Knowledge Discovery of the Internet of Things (IoT) Using Large Language Model

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Abstract—**Internet of Things (IoT) technology quickly transformed traditional management and engagement techniques in several sectors. This work explores the trends and applications of the Internet of Things in industries, including agriculture, education, transportation, water management, air quality monitoring, underground mining, smart retail, smart home systems, and weather forecasting. The methodology involves a comprehensive review of the literature, followed by data extraction and analysis using BERT to identify key insights and patterns in IoT applications. The findings show that IoT significantly impacts the improvement of real-time monitoring, increasing efficiency, and encouraging innovative solutions in various sectors. Despite its transformative potential, cybersecurity threats, data privacy concerns, and the need for strong policy frameworks persist. The study emphasizes the necessity of multidisciplinary approaches to address these difficulties and optimize IoT implementation. Future research should focus on establishing secure IoT systems, maintaining data integrity, and encouraging collaboration between disciplines to realise the benefits of IoT technology.**

Keywords*—*Internet of Things; large language model; BERT; knowledge discovery; data mining; deep learning

I. INTRODUCTION

The Internet of Things (IoT) has appeared as a significant milestone in the digital era of intelligence and creativity that has gone beyond being just a technological innovation and has become a widespread force transforming society, industry [1], and daily life because of the increasing number of networked devices, sensors, and systems. As this study navigates the complex and interconnected world of IoT, it is crucial to thoroughly investigate its fundamental principles, applications, and substantial consequences. IoT combines electronic and analogue domains to enable convenient communication between things and machines. The IoT relies on pervasive connectivity and intelligent automation by incorporating devices, such as sensors, actuators, and networking technologies, into smartphones, wearables, household appliances, and industrial equipment to allow entities to collect, evaluate, and share data in real-time through the network. Knowledge discovery refers to systematically extracting significant patterns and insights from extensive datasets. This approach is crucial for making well-informed decisions, enhancing operations, promoting innovation, managing risks, and enabling customization. Text classification [2], [3] is closely connected to extracting and categorizing textual material into predetermined classes, a crucial aspect of extracting relevant information from text corpora.

The Internet of Things (IoT) is present in every aspect of modern life, including healthcare, manufacturing, agriculture, education, transportation [4], and urban development. IoT healthcare devices and customised and proactive healthcare allow patients to check vital signs, fitness, and chronic conditions in real-time. IoT enables intelligent industries to optimise and automate manufacturing production processes by integrating equipment, robots, and sensors. Additionally, the IoT could revolutionise agriculture. Sensor data, satellite imagery, and machine learning algorithms optimise crop yield, resource conservation, and environmental impact in precision agriculture systems. Smart vehicles and infrastructure systems enabled by IoT enable autonomous driving, intelligent traffic control, and seamless mobility, providing a safer and more efficient transportation network. IoT devices and continual connectivity generate massive amounts of data, raising privacy, security, data ownership, and compliance concerns. Furthermore, the digital divide worsens pre-existing disparities, putting marginalised areas in danger of being excluded from the advantages of IoT-driven progress. As this study explores the complexity of IoT, it becomes clear that its potential is accompanied by obstacles and intricacies. IoT ecosystems' vast size and intricate nature provide significant difficulties regarding compatibility, ability to grow, dependability, and ease of control. Moreover, there is a significant concern about cybersecurity concerns, as IoT devices are often targeted by malevolent individuals who aim to take advantage of weaknesses and damage data integrity. To overcome these obstacles, a multidisciplinary strategy is needed to traverse the changing IoT environment. This method must consider computer science, engineering, economics, sociology, ethics, and policymaking. This study can use the Internet of Things (IoT) to reshape society, innovate, and solve problems by encouraging cross-disciplinary collaboration and knowledge exchange.

This research study aims to thoroughly analyse IoT, encompassing its theoretical basis, technological framework, and societal consequences. By combining current literature, case studies, and empirical research, this study aims to shed light on the intricate and helpful aspects of the Internet of Things (IoT). This will offer valuable insights to guide future research, policy development, and technological advancements.

