Getting to Know the Last Five Years Trend on Microcontroller Research: A Bibliometric Analysis

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Abstract. A microcontroller is a compressed microcomputer manufactured to control embedded systems in office machines, robots, home appliances, motor vehicles, and several other gadgets. This device has played significant and essential roles in daily human life. Unfortunately, an in-depth analysis related to microcontrollers has not been found. Hence, it is compulsory to conduct a comprehensive analysis to understand better the research themes and trends in a specific scientific scope. This study aims to determine the extent of the research development on microcontrollers carried out throughout 2017-2021 through bibliometric analysis. From the bibliometric analysis that has been performed, we can conclude that research on microcontrollers is dominated by sensors, algorithms, voltage, and power. On the other hand, research that shows the relationship between solar panels and microcontrollers is still lacking. With this finding, it is hoped that researchers will focus their research on potential topics that are rarely looked at.

1. Introduction
Since the early 1980s, a small number of manufacturers began to build microprocessors into their products to reduce the number of chips, with the aim of lowering production costs and thereby reducing end-user prices. While microprocessors greatly improved what they replaced, they were not complete magical components for lowering the cost and complexity of product design. The problem was that in order for a microprocessor to be able to do useful things, it must be surrounded by lots of additional input-output (I/O) chips and other supporting chips. In the 1990s, silicon processing and improved chip manufacturing techniques put more circuits with additional functions and features on a single chip. This chip was then called a microcontroller [1].

The existence of microcontrollers in electronic products is no longer a question and an indisputable fact. Their use is no longer limited to home and office equipment, instruments and machines, but has also penetrated into everyday life [2]. Significant increases in capability, speed and cost reduction have contributed to the widespread use of microcontrollers. Lately, microcontrollers have been embedded in intelligent sensors [3], which are suitable for controlling processes and product functions. The revolution in information technology (IT) has made it possible to have a flexible means of controlling home appliances through microcontroller-based systems. This revolution occurs because microcontrollers bring the flexibility of program control and the computing power of computers to solve any problem. The product with an embedded microcontroller behaves as an intelligent system. These systems use intelligence to automatically control electronic devices like lights, fans, radio sets, television sets, air conditioners, security cameras, etc. They focus more on comfort and efficient utilization of electricity [4]. If necessary, it could be an autonomous user more minor system [5].
However, there has been no bibliometric analysis that has reviewed the trends of microcontroller research over the last five years. The study conducted by Hsiung did review the development of microcontrollers in technology, but the study was conducted in 1992 and did not use bibliometric analysis [6]. There are also the studies by Guven et al. [7] and Shi Y et al. [8], which discusses the concept of a microcontroller-based system and the use of a microcontroller for measurement and control. Nevertheless, both of them did not use bibliometric analysis as a research method. Therefore, it is imperative to know how far the development of microcontroller research during the last five years. Based on these facts, the objective of this study is to determine the extent of research related to microcontrollers by providing bibliometric analysis on the Scopus database so that opportunities for further research can be determined.

2. Method
Bibliometrics is a mathematical and statistical methodology that comprises scientific publications, citations, reports, and patent documents [9]. Bibliometric analysis is a scientific computer-aided review technology that recognizes and identifies core research or writers and their connections by enclosing all publications associated with a particular subject or scope [10]. The bibliometric analysis accommodates an accurate and objective method for measuring the implication of an article to the progress of knowledge and is an often-used tool for scrutinizing trends and performance in a particular subject [11]. The data analyzed in this study was taken from the Scopus database, which is well-known as one of the world's largest literature databases and provides good scientific, academic information [12,13]. The data collection was carried out in August 2021 using the keyword "microcontroller" according to the criteria "titles, keywords, and abstract" and was devoted to 2017-2021. The bibliometric analysis had been employed in this study to map the research trend on the microcontroller.

In this study, VOSviewer was used to visualize and explore the trend. This software was chosen because it provides interactive options and functions that are easy to access and explore bibliometric data networks, such as the number of citations or co-occurrence relationships between key terms and concepts [14]. VOSviewer is capable of constructing publication maps, country maps, journal maps built upon a network (co-citation), forming a keyword map based on shared networks, and establishing maps with a copious amount of objects [15].

3. Results and Discussion
A research paper's keywords are an essential element that contains meaningful information about the paper [9]. Because scientific texts may be reduced to a set of combined appearances between the words they include, keyword analysis has enabled the detection of present or future prominent research subjects based on co-occurrence analysis. If two concepts regularly appear together in one group of papers but rarely do so alone in another, their co-occurrence is exceptionally high [16].

