The Development Tendency of Artificial Intelligence in Command and Control: A Brief Survey

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Abstract. Google’s DeepMind’s AlphaStar has achieved great success in the real-time strategy game StarCraft 2, and it has also made the combination of artificial intelligence and command and control, attracted widespread attention. Artificial intelligence theory and its engineering practice accumulated over many years have injected new development momentum into traditional fields, such as command and control. We download more than 900 high-level papers from Web of Science (WoS) that combine artificial intelligence and command and control as the research object, and employ bibliometric, CiteSpace, VOSviewer, and other bibliometric analysis software. From the number of documents, co-citing, co-occurrence of keywords and research hotspots, the four aspects are studied and visualized analysis, which clarifies the research status and key documents of artificial intelligence in command and control, and reveals the frontier hotspots and research directions in this field. Finally, a summary of the four visual analysis aspects points out important references for choosing research directions, exploring the frontiers of disciplines, and assisting scientific decision-making in this field.

1. Introduction

With the rapid improvement of technology and the widespread application of automation, artificial intelligence is playing a more critical role in the development of civilian and military command and control. Tasks and target assignments in command and control, as well as autonomous planning and coordinated decision-making, are becoming more intelligent and powerful with the increasing maturity of artificial intelligence and related methods [1].

At present, artificial intelligence technology combined with the theoretical research and engineering practice of command and control has achieved initial results. Today, countries in the world have issued relevant documents and policies to promote artificial intelligence technology to the height of national strategy, because of its potential to subvert the contemporary international landscape. Understanding and grasping the development trend of artificial intelligence in command and control is of great strategic significance for its application and the development of the country.

Bibliometrics is a discipline that applies quantitative methods such as mathematics and statistics to journals and books. It aims to study the distribution law of documents and the internal correlation between quantitative documents, to discover the development status and trends in certain fields. [2-3] is a typical case of investigation and analysis using this method.

Given the widespread application of artificial intelligence technology in command and control and other fields, it has become a research hotspot and frontier direction in recent years. Combining the method of bibliometrics, from the Web of Science Core Collection, we sorted out, analysed, and
compared the literature related to artificial intelligence combined with command and control from 1999 to 2020, and retrieved a total of 937 pieces of literature to understand and track in multiple ways. The development of theory and application of intelligence in the field of command and control.

2. Data sources and research tools
With the rapid development of information technology and society, as well as the popularization of Internet applications, scholars have realized the importance of visualization in the field of knowledge and mapping of document information in the research field, for the development of subsequent theoretical research, the transformation of research ideas, and the subject area to lay the foundation for the advancement and grasp of the overall direction.

We download the research and analysis literature data from the Web of Science Core Collection. The subject search terms use "artificial intelligence" and "command and control". The types of searched documents are limited to articles and reviews, and related documents in the SCI-E database are set to search to ensure the authenticity and authenticity of the documents [4]. The time is set to 1999-2020. Finally, we obtained a total of 937 articles as data analysis sources.

In the research of this article, we use bibliometric management platforms and software such as VOSviewer, CiteSpace, and Bibliometritric to analyse. From this, the main research progress and frontier hotspots in the field of artificial intelligence combined with command and control are obtained [5].

3. Data analysis and results
We mainly conduct a detailed analysis of the information published in the field of artificial intelligence combined with command and control, cited papers, popular keywords, and research hotspots in the literature to explore the development context of this field. It employs quantitative analysis, co-citation analysis, keyword co-occurrence analysis, and research hotspot analysis, respectively, to analyse and draw conclusions from four aspects.

3.1. Metrological analysis
In general, the development status and trend of a certain research field can be reflected by the distribution and changes in the number of publications [8]. Through the bibliometric analysis platform, we have conducted overall statistics on the published literature in this field in recent years, and found that the total amount of literature has increased exponentially. The changes in the number of papers published and the details are indicated in Fig 1.
Through bibliometric analysis, we can conclude that in the early accusation field, European and American scholars were the most important research force. The United States and European countries account for almost all of the literature output in this field. In 2015, the United States was the main documentary contribution country in this field. China is developing silently, and the contribution rate of literature has increased rapidly after 2016. After 2017, China’s contribution to the literature is the same as that of the United States, and it surpassed the United States in the number of contributions in 2019. It can be predicted that after 2020, nearly 50% of the literature in this field will be produced by China.

The application of artificial intelligence in command and control, based on previous theories and artificial intelligence algorithm research, not only employs new methods to solve new problems, but also further optimizes traditional problems, innovatively solves problems, and improves traditional technologies. Further in-depth work based on drawing on the experience of predecessors. There are sufficient cooperation and research citations between various countries and units in the world. Through the statistics of the number, we have drawn the article citation relationship chart 2 as indicated in Fig 2.
Among them, relative to other countries, the United States and China have a higher number of citations. The number of citations of American literature is slightly higher than that of China. The literature of other countries has cited most of its literature many times, which can reflect that the literature contributed by the United States and China covers certain representative research and innovation points. It highlights the professionalism and practicability of the questions raised, so it will receive extensive and in-depth research from counterparts in the corresponding field.

