Asian Journal of Natural Sciences (AJNS)
Vol. 4, No.2, 2025 : 105 - 116

Bibliometric Analysis on Kernel Regression Models: Identification of Research Gaps and Future Development Directions

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A R T I C L E I N F O

Keywords: Bibliometric analysis, Gaps research, Open knowledge maps, Kernel Regression, VOSviewer

Received : 11, April
Revised : 23, April
Accepted: 20, May

A B S T R A C T

Bibliometric analysis was conducted to identify trends and gaps in research related to kernel regression models. The data of this research is sourced from Scopus metadata from 2000-2025. The co-word analysis method was applied to determine a pattern of relationship between keywords in research, with the Vosviewer visualization tool used to visualize a relationship between keywords and areas that are often researched. Based on the results of the analysis, it is stated that topics such as "kernel density estimation" and "kernel metdhods" have been widely researched, while topics such as "kernel learning" and "Bayesian optimization" tend to be little of rarely researched, which means that there is significant research gap. The keyword co-occurrence analysis result show that there have been many articles on the application of kernel regression in health-related research, especially on the topics of "breasth cancer" and "immunothereapy". Further research on less researched topics is expected to fill the research gap and open up an opportunity for the creation of a new method and new applications in kernel regression. It also provides new insights for readers and researchers to formulate more effective and innovative research strategies in the future.

DOI: https://doi.org/10.55927/ajns.v4i2.30
E-ISSN: 2986-2787
https://journal.formosapublisher.org/index.php/ajns

INTRODUCTION

Technological developments in recent decades have accelerated the growth of scientific publications in various fields of science. The increase in the number of publications poses a new challenge to evaluate and map the development of science at large. One method that has gained attention is bibliometric analysis (Krauskopf, 2019), which uses quantitative data from scientific publication data, such as the number of articles, citations on research, patterns of collaboration between authors, countries that routinely publish them, as well as to identify research trends and scientific developments that are happening in recent years. Bibliometrics is a quantitative approach to measure the pattern of publications, collaborations between researchers and the circulation of a work in the scientific literature.

Regresi kernel merupakan metode yang sering dipakai pada analisis data nonparametrik (Rubio et al., 2007). Topik regresi kernel sudah banyak dilakukan penelitian, meskipun begitu topik penelitian regresi kernel masih terdapat adanya kesenjangan penelitian(Tran, Chi, Tam, Phan, Giang, Latkin, Cyrus, 2020). Menganalisis dan mengidentifikasi suatu kesenjangan pada suatu topik penelitian sangat penting, berguna agar penelitian selanjutnya dapat diarahkan untuk mengeskplorasi topik-topik atau penerapan yang kurang dieksplorasi (Wang et al., 2025). Analisis kesenjangan pada penelitian merupakan hal yang sangat penting untuk kebanyakan peneliti guna memperluas pemahaman serta membuka peluang adanya metode dan penerapan baru pada suatu bidang atau topik (Bartol et al., 2017). Bibliometric analysis can be helpful in identifying a research topic that has been published in Scopus. Bibliometric visualization analysis provides a broader new knowledge, understanding, and view of kernel regression topics, ranging from new and expandable applications (Donthu et al., 2020). In bibliometric visualization, it can also be seen that bibliometrics is able to show an interaction between researchers on kernel regression topics. The use of Vosviewer and Open Knowledge Maps software for researchers to find out a visualization of the relationship between keywords in an article can show a potential collaboration between researchers from different parts of the world (van Eck & Waltman, 2010). This utilization is an important factor in accelerating the progress of regression methods or topics and their application in various fields of science.

The application of visualization software such as Vosviewer and Open Knowledge Maps helps to visualize the network of collaboration between authors and the network between keywords in articles that show dominant topics in a field of research, which are usually underpaid or under-researched in current research (Anker et al., 2019). The Open Knowledge Maps software provides access to publication datasets of relevant topics that can support bibliometric analysis. Identifying gaps in research allows researchers to focus attention on areas that are likely to have great potential that could yield important contributions in areas such as regression. Thus, more in-depth research can be created to address research gaps in kernel regression. This provides an opportunity for researchers to explore the material and applications of more innovative kernel regression in the future.

In this study, bibliometric analysis was carried out to identify a gap in the research with the topic of kernel regression, using software that can visualize the dataset of publications in Scopus, namely Vosviewer and Open Knowledge Maps. The results of the bibliometric analysis can provide an overview of research trends on the topic of kernel regression and identify areas that are less paid attention to so that they need to be developed more deeply in the future to fill the research gap. Through this research, it is hoped that new methods and new applications can be found so that they can be petrified in the future.

