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Synthesis of Concepts and Applications of Information Intelligent Systems and Knowledge Bases in Computer Science: A Systematic Literature Review

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ABSTRACT

In the era of technological advancement, the ubiquity of artificial intelligence necessitates a comprehensive understanding of information intelligent systems and knowledge bases in computer science. This systematic literature review addresses this essential need. The primary aim is to analyze and synthesize key aspects of practical applications of intelligent systems and the creation of knowledge bases in computer science. The research employs a combination of system analysis and analytical study methodologies. It involves a thorough literature search, encompassing various studies that focus on the principles of building information intelligent systems and knowledge bases within the field of informatics. The process includes critical examination and synthesis of data from selected studies, aiming to draw comprehensive insights. The research identifies and discusses various aspects of information intelligent systems, including their practical applications and the interaction with knowledge bases. Key findings include a detailed classification of knowledge bases according to their complexity and the role of artificial intelligence in these systems. The synthesis reveals how these systems fulfill diverse user queries through question-and-answer frameworks, highlighting their significance in modern informatics. The study underscores the importance of advanced knowledge processing technologies in computer science. The findings suggest that the effective development and implementation of information intelligent systems and knowledge bases are pivotal for modern education and various professional fields. This systematic review provides a foundation for future advancements in artificial intelligence applications, offering valuable insights for both academic and practical applications in the realm of computer science.

1. INTRODUCTION

The problematic of this research is determined by the extensive use of intelligent information systems (IIS) and computer science knowledge bases in modern learning processes and the need to develop and implement modern knowledge systems and intelligent systems in teaching. The development of intelligent information systems and their practical implementation in various sectors of economic and social life is currently underway. Information intelligent systems and knowledge bases are vital in computer science and IT as they enable sophisticated data processing and decision-making capabilities, central to advancing technological solutions. By integrating artificial intelligence, these systems enhance accuracy and efficiency in data management and analysis, providing crucial support in solving complex problems and facilitating innovative developments in various technological domains.

The study by Robert et al. [1] emphasizes the need to update informatics education in response to rapid technological advancements, highlighting that computer science classes are crucial for teaching students about information interaction, including network and database usage. Robert [2] further explores the informatization and intellectualization of education, noting the increasing use of intelligent, web-interface-based information systems in the learning process. Haleem et al. [3] identify the dynamic nature of informatics and IT as distinct from other disciplines, stressing the importance of keeping educational curricula in sync with evolving computer science databases. Buynytska [4] discusses the integral role of network infrastructure in modern information technology systems, asserting their dependence on interconnected technologies. Ongarbayeva et al. [5] addresses the growing need for training IT professionals in designing and maintaining knowledge bases and information systems, crucial for today's labor market demands.

The specific knowledge gap this literature review addresses is the lack of comprehensive synthesis and understanding of

how information intelligent systems (IIS) and computer science knowledge bases are practically applied in modern learning and their development in education. Despite the wealth of research on individual aspects of IIS and knowledge bases, there is a need for an integrated analysis that combines system analysis methods and analytical studies to understand their full scope, practical applications, and implications in the field of informatics. This synthesis is crucial for advancing the design and implementation of these technologies in education and other sectors, ensuring they meet the evolving demands of information technology and provide effective learning and problem-solving tools.

The main aim of this research is to analyse the principles of using intelligent information systems and the formation of databases in the field of computer science, used later in the learning process.

2. MATERIALS AND METHODS

The basis of the methodological approach in this research is a combination of methods of system analysis of the key aspects of the formation of information intelligent systems with analytical research of the basic principles of building information knowledge bases used today in various fields. The main scientific research is preceded by a theoretical framework, which is an analysis of the research results of a number of researchers who have studied the problematic aspects of the practical application of knowledge processing technology in the field of informatics. To ensure a comprehensive and systematic literature review, we meticulously searched several academic databases, including PubMed, Scopus, and Google Scholar. The keywords used for this search included "intelligent information systems", "knowledge bases in computer science", and "AI applications in education". Our time filter was set to include studies published within the last decade to ensure contemporary relevance. In total, we included 47 studies published between 2010 and 2023. Our exclusion criteria were stringent: studies not available in English, those not directly addressing the implementation of intelligent information systems in educational settings, and those lacking empirical data were omitted. To extract and analyze data from these studies, we employed a standardized form. This form was designed to uniformly capture key findings, methodologies, and conclusions from each study, thereby maintaining consistency in data handling and interpretation. This rigorous approach underpins the reliability and validity of our review findings, ensuring a comprehensive synthesis of the current state of intelligent information systems and knowledge bases in computer science.

