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Scientometric Study of Research on AI & ML Application in Defence Technology and Military Operations

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ABSTRACT

Application of AI and machine learning in different domains of defence system in increasing rapidly to bring automation and to facilitate all the benefits of modern technologies in military. This article conducts a scientometric analysis on articles that are on application of Ai and Ml in military equipment, military intelligence, cyber security, decision making, military operations, defence medical systems etc. This study has executed a search query on Web of Science for identifying peer reviewed current resources that are contributing to the application of modern technologies in military systems. With extensive query and filtering this study has identified 417 articles with in the period of 1991 to 2023. With analysing all the data, it determines that a lot of varied research is there on the defence system that promotes use of modern technologies in development of weapon, conducting strategic military operation, prioritising military society etc. Prioritising legal and ethical parameters. This study has also highlighted legal, and security concerns surrounding using autonomous systems in military applications. The authorship pattern, document types, country production over time, and most cited countries have also been studied. Bradford's scattering law was applied to identify the core journals, and Lotka's law to check authors' productivity patterns.

Keywords: Scientometrics; Artificial intelligence; Machine learning; Defence technology; Military operations; Research trend

1. INTRODUCTION

Emerging technologies have shaped existing societies since time immemorial. It is well known that the invention of fire and the wheel radically altered societal functions. Similarly, the advent of information and communication technology changed the global scenario since the eighties of the last century, followed by data science, machine learning, AI, and the internet of things. The core element of Artificial Intelligence (AI) is replicating the process of humans using machines. AI has excellent usability in various fields, and it is transforming the livelihood of human beings in a great way[8]. Just like other areas, AI is also effective in defense and security[18]. Artificial technology is a relatively modern technology with a great future ahead, and their various research will capture the enormous scope of AI and execute it for the benefit of mankind.

Machine learning is another vast area that deals with the execution of AI to make machines capable of imitating the behavior of humans. Human expertise is significantly required in effective problem-solving or managing complex tasks, and in such situations, machine learning can be very useful[11]. Casualties and injuries are a significant challenge of military warfare. It is essential to reduce human intervention to mitigate such risk factors. The development of AI and ML results from rapid technological evolution in recent times. As it replicates human intelligence and behavior, it incorporates great scope for reducing human interventions in severe military warfare. Strategic decision-making incorporating factors like height, weight, size, and geographical limitation is required in combat. AI-based decision-making by analysing all the data helps reduce all the risks and use the resources effectively. Automation is also a significant benefit of using AI and ML in the military system, which allows in systematically identifying threats and taking strategic reactions against the threats.

2. RESEARCH RATIONALE

AI is used to develop autonomous weapons systems, such as uncrewed aerial vehicles (UAVs), that can fly, navigate, and engage in combat operations without human intervention[7]. This technology can potentially increase the efficiency and effectiveness of military operations, but it also raises ethical and moral concerns about the accountability and responsibility of autonomous weapons. It can be used to analyse large amounts of image and video data, providing military planners and

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decision-makers with critical information about potential threats and the battlefield environment. Regarding cyber security, AI can be used to defend against cyber-a ttacks on military systems and networks. For example, AI can detect and respond to intrusions in real-time, reducing the risk of data breaches and ensuring the security of sensitive information. It can optimise logistics and supply chain operations, improving the efficiency and speed of delivering essential supplies to troops in the field along with predicting when military equipment will require maintenance, reducing downtime and increasing operational readiness, which can be particularly useful for equipment that operates in harsh environments where care is difficult and costly.

Thus, it can be stated that the application of AI in military technology is diverse and has the potential to transform the way military operations are conducted, making them more efficient, effective, and secure. However, the development and deployment of AI in military technology also raises ethical and moral concerns, and it is essential to ensure that this technology is used responsibly and in accordance with international laws and norms.

