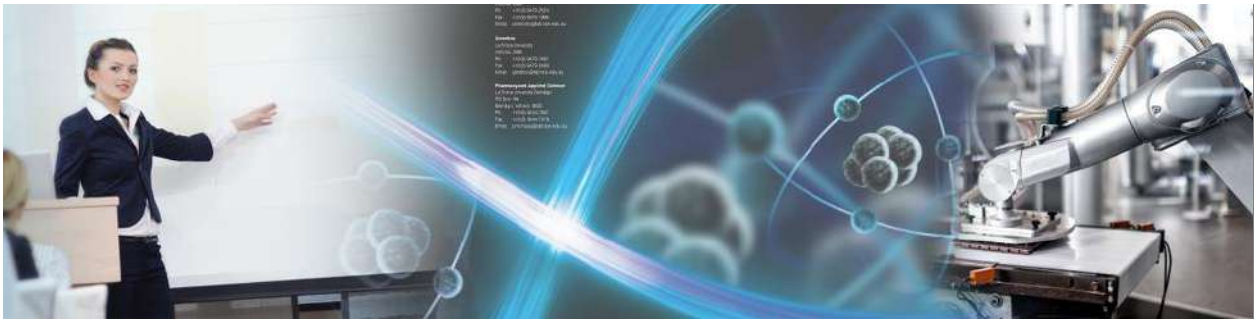
Міністерство освіти і науки України

Харківський національний університет радіоелектроніки

Кафедра комп'ютерно-інтегрованих технологій, автоматизації та робототехніки

VIII Міжнародна Конференція
ВИРОБНИЦТВО
&
МЕХАТРОННІ СИСТЕМИ 2024



VIII International Conference
MANUFACTURING
&
MECHATRONIC SYSTEMS 2024

M&MS

2024

VII International Conference

25-26 October

Kharkiv

УДК: 005:004.896:62-65:338.3

Виробництво & Мехатронні Системи 2024: матеріали VIII-ої Міжнародної конференції, Харків, 25-26 жовтня 2024 р.: тези доповідей / [редкол. І.Ш. Невлюдов (відповідальний редактор)].-Харків: [електронний друк], 2024. – 135 с.

У збірник включені тези доповідей, які присвячені сучасним тенденціям розвитку технологій та засобів виробництва та мехатронних систем, передовому досвіду та впровадженню їх в галузях систем промислової автоматизації та керування виробництвом; системній інженерії; CAD/CAM/CAE системах; мехатроніці (електро-механічних системах, електронних інструментах систем керування, механічних CAD системах); робототехніці та засобахм інтелектуалізації; MEMS (сучасних матеріалів та технологіях виготовлення MEMS) та компонентах і технологіях автоматизації видобутку, переробки та транспортування нафти та газу.

Manufacturing & Mechatronic Systems 2024: Proceedings of VIII st International Conference, Kharkiv, October 25-26, 2024: Thesises of Reports / [Ed. I.Sh. Nevlyudov (chief editor).] .- Kharkiv .: [electronic version], 2024. - 135 p.

The collection includes the thesises of reports on modern trends in the development of technologies and means of production and mechatronic systems, top experience and implementation of them in fields of: industrial automation and production management systems; systems engineering; CAD/CAM/CAE systems; mechatronics (electrical and mechanical systems, electronic control tools, mechanical CAD systems); robotics and intellectual toolls; MEMS (modern materials and manufacturing technologies MEMS) and components and technologies for the automation of oil, gas and oil extraction, processing and transportation.

Міністерство освіти і науки України (МОНУ)
Харківський національний університет радіоелектроніки (ХНУРЕ)
Варшавський університет сільського господарства (WULS - SGGW)
Азербайджанський державний університет нафти і промисловості
Національний університет «Львівська політехніка»
Festo Didactic Україна
Jabil Circuit Ukraine Limited
ТОВ «Науково-виробниче підприємство «УКРІНТЕХ»»
Факультет автоматики і комп'ютеризованих технологій (АКТ)
Кафедра комп'ютерно-інтегрованих технологій, автоматизації та робототехніки (КІТАР),
Державне підприємство «Харківський науково-дослідний інститут технології машинобудування»
Державне підприємство «Південний державний проектно-конструкторський та науково-дослідний інститут авіаційної промисловості»

МАТЕРІАЛИ

VIII-ої Міжнародної Конференції

ВИРОБНИЦТВО
&
МЕХАТРОННІ СИСТЕМИ 2024

(25-26 жовтня 2024)
Харків, Україна

ЗМІСТ

Intelligent tools for optimizing information and search engines

Artem Tverdokhlib, Svetlana Sotnik

Department CITAR, Kharkiv National University of Radio Electronics, Ukraine,
Kharkiv, av. Nauki. 14., email: svetlana.sotnik@nure.ua