Practical application of the method of system analysis of the main aspects of creating information intelligent systems made it possible to derive the definition and essence of the concept of intelligent information system, as well as to define their role in the world of modern technology. In addition, artificial intelligence (AI) has been defined as a key component of an intelligent information system. The key tasks to be solved through the use of an information intelligent system have been considered.

Application of method of analytical research of principles of construction of information databases has allowed to deduce definition of essence of concept of the knowledge base in the field of modern informatics, and also to present schematic representation of their system classification, depending on a level of complexity of information systems in which information databases have found application. The use of this method has illustrated the place and importance of knowledge bases in the creation and operation of effective models of information intelligent systems. The combination of research methods chosen predetermined the specific stages of research, depending on the use of one or another scientific method.

The first stage of this research work identified the varieties of information intelligent systems, as well as the tasks to be solved by these types of systems. These tasks were discussed in detail, noting the role and place of each of them in the overall context of intelligent information systems. In addition, a schematic representation of the place of intelligent information systems in a wide variety of information systems, in general, is presented.

In the second phase of this research study, the classification of knowledge bases in the field of computer science was examined from a theoretical perspective and using the schematic representation provided. The principles of construction of ontological models are considered and the basic elements of models of this kind are indicated. In addition, software tools for creating models of information systems of artificial intelligence are considered, and the main options for the development of such information models are indicated. The possibilities of programming artificial intelligence system models using each of the above options for developing information models are determined.

In the final stage of this research work, an analytical comparison was made between the results obtained in this research and those of other researchers who have worked on topics similar to this research study. This allowed the results to be refined and the final conclusions to be formed on their basis, which are a logical representation and summarize the whole range of research in the field of information intelligent systems and knowledge bases in the field of informatics.

3. RESULTS

3.1 Efficacy and dynamics of intelligent information systems in knowledge-based applications

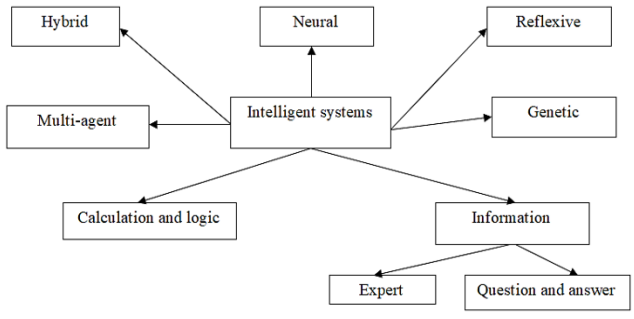

Figure 1. Intelligent information systems in the general classification of information systems

Modern progress in the economic sector is impossible without the development and practical implementation of intelligent information systems that operate using large amounts of knowledge bases. The basis for the operation of such systems is artificial intelligence (AI), which is the science and technology behind intelligent computer programmes, and

which has a well-established connection with a computer device, to provide insight into human intelligence. An intelligent information system is a software or technical system designed to solve practical problems that fall within a particular domain, with knowledge of that domain stored in the database of that software system. Figure 1 presents a scheme for classifying intelligent systems, demonstrating the place of intelligent information systems within them.

Intelligent Information Systems (IIS) are divided into the following varieties: expert systems; Q&A (question and answer) systems. Expert systems accumulate knowledge bases directly within the system, and these knowledge bases include the findings of experts recognised in a particular subject area. In addition, intelligent information systems of this kind include a special system of explanations for various controversial and problematic aspects of the information stored in the knowledge bases. Represent a set of software necessary and sufficient for the user to make informed decisions in a particular area [6].

Q&A systems are searchable, intelligent communication systems whose purpose is to provide interoperable, fact-based knowledge bases whose data is purely problem oriented. The Q&A information systems use natural, business language (business prose) to communicate. When using IIS of this kind, an answer scoring system from 0 to 100 is provided, on the basis of which results are generated in regular reports. Creating a Q&A system with the ability to ask questions in the system involves creating an information system in which it is practically possible to accept questions in natural language and to answer them also in natural language, which in practice means creating a system that has a natural language interface Q&A system. The main approaches to establishing Q&A system: vector word technique; syntax tree methodology.