3. LITERATURE REVIEW

Ullah[18], *et al*. Conducted an in-depth visualisation of the growth of research in Agricultural engineering and execution of A from 2000-2020 using Cite Space software. Sustainable agriculture and management of water resources are critical areas in which researchers have shown more Interest. With practical analysis, this study further indicated that modern technologies will effectively solve agriculture-related problems. Similarly Darko[5], *et al*. Analysed the booming use of AI and ML in the Architecture, Engineering, and Construction (AEC) industry and identified a need for ongoing research in the field and an excellent scope for researching to facilitate the better performance of the AEC industry. Engineering is also a core part of the military system required for developing arms and weapons, and as AI has a significant scope here, scientometric analysis can be beneficial in tracking the current development, and it will also direct areas of further research. In contrast, Jiang[8], *et al*. further identified that strategic decision-making with practical data analysis is required as per the time as it is beneficial in identifying and mitigating risk factors. Geohazard is a significant issue, and it also damages resources. Effective anticipation and precaution are required against geohazard. Therefore, this paper analyses the scientific growth regarding the application of AI in. This study concludes that the growth of research in the application of AI in Geohazard is very promising, and exploring unknown areas is also a significant part of the research.

Rodríguez[13], *et al*. The growth of scientific literature on the execution of AI and ML technology in astrophysics and astronomy has been considerable in recent years. As it is a text mining-based scientometric analysis, it showed a trend of current research in areas like Cosmology, analysis of galaxies, etc. With practical analysis, this study has offered a more detailed and nuanced understanding of the research on astrophysics and astronomy. On the other hand, Bartnec[1], *et al*. identified that in the last six years, the Production of scientific literature and patents regarding the application of IOT in the healthcare system has increased, and worldwide research indicates that IOT health is a globally trending research topic. This study also highlighted that private sector organizations are more inclined towards developing patents in health IOT, whereas public sector organisations are more and more contributing to the research. Secondly, it analysed that the domain of research in the execution of IOT in healthcare is divided into two parts: academic and entrepreneurial fields. Hence, more public-private collaboration will guide to better utilisation of resources and getting more effective output.

3.1 Research Gap

Thus, the literature review shows application of AI and ML in different areas increasing day by day that opening great opportunities in different domains. Similarly, application of scientometric analysis helped in analysing current trend and future scope of the research regarding application of AI and ML. Defence is also started using AI in different domains and as there is not any research that analyse the research trends regarding application of AI and ML in defence system this study aims to analyse the research pattern, and different bibliometric factors of research contributing on using AI and ML in defence practices. Application of this scientometric research along with analysing the current research pattern it will also help in structuring the future research scope in this area.

4. OBJECTIVES

The principal objectives of the study are to find:

- The pattern of growth of literature from 1991 to 2023
- Authorship pattern of the articles and to find out core authors
- Core journal of the subject domain
- Applicability of Bradford's law and Lotka's law
- Collaborating countries
- Document types in which AI and ML research in defence technology and military operations is published

5. METHODOLOGY

Web of science database was searched to retrieve the relevant literature for analysing scientific growth as it is the most reliable international bibliographic database independent of publishers4. The search query was formulated as TS= ("Artificial Intelligence" OR ''AI" OR "Machine Learning") AND TS= ("Military Technology" OR "Warfare" OR "BattleField").

5.1 Data Filtration Process

A list of relevant vital wards was identified, and a search query was developed that caters to all applicable

terms to retrieve relevant documents. Documents that are in the english language were only included in this study. A manual review of all the titles was also incorporated to exclude irrelevant documents. All literature available in Web of science from 1991 to 2023 was included for scientometric analysis. Different filters have provided a more in-depth result that will help get a more appropriate mapping of the scientific growth of the research topic. Biblioshiny was used for this scientometric analysis. It provides a feature-packed web interface of bibliometrics with all the practical and required tools. It is an open-source R package for statistical programming for mapping the growth of scientific literature. It has also provided several visualisation tools that will enhance the quality of the paper.