The rest of the paper is structured as follows: Section II reviews the existing studies and establishes the research gap. Section III discusses the proposed methodology to extract the knowledge of IoT. Section IV and V provide the result and discussion. Section VI concludes and describes the future direction.

II. LITERATURE REVIEW

This section studies some research and reviews papers focusing on information retrieval or data mining approaches to discover IoT's state-of-the-art technologies and applied domains.

Naghib et al. [5] reviewed 110 articles from 2016 to 2022 related to IoT's big data management methods. They distributed the articles into four categories: architectures, processes, analytics types, and quality attributes. Sunhare et al. [6] discussed the data mining methods used in diverse IoT applications, for example, smart home, smart grid, smart agriculture, etc., and big data mining solutions, like reinforcement learning, Markov chain model, and so on. Amin et al. [7] discussed smart cities and how IoT and ML may build data-centric smart environments to improve citizen's satisfaction with technology and data. They also presented smart city functions and the challenges of adopting IoT and machine learning in cities, which can enhance urban surroundings by rendering them more livable, sustainable, and efficient. Cyberattack's growing frequency and complexity significantly threaten sensitive data, financial stability, and national security, making cybersecurity a paramount concern. Cyber-attacks have a significant impact on the IoT environment. Alqurashi and Ahmad [8] proposed a scientometric approach to discover the knowledge of cyber threats, different types of malware, malware detection techniques, etc., from cybersecurity-related research articles. Sarker et al. [9] presented IoT security methods, including machine learning and deep learning algorithms, challenges, solutions, and future directions for further study.

The process of knowledge discovery involves the analysis of a large amount of information to extract contextual information, which domain experts or knowledge-based systems can utilise to address challenges within the domain. Ahmad et al. [4] proposed a deep journalism concept by incorporating different sources, such as research articles, magazines, and newspapers, to discover the multi-perspective knowledge (i.e., academic, governance, and industrial) for transportation.

III. METHODOLOGY AND DESIGN

A. Dataset

We collected 28,160 research articles from the Web of Science (WoS) between 2014 and 2024. The following query is applied to find the research articles: "TS= ("internet of things") OR TS=(IoT)". Additionally, this study selected only "English" written articles, and the following filtering strategies are applied: document type (article and proceeding paper), WoS categories (telecommunication, computer science information systems, computer science artificial intelligence, and Engineer Electrical Electronic), and research areas (computer science, telecommunications, and engineering). Fig. 1 shows the dataset word count vs. the number of articles.

B. Methodology

Fig. 2 shows the research methodology of this study. Initially, the articles collected from WoS are stored in a CSV file. After that, the following pre-processing procedures were implemented in the present research on the dataset: (1) removal of duplicate articles, (2) removing extraneous characters, (3) tokenization, (4) removal of stop words, and (5) lemmatization utilising POS tags. Subsequently, excessive articles were eliminated in the second step to reduce redundant information. In the third step, extraneous characters, such as Unicode characters, were deleted. Additionally, the texts were tokenized in the fourth stage, and stop terms were eliminated in the fifth. Clustering was initially performed using the NLTK predetermined stop word directory, followed by the execution of the BERT model. Following the generation of clusters, a keyword survey was conducted to identify superfluous keywords that exhibited significant likelihood scores. After the testing phase, a complete set of insignificant keywords was compiled for cluster generation. These keywords were incorporated into the stop-word list and extracted from the texts in the ultimate model. Finally, lemmatization was implemented using POS identifiers. The articles that were subsequently cleansed were employed for knowledge discovery.

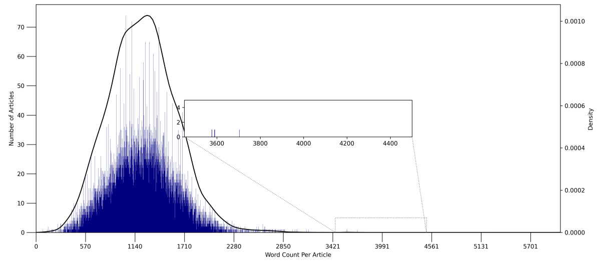

Fig. 1. Dataset word count vs. number of articles.

