

A bibliometric analysis on path planning methods for mobile robots published in scientific citation index-expanded indexed journals between 2000-2020

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Abstract. Robots are currently replacing humans in different tasks in various sectors. Among the vital features desirable in autonomous robots is the capability of navigating safely through a given environment. Robot navigation is a process designed with the ability of avoiding any hitches or obstacles while aiming at a specific predefined position. Many studies have been proposed to find solutions to robot path-planning problems. This paper presents a bibliometric analysis of the relevant publications published from 2000 to 2020. The results show that 5385 articles were published in 1128 journals, hence indicating publication diversity. There is a steady rise in the yearly publication output, reflecting an increase in global research interest in the topic. In general, this research provides useful insight into path-planning research so that researchers in this area can better recognize the relevant research study topics and search for the appropriate research partners.

1. Introduction

At first, the manufacturing sectors were the major areas utilizing the application of autonomous mobile robots. However, recently, it is frequently used in other sectors: Medical, Military, mining, agriculture and so on. For the mobile robot to model its environment, localize its position, detect and avoid using a certain path planning technique, it is required to be provided with intelligent information. Choosing the proper path planning method is necessary in order for the robot to navigate in a clustered environment from a given initial position to the target without colliding with obstacles. Robot navigation can be classified into: global and local navigation. In global navigation, the positions of the elements are defined based on a reference axis while moving towards the target. In the later, the dynamic constraints of the environment are identified the relations among elements positions established.

1.1. Robot path planning

Robot path planning is the process of finding an enhanced collision-free path from a start to a predefined goal point through a certain given cluttered real world environment within the shortest possible time [1], [2]. Siegwart and Nourbakhsh [3] identified path planning as defining a trajectory through a map with which a robotic can reach a known goal point from its starting place while avoiding obstacles. The four integral path planning components that made up the navigation problem are: Perception, localization, motion control and path planning [4]. Figure 1 below shows the four integral parts of robot navigation problem. Localization as well as path planning are necessary components in navigating of mobile robots.

1.2. Bibliometric analysis

Bibliometric analyses, defined by Pritchard [5], is the application of mathematical and statistical methods to books and other means of communication. Bibliometric analysis has actually been used to systematically evaluate the progress of a details scientific field [6]. It has been used to review the distribution patterns of authors, journals, institutions, key phrases, topics, development patterns, as well as predict future research directions based on the search engine result. Bibliometric analysis has ended up being an important tool to measure the scientific progress in numerous fields [7].

There has been little effort made on the systematically review in path planning studies and in order to show the growth of the path planning, this article aims to analyse and visualize the existing path planning articles published with details such as the publication chronological distributions, the most appropriate scientific journals, and the popular key word phrases. Using " robot path planning " as the major key phrase, we determined over 14000 articles prior to being categorized into 5385 main related articles. All these are taken mainly from the Web of Science Core Collection. With the selected 5285 articles, we did an analysis by creating the connection between the abstract, title, publication, citation, research study area, geographical allocation and also the keyword phrases used. Through bibliometric co-citation, cartography analysis, and content analysis of the literature, this article fills the research gap on robot path planning review

The main aim of this survey paper is to perform a bibliometric analysis aiming to answers the following questions

- How are path planning articles clustered?
- What are future path planning research questions that provide opportunities to further the role of robot path planning?
- Which channels (journals, articles, and countries) are the most influential in Path planning?

describes the Bibliometric methods and results respectively. Finally, the last section concludes the survey.

2. Methods and Data sets

In bibliometric analysis, we aim to show affiliations among articles and also research subjects by examining how frequently an article is cited and co-cited by other articles. The article is the standard unit of evaluation [8], [9]. A fundamental presumption in bibliometric co-citation analysis is that published articles in academic journals develop their research study on articles already published. Bibliometric co-citation meta-analysis can help to disclose underlying commonalities among research study [10].