LITERATURE REVIEW

Bibliometric analysis is a useful method to find out a gap and the development of topics in the scientific literature. On the topic of kernel regression, bibliometric analysis can provide a visualization of research trends, development methods in research and can determine the gaps in a research topic (Donthu et al., 2021). The use of keyword analysis and mapping of relationships between studies provides opportunities for researchers to explore a topic, find out the collaborative relationship between researchers, and find out a growth pattern and publication trend in the field or topic being researched (Rohanda & Winoto, 2019). Bibliometric analysis can also help to find new methods and new applications based on existing research gaps.

Bibliometric analysis was able to visualize a surge in publications on the topic of kernel regression in the last five years, indicating that the researchers' sentiment towards the method or topic is favorable. A bibliometric analysis conducted by Hafeez et al. showed that although there has been a significant improvement in the topic or research, most of it is still largely concentrated in one area and less explored about the field of application in a broader context for the future. Therefore, bibliometric analysis is an important factor in helping to identify these deficiencies with the aim of opening up new opportunities for more applicable research advances in the future.

METHODOLOGY

The data of this research is taken from Scopus scientific data, the data taken includes journal publications, conferences, keywords in research, and various other scientific sources published from 2000 to 2025, the articles to be studied are articles with the keyword "kernel regression" being the main focus of the research. The keyword "kernel regression" is a topic that is focused on identifying research gaps and analyzing a trend on the research topic during that period. To identify research trends and develop analytical strategies for future research. This study utilizes a co-word analysis technique that allows to identify a pattern of relationships between keywords in the Scopus study. This analysis provides in-depth insights into how the concepts in kernel regression are interconnected, as well as identifying areas that have opportunities for further and extensive development for future advancements. Bibliometric analysis methods have played an important role in knowing the evolution of kernel regression from various research areas over the past two decades (Vílchez-Román et al., 2021). The analysis in this article focuses on a research

trend to find out developments on the topic as well as look for gaps in research. The main focus is directed at the identification of an increasing number of publications related to keywords in abstracts, paying attention to research trends on kernel regression in various fields of science such as statistics, machine learning, mathematics, health, computer engineering and so on (Muhuri et al., 2019). With this research mindset, it can reveal research gaps and find out the development of theory and its application. The steps of the research are shown in Figure 1.