This study used the BERTopic [10] to cluster the information and conduct knowledge extraction. At first, this study generated a grounded embedding model using BERT. This study applied the pre-trained "distilbert-base-nli-mean-tokens" method for this research because of its capacity to accomplish a satisfactory compromise between accuracy and duration of execution. This study implemented the UMAP approach, which was specifically developed to decrease the complexity of data while retaining the maximum quantity of knowledge. In addition, this study used HDBSCAN to group articles with similarities into clusters. Furthermore, a TF-IDF score that is contingent on the class is employed to ascertain the importance of terms for each cluster. TF-IDF enables the assessment of word importance in different texts by considering both the frequency of a word in a particular document and its significance in the whole collection of texts. By considering each article inside the set as a distinct unit and using TF-IDF, this study may get significant scores for the words within the cluster. The class-TF-IDF score is the numerical value that quantifies the significance of a word in a document compared to a group of documents. The cluster grows more representative as the words' relevance increases. As a consequence, this study could obtain descriptions that are derived from keywords for each measure. Once this study obtained the class-TF-IDF, continue to add all the information and train the BERT model. The class-TF-IDF determinants of the articles were adjusted to reduce the number of clusters. The cluster with the greatest frequency is then combined with the most comparable cluster, as determined by their class-TF-IDF matrices. Ultimately, this study assigned clusters to all

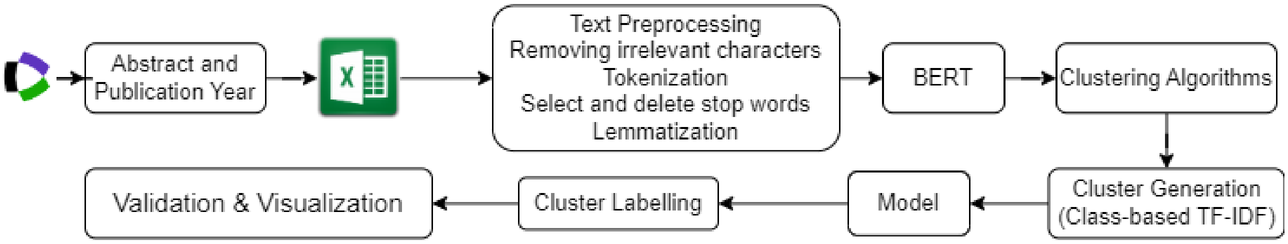

Fig. 2. Methodology.

TABLE I. CLUSTERS FOR IOT

Clusters	No.	Keywords
Technology	0	network, device, system, application, model, sensor, technology, security, performance, design, method, wireless
Agriculture	1	agriculture, food, system, crop, soil, plant, farm, irrigation, moisture, field, disease, temperature
IoT Device	2	device, less, energy, system, battery, network, communication, frequency, voltage, node
Education	3	student, robot, education, teaching, learn, campus, course, application, university, classroom
Transportation	4	vehicle, parking, traffic, car, road, driver, accident, bus, parking lot, congestion, parking space
Water IoT	5	water, underwater, water quality, monitoring, fish, river, consumption, marine, level
Air IoT	6	air, waste, pollution, disaster, fire, garbage, evacuation, air pollution, waste management
Underground Mining	7	mine, railway, underground, gas, train, coal, oil, mining, coal mine, oil gas
Smart Retail	8	visitor, shopping, cultural, tourist, customer, RFID, store, retail, checkout, travel
Smart Home	9	sleep, wake, energy, device, mode, sleep mode, consumption, quality, network
Ride Sharing	10	bike, bicycle, cycling, bike sharing, system, station, city, crash, mountaineer, prediction, rider, team
Weather IoT	11	weather, temperature, rainfall, humidity, rain, weather parameter, collect, wind, rain value, pressure

the articles and saved the model. This study comprehensively analysed the corresponding cluster articles since the cluster is originally represented as an integer number. Subsequently, this study labelled the clusters using specialised knowledge and quantitative analytical methods such as hierarchical clustering.

IV. RESULT

Table I shows the research discoveries by listing the clusters with the corresponding cluster No. and keywords.

