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PHÂN TÍCH TRẮC LƯỢNG KHOA HỌC VỀ NGHIÊN CỨU METAVERSE TOÀN CẦU VÀ NHỮNG SỰ KHÁC BIỆT GIỮA CÁC QUỐC GIA

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TỪ KHÓA

Bibliometric analysis; VOSviewer; Metaverse; Virtual reality; NFT.

TÓM TẮT

Nghiên cứu về Metaverse đã thu hút sự quan tâm toàn cầu như một lĩnh vực liên ngành kết hợp công nghệ, truyền thông và tương tác con người. Nghiên cứu này trình bày phân tích thư mục các ấn phẩm liên quan đến Metaverse trong giai đoạn từ năm 2012 đến năm 2021, sử dụng dữ liệu từ cơ sở Scopus và các công cụ trực quan hóa như VOSviewer để xác định xu hướng nghiên cứu, mối liên hệ từ khóa và mô hình hợp tác quốc tế. Kết quả cho thấy lĩnh vực này đang phát triển nhanh chóng, với Hoa Kỳ, Trung Quốc và Đức là những quốc gia dẫn đầu về số lượng công bố. Thực tế ảo được xác định là chủ đề được nghiên cứu nhiều nhất. Nghiên cứu cung cấp một cái nhìn tổng quan súc tích về hiện trạng nghiên cứu và định hướng cho sự phát triển học thuật cũng như công nghệ trong tương lai của Metaverse.

A BIBLIOMETRIC STUDY FOR MAPPING THE METAVERSE OF GLOBAL RESEARCH PATTERNS AND COUNTRY LEVEL DIFFERENCES

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ABSTRACT

Metaverse research has gained global attention as a multidisciplinary field that brings together technology, media, and human interaction. This study presents a bibliometric analysis of Metaverse-related publications from 2012 to 2021, using data from the Scopus database and visualization tools such as VOSviewer to identify research trends, keyword associations, and patterns of international collaboration. The findings show that the field is growing rapidly, with the United States, China, and Germany leading in publication output. Virtual reality is identified as the most frequently studied topic. This study offers a concise overview of current research and provides direction for future academic and technological progress in the Metaverse.

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1. INTRODUCTION

The concept of the Metaverse was first introduced in Neal Stephenson's 1992 science fiction novel Snow Crash, envisioning a virtual reality–based extension of the Internet that merges with real-world experience [1]. The term combines "meta," meaning beyond, with "verse," referring to the universe [2]. Prior to the popularization of the Metaverse, the Internet had already facilitated vast human–machine interactions, creating an intangible yet powerful social structure. With the advancement of technologies such as virtual reality, augmented reality, and sensors, this structure evolved into what is now considered the foundational layer of the next generation Internet [3]. Early prototypes emerged in the gaming industry, notably with Second Life in 2003, which combined online gaming, social networking, and digital commerce in a shared virtual environment [4], despite criticism for its limited user interface [5]. Roblox emphasized user-generated content and education through game-based learning experiences [6], while Pokémon GO blended virtual and real-world interaction, resonating with Generation Z's preference for immersive, gamified environments [2]. Parallel to these developments, the emergence of blockchain technology and virtual currencies introduced decentralized systems into digital interaction [7], starting with Bitcoin in 2009 and followed by Ethereum and Non-Fungible Tokens (NFTs), which gained widespread attention in 2021 as unique digital assets [8]. Platforms like Decentral and further exemplified the convergence of blockchain and virtual worlds [9], while NFT trading data revealed that the gaming sector dominates digital asset exchange [10]. The release of stablecoins [11] and blockchain games such as Axie Infinity illustrated the growing economic dimension of the Metaverse, highlighting its capacity to create real financial value and new forms of employment [8, 11].