The ISI Web of Science (WOS) consists of different articles with their bibliographic references, institutions as well as authors [11]. Articles for all years (since1900) are available [12]. It is an item stemmed from "Thomson Reuters Institute of Scientific Information" (ISI) with more than 12,000 journals of different titles and multiple disciplinary [13]. The database gives effective searching choices by enabling various alternatives to filter the search results page [14]. In enhancement to the browsing alternatives, the WOS is additionally able to arrange the journals/articles based on particular specifications such as time added, publication date, citation, significance, and usage count. WOS database allows particular omission by article, author, institutions, countries and many more by fine-tuning the search result.

In order to avoid overlap between the data sources, Scopus and Google Scholar were left out in this study. The uncertainty of Google Scholar in carrying out research analysis and low data quality were some other reasons for its exclusion. Some database (like IEEE Explore, Springer and so on) only index their published articles while WOS combines all the high impact articles and journals from all of the databases. Also, WOS is used in this study due to its popularity in performing a bibliometric analysis of articles in scientific fields [15]. WOS database declares it has more quality than both Scopus and Google Scholar [16].

Topic search was "path planning". The search time span was set from the year 2000 to the year 2020. The retrieval time was 2020.03.28. Topic search suggests search from titles, abstracts, and keywords of the articles. A total of over 14304 articles prior to being categorized into 5385 main related articles were retrieved for bibliometric analysis. In this study, the articles publishing trend were first illustrated. The evaluation was performed based on productivity and research focus. Visual results were further provided using the VOSviewer tool [17] due to its availability and great features used in bibliometric analysis.

3. Result and discussion

3.1. Publication trend

Figure 1 shows the year-wise frequency of publications and the trend in the number of publications from 2000 to 2020. It is observed that just a few articles were published between 2000 and 2003. After 2004, the variety of publications began to rise slightly, and also there were more than 500 publications in 2007. Ever since, the number of articles each year has been increasing, which shows that path planning study has received more interest with publication in 2019 having the highest possible number of citations 917 with the year 2020 still counting.

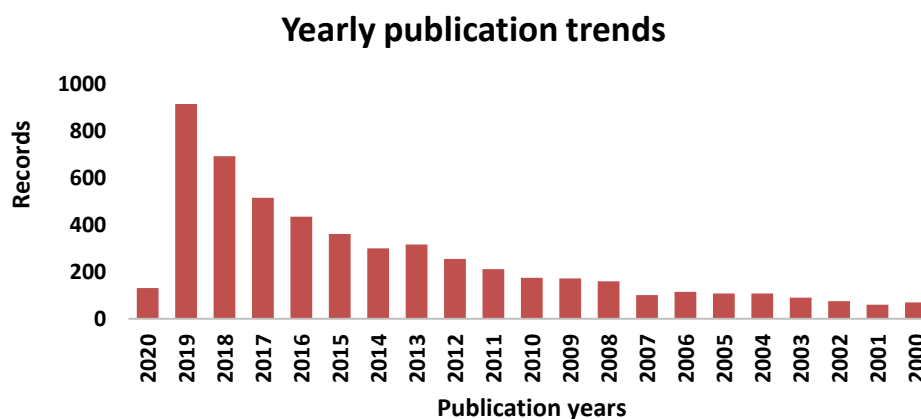


Figure 1. Publication trends

3.2. Publishing journals impact

Relative to the source journals, these 5385 publications were released in 1128 journals. Amongst all the 1128 journals, about 270 journals only released one article in the research study time. Table 1 shows the leading 20 most efficient journals, making up 34.746% of the overall journals. IEEE Robotics and Automation Letters was one of the most efficient journal with 196 write-ups, representing 3.64% of the publication Journal of Intelligent Robotic Systems ranked the 2nd with 171 articles, accounting for 3.179%. The third most productive journal was Robotics and Autonomous Systems, with 157 articles (2.916%).

3.3. Research focus

The keywords frequently used by the published articles in the journals were analyzed. Using the keyword, previously published as well as current articles in the journal can be traced and analyze to identify research gaps. Articles theme with authors keyword have been provided by WOS since 1990 [18], [19]. To measure the co-occurrence link within the path planning keyword phrases, 200 key phrases were drawn out. Nevertheless, the number is also large to classify them into understandable research clusters. Hence, the key phrases were manually further refined to eliminate those words that appeared twice as a result spelling changes, and repetition. 181 key phrases were then picked. Fig 2 demonstrate

how the key phrases are interlinked with each other in the path planning research study domain. 4 clusters were developed, with the biggest cluster having 65 items while the smallest having 16.