Vasco et al. [11] explore the significance of IoT technology for those with impairments, emphasising its capacity to enhance the quality of life and self-determination. This study [12] presents a novel approach for identifying potential attacks on Internet of Things devices using a game-theoretic mathematical model. The approach seeks to address efforts to compromise IoT devices, such as the Mirai botnet, which is the biggest known botnet and orchestrated an assault involving around 100,000 devices. Xie et al. [13] suggest using a knowledge graph-based multilayer IoT middleware to connect IoT devices that use multiple protocols, thereby overcoming the communication barrier between them. Utilising a graph-based knowledge system, it universally oversees all Internet of Things (IoT) devices. The technique's efficacy was shown in a project that monitored rural sewage treatment stations in China.

Smart Agriculture [14] employs automated and ICT-driven technology to tackle climate change and meet nutritional requirements. Cloud services and improved interconnectivity technologies combine and integrate the characteristics of IoT technology. Advanced interfaces are necessary for customisation and remote engagement. This study [15] suggests using Conversational User Interfaces (CUI) to control Internet of Things (IoT) devices in the field of smart agriculture. A chatbot system using natural language processing offers an effective, safe, and user-friendly platform for engaging with Internet of Things (IoT) devices specifically suited for agricultural applications. IoT technology improves the quality of education [16], [17] by offering intelligent recommender systems that enable students to choose courses and institutions depending on their educational standards. This is achieved by using fog-cloud computing to collect data on the academic environment. Sustainable traffic management is rendered possible by smart cities having well-designed smart parking systems. Appropriate parking spot tracking and control may be facilitated by integrating many enabling innovations, such as 5G connectivity, Unmanned Aerial Vehicles (UAVs), and the IoT. This [18] study suggests an intelligent parking system to monitor parking spot availability using various devices and unmanned aerial vehicles (UAVs). This improves precision and lowers the number of false positives and negatives. Water is an essential component of daily existence. Water preservation and control have become vital for human life because of the state of the environment worldwide. There has been a great demand recently for consumer-driven humanitarian initiatives that might be built quickly using IoT technologies [19].

Increasing air pollution, which affects indoor air quality and results in 1.6 million premature deaths yearly, is connected to the world's population growth. Businesses are creating inexpensive sensors with IoT applications to track interior air pollution. Communities must overcome some constraints when choosing sensors to solve this public health issue [20]. The mining sector depends on underground mining to recover rich minerals. Many sectors have used automation to improve worker security, streamline processes, boost event reaction times, and attain cost-effectiveness. An ongoing interaction and tracking framework is required to reduce serious risks and enhance security in underground mines. However, particles and hazardous, flammable, and volatile gases impact the atmosphere in underground mines. Because the hazardous gases can potentially explode, they pose a serious risk [21]. In today's world, tourism is a rapidly growing industry that generates jobs and economic growth. Travellers are using more and more technology to make the most of their trips. With the IoT facilitating information transmission and distribution, smart tourism makes IoT technology [22] a vital element of travellers' toolkits.

Computerised checkout systems provide the potential for increased sales by enhancing the customer experience and decreasing costs through less reliance on shop staff. The current study focuses on the conceptual aspects of an automated checkout system in fashion retail businesses. Integrating a cyber-physical platform into existing retail settings is difficult due to architectural limitations, standard customer procedures, and consumer demands for confidentiality and practicality, which restrict system design options. Hauser [23] focuses on implementing a computerised checkout system in fashion retail outlets, addressing obstacles such as architectural limitations and consumer demands. The system uses an RFID device and software elements to accurately and effectively identify purchases, associating them with specific purchasing baskets. The method is deployed and assessed in a research facility, demonstrating notable precision and effectiveness, though its performance drops to 42% in demanding settings. Utilising wearable sensors for sleep monitoring provides a cost-efficient alternative to the costly polysomnography procedures used in hospitals. This research [24] employs an Internet of Things (IoT) platform and an event-driven microservice architecture to monitor ECG data daily. The prediction of weather across the majority of the globe continues to rely on statistical and computational methods. Statistical and computational analysis yields more accurate outcomes, but its effectiveness relies heavily on consistent past correlations to forecast future values. Conversely, machine learning investigates novel algorithmic methods for making predictions that rely on data-driven analysis. Several elements, such as precipitation, temperature, air pressure, moisture, wind velocity, and other variables subject to change, influence the climatic variations in a certain region. Given that specific locations influence climatic changes, traditional statistical and computational methodologies may sometimes be ineffective and require an alternative strategy, such as using machine learning to comprehend weather forecasting better. Balamurugan [25] demonstrates that conventional forecasting techniques for June 2019 produced a rainfall percentage range of 46-91%. However, predictions generated using machine learning algorithms surpassed statistical approaches in accurately predicting rainfall.

