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Key Directions for Development of Modern Expert Systems

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Abstract*—*The paper reviews areas of application modern expert systems, on basis of which advantages and disadvantages of using ES are considered; main components of typical ES. The paper highlights features of expert systems it is proposed to include criteria for applicability of such systems. In course of review, classification was given, including nine features by which ES can be considered, which differs from existing ones in that it is proposed to take into account features of systems use and type of computer. A general overview of use of ES over past two years in various areas, from production to agriculture, has been carried out.

Keywords—review, application, expert, system, classification.

1. INTRODUCTION

In modern world of computer information systems, development of ES (expert systems) is becoming increasingly relevant, since such systems enable specialist to receive expert advice on any problems that these systems have accumulated knowledge about, which is especially important in context of Covid-19 pandemic [1]-[5].

Due to Covid-19 pandemic, many of them have had to face major changes in their daily lives: telecommuting, lack of physical contact with other members of society – it is not easy to adapt to this new reality. The main convenience is to receive his knowledge from expert at any time and in any place, since they are loaded into computer's memory. However, it should be borne in mind that expert systems do not replace specialist, but are his adviser, an intellectual partner.

ES offer user to make decision that exceeds his capabilities. At the same time, various research and analysis tools can be used here [6]-[15].

Such systems can be used in various fields. So, for example, there are ESs that allow you to evaluate possibility of buying controlling stake with ability to simulate market situations.

ES can be used, which is now relevant, in medicine, for example, for diagnosis of psycho-emotional state.

The use of expert systems for assessing complexity of texts, which can be used to work with texts in various fields of activity: compiling automated textbooks, instructions, descriptions of technical work, writing texts for SEO when developing websites [16].

Thus, areas of knowledge-based systems application can be grouped into several main classes: control and management, medical diagnostics, fault diagnostics in mechanical and electrical devices, and training.

2. RELATED WORK

To date, various studies in field of ES have been presented in scientific publications [17]-[19].

In [17] presents materials in field of expert systems in industry, government and academia. The authors explain expert systems technologies; topics about fuzzy systems, development of genetic algorithms, machine learning, knowledge representation were touched upon.

The issues of intelligent planning and control of process of developing integrated expert systems are considered in [19]. The paper focuses on expert systems based on problem-oriented methodology.

The paper describes some models and technical details of intelligent software environment.

In [19], studies on development of expert systems in data processing networks in web programming are given. The process of developing content management software unit (engine) as its own control system is considered in detail.

ESs are actively used in medicine [20], [21].

A systematic review of computer diagnostics in medicine: past and present developments are described in [20].

The application of expert system technologies in medicine is explained in [21].

The role of expert systems in agriculture and their application in efficient technologies for growing and protecting plants is discussed in [22]. The authors present structure of expert system and possibilities of designing, developing and implementing expert system.

Expert systems in production [23], [24]. For example, in [23] for reengineering of technological equipment. Systems are used to process knowledge for selected methods and techniques of artificial intelligence, decision criteria are considered.

ES in production planning is described in [24].

The study [25] is aimed at analyzing application of expert systems in field of education, namely, providing students with recommendations regarding their career and ensuring high-quality student learning; architecture of expert system is analyzed.

Decision support and expert systems in intelligent transport are considered in [26]. The authors divide transport problems into general structured models, extended structured models, and unstructured models.

3. Features of Expert Systems

The efficiency of using expert system depends, first of all, on experience of expert or group of experts, whose generalized knowledge and experience form basis of system, as well as on technical capabilities of computer tools, quality of specific software.

Consider advantages of using ES:

- improving quality of decisions made;

- ability to reason with doubtful data, ability to solve complex and difficult problems;

- possibility of gradual “building up” of system;

- economic profitability (requirements for its work).

The disadvantages include:

- limited to certain area of expertise;

- errors in rule base can lead to wrong decisions;

- it takes a lot of training before people can use them correctly;

- flexibility, that is, specialist expert can react creatively to changing environments and to unusual situations, expert systems cannot.

The expert system consists of following components (fig. 1).