Table 1. Publishing Journals

Source Titles	records	% of 5385
IEEE Robotics and Automation Letters	196	3.64
Journal of Intelligent Robotic Systems	171	3.175
Robotics and Autonomous Systems	157	2.916
International Journal of Advanced Robotic Systems	144	2.674
International Journal of Advanced Manufacturing Technology	133	2.47
IEEE Access	121	2.247
Robotica	121	2.247
International Journal of Robotics Research	113	2.098
IEEE Transactions on Robotics	108	2.006
Sensors	93	1.727
Advanced Robotics	63	1.17
Autonomous Robots	61	1.133
Robotics and Computer Integrated Manufacturing	61	1.133
Applied Sciences Base	53	0.984
Lecture Notes in Computer Science	49	0.91
International Journal of Robotics Automation	48	0.891
Mathematical Problems in Engineering	46	0.854
Computer Aided Design	45	0.836
IEEE Transactions On Automation Science and Engineering	45	0.836
Applied Soft Computing	43	0.799

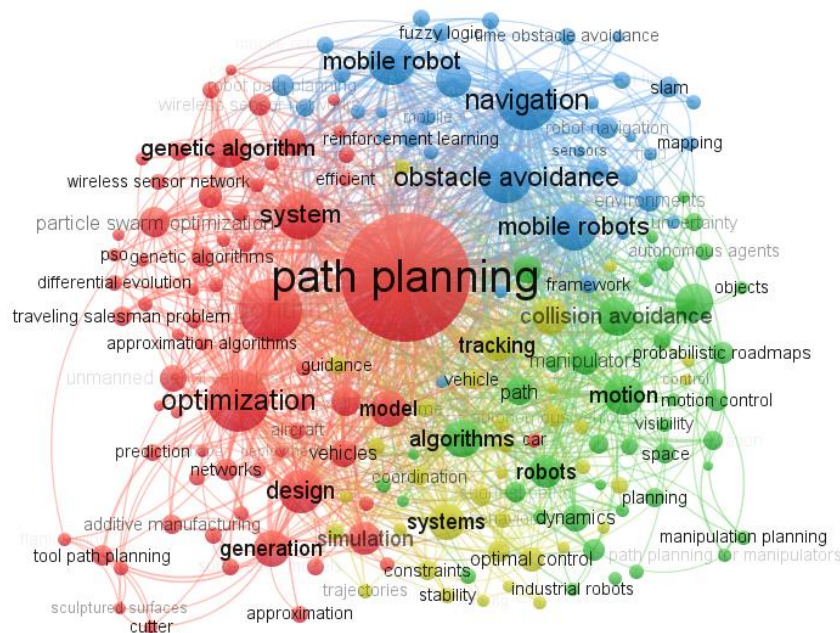


Figure 2: Authors keyword network

Cluster # 1 is the one in red color. As seen, it contains one big circles at the center, about three mediums once and then some small scattered ones. The size of a circle indicates the overall occurrence as well as link strength of the key words in the path planning research area. The leading research subject indicated by the big circle is the Path planning. Path planning is the process of finding a Collision-free path from a start to a predefine goal point through a certain given cluttered real world environment. Path planning plays a major rule in the navigation of autonomous vehicles. It is used in several applications such as automation, games, artificial intelligent etc. Other cluster members are algorithm, Optimization, differential evolution, robotics, genetic algorithm etc. Most of which are path planning algorithms and have proven to be effective in finding an optimal path for a robotic system.

Cluster #2 is the one with the green color, and it has 42 items. The most prominent research topic is motion and collision avoidance with 192 and 180 occurrences respectively. Collision avoidance is one of the key features required by autonomous. The next in the cluster is algorithm with 134 links and 169 occurrences. They are all effective path planning features that are often used in path planning research. Cluster #3 is the one with a Deep-Blue color and contain 37 items in total. The most prominent path planning research keyword is navigation. It appears to be the most significant research area in the entire clusters, as it has the biggest circle size and is densely connected to the other major clusters as shown in figure 3. The remaining phrases are mobile robot, robot navigation etc.