The intertopic distance is displayed in Fig. 3. The knowledge is shown as a circle in a 2D space, where the gap between any two circles reflects the degree of disparity between the knowledge. The diameter of each circle corresponds to the frequency in the dataset. Topics nearby demonstrate more resemblance or a heightened commonality regarding their subject matter or context. The x-axis of this depiction is labelled as "Topic 0" to "Topic 11," suggesting a consecutive numbering of separate subjects. Meanwhile, the y-axis is divided into two distinct dimensions, D1 and D2. This representation simplifies understanding of the data structure and uncovers relationships that are not apparent in a complex setting. For instance, the biggest circle (topic 0) denotes a salient topic in the dataset, and its proximity to another circle suggests a significant link between the two topics. The arrangement of smaller circles on the map signifies a spectrum of less prevalent, distinct subjects within the dataset.

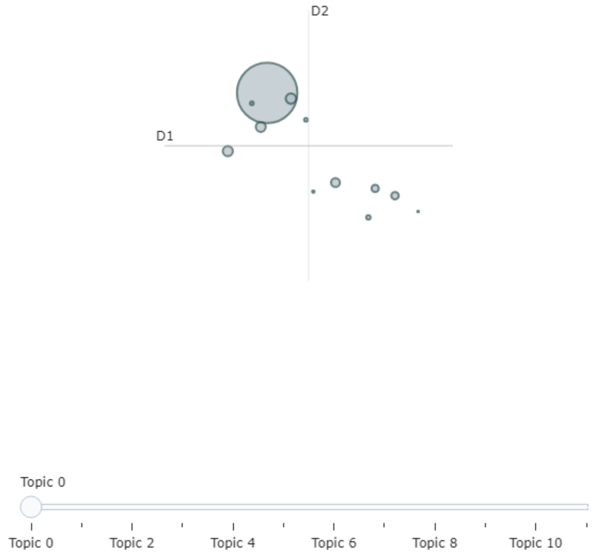

Fig. 3. Intertopic distance.

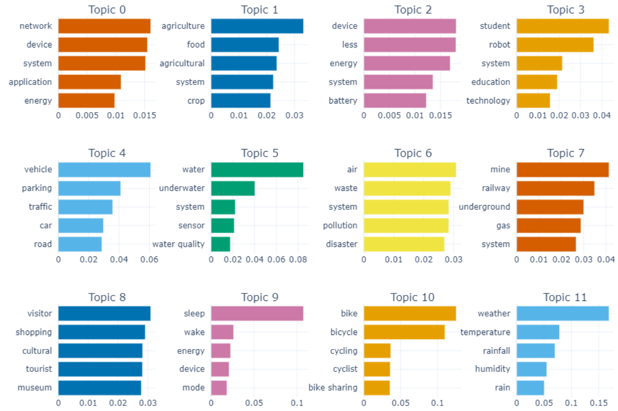

Fig. 4. Top 5 words for each cluster.

Fig. 4 shows a sequence of horizontal bar graphs, where each graph corresponds to a separate cluster or topic. Each bar's size correlates to a word's significance within its respective topic. The subject areas are classified by colour and include a diverse range of subjects, such as technology, agriculture IoT, IoT devices, education IoT, transportation IoT, water IoT, air IoT, underground mining, smart retail, smart home, ride-sharing, and weather in Topics 0 to 11, respectively. Topic 4 is notable for its focus on the transportation aspects of IoT, demonstrated by the following keywords: "vehicle", "parking", and "traffic". The visualisation enables easy recognition of the most prominent words in all topics, which is essential for understanding the major themes of a large amount of text and for summing up the information within each resultant topic. Furthermore, this study uses a class-dependent TF-IDF score to determine the importance of terms for each cluster. TF-IDF enables the assessment of word importance in different texts by considering both the frequency of a word in a particular document and its significance in the whole collection of documents.

