Analysis of Competitive Situation in Basic Research of Global Intelligent Robots

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Abstract. Practically grasp the global development trend of the basic research on intelligent robots and provide support for the scientific development of intelligent robots in China. Relying on bibliometrics, this paper has proposed a four-dimensional competitive situation analysis system for basic research based on activeness and talent distribution, etc., which can effectively analyze the global situation of basic research on intelligent robots, able to reveal and describe the competition status quo and situation of the basic scientific research in specific fields. There is a big gap between China and the United States in basic research on intelligent robots, mainly including such aspects as follows: uneven distribution of high-level basic research talents; insufficient international cooperation in high-level scientific research; lower research activeness; layout of key research and development.

1. Introduction
Basic research is the source of the whole scientific system and the cornerstone of building a powerful country in science and technology. The total output of scientific papers in China has ranked the first in the world and the number of citations of international papers has also risen to global second, but it must be noted that the key technologies in many fields are constrained by others and in a deeper sense, there are various shortcomings highlighted in the field of basic scientific research, such as lack of major original achievements, lack of top talents and teams, inadequate investment and unreasonable structure [1]. The new round of scientific and technological revolution and industrial transformation are ceaselessly deepening, the global competition for scientific and technological innovation is unprecedentedly fierce and the basic research is becoming the commanding height of global competition. China is speeding up the implementation of innovation-driven development strategy; moreover, Shanghai and Beijing are striving to build science and technology innovation centers with global influence. This requires policy makers to have an international vision for competition. On the one hand, they should be able to accurately grasp the trend of scientific evolution and the global competitive situation of scientific and technological innovation; on the other hand, they should also clarify their advantages and gaps between their regions and leading countries and regions in basic research, so as to optimize the layout of regional basic scientific research.

2. Research Approach
The competitive situation is a relatively broad concept and the competitive situation of basic research mentioned in this paper is not only different from the capability evaluation at the level of scientific and technological competitiveness, but also different from the latest progress at the level of micro-
knowledge unit. Actually, it is to grasp the overall development status of the basic research in specific scientific and technological fields from the perspective of competition.

As the main achievement form of basic research, the econometric analysis based on scientific papers has been widely used in the relevant research topics of scientific and technological innovation decision-making, such as research situation analysis, research hotspot finding, innovation effect evaluation and talent selection. Moreover, the econometric analysis method based on massive academic data not only makes it possible to grasp the scientific structure and evolutionary model from a micro perspective, but also becomes a tool for effective management of the forward-looking planning in scientific research [2]. At present, there have been numerous analysis results and studies made on the competitive situation of the basic research in specific fields by using scientific econometric methods. Liu Ya has carried out the analysis and research on the international cooperation situation of basic research based on the distribution of scientific papers at the levels of disciplines, countries and institutions, etc. [3]; Ma Tingchan, et al. has put forward the comprehensive competitiveness index of basic research based on the data of the National Natural Science Foundation of China to make a comparative analysis of the competitiveness and its changes of the provincial basic research in China [4]; based on such three indexes as “activeness index”, “attraction index” and “efficiency index”, Chen Kaihua, et al. has constructed a “comprehensive research capability index” and used such indexes to compare and describe the relative position and competition pattern of different countries in the field of science and technology in terms of the basic research [5]; Zhang Zhiquiang, et al. has chosen such two perspectives as global overall R&D situation and representative research units and consequently proposed a set of competitive situation analysis indexes for basic research from four aspects, such as strategic positioning, paper output, talent team structure and scientific research mode[6]; Li Zexia, et al. has classified the field situation analysis into four aspects: strategic layout, scientific research, technological development and industrial development, focusing on a set of indexes for analyzing technological development situation [7]; Bian Wenyue, et al. has put forward an information analysis framework of the development situation in the frontier of science and technology by combining the micro-analysis of knowledge units with the development situation analysis at the macro level [8].

To sum up, there are two main trends in the development of the original econometric research heavily relying on the external metrological characteristics of literature: Firstly, from a single analysis perspective based on the external characteristics of literature to a multi-comprehensive perspective such as discipline structure, cooperation network and knowledge units; secondly, the dimensions of competitive situation analysis in the field of basic research are diversified and index-oriented. However, the author believes that the existing research perspectives continue to expand and the analysis indexes are more systematic and comprehensive, but still there are two aspects of shortcomings: Firstly, the comparative analysis mostly stays at the horizontal comparison among different countries at the macro level, but pays insufficient attention to the regional meso-level; on the other hand, the existing analysis framework mostly targets the evaluation of the basic research capacity, but less research has been made to propose a bibliometric analysis framework for answering the basic research competitive situation and pattern in a specific area at the global and regional levels.