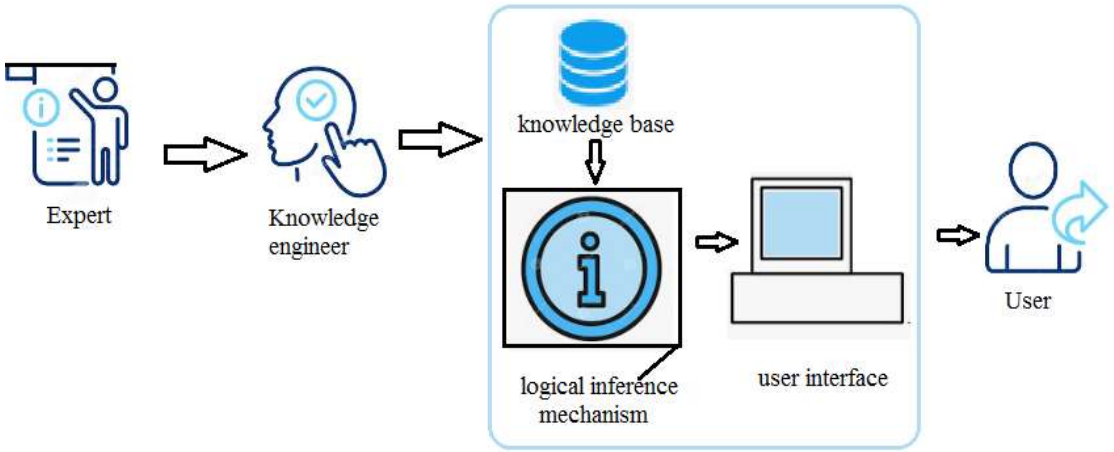

Figure 1: Components of expert system

The user interface is most important part of expert system software. The interface helps user communicate with expert system.

The inference engine is brain of expert system. An inference engine contains rules for solving particular problem. This refers to knowledge in knowledge base.

Modern ES unite several thousand different software systems, which can be classified according to various criteria: task being solved, communication with real time, type of computer, degree of integration (tabl. 1).

Table 1: Proposes classification of ESs

<table>
<tr><td colspan="6">Classification sign
ES type</td></tr>
<tr><td colspan="6">1. In terms of resource costs, expert systems</td></tr>
<tr><td colspan="2">Small</td><td colspan="2">Medium</td><td>Large</td><td>Symbolic</td></tr>
<tr><td colspan="6">2. By applications</td></tr>
<tr><td colspan="5">POr</td><td>DSp</td></tr>
<tr><td>diagnostic</td><td>forecasting</td><td>design</td><td>planning</td><td>education</td><td>Banks, stock exchanges, troubleshooting in various technical means, etc.)</td></tr>
<tr><td colspan="6">3. According to features of application</td></tr>
<tr><td colspan="3">Assistant</td><td colspan="3">True expert</td></tr>
<tr><td colspan="6">4. Linked to real time</td></tr>
<tr><td>static</td><td colspan="2">dynamic</td><td colspan="3">quasi-dynamic</td></tr>
<tr><td colspan="6">5. By methods of knowledge representation</td></tr>
<tr><td colspan="3">Traditional</td><td colspan="3">Hybrid</td></tr>
<tr><td colspan="6">6. By degree of difficulty</td></tr>
<tr><td colspan="3">Surface</td><td colspan="3">Deep</td></tr>
<tr><td colspan="6">7. By subject area</td></tr>
<tr><td>Geology</td><td colspan="2">Medicine</td><td colspan="2">Metrology</td><td>Chemistry</td></tr>
<tr><td colspan="6">8. By degree of integration</td></tr>
<tr><td colspan="3">Autonomous</td><td colspan="3">Hybrid</td></tr>
<tr><td colspan="6">9. By type of computer</td></tr>
<tr><td>ES1</td><td>ES2</td><td colspan="2">ES3</td><td>ES4</td><td>ES5</td></tr>
</table>

In terms of resource costs, ES expert systems can be:

- small ES – can operate on personal computers, are usually used for training or researching capabilities of system;

- medium – installed on workstations and cover all system applications;

- large – on workstations and large computers, usually have access to huge databases;

- symbolic – designed for research and installed on computers with symbolic calculations and languages.

By applications ES:

- POr (problem-oriented) – focused on certain classes of tasks (management, planning, forecasting, etc.).

- DSp (domain-specific) – for various subject areas (banks, exchanges, troubleshooting in various technical means, etc.).

Problem-oriented ES are:

1) diagnostics of systems state, including monitoring (continuous tracking current state);

2) forecasting development of systems based on modeling past and present;

3) planning and development of activities in organizational and technological management;

4) design or development of clear instructions regarding construction of objects that meet requirements, etc.

It is determined that ES can be divided on basis of connection with real time:

- static ES – designed for tasks, during solution of which environmental conditions do not change.

- dynamic ES (real-time systems) – systems with links to external systems and databases, and usually used to control any processes.

- quasi-dynamic expert systems interpret situation, which changes with some fixed time interval.

According to features of application: assistant and real expert, that is, here expert systems are called complex software systems that accumulate knowledge of specialists in specific subject areas and replicate this empirical experience for consultations of less qualified users.

By methods of knowledge representation:

- Traditional ES – systems use mostly empirical representation models.

- Hybrid ES use all available methods, including optimization algorithms and database concepts.

According to degree of complexity, expert systems are divided into superficial and deep.

Surface expert systems provide knowledge in form of "if-then" rules. The condition for deriving solution is continuity of chain of rules.

Deep expert systems have ability, when chain of rules is broken, to determine (based on metaknowledge) what actions should be taken to continue task.

According to degree of ES integration with other applications, there are:

- hybrid ES – systems in which different paradigms (methods, models) of representation and interpretation are implemented. Hybrid ES represent software package that aggregates standard application software packages (for example, mathematical statistics, linear programming or database management systems) and knowledge manipulation tools. It can be integrated environment for solving complex problem with elements of expert knowledge;

- autonomous ES – work directly in mode of consultation with user for specific "expert" tasks, for solution of which it is not necessary to involve traditional methods of data processing (calculations, modeling, etc.).