Abstract: The study highlights transformational impact of intelligent technologies on functioning of IPS. The focus is on integration of artificial intelligence, machine learning and natural language processing, which are revolutionizing the processes of understanding user queries and providing relevant results. The paper analyzes benefits of implementing these technologies, including improved search accuracy, personalized user experience, and system adaptability. Particular attention is paid to semantic search as advanced area of IRS development. The study is not limited to theoretical aspects, but provides specific examples of intelligent tools use in leading search engines. A critical analysis of challenges and limitations of these technologies provides balanced view of their potential. Visual elements of work contribute to better understanding of complex concepts. Overall, study emphasizes key role of intelligent tools in improving IRS and their potential impact on various sectors, from scientific research to everyday access to information.

***Key words*:** intelligent tools, artificial intelligence, optimizing, information, information retrieval systems.

I. INTRODUCTION

In today's digital age, search for relevant and reliable data has become integral part of everyday life. Information retrieval systems (IRSs) play key role in providing access to information that is crucial for effective decision-making in scientific, commercial, and social spheres [1-3]. However, growth in data volume and complexity of search queries pose new challenges for ISAs, in particular, ensuring accuracy and relevance of search results. In this context, integration of intelligent tools (IT), such as artificial intelligence, machine learning, and natural language processing, is becoming prerequisite for optimizing IRS. introduction of intelligent tools into information retrieval systems is closely related to development of automation and robotics. Automation of information processing processes can significantly increase speed and efficiency of search, reducing human factor and minimizing likelihood of errors. Robotics, for its part, contributes to development of IRS by creating autonomous systems capable of performing complex search tasks in real time [4, 5]. integration of these technologies contributes to formation of new, more adaptive and flexible information retrieval systems that can not only respond to user requests but also anticipate their needs, offering most relevant results based on behavioral and contextual analysis [6-10].

Thus, in context of constant growth of data and complexity of search queries, relevance of this study becomes obvious. integration of intelligent tools, automation, and robotics opens up new horizons for improving accuracy, speed, and efficiency of information retrieval.

II. ROLE OF INTELLIGENT TOOLS IN IRS

In today's information environment, where data volumes are growing exponentially and user requests are becoming increasingly complex, role of IRS is becoming critical. Intelligent technologies not only allow processing huge amounts of data faster and with fewer errors, but also adapt to changing conditions, improving relevance and quality of search results. Table 1 below provides detailed overview of how each of these tools affects and contributes to functioning of IRS.

Table 1. Role of intelligent tools in information retrieval systems

Intelligent tool	Role in information retrieval systems
Artificial intelligence (AI)	Recognize patterns in large amounts of data.
	Improving accuracy of search results through intelligent algorithms.
	Adaptation to changing user requests and context.
Machine learning (ML)	Analyze and classify large amounts of data to improve search relevance.
	Recognize and predict user preferences and interests.
	Automatic improvement of search algorithms based on feedback.
Natural language processing (NLP)	Interpreting and understanding human queries in natural language.
	Identify named entities such as people, places, and organizations.
	Generating clear and relevant answers to user requests.
	Reducing human intervention in information processing and indexing.

III. SEARCH OPTIMIZATION USING INTELLIGENT TOOLS

Modern information and search engines use wide range of intelligent tools to provide efficient and relevant searches.

Intelligent algorithms for ranking search results are one of key elements of search engine optimization. They allow search engines to provide more accurate and relevant results, ensuring high level of user satisfaction. These algorithms are based on machine learning and deep

learning, which allow systems to analyze and process huge amounts of data.

Machine learning is used to analyze huge amount of data generated during search sessions. ML algorithms are able to learn from historical data, identifying patterns between user queries and selected results. The ML concept is shown in Fig. 1.

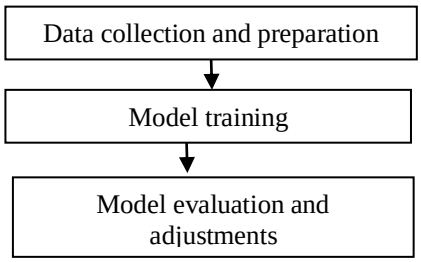


Fig. 1. Machine learning concept

The Data collection and preparation stage collects data on previous user requests, selected results, time spent on page, behavioral factors, etc. This data is used to create training sets on which algorithm will be trained.