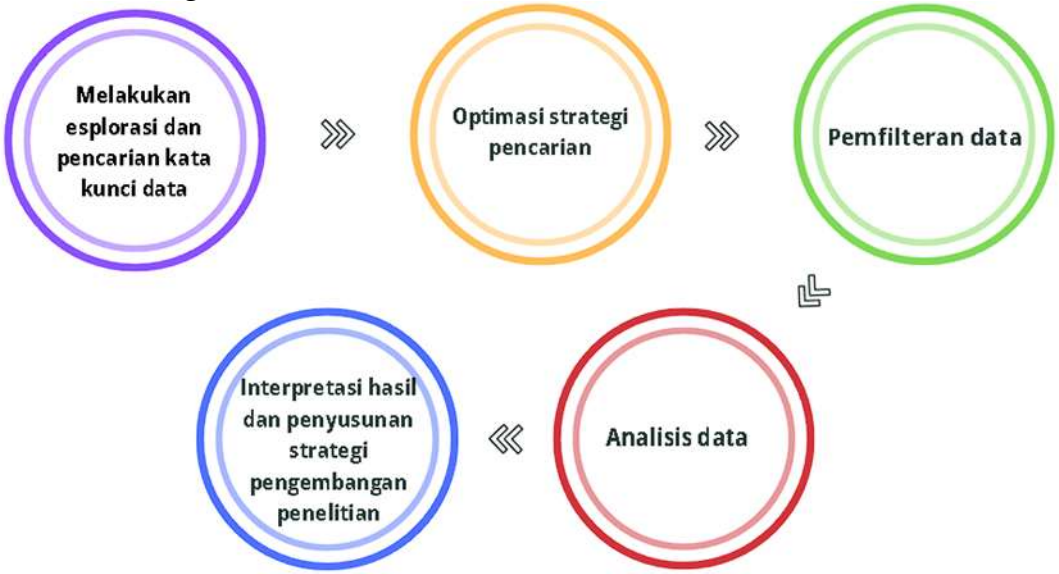

Figure 1. Research steps

Based on Figure 1, the research steps include exploration and search for initial data keywords, optimization of search strategies, data filtering, in-depth data analysis and data mapping, as well as interpretation in the preparation of research strategies to determine the latest topics or applications to fill the research gap. The steps in the image show how research data analysis at Scopus can accelerate the understanding of research trends and facilitate the development of future research (Aria & Cuccurullo, 2017). Advanced analysis uses bibliometric methods to evaluate the relationships between themes or keywords in each study, research area, and subject area of research. With the help of analysis software such as VOSviewer and Open Knowledge Maps, researchers can map dominant themes as well as understudied themes. Interpretation to develop a research development strategy is carried out based on findings from the field of study studied. The thing that must be considered to conduct research on bibliometric analysis to develop a research strategy for a clear future is to understand the areas that need to be further developed, especially those that have not received much attention from researchers based on the Scopus publication site (Halepoto et al., 2022). Advanced analysis uses bibliometric methods to evaluate the relationships between themes or keywords in each study, research area, and subject area of research. With the help of analysis software such as VOSviewer and Open Knowledge Maps, researchers can map dominant themes as well as understudied themes. Interpretation to develop a research development strategy is carried out based on findings from

the field of study studied. The thing that must be considered to conduct research on bibliometric analysis to develop a research strategy for a clear future is to understand the areas that need to be further developed, especially those that have not received much attention from researchers based on the Scopus publication site (Halepoto et al., 2022). The results of this bibliometric analysis process are expected to provide a comprehensive overview of the direction of a research development on the topic of kernel regression. Using visualizations of the results from the VOSviewer software and Open Knowledge Maps, researchers can identify the groups or groups of themes that appear most frequently and those that are rarely or least explored. This visualization provides a more structured view and allows researchers to utilize the information in formulating new topics that are relevant for the future (Aria & Cuccurullo, 2017). This can be helpful in determining a relevant research topic for the future.

RESEARCH RESULT AND DISCUSSION

In the results and discussion section, an interpretation of the size and slices of the set bubble in the visualization of kernel regression research, the identification and analysis of emerging topics in kernel regression research, the analysis of keyword relationships in kernel regression research, and the analysis of the most widely studied fields of science in the research.

Interpretation of Size and Slice of Set Bubbles in Kernel Regression Research Visualization

Visualization of bibliometric analysis data provides an opportunity for researchers to be able to better know and understand a trend in research. Using software such as Open Knowledge Maps, the visualization forms an identifiable pattern of research patterns that help to identify topics that are lacking in research. Data visualization provides a clear picture and can help researchers to know and research topics that need more research (Md Husin et al., 2024). The most important thing about bibliometric visualization analysis is its ability to provide more in-depth and broad information about collaboration between authors and relationships between fields of science. This visualization not only provides information on emerging topics, but also shows the linkages between various scientific disciplines that can enrich the perspective of researchers' knowledge. In the context of kernel regression, visualization analysis can help to find out a relationship between topics through keywords in the article. In addition, bibliometric analysis is also useful to know a topic is developing, this process helps to identify trends in the long term, it indicates that the research topic is debuting is being or may develop over time (Li et al., 2025). The bibliometric analysis method allows researchers to find out the direction of future research trends. On the topic of kernel regression, this visualization provides a great opportunity for a great opportunity to create a development in methods as well as in applications in real fields such as data analysis (Wang et al., 2025). Research on the topic of kernel regression has been widely published in various countries on the Scopus publication site. Scopus is the world's largest database of publications that includes literature and articles from various fields of science.

Scopus includes more than 80 million documents from more than 25,000 peer-reviewed journals, including articles, conference proceedings, books, and patents. With Scopus metadata, mapping and research development strategies can be carried out. Research on kernel regression is shown in Figure 2.