A syntactic tree is a graph built according to a specific algorithm, the elements of which are certain parts of a sentence, the links between which denote the syntactic relationship. An element of the syntactic tree may include certain sentences and words, word combinations, taxonomic units, and other functional elements that lose their syntactic function when separated. The Q&A system includes the following nodes: control scripts; a knowledge base to answer questions; direct questions; vector representation of questions.

The creation of a Q&A system takes place in several stages. In the initial stage, the Q&A database is designed. In the next stage, vector representations of questions are entered into the knowledge base according to a given algorithm, which is then applied to the question that is asked by the user of the system. As a result, the system obtains certain information needed to determine semantic proximity, which is then used as the basis for assuming semantic similarity when a given question differs from a question from the database.

Intelligent information systems are the result of development of generic information systems that have incorporated the most scientifically capable technologies with a significant level of automation of decision-making information preparation processes, as well as the decision-making processes themselves, which are based on information system information from knowledge bases. The last step calculates the cosine similarity between a question from the database and a question asked by the user. The output of this system is the answer to the user's question from the answer database, with which there is maximum cosine similarity. A schematic representation of how the Q&A system works is shown in Figure 2.

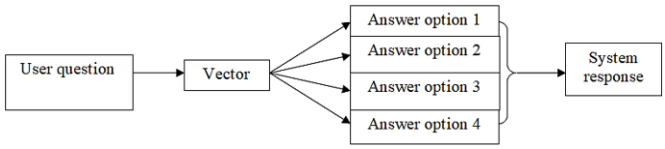

Figure 2. Operation of the Q&A system

Intelligent information systems are designed to solve the following tasks:

- determining the meaning of the data contained;
- task definition; data flow tracking;
- project preparation; performance prediction;
- planning.

Determining the meaning of the data contained involves interpreting and adjusting the data according to the objectives. As a rule, multiple definitions of the meaning of the data are envisaged, which as a result should be fully agreed upon and adjusted. The objective setting involves the alignment of the object with certain varieties of objects and the identification of problems in the individual system. Any deviation from the norm is considered to be a malfunction. Such a definition provides a common theoretical perspective on problems in individual technological systems, diseases, and various deviations of a natural nature [7]. Tracking data streams involves constantly monitoring information in real time and indicating when specific parameters are out of limits. The main problem is the possibility of missing a critical point and false alarms that they have been reached.

3.2 The development of an ontology model

The preparation of projects involves the preparation of normative documentation for facilities with specified characteristics. Such documentation may include drawings, explanatory notes, etc. Outcome prediction involves the ability to anticipate the outcomes of certain activities or events based on the information contained in knowledge bases. Forecasting gives the possibility to foresee the results of performed operations or phenomena on the basis of analysis of information contained in knowledge bases. Planning involves making plans of operations for facilities performing specific actions. It is permissible to use specific facility models in order to logically plan the possible effects of their activities. A knowledge base in the field of computer science is a specific knowledge base created specifically for the purpose of conducting operations on available data. The information in the knowledge base is structured into all available fields of knowledge in order to facilitate searches for specific search queries. Searching is done by a user (human) or a cybernetic device solving a certain task. Knowledge bases in computer science function in parallel with information retrieval systems, which have a certain structure and form of the stored knowledge. Figure 3 shows a schematic representation of computer science knowledge bases in their systemic classification according to the complexity of the systems in which they are used.

The data presented in Figure 3 shows that knowledge bases in computer science vary in terms of the complexity of the tasks in which the data they store are applied. Global knowledge bases include Wikipedia or Internet databases, sectoral knowledge bases contain data relating to a specific industrial or economic sector, and national knowledge bases contain data relating to the national composition and territory of a particular state (Wikipedia). Specific knowledge bases

contain data on specific professions and occupations, organisational knowledge bases include data on various aspects of the life of a particular organisation, and expert knowledge bases include data from expert systems [8].

