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CONTEMPORARY RESEARCH TRENDS IN HUMAN-COMPUTER INTERFACE DESIGN

Objective: *analyzing the current status and developmental trends in the field of interface design, and to establish a classification framework for the characteristics and requirements of various application domains in interface design*

Methodology. *Using the methods of quantitative analysis, literature review, and information visualization techniques with Citespace software to visualize the relevant literature information in the field of interface design. The creation of scientific knowledge maps depict the structure and distribution of scientific knowledge, enabling a comprehensive analysis of the field of interface design from multiple perspectives and levels.*

Results*. This paper presents the development trend of interface design research in Scopus database from 2015 to 2023 in the form of visual knowledge graph. Through literature analysis, the current research focus and future research direction of interface design are obtained. At the same time, ten main application carriers of interface design are listed, their characteristics are analyzed from the perspective of interface design, and corresponding design suggestions are given.*

Scientific novelty. *For the first time, the literature research knowledge map of interface design was summarized by combining Citespace visualization software. The categories and key points of interface design research were presented through visualization maps. At the same time, the main application scenarios and categories of interface design were summarized, thus providing a theoretical basis and reference database for interface design.*

Practical significance. *The study is recommended for practical implementation in the field of interface design.*

Key words: *interface design, visual communication design, visualization, web design, frontier trends, graphic design.*

Introduction. As an important medium for the interaction between human and machine, user interface enables users to operate intuitively and effectively through the interface, perform information processing, task decision-making and response on the computer system according to the requirements of the given task, and finally achieve the completion of the task. Among them, interface design, as an interdisciplinary integration specialty, covers a variety of new disciplines such as ergonomics, information visualization, multi-modal interaction methods, etc., which will improve people's lifestyle in the process of continuous iterative optimization and promote the development of the whole society. With the continuous development of science and technology, the functions, information and structural characteristics contained in the system become more and more complex and redundant, and the quality of interface design will directly affect the actual experience of users and the completion of system tasks, so the interface design plays a very important position in the entire system design.

Analysis of previous researches. Traditional research on human-computer interaction (HCI) interface design has primarily focused on computer software technology, with interface design being considered a peripheral and subsidiary aspect of the overall system development process. This has resulted in inconvenience for users [1]. However, HCI is the medium between the user and the device to transmit and exchange information in the integrated practical operating environment system of the user application device [2]. Under

the same functional structure, the quality of interface design directly determines the operator's perception and operation of the machine, and affects the personal physiological state, thus further leading to the quality of the task operation results [3]. By studying optimization methods for the human-machine interface of mechanical systems, the relationship between the mechanical physical interface and operator adaptability is explored, while meeting the basic operational requirements of the machine system [4; 5]. The concept of "user-centered" design is proposed, emphasizing that interface design should prioritize users and place them at the forefront of the design process, basing design decisions on user characteristics and research on user needs [6]. Moreover, digital interfaces should possess good learnability, usability, pleasantness, and experiential qualities. Based on the connotations of design aesthetics and influential factors, the development of visual aesthetics in interface design and research on design methods are analyzed [7]. Specific guiding design principles are proposed for visual elements such as color design and window layout design in graphical user interfaces, emphasizing characteristics of being intuitive, visually appealing, and conveying substantial information [8]. From a user experience perspective, the trends in human-machine interface development are analyzed to meet users' higher-level experiential needs, such as safety, learnability, fault tolerance, effectiveness, and user satisfaction [9]. The application and current development of artificial intelligence (AI) technology in the field of human-machine interfaces are discussed, focusing on three aspects: recommender systems, computer vision, and speech recognition [10]. The development trends of interface design under the guidance of AI are analyzed [11]. By integrating emerging interactive technologies, users are allowed to utilize their own perceptual and cognitive skills to interact with computer systems through multiple channels, making the integrated and disseminated information more immersive and memorable for users [12]. The basic principles of visual design in the information space are systematized in the monograph [13]. Therefore, interface design as a comprehensive design activities, include the interface design aesthetics, interaction design, ergonomics, cognitive psychology and other relevant fields [14].