5.2 Keywords Used for Search Strategy

TS =((“Artificial intelligence” OR “AI” OR “Machine intelligence” OR “Machine learning” OR “Expert systems” OR “Genetic algorithms” OR “Neural networks” OR “Case-based reasoning” OR “Data mining” OR “Fuzzy logic” OR “Fuzzy sets” OR “Robotics” OR “Knowledge-based systems” OR “Support vector machines” OR “Artificial general intelligence” OR “Computational intelligence” OR “Deep learning”) AND (“Military Technology*” OR “Defence Technology*” OR “Defence industry*” OR “battlefield” OR “ Military Warfare” OR “ Weapon System” OR “Autonomous Weapon” OR “Battlefield of Things” OR “military innovation” OR “warfare” OR “Armament” OR “ Smart munition”))

6 DATA ANALYSIS

6.1 Overview

This section will analyse all the data from scientometric studies conducted in AI and ML-based defence systems. After analysing all the data, this study will conclude on the growth of research, various topics, and areas covered under research, international collaboration, application, etc., in the mentioned domain.

The research field related to the application of AI and ML in defence and military science started in 1991. The web of science is the critical resource of these findings. As per Fig. 1, from 1991 to Jan of 2023, there are 417 documents available that cater to AI-based military warfare from 260 different sources. The availability of papers and diversity of resources indicates the growing research interest. International collaboration is a significant characteristic where other countries share

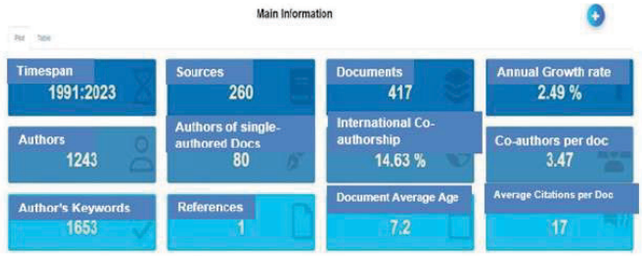


Figure 1. Summary of bibliometric data.

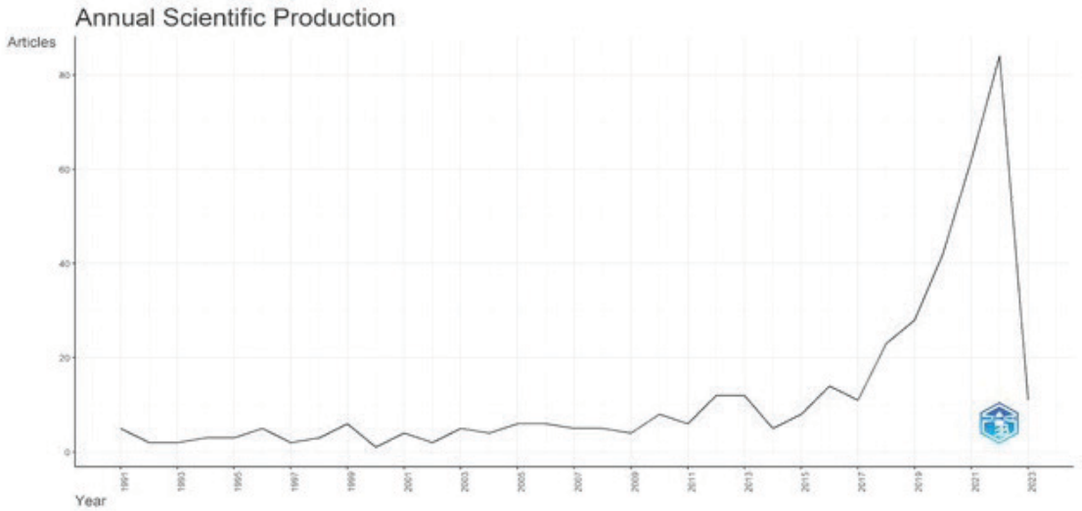
their intellectual capital for collaborative growth, and here, the international coauthorship percentage of 14.63 indicates a global trend of integration of AI and ML in defence. A growing number of authors, as shown in the following diagram, 1243 authors for 417 documents, suggests that scholars are getting more interested in the vast application of machine learning and AI in defence.

