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THE BIBLIOMETRIC NETWORK TO IDENTIFY RESEARCH TRENDS IN MULTI-INPUT TRANSFER FUNCTION

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ABSTRACT

Bibliometrics has become one of the most widely used approaches to examining academic publications. Bibliometric analysis helps researchers obtain references from other researchers, strengthening recent research. In a bibliometric analysis, VOSviewer made the analysis process easier. VOSviewer is used to build and visualize bibliometric networks. This study aims to present and visualize an overview of the development of multi-input transfer function research trends and collaboration networks. The research method used is a literature review from Scopus using VOSviewer in 2007-2023. This study shows a growing trend in multi-input transfer function research, with China leading in publications. The development map of the multi-input transfer function is based on nine co-words and ten co-author clusters. The study's results are dominated by applying the model to real data. However, the estimation of multi-input transfer function parameters has yet to be carried out using a numerical approach.

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1. INTRODUCTION

A transfer function is a function that knows the relationship and influence of input and output over some time [1]. In general, input and output are closely correlated, so the impact of input on production in an event is considered significant. Transfer functions are distinguished into multivariate transfer functions, multi-input transfer functions, and multi-output multi-input transfer functions [2]. The multi-input transfer function is one kind of transfer function used as a prediction model for analyzing several timelines for the multivariate data type [3], [4]. The multi-input transfer function combines causal and time-row approaches [5]. This function has more than one input and one output [4]. The multi-input transfer function is used to understand how input contributes to output. This function includes output rows expected to be impacted by input rows and additional inputs merged into a group known as noise rows [3]. Input and output were prewhitened by the prewhitening filter, and we used conditional least squares estimations for the transfer function weights [6]. Therefore, this study aims to provide a comprehensive overview of the development of multi-input transfer functions and identify the visual of emerging research trends through bibliometric analysis.

Alan Pritchard created the name "bibliometrics" to distinguish it from the term statistical bibliography and bibliography of statistics, meaning that bibliometric refers to the use of mathematical and statistical techniques in reference to books and others. In accordance with the previous definition, mathematical and statistical methods can be applied to all forms of communications media that have been recorded in a broad sense, both graphical and electronic [7]. Bibliometrics is one of the most widely used approaches to examining academic publications [8]. Bibliometric analysis is a comprehensive analysis that consists of quantitative and qualitative analysis [9]. Bibliometrics can identify countries, journals, authors, and institutions that contribute to the field of research, show frequently mentioned studies and commonly used keywords, as well as show collaboration between states, agencies, and authors in specific scientific research fields [10]. Such analysis helps researchers obtain references produced by other researchers to strengthen the latest research [11], [12]. Bibliometric analysis can be used in all fields of science.

Tools like VOSviewer are needed in bibliometric analysis to facilitate the analysis process [13]. Bibliometric networks are created and visualized using a VOSviewer program [14]. These networks contain journals, researchers, or individual publications built on citation analysis, co-citation analytics, bibliographical coupling, co-author analysis, and co-word analysis. Citation data is used in the first three analyses to create influence and similarity metrics. Co-author analysis gauges collaboration by using co-authorship data. Co-word analysis is used to identify conceptual relationships in abstracts, keywords, and document titles. VOSviewer can display bibliometric networks, such as network, overlay, and density visualizations, each emphasizing different aspects. To build a bibliometric network, VOSviewer uses the mapping visualization of similarities (VOS) technique [15].

Citation is an indicator of influence. If a document is highly quoted, the article is considered important, influential, and underlying the content of the document [16]. Citation analysis estimates the influence of a document, author, or journal at the quotation level. McCain [17] states that co-citation analysis creates a similarity metric between a paper, author, or journal based on the number of co-citations. Since citation is considered an indicator of influence, co-citation analysis filters the most important documents [18]. Bibliographic coupling gauges how similar two documents are by counting the references that they have in common [19]. The more bibliographies of two papers in a row, the stronger the link between the two papers [18]. Bibliographic coupling can be used for smaller and unmentioned publications.