Problem statement. This article aims to analyze the spatio-temporal characteristics, research content and development trends of interface design field based on bibliometric and visualization methods, to summarize and classify the application directions of interface design in different domains and to identify and compare the features and requirements of interface design in different application scenarios, and to provide design suggestions and principles for interface designers and researchers. The following tasks have been set in the research: to systematize date on topics and trends in the design of interface in the period of 2015-2023; to characterize the main trends and directions in the future interface design.

The results of the research and their discussion. The data are from the Scopus database. The search was conducted with the keyword "interface design" as the theme, and the search time was June 1, 2023, and the search time was from 2015 to 2023. After sorting and screening, a total of 3,554 original sample articles were obtained. The information visualization tool Citespace is used to present co-occurrence keywords, authors, units, time distribution, co-citation data and other relevant information in the literature in a visual way, and to build a scientific knowledge graph to show the structure and distribution of scientific knowledge

Analysis of Temporal Characteristics in Interface Design

Temporal Distribution Characteristics

The volume of relevant research literature was transformed into an annual distribution discount chart to reflect the development speed and phase changes in the field of study over time. This approach also enables

predictions regarding future development trends and research dynamics in the field. By observing the trend in the number of published papers over the past eight years, it is possible to gain a visual understanding of the overall development status and popularity of interface design research during this period.

From Fig. 1, the number of publications has an increasing trend since 2015, followed by a stabilization of publication volume. This indicates a favorable research outlook and sustained interest in the field of interface design. With the development of Industry 4.0, the focus of industrial development has shifted from the traditional industrial development to the era of information technology-driven industrial change, that is, the era of intelligence. In recent years, with the continuous upgrading of computer hardware technology, system functions have been continuously improved. People's demand for the system has changed from basic functions to diversified interaction needs. Therefore, the research of multi-modal interfaces suitable for various scenarios will be the focus of future HCI research.

Analyzing key milestones in interface design through literature analysis helps to grasp the overall research trends in the field. In terms of temporal distribution, interface design research has gained attention since the 21st century. From the perspective of co-citation timelines, as shown in Fig. 2, there are notable differences in the duration of clustering themes in interface design research. Clusters with the largest scale, such as #0 (graphical user interface), #1 (human), and #5 (visualization), have consistently persisted throughout the selected timeframe. However, based on the timeline graph, it can be observed that the intensity of related research has weakened since 2016. Certain clustering themes, such as #2 (software engineering) and #8 (smartphone), have relatively shorter durations, while #4 (virtual reality) has experienced an increase in research interest within this period.

Through the chart analysis, the user interface design carrier has changed from traditional computers and mobile devices to interface scenes with technologies such as virtual reality, so that users do not have to be restricted by fixed hardware devices and can achieve free interaction. This means that the development trend of human-computer interface has also changed from simple interface function aesthetic design to complex human-computer interaction interface design stage.

Spatial Distribution Characteristics

Country / Region Distribution Characteristics. Figure 3 displays the top 12 countries in terms of the number of publications in the field of interface design from 2015 to 2023.

According to Table 1, the top three countries in terms of publication volume are the United States, Germany, and China, all exceeding 300 papers. Five countries have centrality values exceeding 0.1, namely the United States (0.28), the United Kingdom (0.16), France (0.15), Germany (0.11), and China (0.11). This indicates a close collaboration and strong association between these five countries and other nations in the field of interface design research. It also reflects that at the current stage, European countries have closer exchanges and cooperation on interface design than Asian countries.

Institutional Distribution Characteristics. By constructing a co-occurrence network graph of research institutions in the field of interface design, each node represents a different institution, and the size of the nodes indicates the number of publications by each institution within the specified time period. The connecting nodes show the institutions collaborative relationships, as shown in Fig. 4.

Based on Fig. 4, the top five institutions in terms of publication volume in the past eight years are Aalto University, LMU Munich, Telkom University, Georgia Institute of Technology, and Delft University of Technology, indicating the dominant position of European institutions in the field of interface design.