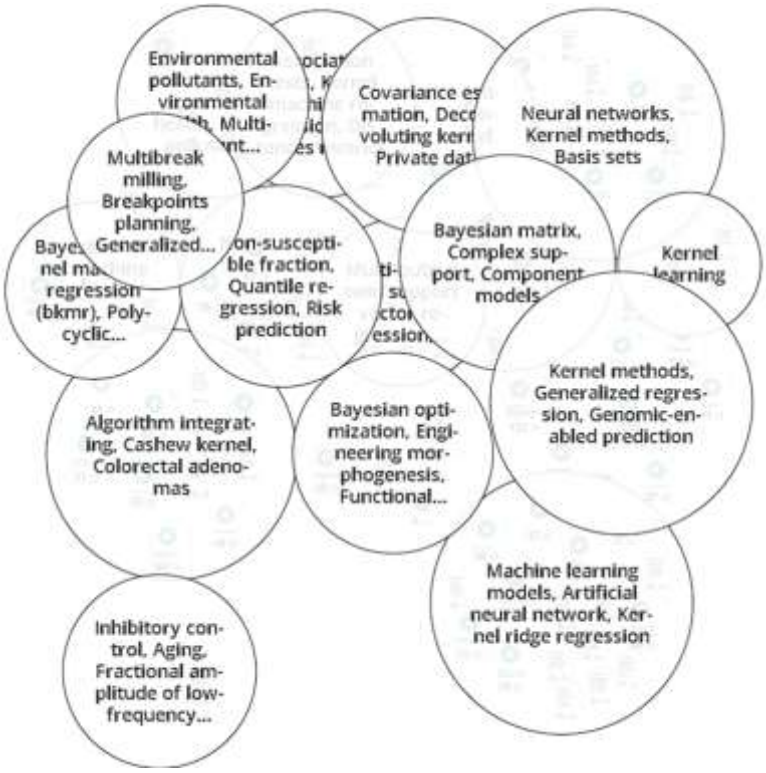

Figure 2. Bubble Map kernel regression research on Scopus

Figure 2 shows the number of late-published studies on kernel regression. In the image, it can be seen that there is the largest research set and has several slices with the surrounding set with research "*kernel density estimation*", "*kernel methods*" and "*Bayesian matrix*" which means that a lot of research has been done on this subject. In the image, it can also be seen that there are research sets that are small in size and have a few slices with the surrounding sets, such as the "*kernel learning*" set and the "*Bayesian opitimization, engineering morphogenesis*" set, which means that there is still little research done on this subject. This indicates that the theme of the research is still rarely researched and may have the potential for gap research.

Identify and Analyze Emerging Topics in Kernel Regression Research

In recent years, research on kernel regression has grown rapidly and along with the increasing interest in nonparametric regression methods. Kernel regression, as a flexible method of addressing data that cannot be processed by parametric models has gained widespread attention across various disciplines (Wang et al., 2025). Various new innovations have emerged, researchers have begun to pay attention to directions, new trends that continue to emerge and evolve with advanced topics. These new trends reflect a shift in the focus of

research, from basic kernel regression techniques to more complex applications in fields such as machine learning. The follow-up topic shows the subject area that is developing in a study (Saputro et al., 2023). In kernel regression research, showing an advanced topic trend is very important for researchers to keep up with the development of new methods, applications, and theoretical advancements. Further topics in kernel regression research in Scopus are shown in Figure 3.

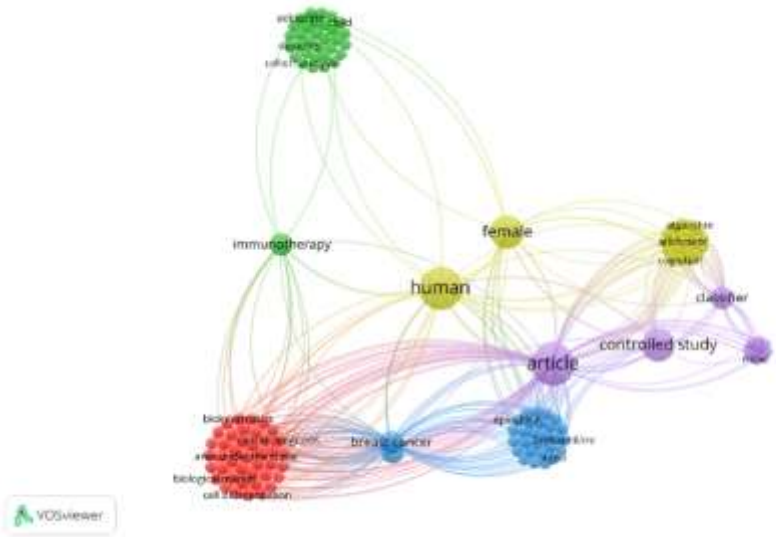

Figure 3. Visualization of advanced topics in kernel regression research

Keyword Relationship Analysis in Kernel Regression Research

Keywords are an important element in understanding the main theme of a research, as they reflect the main concepts discussed in each article (Ellegaard & Wallin, 2015). By visualizing the frequency and interconnectedness between keywords, keywords can identify the most dominant topics and be able to find out how these topics are interconnected. The analysis of co-occurrence in kernel regression research in Scopus is shown in Figure 4.