Accordingly, the current research, focusing on the optimization of regional basic scientific research layout in the perspective of global competition, has proposed to follow such four dimensions as research activeness, distribution of high-level talents, research cooperation and key R&D layout for grasping the competitive situation of the global basic research from the perspective of regional strategies; moreover, it has made an attempt to proposed a new analytical framework on the basis of expanding and optimizing the existing relevant analysis indexes and select the technological field of intelligent robots for an empirical research, thus to verify the scientificity and effectiveness of this analytical framework.

3. Design of Competitive Situation Analysis Framework for Field Basic Research
The basic research, as one of the most complex intellectual activities in human society, is subject to many factors affecting its level development. Generally speaking, there are four aspects: Firstly, primitive accumulation, including academic output, basic research talents and capacity basis, etc.; secondly, investment in basic research and government guidance; thirdly, distribution of high-level research groups, mainly referring to research institutions and researchers with certain academic influence; fourthly, high-level research cooperation network [9, 10]. Based on the above knowledge, this paper has put forward four dimensions for competitive situation analysis (namely, activeness level of basic research, distribution of high-level research talents, network for international cooperation research and layout of key R&D projects), focusing on horizontal comparison among domestic and foreign cities (regions) to refine relevant analysis indexes and strive to describe the macro-competitive situation for international competition at the urban or regional level (as shown in Figure-1). Compared with the existing research, the analytical framework proposed in this paper has the following three characteristics: Bibliographic representations are used to define the high-level talents for basic research and simultaneously the distribution of such talents is taken as an important research index for competitive situation analysis; the correlation analysis is carried out at three levels: nations, cities and institutions, with the regional basic research level compared in the perspective of global competitive environment; the dimensions have been expanded for analyzing the competitive situation in the field of basic research, with such key elements as R&D layout, network for international research cooperation and distribution of high-level talents brought into the same analysis index system.

3.1. Situation analysis of research activeness
From such two dimensions as national geospace and time, it can reflect the activeness level of the basic research in specific fields. The national geospatial analysis can clarify the overall competition pattern of global basic research in the field and find out the competitive potential of the research object; the time dimension analysis can help us to realize the trend relationship between the basic scientific research in the field and the evolution of the applied technology.

3.2. Situation analysis of high-level talents distribution
The number of high-level research talents determines the level of basic research, so the distribution of high-level talents has become the key factor to judge the competitive situation of the basic research. Based on the bibliometric characteristics of high-level talents for basic research, this paper has comprehensively measured the rationality of the distribution of high-level talents in target areas under their own strategic positioning from three levels, such as countries, cities and institutions.

3.3. Situation analysis of international cooperation research
With the continuous strengthening of the integration between different disciplines and fields, international cooperation has become one of the prominent features of contemporary basic research [11]. The research also proposes to judge the dependence of the target area on international cooperation and whether the selection of partners is conducive to the improvement on the basic research level in this field through statistical analysis of the cooperation frequency from three levels: countries, cities and institutions.

3.4. Situation analysis of key R&D layout
The improvement of the original innovation level needs not only to follow the laws of the science itself, but also to be supported and guided by the government. The support of the scientific fund can reflect the layout and competitiveness of a country or region in terms of basic research. In this paper, the types and proportion of scientific funds corresponding to SCI papers are included in the proposed analytical framework. At the same time, the competition analysis of regional basic research supported by scientific funds has been extended to the main hotspots in the established fields.
4. Analysis of Global Competitive Situation for Basic Research in the Field of Intelligent Robots

Intelligent service robots are a kind of high-tech integrated intelligent equipment which provides essential services for human beings in an unstructured environment. As a new interdisciplinary application technology combining artificial intelligence and automation technology, it has become one of the focus areas of global response to the new round of scientific revolution and industrial transformation. At present, our country is lagging behind in several key technology fields of intelligent robots, such as bodywork and drive, perception and information fusion, intelligent control and human-machine interaction. The core components of high-precision reducers, servo motors and so on have been long relying on imports, and the technological breakthroughs in such fields must be driven by basic sciences [12]. For this reason, this paper has chosen the intelligent robot technology as the field for empirical verification of the analysis framework and index system proposed by the research institute.

4.1. Data Sources and Processing Methods

Intelligent robots belong to a comprehensive technology field obvious in cross-disciplinary characteristics. Therefore, the accurate retrieval of the scientific research papers in this field must be achieved by constructing a key technology system. As shown in Fig. 2, based on the development status and trend of global intelligent robot technology as well as the suggestions of experts in the field, the current research has preliminarily put forward the key technology system of intelligent robots consisting of 8 key technical categories and 43 sub-technologies, such as new materials, interaction and sensing.