Through the above research, can know that most of the colleges and universities that focus on interface design are science and engineering colleges and universities, because interface design is a systematic discipline that includes knowledge content in multiple fields such as computer science, ergonomics, color psychology, cognitive psychology, etc. At the same time, with the continuous development of technology, the methods of interface interaction are also constantly innovating. These universities have rich resources and advanced equipment to support relavant research, continuously optimize interface design methods and interaction methods to realize the integrated development of man, machine, and environment.

Table. 1

The top 12 countries in the number of posts are ranked

Numerical order	Country	Quantity	Centrality
1	United States	753	0.28
2	Germany	341	0.11
3	China	315	0.11
4	United Kingdom	253	0.16
5	Indonesia	148	0
6	Japan	144	0.01
7	Canada	138	0.03
8	India	137	0.01
9	Australia	116	0.07
10	France	115	0.15
11	Italy	112	0.02
12	South Korea	94	0.05

Interface Design Research Content Map and Analysis

Co-occurrence Analysis of Keywords

In bibliometric research, keyword extraction can summarize the core content of references and indicate the research hotspots in a specific field. The size of the keyword node in the graph indicates the frequency of the keyword appearing in the reference. As shown in Figure 5, the largest keyword node is "human-computer interaction", and other important keyword nodes include "user interface", "user interface design", "virtual reality" and "software design". "Human-computer interaction", "user interface" and "interface design" constitute the knowledge graph of interface design research, and each keyword has a certain correlation.

By analyzing the time dimension of the appearance of keywords and classifying them according to the time development in citespace, it can be found that after 2020, the focus of interface design research has shifted from machine system design to human-centered interface, focusing on the user's experience. At the same time, new technologies such as virtual reality and artificial intelligence have been studied in the cross-integration of interface design.

Burst keywords provide insights into the rise and fall of the frequency of use for specific keywords within a given period. They help identify the keywords that are central to the research in a particular field, thus facilitating better prediction of future research hotspots. By applying Citespace, an analysis of keywords was conducted, resulting in Fig 6. It presents the top 30 burst keywords in the field of interface design from 2015 to 2023, with the highest burst intensity recorded as 85.31 (Graphical User Interface) and the lowest as 4.26 (3D modeling). And "human-centered computing" ranked second, following behind Graphical User Interface, and its burst started around 2020.

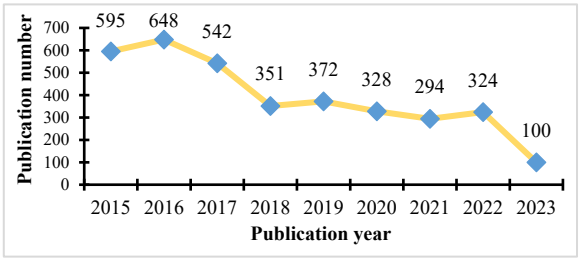

Fig. 1. Literature quantitative trend plots (Zhou T., 2024)

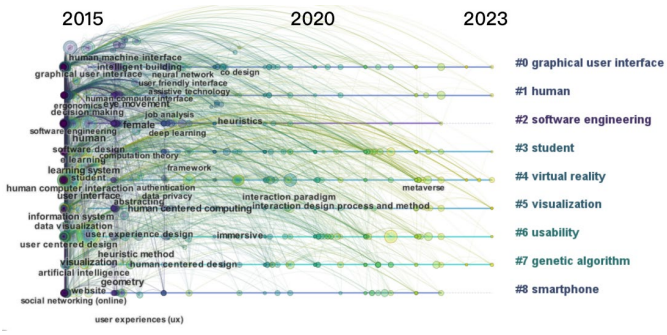

Fig. 2. Interface design keywords cluster timeline map (Zhou T., 2024)

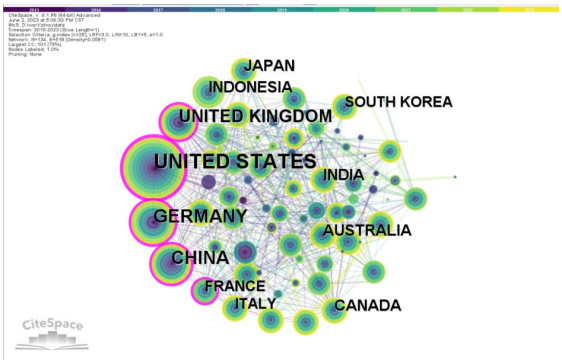

Fig. 3. National distribution chart of the number of publications (Zhou T., 2024)