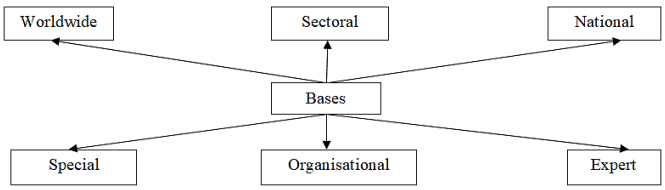

Figure 3. Classification of knowledge bases in computer science

When developing knowledge-based intelligent information systems and their management, the main objective is to meet the needs of the user as closely as possible. This is because most modern applications are built on the principles of applying and transforming information derived from knowledge bases and revealing knowledge areas of interest to the user, which are incorporated into the information system during its development. This information can be retrieved from available knowledge bases in a dynamic search mode. Predominantly, knowledge bases are accessed via the Web, where a wide variety of formalisation models, storage methods and formats, access conditions and processing methods can be applied to their presentation [9].

The development of an ontology model helps to ensure that the user's queries in a given domain are best met, based on the information currently accumulated in the knowledge bases [10]. An ontology model is a description of a given domain in which:

- typical elements of the metamodel (specific objects, systems of relationships) are applied;
- the aim is to repeat explicitly the expressed aspects of the subject area in the most complete and credible way possible.
- Ontological models have the following characteristics:
- using the most versatile tools to describe knowledge;
- there is a clear focus on the practical application of structured information and its preservation in knowledge bases;
- they may not be used for the purpose of making plans for the future state of the subject area under study.

When developing an ontology model, its constituent elements should be highlighted. For example, when constructing an ontology model for providing user queries in semantic search using the capabilities of information intelligent systems, the main elements of this model are [11]:

- actual user himself;
- the user's need for specific information;
- user requests used;
- the user's task, for which they need information from knowledge bases;
- the documentation required to ensure that the user's need for information from knowledge bases is resolved;
- information on the structure of the user-defined object contained in the user documentation;
- a set of information resources available to the user, as well as information on the user's evaluation of these resources;
- an intelligent software agent that represents the user when interacting with an information retrieval system.

In order to formalise the descriptions of the main elements of the ontological model and to ensure that their processing is automated, it is useful to apply an ontological representation of knowledge about these elements. The development of an ontology model solves the problems of describing user information needs, with the classes of this model being in accordance with the above elements, and the relationships correspond to the relationships between them. To determine the attributes that the classes possess, an analysis of the history of the development of user information queries should be made and the prospects for their improvement should be identified [11].

The paper presents an example of developing an ontological model for forming the composition and assessment of practical competencies of higher education students in the field of "IT solutions for business based on 1C: Enterprise". The development of the ontological model was carried out in the software package Protégé, in which the frame concept of knowledge representation was implemented. According to the terminology adopted by this software package, the concept of classes and subclasses of the ontological system is introduced. Figure 4 shows the classes and subclasses of the ontology system under development and their properties.

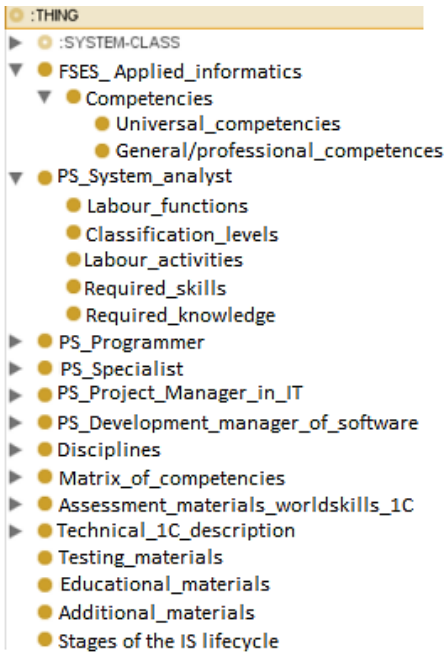

Figure 4. Classes and subclasses of the ontological model of forming the composition and assessment of practical competences of higher education students in the field of "IT solutions for business based on 1C: Enterprise"
Source: refer to literature [12]

In the context of the task set in creating this kind of ontology model, these classes and subclasses will be sufficient to implement the student competency assessment programme "IT solutions for business based on 1C: Enterprise". The ontology model provides direct interaction of all classes and subclasses with each other. This model implements the following requirements for the development of ontology models:

- key conceptual terms are introduced into the subject ontology and their structure is acceptable for training IT professionals within a given software plane;
- the conceptual terminology allows the addition of new

elements without breaking previous terminological links.

Figure 5 shows a schematic of the ontology model developed in the above software area.