The research has chosen the WOS Core Collection (SCIE) as the source of literature data and taken secondary sub-technologies as the key words for retrieval to carry out literature retrieval for eight key technical categories respectively. Moreover, the research targets the latest research situation and simultaneously the attention of the basic science circles to each technical category is chronologically different, so the time span varies from 5 to 8 years for retrieving the data of papers in different technical categories. With the help of Derwent Date Analyzer (DDA), we have cleaned the data and finally obtained a total of 15094 literatures containing effective original data.

In addition, according to the research needs, this paper has defined the basic high-level talents under the bibliometric characteristics. Referring to the ESI definition of highly cited papers, the research has taken the papers featuring concentrated research data and ranking top 10% in terms of key technologies, years of retrieval and citation frequency in the same year as the high-level papers in this research, and then identified the first authors and corresponding authors of such papers as high-level research talents. To have this strategy more scientific, the research has used relevant literature
retrieval tools to automatically identify the papers from SCI journals not ranked among 10% of the original data, and to supplement such papers to the data set for high-level papers research.

Figure 2. Key Technologies System of Intelligent Robots.

4.2. Situation Analysis of Basic Research Activeness

4.2.1. Comparison of Countries Leading in SCI Papers. The research has chosen SCI and its high-level papers as two analysis indicators to analyze the output of papers in order to grasp the global macro-competition pattern of basic research in the field of intelligent robot technology. As can be seen from Figure 3, the United States and China have formed the first competitive echelon, which has opened a certain gap with other countries. In this field, the output level of SCI papers in China has approached that of the United States. In terms of high-level SCI papers, China has become the second largest country in the world, but still there is a big gap to the United States.

4.2.2. Comparison of the trend for SCI papers in leading countries. In addition, from the statistical analysis of the annual publications of SCI and its high-level papers in the past eight years by robotic powers such as the United States, Japan and Germany as shown in Figure 4 (1), the competitive situation is clearer between the two camps in the world. Compared with the trend of relatively stable rising in the United States, the output level of basic scientific research in the field of intelligent robotics in China has shown a rapid upward trend since 2012 and surpassed the United States in 2017. In terms of high-level achievements, as shown in Figure 4 (2), China emerged from the second camp in 2015, and the number of high-level papers showed a linear growth trend in the following two years, surpassing the United States in 2017. In summary, we can see that the output scale of basic scientific research in the field of intelligent robot technology in China is close to that in the United States, but still there is a gap to the United States in the level of academic influence.

Figure 3. Distribution of Nations with SCI and High-level Papers.
4.3. Analysis of Distribution Situation of High-Level Talents

4.3.1. National and Regional Distribution of Field High-Level Talents. The empirical case study in this paper has made a statistical analysis of the country, city and institution-based distribution of the first and corresponding authors of the high-level papers. At the national level, as shown in Figure-5, corresponding to the number of high-level papers, the number of high-level talents for basic research in the field of intelligent robot technology in China is the second highest in the world, only second to the United States, but still there is a certain gap in the number with the United States. Other eight countries, such as Italy and Germany, are basically at the same level.

4.3.2. City and Region-based Distribution of Field High-Level Talents. At the urban level, as shown in Table-1, Beijing ranks first in the world in the number of high-level talents, which surpasses Cambridge in the United States, but it also accounts for only one quarter of the total number of the talents in this field in China; moreover, Beijing and several other domestic cities in the global TOP20 account for only 55% of the total number of domestic high-level talents in this field. This group of data reflects that the geographical distribution is relatively scattered for high-level talents in basic research in the field of intelligent robots in China. Under the strategic background of building a national science and technology innovation center, Beijing's advantage in gathering high-level talents in this field has not yet appeared.

4.3.3. Distribution of high-level research institutions in the field. The number of high-level talents directly represents the competitiveness of scientific research institutions. At the institutional level, we have ranked domestic and overseas research institutions according to the number of high-level talents and compared the top 10 institutions respectively. As can be seen from Table-2, several famous universities in the United States have obvious advantages in high-level talents for basic research in the field of intelligent robots; however, there is a huge gap between domestic and international leading institutions in the scale of talents; the advantages are not obvious for high-level talents of scientific research institutions in Beijing area, and Harbin Institute of Technology is more prominent at the level of domestic institutions.
4.4. Situation Analysis of Basic Research Cooperation in the Field

The frequency of international cooperation in publishing SCI papers was counted, and a network of cooperation was formed (see figure 6). The United States is the most active country in the field of basic research and international cooperation in the field of intelligent robotics. The volume of cooperation with other countries is generally high, especially with China. However, China's international cooperation is ranked fifth in the world with fewer publications than Italy, Germany and Italy. In addition to more cooperative research with the United States, China also has a certain degree of research cooperation with the United Kingdom and Japan.
4.5. Analysis of Key R&D Layout Situation