Fig. 5 depicts a dendrogram that is the outcome of a hierarchical cluster analysis. The horizontal axis depicts the

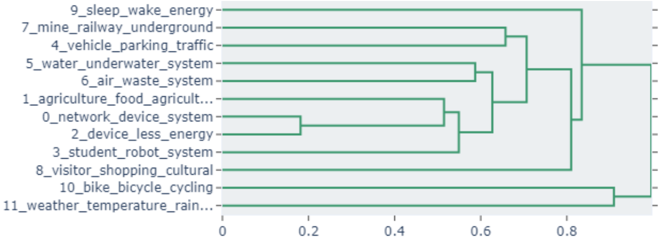

Fig. 5. Hierarchical cluster.

disparity between groups, with a smaller distance indicating a greater similarity. It is evident that some clusters exhibit a tight grouping, such as the cluster “0-network-device-ssystem” with the cluster “2-device-less-energy.s” This indicates the presence of closely associated topics within the data.

V. DISCUSSION

This research examines the diverse range of industries in which IoT technology is being used, such as agriculture [26], education, transportation, water management, air quality monitoring, underground mining, smart retail, smart home systems, ride-sharing services, and weather forecasting. This study investigation revealed the widespread impact of IoT devices in transforming conventional procedures and improving efficiency and production in various areas. IoT solutions in agriculture provide immediate monitoring of environmental conditions, soil moisture levels, and crop health, allowing for precise farming methods and efficient use of resources. Similarly, in the field of education, smart classrooms equipped with IoT technology provide interactive learning experiences and personalised instructional techniques. Transportation Internet of Things (IoT) applications optimise logistical operations, increase fleet management, and improve passenger experiences using real-time traffic monitoring and predictive repair. Water Internet of Things (IoT) technologies aid in the sustainable management of resources by monitoring water quality, identifying leaks, and optimising irrigation techniques. Airborne Internet of Things (IoT) devices serve a crucial role in monitoring and assessing the levels of air pollution, ensuring the general population’s protection and well-being. IoT-enabled safety monitoring, asset tracking, and predictive maintenance in underground mining operations enhance worker safety and operational efficiency. In addition, IoT technologies are transforming retail experiences by providing personalised purchasing suggestions, optimising inventory management, and improving consumer interaction. Smart houses utilise Internet of Things (IoT) devices to automate household duties, improve security measures, and optimise energy usage. Ride-sharing services use the Internet of Things (IoT) to optimise routes, estimate demand, and enhance passenger safety. In addition, weather forecasting technologies provided by the Internet of Things (IoT) offer precise and fast information for preparing for disasters and allocating resources. The extensive use of IoT technology in many industries highlights its significant capacity to shape the future of linked systems and services.

The benefits of IoT devices include enhanced efficiency, productivity, and security in various applications. However, the research’s comprehensive scope may overlook technological complexities, cybersecurity threats, economic obstacles, and interoperability challenges. Additionally, the study lacks detailed discussions on regulatory and ethical considerations and the dependence on stable internet connectivity. Addressing these challenges is crucial for fully harnessing the potential of IoT, providing a balanced view of the future of connected systems and services.

VI. CONCLUSION

This study provides a comprehensive analysis of the influence of IoT technology in many sectors, such as agriculture and transportation. The statement emphasizes the ability of the Internet of Things to facilitate immediate monitoring, enhance effectiveness, and stimulate innovation. In the future, it is important to prioritize conducting additional research to improve cybersecurity measures and reinforce data privacy rules to reduce the dangers and weaknesses inherent in IoT systems. Furthermore, it is imperative to guarantee the authenticity and dependability of data within IoT frameworks and address concerns regarding data’s precision and credibility. To optimize the societal advantages of the IoT, fostering interdisciplinary collaboration and forging collaborations across many industries is crucial. Researchers can accelerate the progress of IoT technology by concentrating on these specific areas. This will involve tackling the obstacles associated with IoT and promoting its incorporation into many sectors and fields.

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