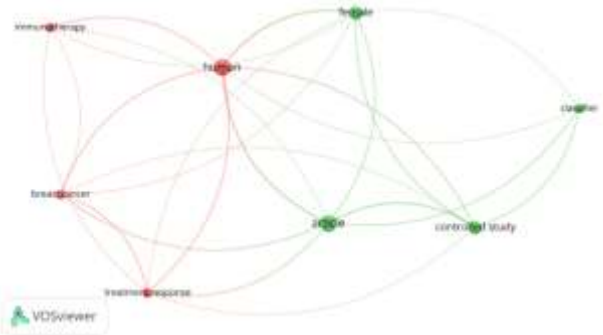

Figure 4. Co-occurrence visualization in kernel regression research

Figure 4 shows studies that use kernel regression, it can be seen that several keywords such as "breast cancer", "treatment response", "immunotherapy" are interconnected with the keyword "human" which means that research that uses kernel regression is dominated by research related to the

world of human health (Li et al., 2025). Keywords in Figure 4. It can be seen if the research topics have been researched and written in abstracts at least four times. Based on Figure 4. It can be seen that there are studies related to the field of soft computing, mathematics is still not too much. This identifies that keywords that are not visible in the image above are opportunities for researchers to fill research gaps and can contribute to the development of new themes in kernel regression so that they are useful for future technological advancements.

The Most Studied Fields of Science in Research

The influence of disciplines in scientific publications is an important indicator of the development and contribution of science in a field. Disciplines with strong publication influence can be key to solving global challenges and accelerating technological innovation. Many fields of science have resulted in publications in leading databases, one of which is at Scopus (Erfanmanesh et al., 2017). The following shows the use of advanced analysis methods such as kernel regression in various studies, as shown in Figure 5.

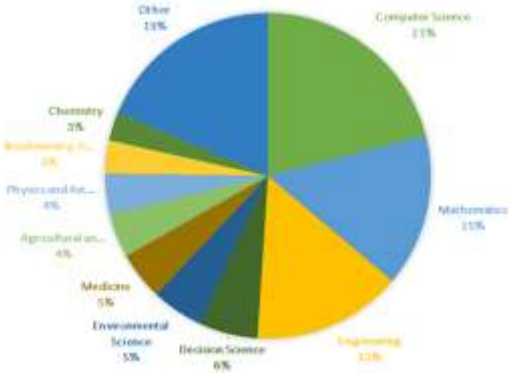

Figure 5. The research uses kernel estimation in various scientific fields

Figure 5 shows the various scientific fields that used kernel regression in Scopus from 2000 to 2025. The most scientific fields were researched using kernel regression, namely in the field of "computer science" which was 21% or as many as 9,217 documents, followed by other fields containing 11 scientific fields with a total of 18.7%. Based on Figure 5. It can be said that research on kernel regression in the field of science whose number of publications is less than 3% of the number of Scopus publications on the keyword "kernel regression" has a greater level of research gap compared to the field of science that has the number of publications above 3% of the number of Scopus publications on the keyword "kernel regression". Figure 5 shows the various scientific fields that used kernel regression in Scopus from 2000 to 2025. The most scientific fields were researched using kernel regression, namely in the field of "computer science" which was 21% or as many as 9,217 documents, followed by other fields containing 11 scientific fields with a total of 18.7%. Based on Figure 5. It can be said that research on kernel regression in the field of science whose number of publications is less than 3% of the number of Scopus publications on the keyword "kernel regression" has a greater level of research gap compared to the field of science that has the number of

publications above 3% of the number of Scopus publications on the keyword "kernel regression".

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and discussion, this study succeeded in identifying research gaps in the application of kernel regression, especially on topics such as "Bayesian automation" and "kernel learning" which appear to have a small set size and a less strong slice in the surrounding set which means that there are still few studies that address these topics. Based on the results of bibliometric analysis using Vosviewer, it can be seen that topics with a small bubble size indicate that research on these topics or areas is relatively limited. Therefore, there is a great opportunity for researchers to explore these topics further, reduce research gaps, and open up an opportunity for innovation in the development of methods and applications of kernel regression in various fields, including in the fields of health and technology. This research provides important insights for the development of more relevant and innovative research strategies in the future, with a focus on areas that are less explored and have the potential to make a significant contribution.

ADVANCED RESEARCH

This study has certain limitations; therefore, future research is recommended with broader scope and approach to obtain more optimal results.

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