The COVID-19 pandemic significantly accelerated the evolution and integration of the Metaverse across industries by reshaping social norms and technological engagement patterns [12]. Entertainment and commercial operations have emerged as the central focus of Metaverse applications, with increasing investment from startups and major tech corporations. Facebook's rebranding to Meta in 2021 marked a pivotal shift, signifying long-term investment in immersive technologies, including its earlier acquisition of Oculus [13]. Simultaneously, the Metaverse began expanding into healthcare, education, and smart city development. In healthcare, it enabled remote diagnosis, rehabilitation, and surgical simulations, while also enhancing training infrastructures through tactile and immersive technologies [14]. In education, institutions like UC Berkeley adopted virtual platforms for academic ceremonies and interactive learning, demonstrating the Metaverse's capacity to foster motivation and engagement [15]. Urban development also embraced the Metaverse, with cities like Seoul and Dubai launching initiatives to provide digital public services and stimulate economic growth [16]. Despite this rapid adoption, the Metaverse's architectural structure remains under debate, with models ranging from layered frameworks to conceptual roadmaps emphasizing user experience and technological integration [17]. Early definitions focusing on immersive 3D interaction now evolve into broader understandings involving 5G/6G, IoT, cloud computing, digital twins, blockchain, and mixed reality, supporting secure, interconnected virtual–physical environments [18]. Thus, the Metaverse represents a complex socio-technical convergence, extending beyond entertainment into infrastructure, governance, and collective experience.

The Metaverse represents a transformative evolution in human interaction, marked by three key developments. First is the globalization of sensory stimulation, which reflects an irreversible shift from single-sensory mediums such as books, music, and visual arts to immersive, multi-sensory experiences enabled by the Metaverse. Second is the convergence of cutting-edge technologies, as the Metaverse integrates extended reality, brain computer interfaces, digital twins, blockchain, and AI to offer immersive experiences, real-time content creation, and interconnected socio-economic systems [19]. This technological synthesis enables seamless interaction between virtual and real-world environments, promoting equal participation across users [6]. Third is the virtualization of daily life, intensified by the COVID-19 pandemic, which normalized remote engagement and catalyzed the emergence of the Metaverse as an evolved digital counterpart to the physical world, no longer merely a supplement but a parallel sphere of social and economic activity.

Driven by the convergence of technological innovation and user demand for immersive experiences, the Metaverse has emerged as a pivotal intersection of digital transformation, signaling an inevitable trajectory in technological evolution. While recent studies have explored specific domains such as the "Health Metaverse" and the "Metaverse in education" [1, 4], comprehensive bibliometric analyses of the field as a whole remain limited. This study addresses that gap by presenting a global bibliometric analysis of Metaverse research from 2012 to 2021, examining key contributors including leading authors, sources, institutions, and countries mapping international collaborations through VOS viewer software.

2. METHODOLOGY

2.1 Data Collection

This study adopts bibliometric analysis to quantitatively evaluate the development and structure of Metaverse research. As a multidisciplinary field, the Metaverse encompasses technologies such as virtual reality, blockchain, and cloud computing [20]. Therefore, keyword selection was critical for capturing both core concepts and related technologies. The process began with a manual review of foundational sources, including the White Paper on China's Metaverse and key review articles [21], as well as publications from leading institutions [22]. Keyword clustering and trend analysis further identified high-frequency terms. To ensure comprehensiveness and accuracy, experts across relevant fields were consulted, and the keyword set was refined through iterative testing based on their feedback.

Through multiple iterations, the search expression was refined to accurately reflect the research landscape of Metaverse-related fields. The core keywords included "Metaverse," "Meta universe," "Meta-cosmic," "Meta-cosmum," and "virtual universe." Additionally, to broaden the scope of research, related technological areas were incorporated, such as Extended Reality, Virtual Reality, Augmented Reality, Mixed Reality, Digital Twins, Blockchain, 5G/6G Networks, Intelligent Networks, Internet of Things, Cloud Computing, Edge Computing, Virtual Human, Digital Human, 3D Modeling, Game Engine, Computer Vision, Computer Graphics, User-Generated Content, Helmet Mounted Display, Brain-Computer Interface, and Non-Fungible Token (NFT). Overall, the Metaverse's core supporting technologies were categorized into physical space, virtual space, virtual-real interaction, and virtual-real generic technologies [21].

It was established that both the number of papers and citations by countries, as well as across various fields, were significantly high in the Scopus databases, with Scopus demonstrating broader journal coverage across all fields. Consequently, the Elsevier Scopus database was selected for this study, covering the period from 2012 to 2021 to track the key developments in Metaverse-related research over the past decade. The choice of starting in 2012 was driven by the release of the first NFT Coins, marking an economic connection between the Metaverse and the real world, which spurred greater integration between them. NFTs have allowed the Metaverse to expand its social dimensions, including fashion, activities, gaming, education, and more, differentiating it from earlier concepts of the Metaverse. A triangular search approach (title, abstract, keywords) was used to identify the central focus of Metaverse research . The search was restricted to articles and conference papers published by December 31, 2021, yielding 45,178 scientific documents from the Scopus database, which included data on publication year, authors, affiliations, titles, abstracts, journals, subject categories, and references. For simplicity, we will refer to Metaverse-related research as "Metaverse".