3.2. Co-citation analysis
Co-citation analysis is an important intelligence research method that can reflect the research focus of researchers in a certain field in all directions [9]. Generally speaking, the higher the citation frequency of a paper, the higher its academic value. We use the document clustering function module in CiteSpace to import search documents, pre-screen documents by weight reduction, select algorithms, and adjust parameters to ensure that the results are concise and accurate. Finally, a cluster recognition map with hot terms, keywords, and references as the research object is obtained [10]. The analysis result is indicated in Fig 3.
After the co-cited clustering results are screened and processed, we found through analysis and research that the documents of the cluster centers in this field are all around "classification", "reinforcement learning", "decision support system" and so on.

Then, based on the analysis results, we find the most cited documents, which can reflect the basic methods and theories of the current research in this field. The most cited documents in this field are as follows:

Table 1. The most cited literatures.

| Literature name                                      | Published time | Cited the number | The paper source   |
|------------------------------------------------------|----------------|------------------|--------------------|
| Human-Level Control through Deep Reinforcement Learning | 2015           | 73               | NATURE             |
| Mastering the Game of Go with Deep Neural Networks and Tree Search | 2016           | 50               | NATURE             |
| Deep learning                                       | 2015           | 42               | NATURE             |
| Mastering the game of Go without human knowledge     | 2016           | 28               | NATURE             |
It can be seen from the above table that most of the most cited documents focus on artificial intelligence implementation methods and engineering practices, such as reinforcement learning, deep learning, and other improved algorithm articles. The high number of citations indicates the implementation methods needed in this field. It is closely related to basic artificial intelligence methods. Also, there are representative documents that successfully use artificial intelligence methods to solve typical applications in command and control.

3.3. Keyword co-occurrence analysis
Generally, popular keywords that have appeared many times in the literature can, on the other hand, reflect topics that have received much attention in this field. For the co-occurrence analysis of keywords in the retrieved documents, we use the VOSviewer software. To reduce the number of occurrences of unimportant words and improve the overall analysis speed, we set the selected keyword node to 4\cite{11}. After removing duplicate references with CiteSpace, import VOSviewer according to the prescribed format. Finally, after clustering the generated keywords, the keyword appearance frequency density map is obtained, and the result is indicated in Fig 4.

Based on the annual distribution of keywords, we can analyze and study the keyword information that has attracted the attention of researchers in each period. We use the time zone clustering function in CiteSpace to visualize the changes in the number of keyword citations, as indicated in Fig 5.

Through the above analysis, we can draw the following three preliminary conclusions:

- The most widely employed keywords are environment and algorithm. This indicates that the machine learning algorithm and its derivatives, as the basic method of artificial intelligence, are the core content of the current realization of intelligence in command and control. With the continuous evolution of machine learning algorithms, new methods continue to emerge, and it is believed that it will bring greater technological innovation to the field of command and control.

- There are many keywords related to different aspects in the application of artificial intelligence, including control, network, system, etc. It indicates the practical problems that can be solved by artificial intelligence at present. The range of problems that can be solved using artificial intelligence methods is very wide, which indicates that artificial intelligence and related technologies still have huge development potential in the issue of the efficiency of allegations and decision-making.

- In the command and control field, keywords that appear frequently are expert system, decision tree, fuzzy logic, etc. This indicates that in the current command and control field when dealing with some complex scenarios or problems, traditional rule-based methods are still widely employed, Modern artificial intelligence technology still has some limitations \cite{12}.
At present, the application of artificial intelligence technology directly in command and control is relatively few and not mature enough. The battle scene is complex and changeable, the battlefield situation is changing rapidly, and the reliability of the machine to replace humans to command. The current artificial intelligence technology cannot fully explain and solve the above problems. However, countries all over the world are striving to find breakthrough methods and strive to gradually solve the above problems. [13]
3.4. Research hotspot analysis

We use CiteSpace to cluster the co-cited documents of the retrieved documents, and then export the data report. The explosive point discovery function can obtain the cluster frequency index corresponding to each research hotspot [14]. The index directly reflects the frequency of each hot spot, that is, the popularity of relevant research points. The results are indicated in Table 2.

| Hotspot                        | Frequency indicator | Hotspot                              | Frequency indicator |
|--------------------------------|---------------------|--------------------------------------|---------------------|
| support vector machine         | 0.40                | smart cities                         | 0.15                |
| deep reinforcement learning    | 0.35                | function-based reinforcement learning| 0.15                |
| machine-learning technique     | 0.20                | further critique                     | 0.15                |
| business process               | 0.16                | artificial intelligence application   | 0.09                |
| nuclear power plant state      | 0.15                | sound economic valuation             | 0.05                |
| landslide susceptibility       | 0.15                | soft policy enforcement              | 0.05                |

Table 2 indicates that, as reflected in the previous literature, current research hotspots include support vector machines, deep reinforcement learning, function-based reinforcement learning, and machine learning technology. Besides, it has expanded on cutting-edge topics such as smart cities. Technological progress and the development of the times will make artificial intelligence play a more prominent role in the field of command and control. It will not only provide it with more cutting-edge machine learning algorithms to solve traditional problems and provide optimized solutions but will also redefine the information age. Under command and control, the field is developing towards automation and intelligence. [15]