At «Model Training» stage, using prepared data, machine learning model is trained by identifying relationships between query and result that users most often choose. The most popular models are those based on decision trees, random forests, and gradient boosting methods.

After initial training, model is tested on new data. If accuracy of predictions is unsatisfactory, model's hyperparameters are adjusted or another model is selected.

Deep learning and neural networks are subset of machine learning that uses multi-layer neural networks to process data. These networks are able to recognize complex patterns in data and use them to improve ranking of search results. Deep neural networks consist of numerous layers, each of which is responsible for extracting certain features from user queries.

Examples of ML application in information search engines:

- Google's RankBrain ML algorithms are used to rank search results, analyzing many factors (content relevance, link quality, user behavioral signals) to determine most relevant results for particular query. For example, if user searches for «apple», system can determine whether search is for fruit or technology company based on user's previous queries and context;
- automatic error correction and query suggestion – ML models analyze large number of correctly spelled queries to identify and correct common spelling mistakes;
- personalization of search results – ML algorithms analyze user's search history, for example, Amazon system, here, if user has repeatedly searched for books from certain genre, system will recommend similar books based on previous searches and purchasing activity;
- image recognition and classification – ML models, such as convolutional neural networks, are used to analyze and classify images in search engines. This allows users to search for visual content by description or similarity, not just by textual labels.

The concept of deep learning and neural networks in Fig. 2:

1. Understanding context of query. Deep neural networks, such as transformers (e.g., BERT, GPT), allow search engines to better understand context of user queries, including complex or ambiguous queries. This enables system to answer queries more accurately by recognizing user's true intentions.

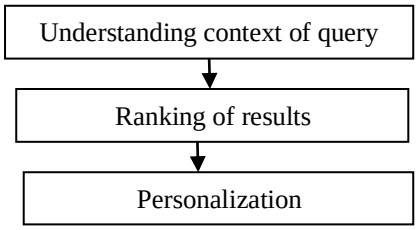


Fig. 2. Concept of deep learning and neural networks

2. Search engines use deep learning models to analyze and rank large number of documents or pages based on their relevance to specific query. These models take into account many factors, such as textual content, context, page popularity, and behavior of other users.

3. Neural networks allow you to adapt search results based on individual preferences and past user behavior. This provides more relevant results for particular person, which increases overall quality of search engine.

Examples of deep neural networks application:

- Google Search uses models such as BERT to improve understanding of natural language and query context;
- Bing uses neural networks to improve accuracy of search result rankings, especially in complex cases;
- Amazon uses deep learning to improve its «product» search by providing accurate recommendations.

The concept of natural language processing in information retrieval systems aims to improve interaction between users and systems by facilitating understanding and processing of textual queries and answers provided and is summarized in Fig. 3:

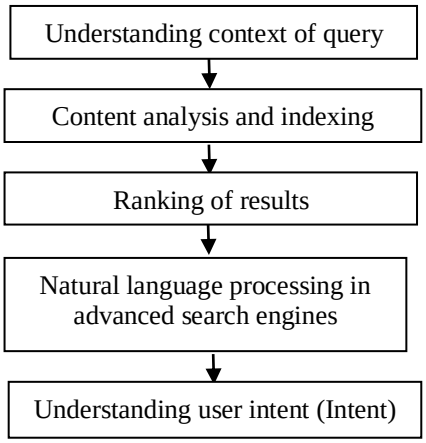


Fig. 3. Concept of NLP

1. Query understanding becomes more efficient thanks to NLP, which allows systems to better interpret natural language queries, taking into account context, synonyms, morphological features, and grammatical structures. This significantly improves accuracy of search results, even if query is ambiguous or contains errors.

2. Content analysis and indexing in IRS is also enhanced by NLP, which allows for efficient analysis and categorization of large amounts of textual information, creating more relevant indexes. This includes keyword discovery, thematic analysis, and entity recognition, such as names, dates, places, etc.

3. Ranking of results becomes more accurate through use of NLP, which analyzes semantics of query and documents. This allows IRS to take into account not only keywords, but also more complex concepts such as similarity between query and content, tone, etc.

4. Natural language processing in advanced search queries also benefits from use of NLP, which allows you to correctly interpret complex queries that may contain logical operators, phrase queries, or queries in languages with different grammatical structures, and find relevant results.

5. Understanding user intent is made easier with NLP, which helps system determine exactly what user wants to find, even if their query is imprecisely worded or has several possible meanings. This enables IRS to provide more accurate answers or offer clarifying queries.