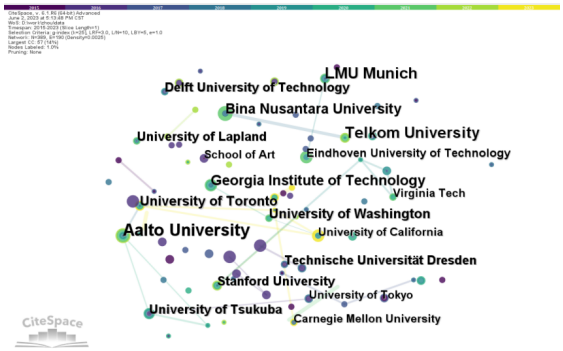

Fig. 4. Co-occurrence map of research institutions (Zhou T., 2024)

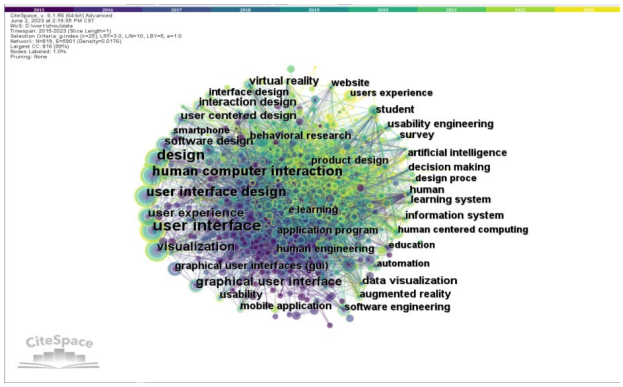

Fig. 5. Network the co-occurrence of keywords (Zhou T., 2024)

Keywords	Year	Strength	Begin	End	2015 - 2023
graphical user interface	2015	85.31	2015	2017	
image processing	2015	5.81	2015	2017	
wearable technology	2015	4.75	2015	2017	
signal processing	2015	4.57	2015	2017	
open system	2015	4.57	2015	2017	
user centered design(ucd)	2016	5.68	2016	2018	
controller	2015	4.41	2016	2018	
visual analytics	2017	4.47	2017	2020	
visualization technique	2018	13.15	2018	2020	
information use	2015	11.17	2018	2020	
usability problem	2017	6.88	2018	2020	
virtual reality	2015	14.27	2019	2023	
machine learning	2017	10.72	2019	2023	
interaction paradigm	2019	9.74	2019	2023	
mixed reality	2015	7.05	2019	2023	
visual communication	2016	4.71	2019	2023	
transparency	2019	4.29	2019	2023	
3d modeling	2019	4.26	2019	2023	
human centered computing	2017	32.47	2020	2023	
user study	2015	8.54	2020	2023	
deep learning	2017	8.38	2020	2023	
design proce	2015	8.19	2020	2023	
immersive	2018	6.2	2020	2023	
interaction design process and method	2020	6.14	2020	2023	
survey	2015	5.52	2020	2023	
recommender system	2015	5.44	2020	2023	
design space	2015	5.31	2020	2023	
chatbot	2020	4.91	2020	2023	
design tool	2020	4.5	2020	2023	
autonomous vehicle	2020	4.35	2020	2023	

Fig. 6. Top 30 keywords for citation burst intensity (Zhou T., 2024)

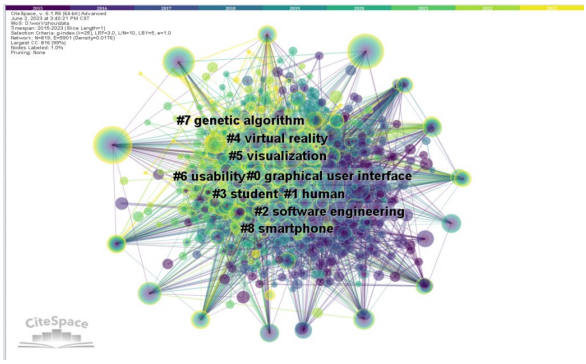

Fig. 7. Clustering map of high-frequency keywords (Zhou T., 2024)