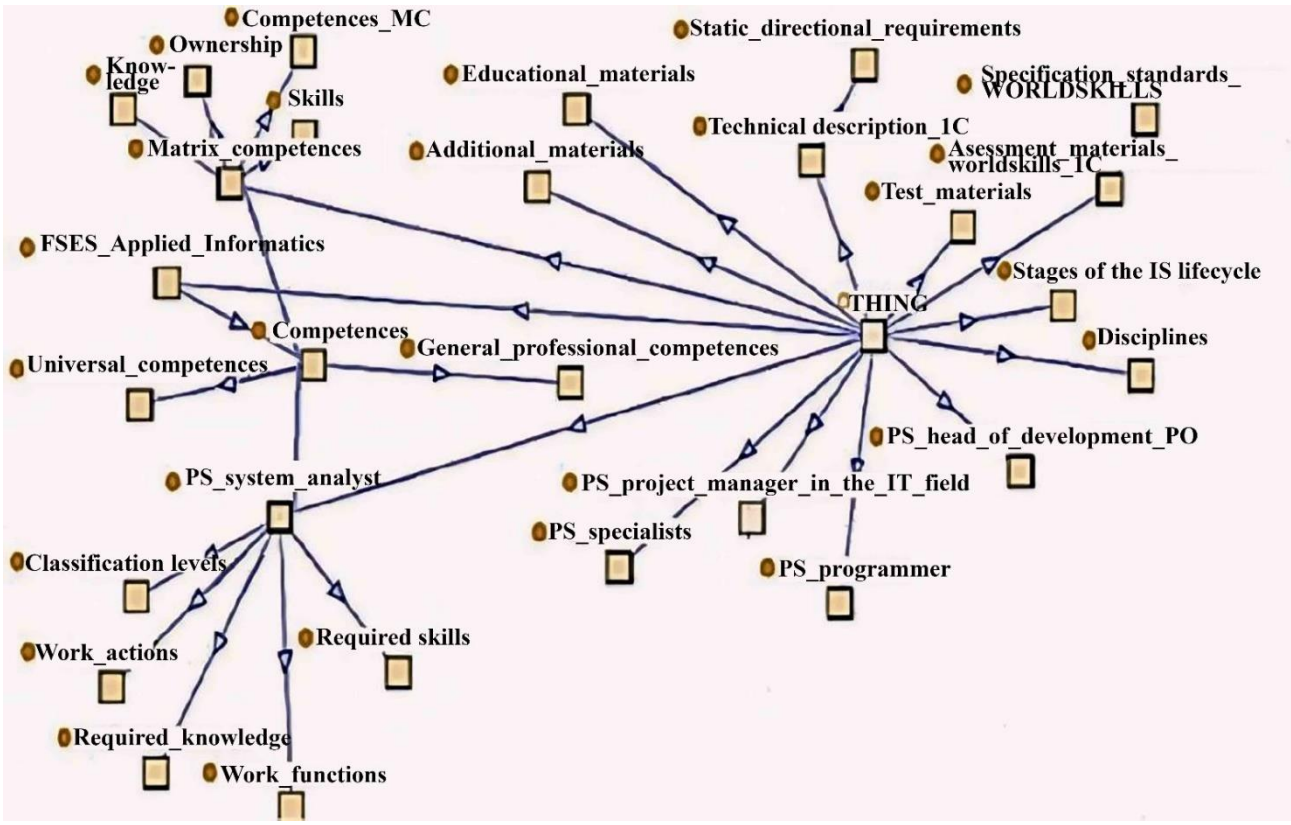

Figure 5. Ontological model for forming the composition and assessment of practical competences of higher education students in the field of "IT solutions for business based on 1C: Enterprise"
Source: refer to literature [12]

3.3 The development of software for creating models of intelligent information systems

The development of software for creating models of intelligent information systems involves the use of special tools containing computer vision, machine learning, and artificial neural networks at their core. To date, existing tools for the development of software and models of information intelligent systems can be divided into two large subgroups: universal programming languages; software applications, shells and tools containing modular structures for building computer-based artificial intelligence. The use of software applications involves the user in programme development as an operator, applying tools to solve a specific problem, specifically designed for that purpose. This option, which does not involve the need for universal programming languages, is considerably less time-consuming, but there are some limitations on the flexibility of the algorithmic process models created. Of these, Microsoft Excel, Statistica Soft and SPSS are statistical packages that are directly related to the processing of large quantitative data and solve all key automation problems related to regression, clustering, factor analysis, spectral analysis, and other tools of mathematical statistics [13].