4. Conclusion

In our research, we employed CiteSpace and VOSviewer to analyse 937 documents in related fields from the Web of Science Core Collection, generate a network map of research hotspots, and analyse the distribution of papers, common citations, keywords, and research hotspots. And we further explored the distribution of research hot topics and cutting-edge development trends in the cross-fields of artificial intelligence and command and control, which led to the following conclusions:

- From the perspective of the growth and distribution of papers, in recent years, the number of papers has increased exponentially. The next few years will be the "blowout period" of literature output. The contribution rate of domestic literature is increasing year by year, and it is foreseeable that the country will lead the research of key technologies in this field, and gradually increasing the right to speak in the field of command and control.

- From the perspective of co-citation analysis, artificial intelligence methods are currently being widely employed, such as machine learning, classification, and clustering algorithms, to analyse complex battlefield intelligence and information by data mining to solve traditional problems in the command and control field, replace manual operation with intelligence, improve the automation and accuracy of large workload tasks such as task and target allocation, and collaborative application decision-making.

- According to the results of keyword co-occurrence, machine learning algorithms are at the core of the field of artificial intelligence, and the practical application of algorithm innovation and engineering can bring new command and control solutions. Documents focusing on unmanned systems, deep learning, and command and control have begun to appear. In the future, the field of combining artificial intelligence and command and control is gradually beginning to focus on the research of new intelligent unmanned systems.
In general, the specific application of artificial intelligence combined with command and control is in a rapid development stage, and there is still plenty of research space in all aspects of this field. The complex and changing battle command scenarios and massive battlefield situation data determine that there are bound to be many challenges and opportunities in this field.

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References
[1] Kang, J.L, Chen, S.S, Tian, R.(2019) Analysis of the status quo and development of artificial intelligence technology in the command and control system. In: Proceedings of the 7th China Command and Control Conference in 2019. Beijing, pp. 211-214.

[2] Sun, J., Tong, Z.H., Jiang, Z.Y., Shi, W.D, Liu, X.T, Xue, X.N. (2020) Mapping knowledge of artificial intelligence research in China based on bibliometric analysis. J. Journal of Shandong University of Technology (Natural Science Edition), 34(01): 46-51.

[3] Lv, W.J., Xù, L., Liu, J., Chen, J. (2018) Review on Chinese Artificial Intelligence Research in Past Decade: Bibliometric of Knowledge Atlas during 2008-2017 J. technical economy, 37(10):73-78+116.

[4] Zhang, Z.Q. (2020) Bibliometric and Visual Analysis of Artificial Intelligence. J. Think Tank Times, 3(08): 13-15.

[5] Analytics, Clarivate. (2017) Acquisition of the Thomson Reuters Intellectual Property and Science Business by Onex and Baring Asia Completed. www.prnewswire.com.

[6] Xu, J.Y., Lu, C.W., Huang, Y.S. (2020) A comparative study of chinese and foreign artificial intelligence from the perspective of mapping knowledge domains. J. Journal of Central China Normal University (Natural Science Edition), 54(02): 301-312.

[7] Zeng, B., Lv, J.Q. (2019) Hot Spot and Frontier Analysis of Domestic TRIZ Research Based on CiteSpace. J. Science and Technology Management Research, 39(18): 260-265.

[8] Zhang, X.Z., Yang, C. (2019) Bibliometrics and Knowledge Mapping Based on CNKI and CiteSpace. J. Contemporary Library, (09): 12-17+64.

[9] Song, X.F., Chi, P.J. (2016) A Comparative Study of Vosviewer and Citesea Applications. J. Information Science, 34(07): 108-112+146.

[10] Chen, Y.H., Liu, J.W., Long, Z.Q., Zhao, P. (2020) Bibliometric Analysis of Literatures on Corona Virus Disease 2019 based on CNKI and PubMed Database. J. Chinese Journal of Social Medicine, 37(02): 115-118.

[11] Jin, X. (2018) Review of Foreign Development of Command & Control Artificial Intelligence. In: Proceedings of the Sixth China Command and Control Conference. Beijing, pp. 84-90

[12] Hu, X.F., Guo, S.M., He, X.Y. (2016) Challenges to Intelligent Command Information System: Reason and Revelation on “Deep Green” Plan and AlphaGo. J. Command Information System and Technology, 7(3):1-7.

[13] Li, S.M. (2017) Hot-spot and Cutting-edge Analysis of Domestic Smart Libraries Based on CiteSpace and Vosviewer. J. Journal of Xinyang Agriculture and Forestry College, 27(04): 106-110+114.

[14] Wu, J.P., Yang, J., Fan, X.M. (2020) Intelligence Decision System and Technology Research of Command and Control. In: Proceedings of the 8th China Command and Control Conference. Beijing, pp. 368-373

[15] Mnih, V., Kavukcuoglu, K., Silver, D., et al.(2015) Human-level control through deep reinforcement learning. J. Nature, 518(7540):529-533.