2.2 Tool

This study applied both performance analysis and science mapping, which are the two main approaches in bibliometric research. Performance analysis focuses on evaluating the contributions of key scientific actors such as authors, institutions, and countries, while science mapping explores the structural and temporal development of knowledge within a research field. Bibliometric mapping in this context involves both constructing bibliometric networks and visually representing these networks [23].

The VOSviewer, a software program designed for building and visualizing bibliometric networks. It offers various forms of visualization including network, overlay, and density maps, and it is capable of processing large bibliographic datasets. VOSviewer uses clustering techniques to group related publications and provides analytical insights based on these clusters. In this study, VOSviewer was employed to create network visualizations of keyword co-occurrence in Metaverse research from 2012 to 2021. These visualizations were generated at the global level as well as for specific countries including the United States, China, and Germany. VOSviewer also facilitated the analysis of international collaboration through co-authorship network visualizations.

3. RESULTS

3.1 Publication and Trend

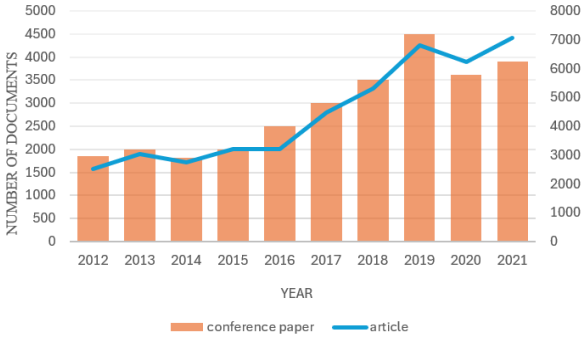

Figure 1. *Publications relating to the Metaverse.*

In Fig. 1 shows a total of 45,178 scientific documents related to the Metaverse were identified in Scopus, over 60% of which were conference papers, from 2012 to 2021. This reflects the importance of conferences in disseminating Metaverse research. Publication volume grew steadily, from 2,528 in 2012 to over 7,000 in 2021, despite slight dips in 2020–2021 likely due to pandemic disruptions. The growth in publication output likely reflects a combination of researchers' intrinsic interest and increasing societal demand, driven especially by advances in AI, cloud computing, and related technologies. To highlight the main contributors in this field over the past decade, the top 10 most productive authors, publication sources, and institutions were identified from the Scopus database (see Table 1), with publication counts over the 10-year period noted in parentheses. The leading contributor was Billinghurst M. (University of South Australia), known for his work on AR and wearable displays [24], followed by Steinicke F. (Universität Hamburg) and Latoschik M.E. (Julius-Maximilians-Universität Würzburg) [25]. The *Lecture Notes in Computer Science* series led Metaverse research publications from 2012 to 2021 with over 3,000 papers, followed by key conferences such as the ACM International Conference and CHI. The most cited paper introduced a deep learning framework for time-series classification [26]. Top contributing institutions included the Chinese Academy of Sciences and CNRS, with major universities from China, the US, Germany, and Japan also among the leading contributors.

Table 1. *Top 10 publication authors and* institution *contributors*

Author	Source Title	Institution
Billinghurst, M.	Lecture Notes In Computer Science	Chinese Academy of Sciences
Steinicke, F.	ACM International Conference Proceeding Series	Centre National de la Recherche Scientifique

Latoschik, M.E.	Advances In Intelligent Systems And Computing	Beihang University
Bruder, G.	Conference On Human Factors In Computing Systems Proceedings	Technical University of Munich
Narumi, T.	Communications In Computer And Information Science	The University of Tokyo
Slater, M.	IEEE Access	University of Southern California
Hirose, M.	Proceedings Of SPIE The International Society For Optical Engineering	Beijing University of Posts and Telecommunications
Navab, N.	Journal Of Physics Conference Series	Shanghai Jiao Tong University
Woo, W.	Proceedings Of The ACM Symposium On Virtual Reality Software And Technology VRST	University of Central Florida
Kiyokawa, K.	IEEE Conference On Virtual Reality And 3D User Interfaces VR Proceedings	Tsinghua University