Co-author analysis can present the scientific and social structure and show evidence of collaboration. When the two authors collaborated to produce a paper, their partnership was created [20]. Co-author analysis can look at collaboration concerns at the institutional and state levels because bibliographic data contains details on the author's location and affiliation with institutions. Callon et al. [21] define co-word analysis as a bibliometric analysis that builds conceptual structures and links between document words. Words frequently occurring together in documents suggest a tight, meaningful relationship. Co-word analysis can be used on the abstract, complete text, keywords, or titles of documents.

Scopus is the largest indexer of global research content. Scopus includes titles from more than 7.000 publishers worldwide: journals, books, and conference papers [22]. Research data was taken from Scopus, a science journal database service provider. The Scopus metadata contains the keywords "transfer function" and "multi-input" from articles, conference papers, conference reviews, book chapters, reviews, and books in 2007-2023. Several previous studies have explored the multi-input transfer function.

However, no bibliometric analysis of the multi-input transfer function is available. Therefore, bibliometric analysis with VOSviewer is needed to explore the spread of research on multi-input transfer functions.

2. RESEARCH METHODS

This research reviews the literature to summarize and assess datasets of multi-input transfer functions. Using co-word analysis, VOSviewer may be used to visualize research trends and collaboration networks. Co-word analysis creates connections between two or more keywords when keywords occur in the same title, abstract, or keyword list [23]. The research was carried out by examining documents from Scopus [24] in the years 2007-2023 with the keywords "transfer function" and "multi-input." The total number of related papers in 2007-2023 amounted to 2,004 documents and were compiled into one file in the RIS format, as for the research stream depicted in Figure 1.

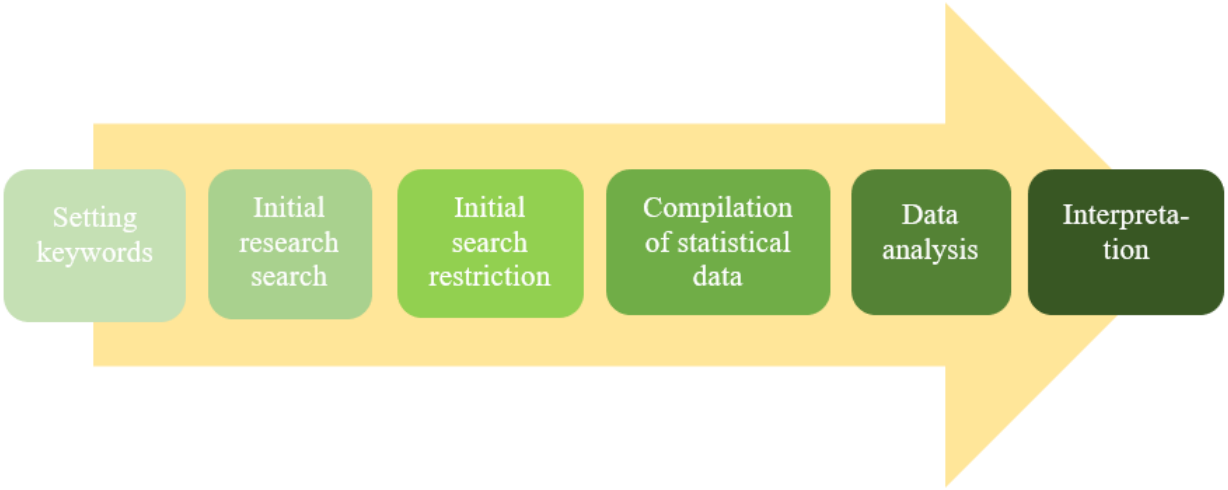

Figure 1. Research stream

According to Figure 1, bibliometric analysis has six stages: setting keywords, initial research search, initial search restriction, compilation of statistical data, data analysis, and interpretation. Filters define the initial search limitation according to the need to select related publications obtained at the previous stage in VOSviewer. Compilation statistics are seen in the graphical visualization of each piece of data. Data interpretation from such visualizations produces information, knowledge, or new science that researchers can develop.