6.2 Growth of Literature (Annual Scientific Production)

The above graph represents the growth of scientific production regarding the integration of AI and ML in various aspects of military warfare. From 2015, the above diagram in Figure 2 indicates a rapid growth in scientific production, and that is because of the recent development of AI and ML and understanding of its immense scope in different areas. Digital advancement in recent times has had a significant impact in other locations, and the above graph also indicates a high growth in the research output where modern technologies meet the crucial requirements of military warfare. For example, Rasch and Kott[11] suggested that threat monitoring is a significant area of contemporary war that indicates the situational preparedness of the military. Situational preparedness further helps in developing efficient reaction teams and prioritising positive outcomes. Modern technologies also have significant advantages in monitoring and automatic response in high-risk border areas. Maintaining an appropriate healthcare system in a war situation becomes very challenging, and robotics, with machine learning and AI applications, can be a great solution during extreme circumstances. The high increase in research output in the following graph also supports the statement.

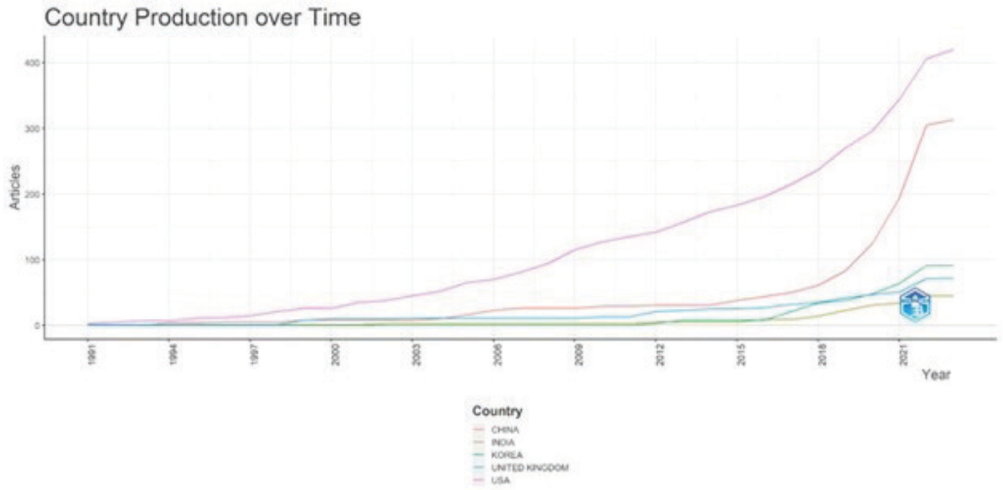
6.3 Country Production over Time

The above graph in Figure 3 represents the top 5 countries regarding scientific production of AI-based military systems. As mentioned above, the USA, United Kingdom, Korea, India, and China are leading contributors in this area, and the UK and the USA are ahead in the race against the other three competitors. Defence plays a significant role in the socio-economic aspect of the country, and it also contributes to the country’s global positioning. Exploring the incredible scope of AI and ML in the different areas of the military system opens up new areas for incorporating technology and reducing human interpretation while minimising the risk factors. Several factors include the socio-political and socio-economic situation of the place, international relations, and positioning of the country. Technological development: Education has a significant role in the country’s defense strategy. The above graph indicates that countries like China, India, Korea, the UK, and the USA have a lot of investment in AI-based military warfare, where most of the research output is from those countries. For example, the production of military equipment plays a significant role in the country’s socio-economic development, the global position of the country, etc., and AI can also substantially boost the quantity and quality of production.



Source: Biblioshiny.org

Figure 2. Annual scientific publication.



Source: Biblioshiny.org

Figure 3. Top five countries in terms of production over time.

6.4 Most Cited Countries

The above diagram in Figure 4 indicates the countries' contribution to the research on the domain, as mentioned earlier. Countries like the USA, China, India, the UK, and Germany have made essential contributions to this area of research. The domination of the USA in research, particularly in this area, indicates the country's focus on its defence[14]. It is also shown that the USA is essential in the global defense system, and different countries depend on the government for getting defense-related equipment and developing their defense system. As a result, it also provides excellent financial benefits and further enhances the country's global positioning.