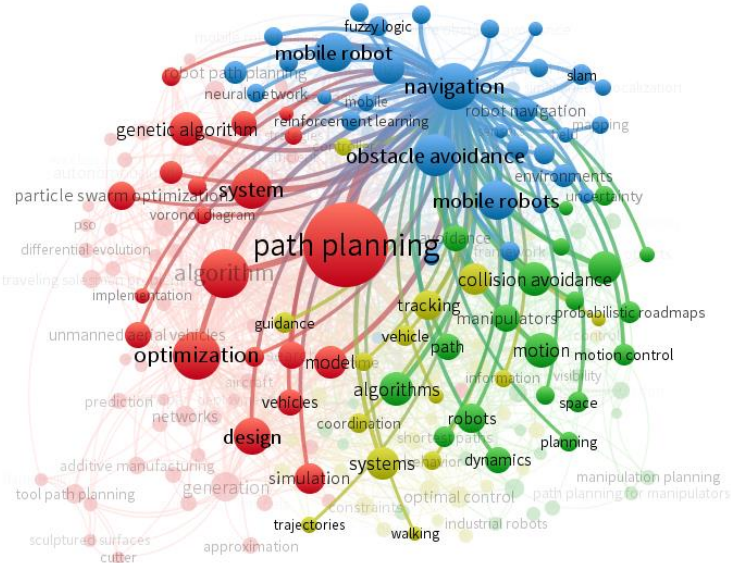


Figure 3. cluster #3 keyword network

Cluster #4 has 35 keywords, and its denoted by the Yellow color figure 4. The three dominant research phrases in the cluster are system, tracking, optimal control, constraints, trajectory coordination are some of the major trending research optimizers in the cluster.

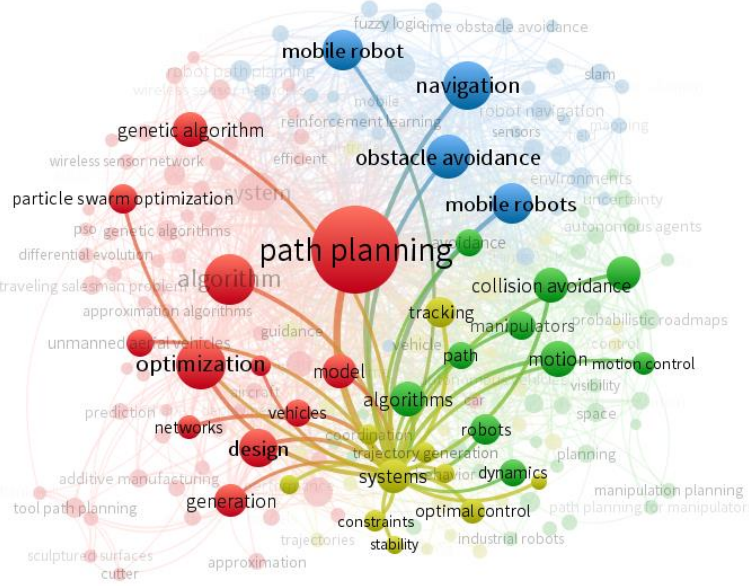


Figure 4. cluster #4 keyword network

4. CONCLUSION

Path planning has actually been practiced worldwide as such a lot more academic efforts have actually been made in this field. In order to summarize the research progression and also suggest future directions of path planning research, this study carries out a bibliometric analysis on the relevant publications published during 2000 to 2020. Result show that 5385 articles were published. The yearly publication rises rapidly after the year 2007, reflecting global interest in the topic. These publications were published in 1128 journals, indicating the publication diversity. IEEE Robotics and Automation Letters, Journal of Intelligent Robotic Systems, Robotics and Autonomous Systems ranked the leading three journals in regards to total publications. keywords search phrases was carried out to track the top topics and research trend. The hot topics includes: path planning, robot navigation, optimization and obstacle avoidance. With the rise of obstacle avoidance and optimization more research will focus concentrate on such an area in the near future. Generally, this research provides useful insights as well as future research study directions on path planning research study so that researchers in this area can better recognize their research study topics and also look for appropriate research partners.

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