4.5.1. Comparison of Scientific Fund Subsidies for SCI Papers in Leading Countries. In order to reveal the global layout of basic scientific research and development in the field of intelligent robot technology, the current research has quantitatively analyzed the scientific fund subsidies for SCI and its high-level papers published by major leading countries. As shown in Figure-7 (1), more than 80% of SCI papers in the field of intelligent robot technology in China are subsidized by relevant scientific funds, before the United States, but only after Korea; besides, more than 50% of subsidies are funded by national funds. Compared with Figure-7 (2), the proportion of scientific fund subsidies for high-level SCI papers in various countries has generally increased, especially in China and Korea. From the perspective of fund types, the National Science Foundation (NSF) and the National Institutes of Health (NIH) are the main funders in the United States; besides relying on their own local research funding institutions, European countries also have important access to funding from various EU R&D programs; many large-scale scientific research funds in Korea have provided funding for robot scientific research; the robot scientific research in China has mainly been subsidized by the “Natural Science Foundation of China” and the “National Key R&D Program of China”.

4.5.2. Comparison of Scientific Fund Subsidies for Key Technology Categories between Domestic and Foreign Leading Cities. Furthermore, based on the eight key technology categories proposed in the current research in the field of intelligent robot technology, it has counted the number of papers classified in different technology categories and supported by scientific funds in the leading cities of SCI papers, compared with Cambridge, the United States, which ranks first in the world, and achieved the results as shown in Figure-8. By virtue of the geographical advantages in scientific and technological resources, Beijing's scientific research institutes have gained much more support from scientific funds than other domestic cities in basic research of all key technology categories. Relevant research shows that sensing, driving and control, interaction and recognition are three major important categories of intelligent robot technology for fostering strategic emerging industries and developing high-tech industries in the future [13]. Compared with U.S. Cambridge, Beijing has been paying more attention to the original innovation of the sensing technology, but the basic research layout in such two directions as driving and interactive technology needs to be further strengthened.
Figure 8. Scientific Fund Subsidies for SCI Papers in Domestic and Overseas Leading Cities in Key Technological Fields

4.6. Conclusion
As can be seen from the analysis results, China is at the same level as the United States in the output of basic research achievements in the field of intelligent robot technology, and the research achievements show a rapid upward trend in both “quality” and “quantity”, but still there is a certain gap to the United States in the level of influence. In China, the geographical distribution of high-level talents for basic research in this field is relatively scattered. Beijing is leading in domestic cities, but the advantages for gathering high-level research talents have not yet emerged under the dual strategic positioning of building a national science and technology innovation center and forging a high-grade, precision and advanced economic structure. The systematic support of various scientific funds is an important guarantee for the output of high-level basic research achievements. The scientific research institutes in Beijing have obvious advantages over other cities in obtaining scientific funds, but they need to strengthen the research layout of original innovations in such two key technologies as driving and interaction.

5. Summary and Prospect
Orienting at the application of supporting the strategic planning for regional scientific research and targeting comprehensively grasping the competitive situation of regional basic research in a global perspective, this paper has carried out multi-dimensional correlation analysis from such three levels as countries, regions and institutions based on bibliometrics, incorporated such key competitive elements as R&D layout, international cooperation network and distribution of high-level talents into the same analysis framework in order to reveal and describe the competition status quo and situation of the basic scientific research in specific fields, and simultaneously has verified the practicability and effectiveness of the proposed analysis framework, taking the intelligent robot technology as an example.

The analytical framework proposed in the current research has helpfully expanded and improved the existing research in terms of analytical perspectives and dimensions, but, as mentioned in this paper, many factors may affect and determine the development of basic research and its competitive situation, especially in answering the related strategic layout of science and technology from the regional perspective. The four analysis dimensions and related analysis indexes proposed in this paper have improve the existing methods of grasping the competitive situation of basic research by means of bibliometric analysis, but no systematic comparison or measurement has been made, and some scientific limitations may exist in grasping the competitive situation of basic research in a certain field from the perspective of bibliometrics. In addition, some of the analysis indexes proposed in this paper have only considered too single factors, for example, the part of international cooperative research has only revealed the geographical distribution of cooperative partners by the number of cooperative publications, but not considered the influence of co-authored papers; simply identified the first and corresponding authors of highly cited papers as high-level authors, but not incorporated authors’ H index or average number of citations in the analysis indexes together.
With the integration of basic research, applied research and industrialization, the weakness and one-sidedness starts to appear for bibliometric methods applied in basic research capacity evaluation or competitive situation analysis [14]. In the future, the innovation and application of relevant analysis methods should organically integrate the national objectives for scientific development, have bibliometrics mutually complemented and corrected with such indexes as scientific research project funds, scientific awards, patents and achievement transformation, so as to further improve the effectiveness and scientificity in analyzing the competitive situation of the basic research.

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