Specific computer tools capable of dealing effectively with such tasks include Power BI, which is a software, computer-based service for business intelligence and visualisation of data from the field. When using this tool, it is possible to generate interactive graphical reports that are generated from connected knowledge bases and to create management decisions based on them, using the artificial intelligence tools built into the programme for this purpose. Programs of this kind are not the only one on the market and have a number of counterparts such as QlikView; Klipfolio; Tableau, etc. The use of universal programming languages for the development of artificial intelligence programs opens up considerably more possibilities in terms of the independent creation of model algorithms. In the end, it all depends on the tasks that are set for the development of the programs. Information intelligent systems programmed using universal programming languages have a wider variability and versatility. In doing so, they can be applied in different fields of knowledge, or be combined in a single project with a single information system.

4. DISCUSSION

Research scientist Abdulrahaman et al. [14] in his research paper on the application of multimedia technologies in teaching database basics in a university computer science course notes that the accumulated experience of training university students in computer science shows that the use of modern information technologies based on the use of given arrays of databases is one-sided. The author has come to the conclusion that some sort of information technology is used in training, which is related to the need to create, provide, and then use databases. As a rule, such a scheme uses professional intelligent systems to build databases and maintain them [15]. The researcher's conclusions correlate with the findings of this research paper, as it is the use of knowledge bases that is a key

aspect of the practical application of modern information systems. The topic is developed by Feng [16] in his own research on the practical application of information technology systems in the biomedical field has concluded that intelligent systems, the operation of which is based on the use of significant databases, are indispensable in solving the most complex technological problems. In the scientist's opinion, it is simply not possible to fully train future biomedical professionals without the use of intelligent information retrieval systems to organise the management, flow, and preservation of databases. The field continues to evolve, aided by the development and implementation of the latest intelligent technological systems that fully meet the current needs of modern biomedicine. The researcher's conclusions build on the results of this research work, as they clearly illustrate the importance of the practical application of knowledge base information intelligent systems in various fields and specifically in biomedicine.

According to Jiang [17], who researched the specifics of knowledge processing technology development in the area of informatics in modern China in his own research work, believes that the country's gradual transformation into one of the centres of the global IT industry by 2020 will be possible if sufficient numbers of intelligent database processing systems capable of simultaneously handling huge amounts of information are developed and put into practice by local information technology companies. The scientist notes that innovations in knowledge base processing in the field of informatics are among the fastest growing, most widely used and most promising technologies in the world today. The level of development of the IT-industry of a modern state is one of the key indicators of the economic development of the state as a whole [18-20]. Although the author's conclusions are somewhat off-topic, they can be accepted with the caveat that high-tech development is a key, but not the main, indicator of a country's economic development.

A group of authors, represented by Lytras and Srairete [21], who investigated various aspects of the practical application of modern innovations in the application of IT technologies in health care. According to the authors, information technology in healthcare has made a real breakthrough, as knowledge processing technologies in the field of informatics provide timely information on the nature of the course of diseases and key signs to make the right diagnosis and prescribe quality treatment. The integration of innovative technological systems with large amounts of databases into the healthcare sector is now a key aspect of the development of advanced information systems in the healthcare industry [22-24]. The findings of the researchers highlight the importance of the practical application of information intelligent systems in various fields of knowledge.

For their part, the team of authors represented by Lokse et al. [25], conducted scientific research into the practical application of knowledge processing information technology in higher education. Researchers have concluded that the development and practical use of intelligent learning systems that rely on large amounts of databases can improve the efficiency of instructional planning, accelerate the distribution of teaching load among the teaching staff, and improve the quality of the learning process as a whole. Modern knowledge processing technologies in the field of informatics in education open up new possibilities in teaching and the construction of the learning process [26, 27]. The findings of the research team are fully consistent with the findings of this research work, extending and complementing them.

Baker and Ellis [28], in an academic study of the future of the digital information mainstream, point to the fact that the future directions in digital information development represent the latest ideas and approaches to the industry around the world, while demonstrating the transition from the old to the new. Researchers have concluded that artificial intelligence information technology literacy makes it possible to fully understand the differences in intelligent systems being developed and to select the best models for their practical use. The creation of an intelligent information system in the field of computer science is an essential part of the formation of artificial intelligence, for its further application in various fields of the practical sphere [29-32]. In part, the researchers' conclusion seems controversial due to the fact that intelligent information systems are far from being the only indicator of artificial intelligence.