3.2 Keyword Analysis

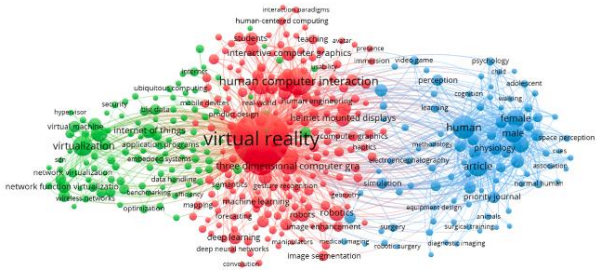

Figure 2. *Co-keyword network*

Using VOS viewer, 132,017 keywords were analyzed with a threshold of 200 co-occurrences as shows in Fig. 2. Synonyms were merged (e.g., HCI and human computer interaction) [27]. "Virtual reality" emerged as the most frequent keyword, with a total link strength of 164,198.

As listed in Table 2, three major clusters were identified:

- Red Cluster (Human–Computer Interaction): virtual reality, augmented reality, user interfaces, AI, e-learning.

- Green Cluster (Network and Computing): cloud computing, IoT, network security, SDN.

- Blue Cluster (Clinical Applications): surgical training, patient rehabilitation, robotics surgery.

Table 2 shows country-specific keyword analysis showed common interest in "virtual reality," "augmented reality," and "human–computer interaction." China focused more on robotics, while the US and Germany emphasized imaging.

Table 2. *Comparison of the top 10 keyword occurrences of the United States, China and Germany.*

Keyword	United State	*China*	*Germany*
virtual reality	6,465	5,687	2,792
augmented reality	1,898	1,071	1,048
HCI	1,454	870	709
virtualization	1,417	831	545
VR technology	1,059	636	452
artificial intelligence	836	569	425
user experience	801	567	340
helmet mounted displays	765	536	336
cloud computing	700	516	330
3d modelling	635	453	313

3.3.1 Contributions by Countries

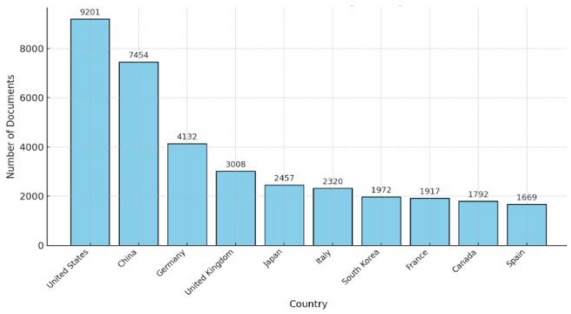

Figure 3. *Top 10 countries related to the Metaverse.*

Figure 3 illustrates the top 10 countries by publication volume in Metaverse research and their corresponding national contribution index. The figure highlights the global distribution of research efforts, showing that the United States and China dominate the field, together contributing over one-third of all publications. Germany, the United Kingdom, Japan, and other countries follow with lower, yet notable, contributions. This visualization underscores the concentration of Metaverse research activity in a few leading nations and reflects their competitive advantage in technological innovation and academic output related to the Metaverse.

3.3.2 International Collaboration Analysis

To understand global collaboration in Metaverse research, a co-authorship network was constructed using VOSviewer. Countries or regions with at least 60 publications were included, resulting in 63 items visualized. As shown in Figure 4, the size of each circle represents the number of documents, while the links reflect co-authorship relationships.

The United States, with the largest node and 60 collaboration links, emerges as the central hub of global cooperation. The collaboration network reveals five distinct scientific clusters:

Cluster 1 (Red): Dominated by Germany and the United Kingdom, this cluster includes 28 mostly European countries, indicating strong intra-regional cooperation.

Cluster 2 (Green): Includes 19 countries such as Canada, France, and Japan, showing a broader mix of North American, Asian, and European partnerships.

Cluster 3 (Blue): Composed of 8 countries, primarily from South America with some European participants.

Cluster 4 (Yellow): Centers on the United States and China—also the top two in publication output and citations—demonstrating their leading influence and bilateral collaboration in Metaverse research.