3. RESULTS AND DISCUSSION

3.1 Multi-Input Transfer Function

A transfer function is a function where there is an output (y_t) influenced by an input (x_t) and other inputs combined in a group called noise [25]. This function can determine the relationship and influence between input and output over a period of time [1]. The transfer function maps the input to the output. A multi-input transfer function is a transfer function that has more than one input and one output [26]. This function can be formed when it consists of an output process (y_t) and a number of k input processes. Multi-input transfer functions are generally written as

$$y_t = \sum_{j=1}^{k} \frac{\omega_s(B)}{\delta_r(B)} x_{jt-b} + \frac{\theta_q(B)}{\phi_p(B)} a_t \qquad (1)$$

with $\omega_s(B)$: numerator at s, $\delta_r(B)$: denominator at r, x_{jt-b}: input of j at t, $\theta_q(B)$: parameter of moving average at q, $\phi_p(B)$: parameter of autoregressive at p, and a_t: residual value at t.

3.2 Bibliometrics with VOSviewer

The term bibliometrics itself just crystallized and became popular after the 1970s [27]. The first person to suggest using the word bibliometrics was Pritchard, who argued that the term bibliometric is in harmony with other mathematical studies, such as econometrics (in economics) and biometrics (in biology). Pritchard [27] restricted bibliometrics to "the application of mathematical and statistical methods to books and other media of communication" (p. 348). He's also expanding the area of study. From the brief history of bibliometrics, it can be seen that, at first, this study only focused on matters related to scientists in a particular field before eventually expanding into interdisciplinary studies. Bibliometrics is also closely related to retrieval. This can be seen from the bibliometric relationship with the analysis of the situation.

Bibliometric analysis shows the distribution of publications and quotations from different literature [28]. Both qualitative and quantitative descriptions are possible for topics in bibliometric analysis. Elsevier introduced Scopus as a brand-new search and discovery appliance in 2004. Scopus is a database of quotations and abstracts with peer-reviewed scientific material [29]. The editor and publisher submitted a journal, a conference proceeding, and a book series for inclusion in Scopus. Then, it was evaluated and chosen according to scientific quality standards. Scopus indexed various components from scientific articles acquired from outside publishers, including abstracts, titles, authors' names and affiliations, references, and drug terms [30]. Various publications on multi-input transfer functions in several countries demonstrate this.

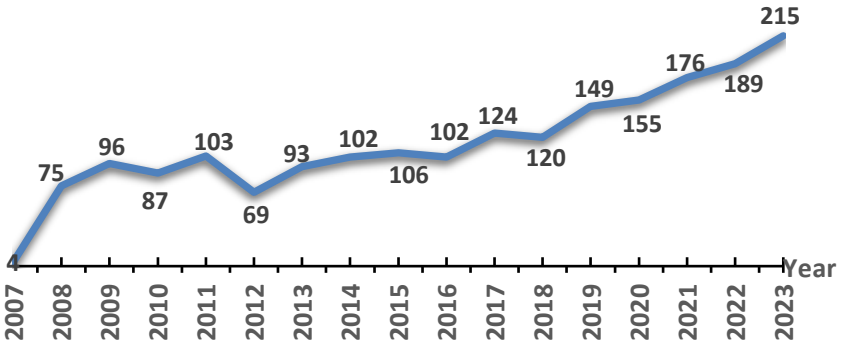

Figure 2. Visualization of previous research on multi-input transfer functions

Figure 2 represents the trend of publications from 2007 to 2023 regarding the multi-input transfer function. It is seen that the trend is rising. The highest increase occurred in 2007-2008, with 32 documents (74.42%), and in 2013, the upward trend began in 2023. Next, in Figure 3, the publications spread to different countries.