6.5 Most Relevant Sources

Further, with more extensive study, this study has identified the most relevant sources that have produced more research work in the area. Figure 5 indicates that IEEE Access and the Journal of Strategic Studies have more relevant contributions. It also shows that AI magazine, Defence Science Journal, and Leiden Journal of International Law are critical sources with noteworthy contributions. Other vital sources that published research in this area are the Bulletin of the Atomic Scientists, California Law Review, Cambridge Review of International Affairs, etc.

6.6 Corresponding Authors' Countries

As depicted in Figure 6, the single-country publication is more prominent in different countries. Defense is a matter of national secrecy, which may be a significant reason for the number of single-country publications. Various data related to armament are confidential, and cross-border sharing of those data is a substantial threat to the country, and that limits the chances of global contribution between authors regarding armament. International politics, bureaucracy, global positioning, and competition in the worldwide market can also be a reason for the small

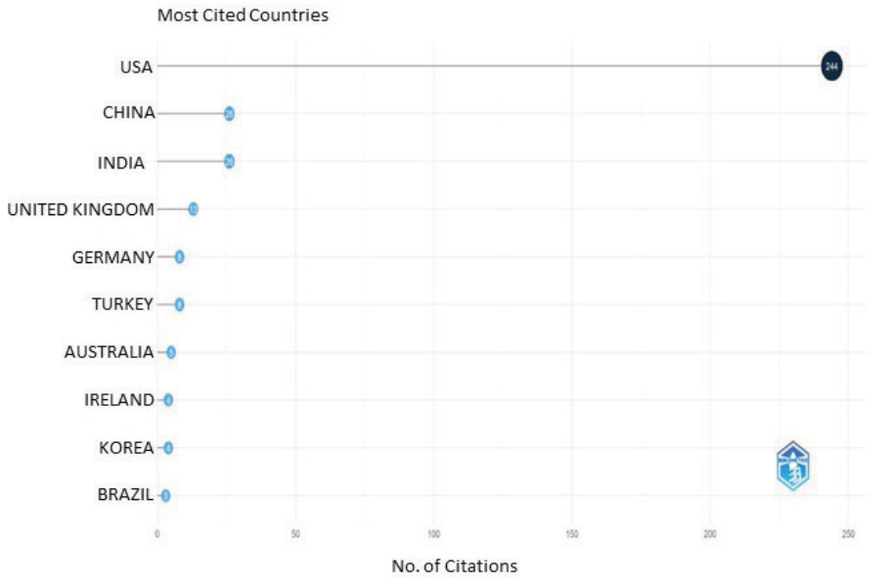


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Figure 4. Top cited countries.