Thus, in the process of creating an ES, the developers do not have a goal - the development of the final product. ES should solve typical problems of the subject area. The time and effort required to develop a prototype should be minimal.

4. Overview of Existing ESs

ES is branch of artificial intelligence that is used to solve various problems using interactive computer decision-making process [25].

Consider examples of ES for most popular tasks. Table 2 provides an overview of modern ES in different areas and wide range of tasks.

Table 2: Modern ES

Name	Description
Diagnostics	
Network Hardware Diagnostics Expert System (NHDES)	Can be used for online diagnostic expert systems. Designed based on rules and based on knowledge. In systems, knowledge base information can be obtained online from sensors. Basic structure of rule-based expert system (fig. 2) [27].
Deep embedded neural network expert system (DeNNeS)	Expert system with deep built-in neural networks for detecting cyber attacks. The system can not only detect incoming threats, but also needs to know built-in functions that cause each specific security incident. DeNNeS achieves an accuracy of 95,8 % [28].
Forecasting	
Combined Belief Rule Based Expert System (CBRBS)	The combined expert system is based on rules of trust for prediction of coronary heart disease (CHD). The system can predict severity of four classes of CHD: normal or no blockage in any artery, blockage in one artery, blockage/stenosis in two arteries, and blockage or stenosis in three arteries. Average success was 93,97 % [29].

continuation of table 2

Land-use/cover change (LUCC)	Hybrid expert system for forecasting, combining fuzzy logic, systems based on equations. The system can predict land use/cover change determined by water resources and other factors [30].
Design	
MVP	The system can be applied for technology screening and approaches to reservoir development, drilling, completion, reservoir stimulation [31].
SeDeM Expert System	An expert system in field of particle design for co-processing of solid fillers to develop new composites with optimal direct compression properties using corn starch powders and microcrystalline cellulose as model primary fillers [32].
Planning	
Fuzzy Logic Expert System (FLES)	A fuzzy logic expert system can be applied in course of pavement condition assessment, which takes into account expected distress-based condition index, expected traffic and prevailing climate, age of pavement, and treatment budget. The system can be used for maintenance planning [33].
Chematica	Expert synthesis planning system combining extensive expert coded chemistry rules and search algorithms [34].

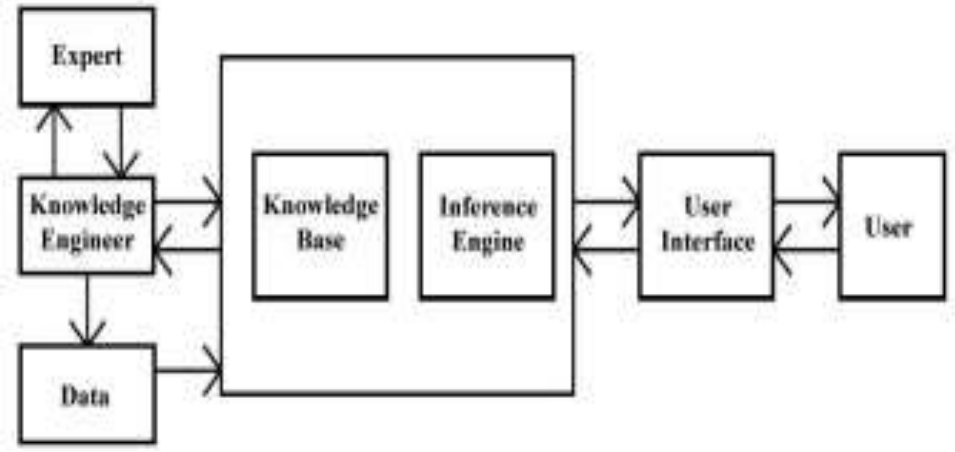

Figure 2: Basic structure of rule-based expert system

Thus, if we generalize, then all knowledge-based systems can be divided into systems that solve problems of analysis and systems that solve problems of synthesis.

In analysis tasks (data interpretation, diagnostics, etc.), set of solutions can be listed and included in the system.

In synthesis problems (design, planning, etc.), set of solutions is potentially built from solutions of components or subproblems.

However, there are still combined tasks: training, monitoring, forecasting.

5. CONCLUSION

The practical application of ES at enterprises contributes to efficiency of work and improvement of specialists qualifications.

The paper reviews areas of application modern expert systems, on basis of which advantages and disadvantages of using ES are considered; main components of typical ES.

The paper highlights features of expert systems, it is proposed to include criteria for applicability of such systems.

In course of review, classification was given, including nine features by which ES can be considered, which differs from existing ones in that it is proposed to take into account features of systems use and type of computer.

A general overview of use of ES over past two years in various areas, from production to agriculture, has been carried out.

In general, ES is not recommended for solving following types of problems:

- mathematical, solved in usual way – formal transformations and procedural analysis;

- recognition problems, since in general case they are solved by numerical methods;

- tasks, knowledge of methods for solving which is absent (it is impossible to build knowledge base).

In general, review can become prerequisite for development of modern ES in any area.

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