Cluster 5 (Purple): A smaller group linking New Zealand, South Africa, and Morocco, reflecting emerging regional engagement.

Figure 4. *Co-authorship visualization map of countries*

4. DISCUSSION

The Metaverse represents a rapidly evolving interdisciplinary field, integrating technologies such as blockchain, digital twins, AI, cloud computing, IoT, and high-speed networks. As a virtual environment capable of interacting with the real world and shaped by user-generated content, it has drawn increasing scholarly attention. This study conducted a bibliometric analysis of over 45,000 publications from 2012 to 2021 using Scopus and VOSviewer to explore research trends and developments. The key findings are as follows:

- Publication Trends: Research output on the Metaverse has grown significantly over the past decade, with conference papers (63.85%) exceeding journal articles (36.15%). Peak publication years were 2019 and 2021. Lecture Notes in Computer Science led all sources with 3,060 publications, while Billinghurst M. emerged as the most prolific author. The Chinese Academy of Sciences ranked as the top contributing institution.

- Geographic Contributions: The United States, China, and Germany were the leading countries by publication volume. Notably, China experienced exponential growth in output from 2016 and led globally in 2021. Institutional contributions varied: in China, the Chinese Academy of Sciences dominated; in the U.S. and Germany, top contributions came from universities like the University of Southern California and the Technical University of Munich.

- International Collaboration: A VOSviewer co-authorship network revealed five major clusters of country collaboration, led by the UK, France, Spain, the U.S., and New Zealand. While the U.S. and UK held dominant positions in global research partnerships, these clusters illustrate the geographically diverse and collaborative nature of Metaverse research.

- Through keyword co-occurrence network mapping and citation burst analysis using VOSviewer, this study identified key research hotspots and their evolution over the past decade in the Metaverse field. The co-occurrence network comprises 401 nodes grouped into three major clusters, with "virtual reality" emerging as the most prominent keyword, linked to 400 other terms and cited 30,794 times. Early research interests centered around virtualization, cloud computing, virtual worlds, algorithms, network avatars, and 3D systems. In more recent years, the focus has shifted to advanced topics such as distributed computing systems, network function virtualization, software-defined networking, and edge computing. New frontiers emphasize HCI, user experience, 3D modeling, deep learning, human-centered computing, digital twins, e-learning, and innovative interaction paradigms. These reflect the broader trend toward enhancing interactivity and personal engagement within the Metaverse.

5. CONCLUSION

This study analyzed over 45,000 Metaverse-related publications from 2012 to 2021 using bibliometric methods and VOSviewer. Results show a rapid growth in research, driven by emerging technologies like AI, cloud computing, and digital twins. The U.S. and China lead in publication output, with strong institutional and international collaboration networks. Key research hotspots have evolved from virtualization and network systems to user experience, 3D modeling, and human–computer interaction. Overall, Metaverse research is expanding quickly and diversely across countries and disciplines.

6. REFERENCES

[1] S. Singh and P. Gupta, "Comparative study ID3, cart and C4. 5 Decision tree algorithm: a survey," Int. J. Adv. Inf. Sci. Technol., **2014**.

[2] L. Breiman, "Random forests," Mach. Learn., vol. 45, no. 1, pp. 5-32, **2001**.

[3] H. Aydadenta and Adiwijaya, "A Clustering Approach for Feature Selection in Microarray Data Classification Using

Random Forest," J. Inf. Process. Syst., vol. 14, no. 5, pp. 1167–1175, **2018**.

[4] A. Sonak and R. A. Patankar, "A Survey on Methods to Handle Imbalance Dataset," Int. J. Comput. Sci. Mob. Comput., vol. 4, no. 11, pp. 338–343, **2015**.

[5] A. Ali, S. M. Shamsuddin, et al. "Classification with class imbalance problem: A review," Int. J. Adv. Soft Comput. its Appl., vol. 7, no. 3, pp. 176-203, **2015**.

[6] S. Du, F. Zhang, et al. "Semantic classification of urban buildings combining VHR image and GIS data: An improved random forest approach," ISPRS J. Photogramm. Remote Sens., **2015**.

[7] Z. Wu, W. Lin, et al. "An Ensemble Random Forest Algorithm for Insurance Big Data Analysis," in Proceedings 2017 IEEE International Conference on Computational Science and Engineering and IEEE/IFIP International Conference on Embedded and Ubiquitous Computing, CSE and EUC 2017, **2017**.