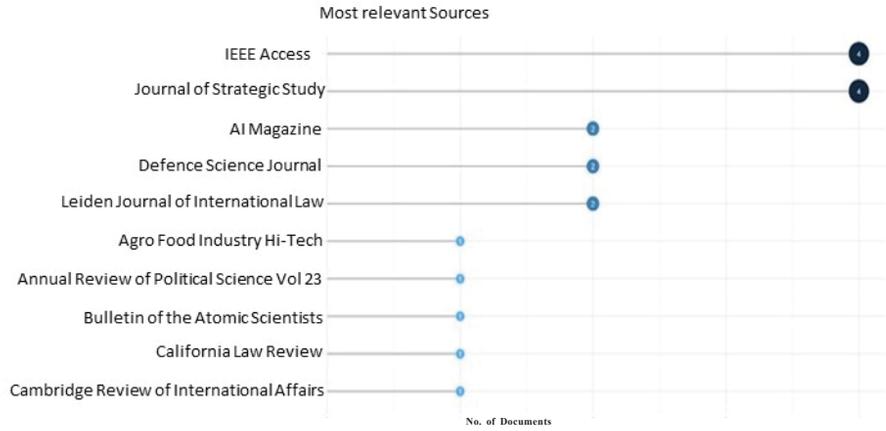

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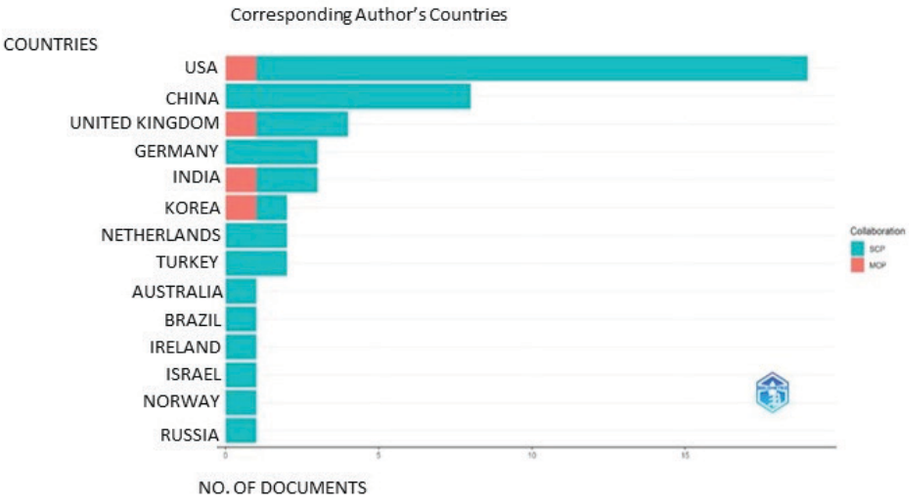
Figure 5. Most relevant sources.



Source: Biblioshiny.org

Figure 6. Corresponding author's countries.

number of multiple country publications[1]. On the other hand, some effort toward multiple-country collaboration indicates that there may be a vast scope of multiple-country cooperation for effective sharing and execution of intellectual property.

6.7 Core Journals and Bradford's Law

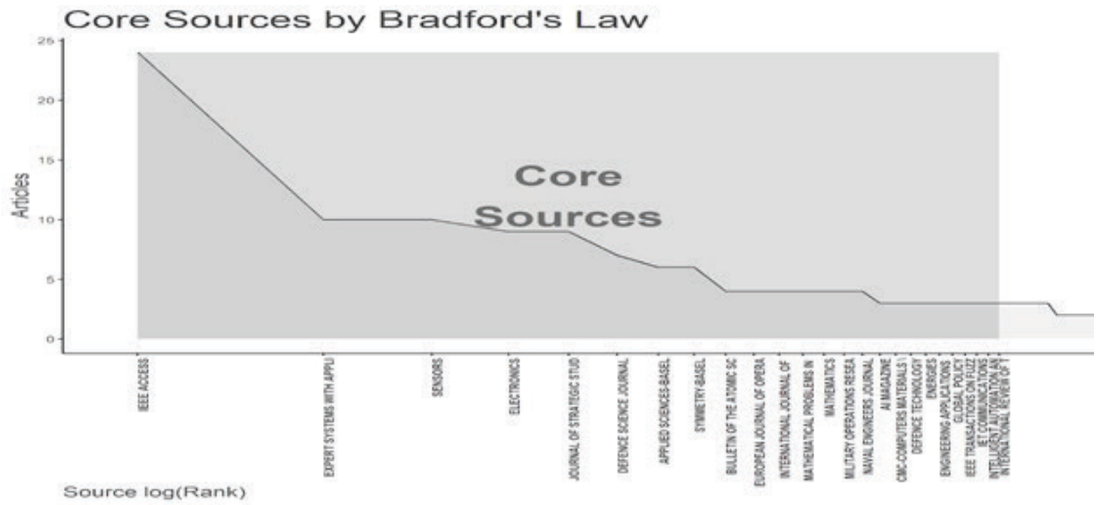
Bradford's law indicates the scattering nature of the literature, which helps to identify different journals from different areas that have contributed to a particular research area. As shown in Figure 7, Bradford's law has guided immensely in identifying core sources with the most contribution. Most publications include IEEE Access, Expert System with Application, Sensors, Defence Science Journal, and Electronics. In contrast, several journals of international politics, pure science, and mathematics have also contributed to space.