Example of NLP application in information search engines – Google Search uses NLP to improve search results. For example, when user enters query «best places to visit in Ukraine in winter», system uses NLP to understand intent of query and context. Even if specific web pages don't contain exact words «best», «place» or «in winter», Google can show pages that contain useful information about winter tourist destinations in Ukraine by semantic analysis and understanding context of query. This allows user to get more relevant and accurate results.

IV. INTELLIGENT TOOLS FOR SEMANTIC SEARCH

Semantic search is one of most innovative technologies in field of IRS, which radically changes approach to processing and interpreting search queries. Unlike traditional methods that rely on simple keyword matching, semantic search uses IT to gain deeper understanding of user's context and intentions.

Semantic search is based on principles of NLP and machine learning, which allow II to

- understand meaning of words in context because IT analyzes not only individual words but also their interrelationship in sentence or phrase;
- interpret user intentions because system tries to understand what exactly user wants to find, even if query is ambiguously worded;
- take into account semantic relationships between concepts, as IT can find information that is semantically related to query, even if it does not contain exact keywords.

Challenges and limitations of semantic search in Fig. 4, a, b.

Challenges of semantic search:

1. Challenges of semantic search include proper understanding of queries context. Words can have different meanings depending on situation in which they are used, and semantic search must effectively take these nuances into account, which is not always easy, especially when words are polysemous.

2. Language barriers also create difficulties. Even if system supports multiple languages, different language structures and cultural characteristics can cause errors in understanding queries or interpreting results.

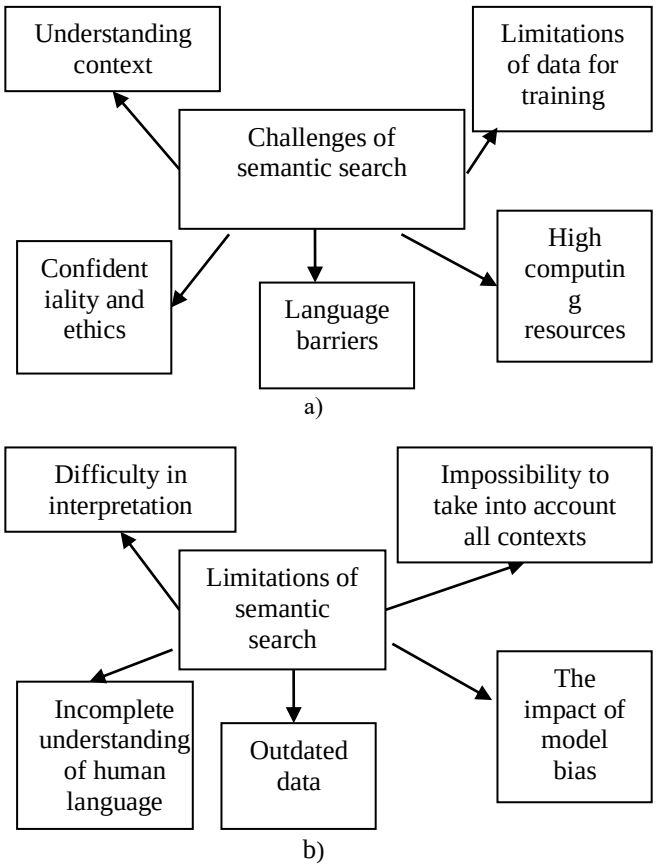


Fig. 4. Concept of deep learning and neural networks: a) challenges of semantic search; b) limitations of semantic search

3. Limiting training data is another challenge, as semantic models require large amount of data to train. The quality of this data is crucial, and if it is incomplete or biased, it can lead to incorrect search results.

4. Another limitation is need for high computing resources. Using NLP for semantic search requires significant resources, especially when it comes to real-time processing, which can be problem for large systems with high query frequency.

5. Privacy and ethical issues are also important challenge. To improve search, systems often collect and analyze data about users, which raises concerns about how this data is protected and used.

Limitations of semantic search:

1. Difficulty in interpreting ambiguous queries because queries that have several possible interpretations can be difficult for semantic search engines. For example, query «family movies» can mean both searching for family movies and searching for movies about families.

2. Inability to take into account all contexts because even most advanced semantic search engines cannot always take into account all possible query contexts, especially if user does not provide enough information or query is formulated too generally.

3. Semantic search often relies on indexed data. If this data is outdated or not updated in real time, it can lead to less accurate or irrelevant results.

4. Semantic models can be biased due to nature of data they are trained on. This can lead to irrelevant or unfair search results, especially for socially sensitive topics.

5. Despite progress in NLP, computer systems still cannot fully understand human language at level similar to that of humans. This limits effectiveness of semantic search in some cases.