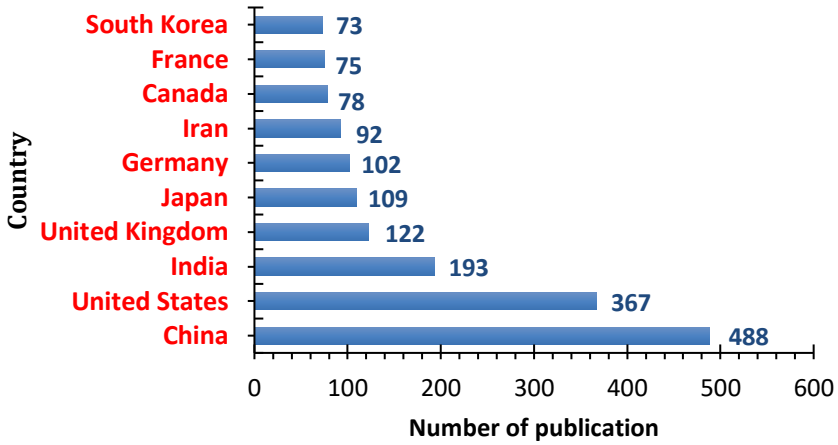

Figure 3. Visualization of research in different countries

Figure 3 represents the ten countries with the most publications, with the top five being China, the United States, India, the United Kingdom, and Japan. Figure 4 shows the types of documents that the researchers have produced.

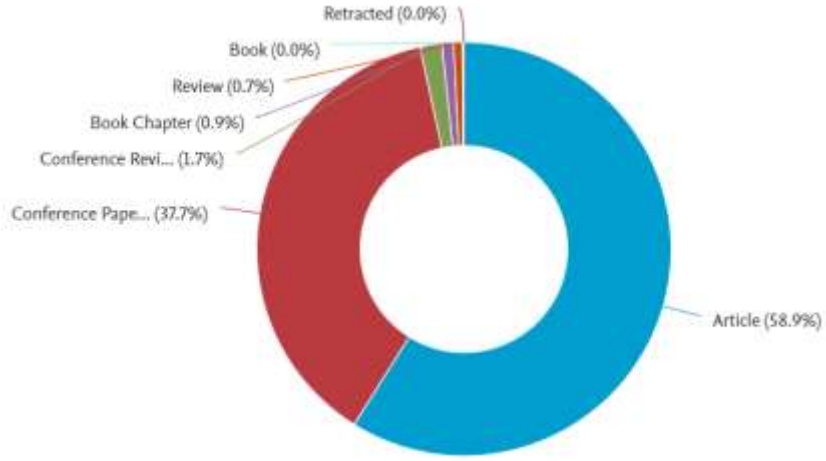

Figure 4. Document-type visualization

According to **Figure 4**, articles, conference papers, and conference reviews are the most commonly used types of documents. Researchers also use other types of papers but need to be more dominant.

Further, the metadata is examined with the VOSviewer by choosing the "create a map based on text data and bibliographic data" option, which tries to establish a relationship between terms or networks **[31]**. Text data creates a term co-occurrence map for title and abstract fields. Bibliographic data is used to create a co-authorship and keyword co-occurrence map. This research uses complete counting to explore the spread of research on multi-input transfer functions and their derivatives by default. **Figure 5** shows that 9 clusters use complete counting methodologies, with a minimum of 10 co-occurrence terms for title and abstract fields.