6.8 Cloud of Literature

Figure 8 indicates the word cloud of literature regarding the execution of AI and machine learning in different areas of armament and military operations. Above word cloud indicates that famous AI-related words like neural network, algorithm, and biosensors have integrated with defense-related terms like security, warfare, decision making, the military system, etc., and that indicates the scope of AI in various areas of armaments.

7. FINDINGS

With extensive analysis of all the data the study prevailed that the humungous growth of research regarding use of AI and ml in modern defence operations is the result of the effectiveness of modern AI based technologies that bring new opportunities, automations, safety parameters, strategic decision making, in military warfare. Though the



Source: Biblioshiny.org

Figure 7. Scattering of literature.

Source: Biblioshiny.org

Figure 8. Keyword cloud.

annual growth rate is 2.49 % but after 2017 research in this area source a sharp increase. International collaboration is also important aspect of international politics and global security and the 14.63 % of international indicates the trends of global collaboration regarding development of modern military technology. Co-authorship per documents is also a significant aspect that shows different skill sets and expertise required for conducting a particular research, here it is 3.47 that shows different type of skill sets and scientific knowledge required for integrating modern AI-based technologies with military procedures. Production overtime is also a significant factor that helps to identify countries that are performing more effectively in this domain and the data indicates China India, UK, USA, Korea are the top 5 countries that are producing more research in this topic and among them USA is the most cited country that indicates that in comparison with other countries USA holds a great comparative advantage regarding research and development on improving welfare related technology and this competitive advantage gives them immense power in international politics and global security. This study also shows that USA, India, and Korea are more interested in strategic collaboration, shared growth and strategic use of resources as they promote multiple country production. Finally it showed that AI and ML is a key to stay at the forefront of technological advancements in defence and military operations. Collaboration between academic institutions, industry leaders, and government agencies will remain pivotal in driving innovation and establishing best practices in the field.

8. CONCLUSION

In line with the objectives this article with a broad examination of the multitude of information, found that the humungous development of exploration regarding the utilisation of artificial intelligence and ml in current military activities is the aftereffect of the viability of present-day artificial intelligence-based advances that bring new doors, computerisations, cyber security, strategic direction, in military system. Taking an extra step in defence is likewise a huge component that assists with nation's global performance. The information demonstrates that China, India, the UK, the USA, and Korea are the leading five nations delivering more exploration on this point. Among them, the USA is the most referred country, which shows that in examination with different nations, the USA holds an extraordinarily benefit regarding innovative work on further developing defence assistance-related innovation. This upper hand gives them tremendous power in governmental issues and security. However, while AI and ML offer numerous advantages, the study also underscores the importance of addressing ethical, legal, and security concerns surrounding the use of autonomous systems in military applications. Striking a balance between leveraging advanced technologies and ensuring human oversight and accountability remains a critical consideration for military organizations. The yearly development rate is 2.49 %, yet after 2017, exploration in this domain has a great increment.

A worldwide coordinated effort is a significant part of international relation and worldwide security concerns, and 14.63 % of the collaborative production globally demonstrates the patterns of international cooperation is advancing in present-day military innovation. Reports with multiple collaborators is likewise a vast viewpoint that shows different ranges of abilities and mastery expected for directing a specific examination; here, it is 3.47, which indicates various skills and logical information expected for incorporating present-day artificial intelligence-based innovations with military technology and procedures. This study also demonstrates that, as they promote production across multiple nations, the United States, India, and Korea are more interested in strategic collaboration, shared growth, and strategic resource use.

This study has explored use of modern technologies in developing modern armaments, defence practices, Military healthcare systems, Strategic decision making etc. Defence system is also a significant part of international relationship and global positioning of the country and studying the impact of modern technological development in shaping the global positioning or international trade and political strategies of the country can be a significant area for future research.

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