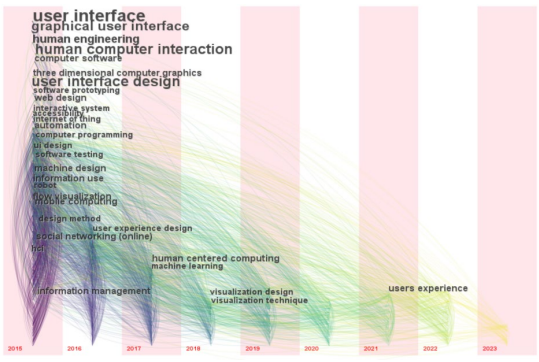

Fig. 8. Time zone diagram of research frontier in interface design field (Zhou T., 2024)

Keyword Clustering Analysis

According to the keyword map analysis, the high-frequency keywords of interface design are clustered and analyzed, so as to obtain the cluster analysis map of high-frequency keywords of interface design. As shown in Figure 7, the map shows the 9 largest clusters of research keywords in this field: #0 Graphical User Interface, #1 Human, #2 Software Engineering, #3 Student, #4 Virtual Reality, #5 Visualization, #6 Usability, #7 Genetic Algorithm, #8 Smartphone. Keyword cluster analysis can not only understand the focus of the current research field, but also help predict the development direction of future research.

Analysis of Research Evolution Trends

As shown in the time zone diagram of Figure 8, combined with Figures 6 and 8, the research and development of interface design can be divided into three stages.

The first stage was before 2017. This stage was the embryonic stage of the development of human-computer interface. The research types mainly included keywords such as computer graphical interface and controller buttons. The application carriers were mechanical equipment and traditional industrial system software, reflecting that the current period mainly studied the basic use functions of the interface in the system functions.

The second stage was from 2018 to 2020. The development of human-computer interface in this stage began to shift from functionality to people-centered. It can be found that the research keywords in the current period are visualization technology and usability. On the basis of meeting basic functions, attention should be paid to the standardization and user needs of interface design.

The third stage is after 2021. In this stage, the interface is no longer limited to the screen, but integrated into virtual or real scenes. By combining technologies such as deep learning and virtual reality, the research on interface design is further deepened, and the application fields are further subdivided, such as education, games, and displays. The purpose is to create an interactive interface with immersion, realism, and naturalness.

Through the interface design research knowledge graph, we can not only clearly understand the research focus at different stages, but also infer the future trend of interface development, thereby providing a reference for relevant researchers or designers and promoting the continuous development of the entire human-computer interface.

Research on the application direction and development trend

Mobile Application Interface Design

With the development of smart devices, mobile devices have also been updated to the era of smart phones. The corresponding interface design range has also changed from computer screen size to mobile phones, tablets and other sizes. Different devices have different size requirements, which also affect the display of interface functions and content. Designers need to fully consider the display and control size of interface elements such as function icons and pictures on different devices, so that they can display the corresponding information content to the greatest extent within the limited size control. At the same time, mobile application devices cover different application functions, and the consistency characteristics of multiple application functions and the original system interface of the device should be considered to maintain the overall sense and simplicity of the interface, and provide users with a more intuitive, easy-to-use, and feature-rich mobile interface (Fig. 9).

Computer System Interface Design

The computer system interface refers to the graphical user interface of the computer system that can be displayed and operated (fig. 10). Compared with the command line interface operated by professional computer personnel in the early days, the information in the device is presented in the form of graphical visualization, in the form of function icons, text, and pictures, allowing users to

switch from traditional text code interaction to control icon interaction, which greatly reduces the learning difficulty and operation burden of new users. At the same time, as the interface design of a complex system, it is a fusion design form of human-computer interaction, information hierarchy, color aesthetics, functional distribution and other aspects. Its purpose is to allow operators to use the computer system more conveniently, efficiently and naturally.