Semantic search in context of intelligent tools for optimizing information retrieval systems is important because this approach significantly improves accuracy of results. Semantic search allows IRS to understand meaning of query at deeper level, taking into account context, user intent, and relationship between concepts. This not only increases relevance of results, but also provides more intuitive and efficient user experience, which is key for modern IRSs focused on providing quality and personalized information. Thus, semantic search is critical tool in evolution of IRS, contributing to their optimization and meeting needs of users.

V. CONCLUSIONS

Intelligent ranking algorithms based on machine and deep learning techniques are significantly improving functioning of IRS, making them better able to understand user queries and intentions. With introduction of these technologies, IRSs can provide more relevant, accurate, and useful search results. Important aspect of this process is use of neural networks and natural language processing models, which allow systems to efficiently process complex queries, take into account context, and personalize responses. This ensures more intuitive user experience and allows IRS to adapt to their ever-changing needs. Thus, introduction of intelligent tools not only optimizes search engines, but also improves overall quality of information provision, making it more accessible and useful to users in modern information environment.

This summary outlines key findings, implications, challenges, and overall conclusion regarding use of intelligent tools for optimizing information retrieval systems. The research highlights significant improvements these tools bring to search accuracy, efficiency, and user experience, while also acknowledgingthe challenges and limitations that need to be addressed.

The integration of AI, ML, and NLP into IRS represents major advancement in how we interact with and retrieve information from vast data repositories. These technologies enable more intuitive, context-aware, and personalized search experiences, which is crucial in our increasingly data-driven world.

The development and implementation of these intelligent tools will continue to be key area of focus for improving information retrieval systems, with potential far-reaching impacts on various sectors including research, business, and everyday information access for users worldwide. The work discusses different types of intelligent tools (AI, ML, NLP) and their specific roles in optimizing IRS. It provides concrete examples of how these technologies are applied in real search engines such as Google, Bing, and Amazon.

Considerable attention is paid to semantic search as advanced technology in field of IRS.

The article not only describes advantages of these technologies, but also critically analyzes challenges and limitations faced by developers and users.

LIST OF REFERENCES

[1] V. Kaponkin, et al., “The role of big data in improving functionality of search engines,” *The 8th International scientific and practical conference “European congress of scientific achievements” (August 12-14, 2024) Barca Academy Publishing, Barcelona, Spain*. 2024, pp. 69-76.

[2] I. S. Nevludov, et al., “Cloud giants: AWS, Azure and GCP,” *2023 2nd International Conference on Innovative Solutions in Software Engineering Ivano-Frankivsk, Ukraine, November 29-30*. 2023, pp. 18-23.

[3] S. Sotnik, I. Borysenko, “Chat GPT features in data search,” *9th International scientific and practical conference “Scientific progress: innovations, achievements and prospects” (May 29-31, 2023) MDPC Publishing, Munich, Germany*. 2023, pp. 139-144.

[4] I. Sh. Nevliudov, et al., Tekhnolohii informatsiino-poshukovykh system. – Kyiv-58, prosp. 76 Kosmonavta Komarova, 1, 2022. – 349 p.

[5] Z. Deineko, et al., “Features of Database Types,” *International Journal of Engineering and Information Systems (IJEAIS)*. 2021, vol. 5(10), pp. 73-80.

[6] S. Sotnik, “Development of automated control system for continuous casting,” *Radio Electronics, Computer Science, Control.* 2024, issue 2, pp. 181-189.

[7] A. Y. Hubar, et al., “Impact of automation and cals technologies on human factor in production,” *The 8th International scientific and practical conference “European congress of scientific achievements” (August 12-14, 2024) Barca Academy Publishing, Barcelona, Spain*. 2024, pp. 243-249.

[8] І. С. Зарубін, С. В. Сотник, “Ефективність використання роботизованих систем у виробництв,” *Комп’ютерно-інтегрованих технологій, автоматизації та робототехніки 2024: матеріали І-ої Всеукраїнської конференції, Харків, 16-17 травня 2024 (CITAR-2024)*. 2024, pp. 150-153.

[9] Я. І. Халімонов, и др., “Створення інтелектуального модулю для автоматизованого моніторингу середовища у приватних та комерційних приміщеннях з використанням комп'ютерно-інтегрованих технологій,” *International Conference on Advanced Trends in Radioelectronics and Telecommunications dedicated to the 85th anniversary of the Department of Theoretical Radio Engineering and Radio Measurements.* 2024, pp. 176-181.

[10] S. Sotnik, et al., “Optimization of work: in-depth look at Kanban, Scrum and Lean,” *Journal of Natural Sciences and Technologies*. 2024, Т. 3, №. 1, pp. 290-301.