[8] V. Effendy and Z. K. a. Baizal, "Handling imbalanced data in customer churn prediction using combined sampling and weighted random forest," 2014 2nd Int. Conf. Inf. Commun. Technol., **2014**.

[9] E. Dwiyanti, et al. "Handling imbalanced data in churn prediction using RUSBoost and feature selection (Case study: PT. Telekomunikasi Indonesia regional 7)," in Advances in *Intelligent Systems and Computing*, **2017**.

[10] S. Ghosh and S. Kumar, "Comparative Analysis of K-Means and Fuzzy C-Means Algorithms," Int. J. Adv. Comput. Sci. Appl., **2013**.

[11] Ł. Kobyliński and A. Przepiórkowski, "Definition extraction with balanced random forests," in *Lecture Notes in Computer Science* (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), **2008**.

[12] S. Venkateswara and V. Swamy, "A Survey: Spectral Clustering Applications and its Enhancements," Int. J. Comput. Sci. Inf. Technol., vol. 6, no. 1, pp. 185–189, **2015**.

[13] A. Y. Shelestov, "Using the agglomerative method of hierarchical clustering as a data mining tool in capital market," Int. J. "Information Theor. Appl., vol. 15, no. 1, pp. 382–386, **2018**.

[14] A. Chowdhary, "Community Detection: Hierarchical clustering Algorithms," Int. J. Creat. Res. Thoughts, vol. 5, no. 4, pp. 2320–2882, **2017**.

[15] D. Ramyachitra and P. Manikandan, "Imbalanced Dataset Classification and Solutions: a Review," Int. J. Comput. Bus. Res., vol. 5, no. 4, **2014**.

[16] S. Sardari, M. Eftekhari, and F. Afsari, "Hesitant fuzzy decision tree approach for highly imbalanced data classification," Appl. Soft Comput. J., **2017**.

[17] E. AT, A. M, A.-M. F, and S. M, "Classification of Imbalance Data using Tomek Link (T-Link) Combined with Random Under-sampling (RUS) as a Data Reduction Method," Glob. J. Technol. Optim., **2018**.

[18] J. S. Akosa, "Predictive Accuracy: A Misleading Performance Measure for Highly Imbalanced Data," SAS Glob. Forum, **2017**.

[19] T. Fawcett, "An introduction to ROC analysis," Pattern Recognit. Lett., **2006**.

[20] F.J. Agbo, et al. "Application of Virtual Reality in Computer Science Education: A Systemic Review Based on Bibliometric and Content Analysis Methods". Educ. Sci., 11, 142, **2021**.

[21] L. H. Lee, et al. "All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda". arXiv **2021**, arXiv:2110.05352.

[22] Q. Yang, et al. "Fusing Blockchain and AI with Metaverse: A Survey". arXiv **2022**, arXiv:2201.03201.

[23], N.J. Van Eck, and Waltman, L. "Software survey: VOSviewer, a computer program for bibliometric mapping". Scientometrics, 84, 523–538, **2010**.

[24] Piumsomboon, T.; Lee, G.A.; Hart, J.D.; Ens, B.; Lindeman, R.W.; Thomas, B.H.; Billinghurst, M. Mini-me: An adaptive avatar for Mixed Reality remote collaboration. *In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, Montreal*, QC, Canada, 21–26 April **2018**.

[25] Latoschik, M.E.; Roth, D.; Gall, D.; Achenbach, J.; Waltemate, T.; Botsch, M. The effect of avatar realism in immersive social virtual realities. In Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology, Gothenburg, Sweden, **2017**; Volume F131944.

[26] Zheng, Y.; Liu, Q.; Chen, E.; Ge, Y.; Zhao, J.L. Time series classification using multi-channels deep convolutional neural networks. In Proceedings of the 2014 International Conference on Web-Age Information Management, Macau, China, **2014**; vol. 8485, p. 310.

[27] Tu, Y.; Xu, J.; Shen, H.-W. KeywordMap: Attention-based Visual Exploration for Keyword Analysis. *In Proceedings of the 2021 IEEE 14th Pacific Visualization Symposium (PacificVis)*, Tianjin, China, **2021**.