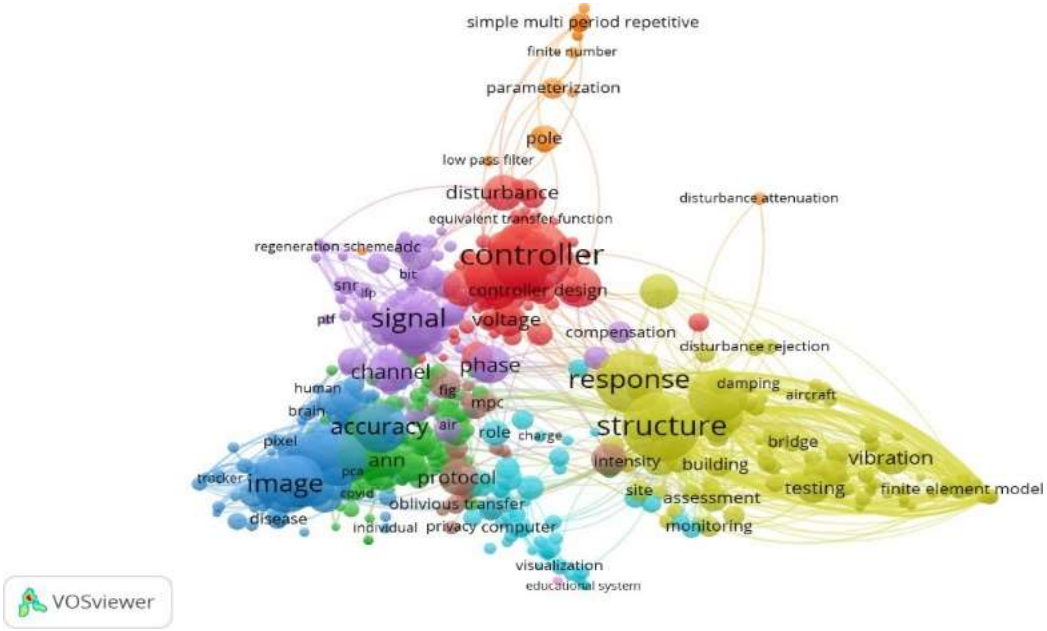

Figure 5. Visualization of titles and abstracts

Figure 5 shows the frequently appearing variables associated with multi-input transfer functions. Every variable is used more when its node (circle) is larger than what it indicates. The dominant clusters are controller, neural network, accuracy, structure, signal, aspect, pole, computation, and multi-point. According to **Figure 6**, there are 10 clusters for co-authorship analysis using complete counting methodologies and author analysis units, with a minimum of 5 documents for each author and a maximum of 25 authors for each document. This map explains a correlation or relationship (represented as an edge or network) between the author's research on multi-input transfer functions.