Whitworth [33], in a research paper on prospective opportunities for information literacy in the field of IT, concluded that modern information technology forms the basis of economic information systems, therefore economic progress is not possible without the use of information technology and the development of intelligent systems that meet today's requirements. The author notes that the functioning of information systems involves the processing of large arrays of databases in modern computer networks, with the necessary speed of these systems. As for the speed of used systems, one can argue with the scientist's conclusions, as the emphasis in the efficiency of artificial intelligence systems should be placed on the quality of satisfaction of user requests for obtaining the necessary information.

In turn, Sukovic [34] in his own research on the problematic aspects of trans-literacy in complex information environments and systems points to the fact that modern advances in various fields of science and technology significantly stimulate the intensive development and use of artificial intelligence information systems to solve a wide range of problems of varying degrees of formalisation. In the scientist's opinion, it is often the case that generally accepted methods for solving problems, in particular, those solved in the management of industrial, medical, or educational facilities, are quite complex and require finding the best ways to solve them. This largely explains the need to develop and implement effective artificial intelligence systems to improve the methods of solving technological and other problems. The author's conclusions seem arguable in the context of the fact that the introduction of artificial intelligence systems does not, in itself, solve the management problems of the area in question if such systems are not properly used.

Davim [35] in a scientific study of innovative ideas in engineering education, points to the fact that it is the creation and practical implementation of artificial intelligence technologies into the educational process that is a factor capable of raising the educational process to a new technical level and formally facilitating and accelerating a number of practical tasks. According to the researcher, today many world research institutes show considerable interest in the problem of the creation of artificial intelligence systems and their subsequent implementation in the practice of construction of educational process in educational institutions. The scientist's conclusions correlate with the results of this scientific research; at the same time, attention should be paid to the fact that the knowledge processing technologies used in computer science require competent use to achieve the desired result in any field

of activity.

The systematic review synthesizes key insights into the role of IIS across various domains, underlining their criticality in complex data management and decision-making. The primary takeaways include the evident trend towards the increasing adoption of IIS in diverse fields such as education and biomedicine, highlighting their versatility and importance in effective large database management. Additionally, the review brings to light the evolving capabilities of IIS in supporting intricate problem-solving and decision-making scenarios. When compared with previous literature, this review aligns with and expands the current understanding of IIS, confirming their growing importance and sophistication across various sectors.

However, this review acknowledges certain limitations. Focusing predominantly on studies published in English and excluding specific study designs may have constrained the breadth of conclusions drawn. Also, the representation of studies across different sectors was uneven, with some areas being more extensively covered than others.

From a practical perspective, the findings of this review offer significant implications. They provide guidance for future developments in AI and database management, especially in sectors where handling complex data and decision-making are paramount. In education, the integration of IIS could improve personalized learning experiences and curriculum development. In the biomedical field, leveraging these systems for diagnostics and patient data management could lead to transformative changes in healthcare delivery. Thus, this review contributes to both the academic discussion on IIS and proposes practical applications in various professional fields.

5. CONCLUSIONS

This review reaffirms the pivotal role of IIS as automated, knowledge-based systems integral to modern informatics. The key takeaways include: 1) IIS's unique capability to facilitate natural language dialogues for data retrieval, thereby enhancing user interaction and access to information; 2) the classification of knowledge bases in computer science based on their complexity and application within various IIS; 3) the vital role of ontological models in fulfilling user requirements through IIS, particularly in knowledge retrieval from web-based resources.

Addressing the identified knowledge gap, this review has clarified the classifications and functionalities of IIS and their associated knowledge bases, providing a more nuanced understanding of their roles in information processing and retrieval. The practical applications and theoretical underpinnings of IIS in various domains have been elucidated, contributing to a deeper comprehension of their significance in the digital information era.

Future research should focus on exploring the development of more advanced ontological models to further enhance the efficacy of IIS. Additionally, investigating the integration of IIS in less represented sectors and languages, beyond the scope of this review, could provide a more comprehensive understanding of their global application. Finally, considering the rapid evolution of AI and informatics, ongoing studies should monitor and evaluate the emerging trends and technologies in IIS to ensure their continued relevance and effectiveness in various fields.

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