Media and Entertainment Interface Design

This type of interface is mainly based on video game interfaces (Fig. 12), which can give the interface designer a higher degree of freedom, so that the interface is designed for each user, to achieve personalized customization of the interface. Thus, designers need have the ability of the relevant knowledge such as ergonomics, color psychology, and user experience, to stimulate users' curiosity and entertainment of applications.

Interface Design for Smart Devices

With the rapid development of the Internet of Things technology, smart devices have entered People's Daily life. Users can operate with hardware devices in life anytime and anywhere through mobile phone software or devices, such as smart homes, wristbands, cars, etc., which can display the status data and information of the environment or device functions through the interface to achieve a more convenient lifestyle (Fig. 12).

Interface Design for Industrial Systems

The industrial system interface is a visual display through a physical or graphical interface, such as physical control buttons and indicator lights, and screen interface function controls, etc., which provides the operator with real-time status information of the system operation and a functional interface for operation control. It mainly includes automated production equipment, monitoring equipment, big data platforms, etc (Fig. 13).

Interface Design for Education and Training

Education and training interface usually include mobile education apps, online learning platforms (Fig. 14), online virtual classrooms, etc. which are the important part of modern teaching. Learners and educators can learn and transfer knowledge through interface. And it can also provide learners with a better learning experience in a more convenient and diverse teaching methods, so that knowledge can be better understood and applied.

Interface Design for Healthcare and Medical Applications

Medical application interface design is usually applied to medical equipment, health testing equipment (Fig. 15), etc., to provide doctors and patients with relevant medical information, personal physical conditions and other functions. Relevant personnel can operate medical and health-related functions according to the corresponding interface controls, thereby assisting doctors and users to conduct professional diagnosis and treatment of their own conditions or illnesses.

Head-Up Display (HUD) Interface Design

HUD is known as head-up display system, refers to the interface system design of a car or airplane driver-centric, blind-operated, multi-function dashboard (Fig. 16). Through HUD technology, operators can obtain relevant information without turning their heads or sights during visual search, allowing operators to maintain their focus on the environment ahead and avoid accidents caused by sight diversion or distraction.

Multi-Modal Interaction Interface Design

A multi-modal interactive interface is an interface that combines multiple forms of interaction, such as eye control, voice control, and gesture control (Fig. 17). Compared with ordinary single interaction methods, multimodal interaction can make up for the lack of operational feedback, so that it can be used reasonably in different work scenarios

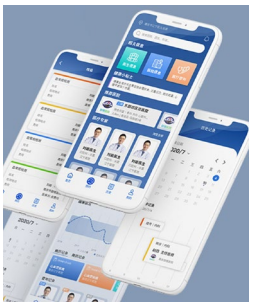

Fig. 9. Medical application interface design (Zhou T., 2024)

Fig. 10. Mac OS 11 Big Sur [15]

Fig. 11. Overwatch game interface [16]

Fig. 12. Xiaomi intelligent screen interface [17]

Fig. 13. Complex information system interface design [18]

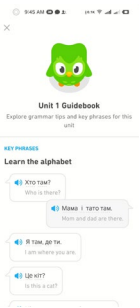

Fig. 14. Duolingo interface design [19]

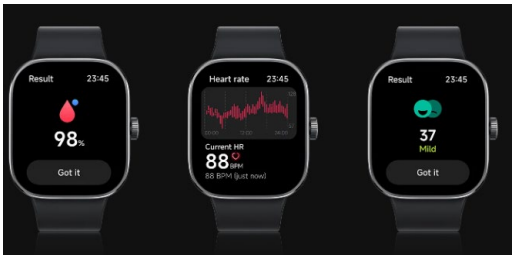

Fig. 15. Redmi watch 4 interface [20]

Fig. 16. XiaomiEV interface [21]

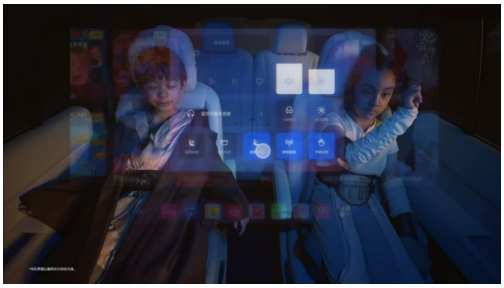

Fig. 17. Lixiang suv gesture, voice, button interaction interface [22]