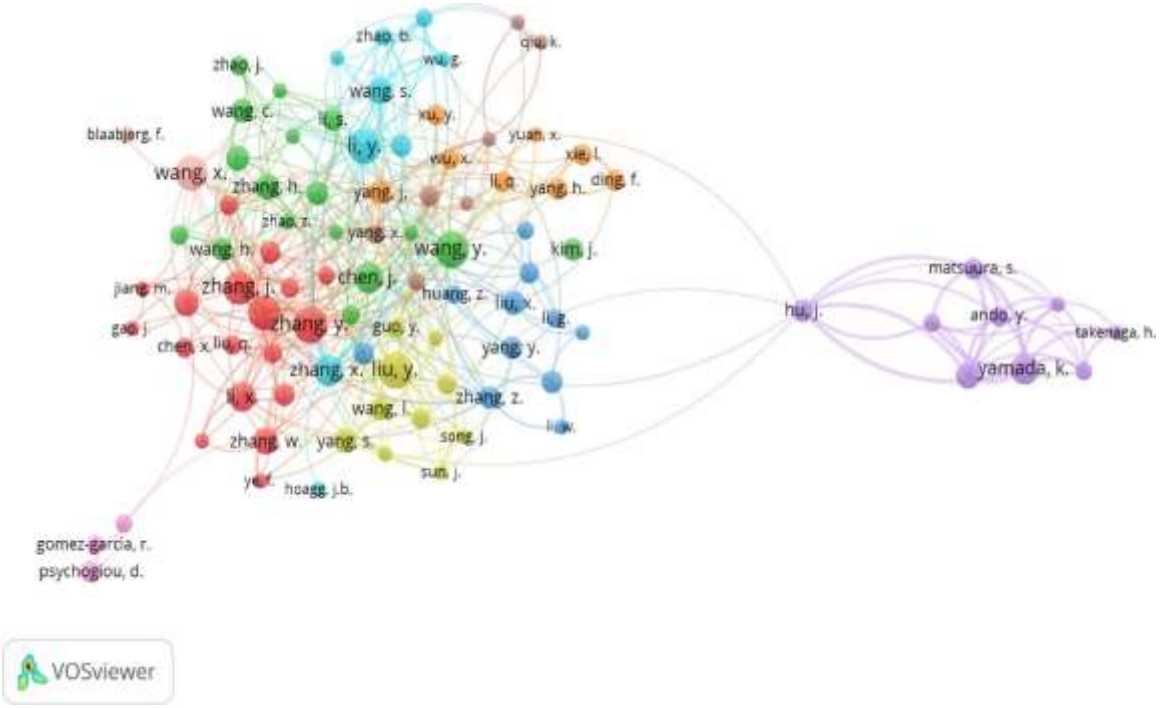

Figure 6. Co-authorship visualization for author

It appears that Zhang y; Wang y; Zhang z; Liu y; Yamada k; Li y; Yang j; Yang x; Yang l; and Wang x dominates each cluster. Then, co-author analysis revealed ten clusters, with prominent researchers like Zhang Y. and Wang Y. dominating. By **Figure 6**, the more times an author publishes his research, the bigger the node (circle) around their name.

