dedicated OLAP systems. Typical applications are predicting volatility of share prices, currency fluctuations, or long-term valuation of other highly liquid financial instruments based on historical data, as well as analysis or prediction of the effectiveness of marketing and advertising campaigns and analysis of production, industrial processes, logistics, transport and storage. You can use virtually any predictive models used to analyse the complex relationship.

The data-mining models presented here result in BI systems and expert systems with a knowledge base as advance information technologies. Implementations available on the market can be obtained after purchasing a license or via access to services in the computing "cloud" [7] (as mentioned earlier, this solution can be especially dedicated to the SME sector, which has limited investment in computer equipment and especially more expensive technologies).

5. Models of management of modern organisations using AI

One of the factors determining the success of modern organizations is the management implemented towards the creation of such a structure in the organization's system of operation that ensures its ability to adapt to a dynamically changing environment. The implementation of such a management model requires the use of Integrated Information Systems Management (MIS) performing forecasting, planning and monitoring functions. The management of modern organisations takes place under conditions of high uncertainty. Consequently, actions undertaken are conditional upon the diligent pursuit of alleviating the influence of those conditions.

Contemporary models of management of an organization are focused on the active use of MIS and on the generation of reliable information. They represent a way of linking support systems for the management of processes in the organization with statistical, prognostic and analytical systems. In view of the very high complexity of the processes supported by MIS, these systems are based on artificial intelligence algorithms. Process management strategy requires the use of information and decision-making systems, which adds an additional determinant in the discovery of knowledge about the future. The implementation the active functions of management is made possible by the intelligent use of information gained by the system; both from specific areas of activity of the organization and from outside it (the operational environment of the organization). MIS are, today, among the most advanced, innovative and growing technologies available on the market [8].

6. Risk and the effectiveness of information processes using AI

The level of computerisation and subordination to information technology of organisations remains in close correlation to the effectiveness of the Integrated Management Information System (MIS). This results directly from the relationship of the obtained results to the incurred investment, and the effectiveness can be seen as the efficacy of realisation of relevant tasks towards a set purpose or the ability to select an appropriate purpose. The effectiveness, therefore, of management implemented using dedicated MIS is directly proportional on the efficacy of these systems. Maximizing effectiveness [6], however, requires the stabilization of the operational environment of the organization, which is in contradiction with the market rules created by reality. By analysing the relationship between the system parameters, it can easily be demonstrated that risk management plays a key role in the process of mitigating the effects of destabilization. The following (in its own way recursive) sequence of cause and effect can thus be defined: management efficacy is maximized by minimizing the effort required to effectively handle risk, this in turn increases the likelihood of success, minimizing the possibility of an undesirable situation. Maximizing the potential associated with the value of information services enables the management of risk to achieve additional benefits. Taking into account the most likely directions of the development of support systems for the management of organizations, which are primarily expert, multi-agent systems in as well as hybrid systems with built-in artificial intelligence, it is to be expected that there will be effective mechanisms for the optimization of business information processes.

Expert systems are used in many areas of operation of an organization (Table 1) and enable efficient support of complex information and decision-making processes in different categories.

Table 1. Types of expert system

CATEGORY	EXAMPLES OF TASKS CARRIED OUT IN SELECTED AREAS
Interpretation	Speech, image and data structure recognition
Prediction	Prognosis
Diagnosis	Medicine, electronics, mechanics
Assembly	Computer system configuration
Action planning	Movements of a robot
Monitoring	Nuclear power plants, medicine, traffic
Controlling	Management of the behaviour of a system
Correction	Correction of the proceedings in cases of malfunction
Repairs	Schedule or procedure for implementing steps for repair
Instruction	Systems of professional development of students

Source: Mulawka J. J.: Systemy ekspertowe, WNT, Warszawa, 1996

There are also so-called expert system frameworks available on the market, which are domain independent and can be used in any area (from banking and finance, starting and ending on technical applications). Modern expert systems are typically hybrid architecture systems. In other words, they combine various methods of problem solving and knowledge representation. The knowledge stored in the form of sets of facts, rules and metadata may take the form of:

- declarative (classic – rules and facts),
- tripartite – object, attribute, value,
- imperative – in the form of a program or Algorithm,
- textual,
- distributed in a neural network,
- thematically distributed to a number of sources of knowledge.

Sets of rules processed by expert systems often rely on assumptions of the theory of fuzzy sets, as in the case of inference built on the method of fuzzy similarity of method based on the rules (i.e. the dominant characteristics), e.g.:

If the distance for property 1 is „different”
then the distance of objects x, y are „different”.

The properties of expert systems mean that their usefulness in identifying risk in the organization is dependent entirely upon the availability of an appropriate knowledge base. Furthermore, it should be noted that the essence of these systems is to provide detailed knowledge on the basis of general, often imprecise, environmental parameters of the tested problem. Still, the decisive feature of their particular importance is the ability to explain knowledge and the way in which conclusions emerge.