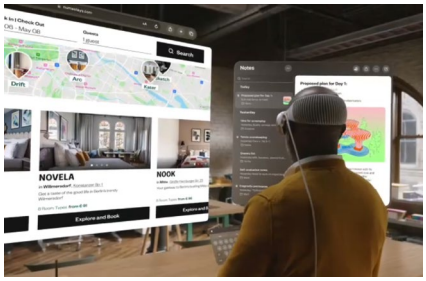

Fig. 18. Apple vision pro interface [23]

and operators, realize natural human-computer interaction, and improve interaction efficiency. At the same time, it can increase the fun of using the system and the breadth of application. However, this type of interaction needs to avoid conflicts caused by the coexistence of multiple interaction methods.

Extended Reality Interface Design

Extended reality interface design mainly includes virtual reality technology (VR), augmented reality technology (AR), mixed reality technology (MR), etc., which combines real-world scenes with computer virtual information to create a new immersive user experience interface (Fig. 18).

Conclusions. This study conducts a quantitative analysis and visual representation of the literature in the field of interface design from the Scopus database covering the years 2015 to 2023. It explores the spatiotemporal characteristics, research topics, and development trends in interface design. The research findings indicate a continuous increase in research activity in the field of interface design, with dominance from European, American countries, and institutions. Human-computer interaction, user interfaces, virtual reality, and other related topics are identified as core themes in this field, along with emerging research directions and technological applications. Furthermore, this study categorizes and analyzes the application areas of interface design, including mobile applications, computer systems, media and entertainment, smart devices, industrial systems, education and training, healthcare, heads-up displays, and augmented reality. The characteristics and requirements of each category are examined from the perspective of interface design, and corresponding design recommendations are proposed. The aim of this paper is to provide a comprehensive reference framework for researchers and practitioners in the field of interface design, helping them understand the development history and trends in interface design, as well as the methods and principles of interface design in different application scenarios.

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СУЧАСНІ ТЕНДЕНЦІЇ ДОСЛІДЖЕНЬ ДИЗАЙНУ ІНТЕРФЕЙСУ «ЛЮДИНА-КОМП'ЮТЕР»

Мета: *аналіз поточного стану та тенденцій розвитку в області дизайну інтерфейсу, а також створення класифікаційної основи для характеристик і вимог різних областей застосування в дизайні інтерфейсу*

Методологія. *Використання методів кількісного аналізу, огляду літератури та методів візуалізації інформації з програмним забезпеченням Citespace для візуалізації відповідної літературної інформації у сфері дизайну інтерфейсів. Створення карт наукових знань, що відображають структуру та розподіл наукових знань, уможливлюючи комплексний аналіз сфери дизайну інтерфейсу з різних точок зору та на різних рівнях.*

Результати. *У статті представлено тенденцію розвитку дослідження дизайну інтерфейсу в базі даних Scopus з 2015 по 2023 рік у формі візуального графа знань. Шляхом аналізу літератури виявлено поточний фокус дослідження та майбутній напрям наукових розвідок в царині дизайну інтерфейсу. Виокремлено десять основних прикладних носіїв дизайну інтерфейсу, проаналізовано їхні характеристики з точки зору дизайну інтерфейсу та надано відповідні пропозиції щодо дизайну.*

Наукова новизна*. Вперше сформовано карту знань про дизайн інтерфейсу з наукових публікацій засобами програмного забезпечення Citespace. За допомогою карт візуалізації виявлені основні категорії та ключові моменти дослідженнь в царині дизайну інтерфейсу. Узагальнені основні сценарії застосування та категорії дизайну інтерфейсу, що забезпечило теоретичну основу та інформаційне забезпечення для дизайну інтерфейсу.*

Практична значущість. *Дослідження рекомендується до практичного впровадження в галузі дизайну інтерфейсу.*

Ключові слова: *дизайн інтерфейсу, дизайн візуальної комунікації, візуалізація, веб-дизайн, сучасні тренди, графічний дизайн.*

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