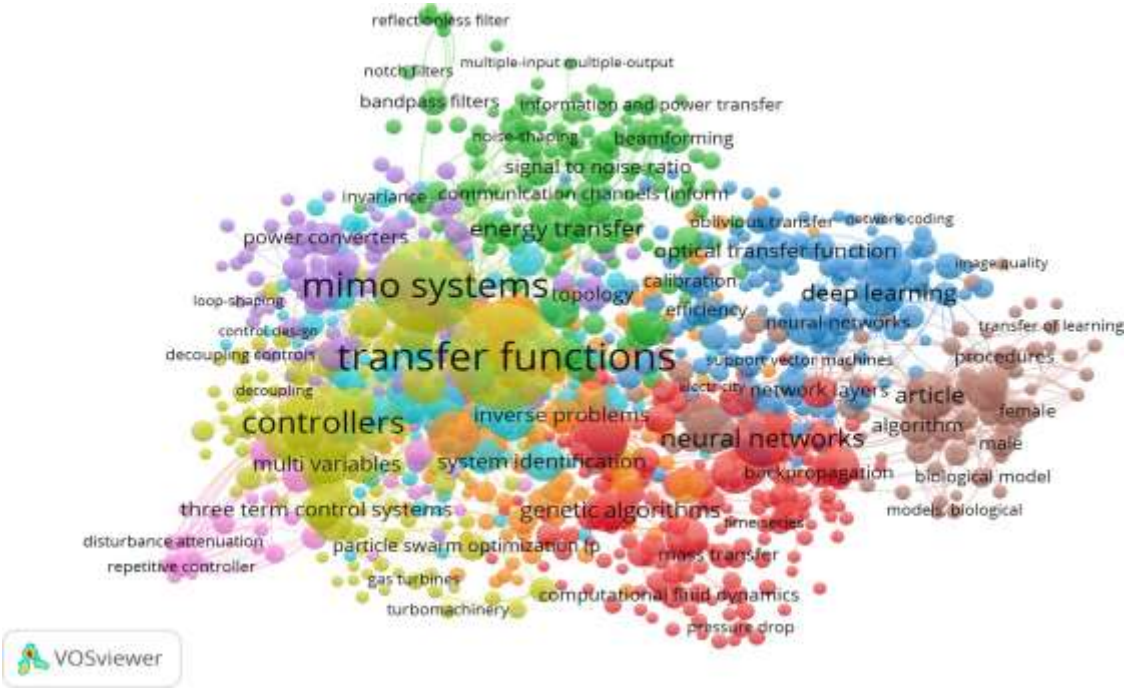

Figure 7. Co-occurrence visualization for keywords

There are 9 clusters for co-occurrence analysis using complete counting methodologies and keyword analysis units, with a minimum of 5 keyword restrictions, as shown in **Figure 7**. Out of 1138 criteria met, 1000 keywords were selected with the strongest co-occurrence link with other keywords. Still, based on **Figure 7**, keyword co-occurrence analysis highlighted optimization, energy transfer, and transfer functions as central themes. Transfer functions have become one of the most frequently used keywords in research.

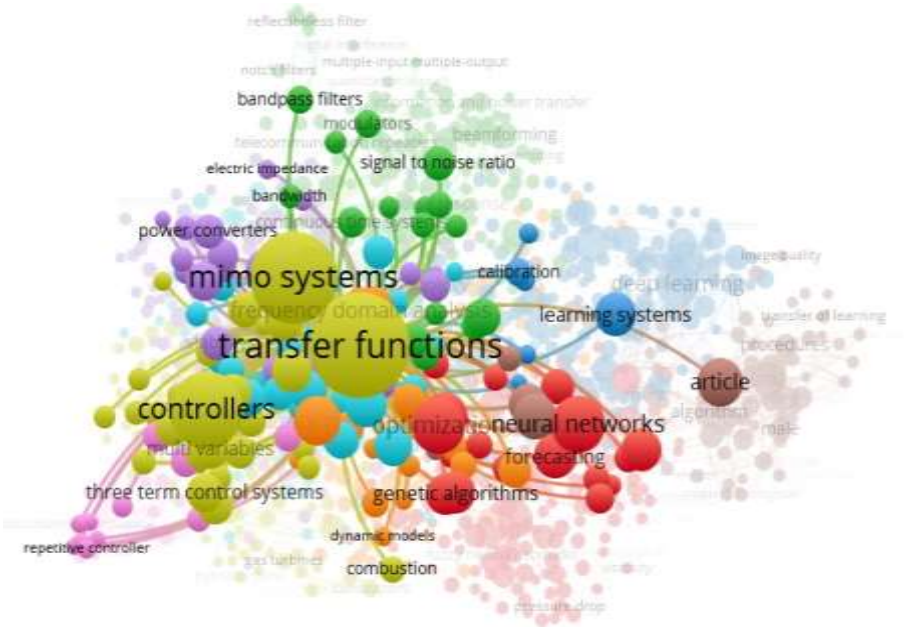

Figure 8. Function transfer term network visualization

Based on **Figure 8**, the development of research on multi-input transfer functions is closely related to transfer functions, MIMO systems, multivariable, noise, impulse response, and so on. Some of these terms are directly related to the formation of the multi-input transfer function. The multi-input transfer function is closely related to the transfer functions because the aggregation of each input of the transfer function produces the multi-input transfer function. In addition, other related terms are MIMO systems, nonlinear, estimation, multivariable process, and error.

4. CONCLUSIONS

Based on the results and discussion, this study demonstrates a growing trend in multi-input transfer function research, with China leading in publications. Research has shown that bibliometric analysis has recently become highly utilized. The bibliometric analysis using VOSviewer revealed significant collaboration and identified key research clusters and themes. The development map of multi-input transfer functions is based on nine co-words and ten co-author clusters. Based on co-occurrence mapping (keywords), transfer functions have become a commonly used term in research. Despite extensive applications of the model, numerical approaches for parameter estimation still need to be explored. Future research should focus on developing these numerical methods to enhance the accuracy and applicability of multi-input transfer functions.

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