Another innovative path in the development of integrated management information systems is set out by multi-agent systems. An agent, in this case, is a specialized piece of software or algorithm bearing signs of intelligence. To some extent, these algorithms can perform tasks mimicking human behaviour. They often have the ability to learn, adapt to changing conditions and make complex decisions. The diversity of applications and methods of simulating intelligence significantly differentiates the various implementations. A multi-option, visual model of an agent is shown in figure 2.

Multi-agent systems offer the unique functionality of real-time monitoring of basic (defined) parameters of the organization (they can be financial indicators – like KPI’s, parameters of the production line, or equipment, location of resources, or virtually any other data of any degree of dispersion. Systems of this class support risk monitoring process in the organization and allow the early identification and promoting active response to any alarming signals). A characteristic feature of multi-agent systems that distinguishes them from other solutions designed for monitoring is the ability to predict events, the occurrence of which, under normal conditions, is manifested in the attainment of established threshold values for monitored parameters.

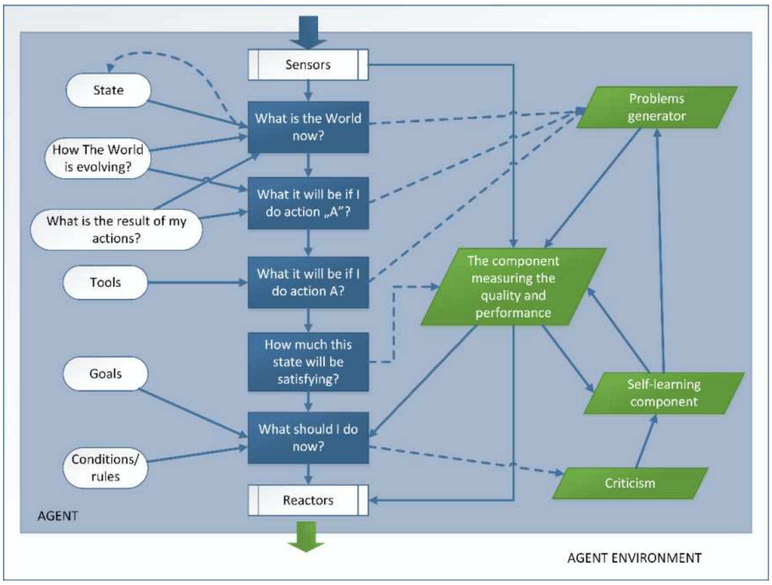

Figure 2. Extended multi-option model of agent
Source: own preparation based on [3]

Of particular importance for the development of MIS are hybrid implementations of various techniques of artificial intelligence. Hybridity, in this context, means combining different algorithms to extract and emphasize the unique characteristics of the individual methods and synergies. A commonly used example of such a hybrid system is the Co-Active Neuro-Fuzzy Inference System (CANFIS). CANFIS networks combine the features of high precision in artificial neural networks with the flexibility and naturalness of fuzzy logic. They are used in solving highly complex nonlinear estimation, classification, association, recognition, optimization and control. These methods are used in the risk analysis of information processes. The decisive factor in determining their use is the synergy effect manifested in the ability to manipulate linguistic data (the values of system parameters) in classification, prediction and estimation tasks.

7. Summary

Structure, models and concepts of operation of process-oriented modern organizations are submerged in an environment of solutions and information systems. The ability and the possibility of evaluating processes and their performance results is conditional upon access to appropriate resources. The model of the operation and management of processes in modern organizations should include formal methods and advanced information and communication technologies. The solutions that provide access to current and reliable information can be found in the development strategy of each organization. Hence the emphasis these days on the need to implement MIS class OLTP and BI (OLAP with DM functions based on artificial intelligence models). Artificial Intelligence plays a special role in the systems used to obtain knowledge from data sets [11, 12, 13]. Modern methods of obtaining and storing data clearly develop in the direction to be known as Big Data. It not means in this case extremely huge volumes of data sets (although this fact usually goes hand in hand with the term Big Data), but about the structure of the data. The term Big Data is used to describe unstructured and non-relational data sets, whose analysis and processing to extract the knowledge (Data Mining) must be based on finite period of time (sometimes in real time). Such rigorously formulated conditions practically exclude use for analytical purposes classic statistical methods. In contrast, tasks such initial classification, search patterns, syntactic and semantic analysis, etc., are supported by various techniques of artificial intelligence.

Increasing the efficiency and flexibility of modern organizations may ensue from increasing the independence of process implementers and their dynamic selection according to criteria of availability and administrative competence (these process becomes the object of the organization with the ability to manifest intra-organizational relationships and the outcomes of the processes; it should also be borne in mind that the quality of the process rests with the executors appointed in the process of structural integration, information and personnel). MIS enhance the potential of the organization, but require the collection of relevant information resources and the extraction of useful knowledge about the future (forecasting, discovery trends, clusters, etc.).

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