In this study, a search for the keyword "microcontroller" from Scopus yielded 1,662 documents of various types (conference papers, book chapters, reviews, books, notes, and editorials). These 1,662 documents are the result of publications from 2017 to 2021, as seen in Figure 1.
Figure 1. Number of publications on microcontroller topic in 2017-2021 taken from Scopus

We can see in Figure 1, the most microcontroller-topic research documents were produced in 2019. On the other hand, in 2021, the number of publications on this topic reached the lowest number. This number can still increase because the number of documents recorded in Scopus when this data was taken from January to early August 2021.

As previously mentioned, the 1,662 documents consisted of various types of documents with details of 1,131 conference papers, 494 journal articles, 20 book chapters, eight reviews, six books, two notes, and one editorial (Table 1). According to Table 1, conference papers dominate research on the microcontroller. This dominance is followed by journal articles, whereas notes and editorial ranked at the bottom.

Table 1. The number of document types

| Document type   | Number |
|-----------------|--------|
| Conference paper| 1,131  |
| Journal article | 494    |
| Book chapter    | 20     |
| Review          | 8      |
| Book            | 6      |
| Note            | 2      |
| Editorial       | 1      |

3.1. The overlay visualization of microcontroller

In the overlay visualization, the novelty of the publication year of each published article can be seen based on the keywords/terms described by colour gradations from dark blue to bright yellow, or in other words, showing traces of research history from year to year. Keywords with the dark blue colour indicate that they were included in the research of around 2018. In the meantime, research with the term/keyword "pulse", which is bright yellow concluded that studies related to this keyword were published in 2019. By conducting an in-depth analysis of each yellow keyword/term in the visualization overlay, it will follow new trends in microcontroller research in the world.
Judging from the visualization of Figure 2, the lines connecting the points or nodes are pretty many. However, the most prominent is the nodes connecting the temperature and algorithm to the sensor. Both the temperature and algorithm have been around since 2018. Although other nodes showing 2018 also exist, but both of them look the most prominent among the others. This indicates that temperature and algorithms are the most popular topic compared to other topics such as converter, humidity, and platform.
3.2. The density visualization of microcontroller

The density view is beneficial for getting a quick overview of the overall structure of the map and for highlighting the most critical sections on the map [17].

![Density visualization of microcontroller topic during 2017-2021](image)

**Figure 3.** Density visualization of microcontroller topic during 2017-2021

Figure 3 depicts the depth of research related to the topic area. The proportion of two colours mixed depends on the total item density of a point. The closer a point’s colour is to the background colour, the lower its overall item density. Also, it is reasonable to assume that higher density means the topic is well-developed to study [18].

In Figure 3, some topics are rarely investigated, for example, FPGA and solar panels. Sensors and algorithms, on the other hand, remain the prima donnas of microcontroller-related research.

3.3. The network visualization of microcontroller

Using VOSviewer, a network visualization was carried out on all these documents (Figure 4). The thickness of the connecting line indicates the strength of the topic field or keyword pair [15]. In the network, the nodes and more prominent words reflect their highest occurrence, the colours indicate clustering, and the lines show the interrelationship of the keywords [19].

There are five clusters (red, green, blue, yellow, and purple) in the mapping of microcontroller research. The cluster represented by different colours shows a relationship between one topic and another, and nodes in the same colour cluster suggested a similar topic among these publications. Of the five clusters, the yellow and purple clusters are topics that are rarely explored. It can also be seen from Figure 4 that sensor, algorithm, voltage, and power are the dominant topic in microcontroller research, and this means that researchers discuss these four topics mainly. Among the four, the sensor is the most popular one because of its largest node size, which indicates that the keyword “sensor” is chosen together in microcontroller-related research.

We can see in the red cluster that temperature and humidity are the most frequently associated topics to the sensor. From this, it can also be known that temperature and humidity sensors are the types of sensors that are developing rapidly in their research when compared to other types of sensors.
As we know, one of the nodes in the yellow cluster is the sun. When the sun is chosen as the keyword to visualize the network as pictured in Figure 5, it is clear that there are only seven nodes connected to it. Sensor, power, position, source, efficiency, solar panel, and solar energy are among the seven points. Note that three of the seven points are part of the red and blue clusters, namely sensors and positions that belong to the red cluster and positions that belong to the blue cluster.

Perhaps, not many researchers conduct studies on the sun because it is constrained by the high initial installation cost, which is one of the most significant drawbacks of solar energy systems [20]. This fact corresponds with the findings of David et al. They claimed that articles discussing solar energy from a technical point of view were still few compared to those discussing solar energy management [21].
4. Conclusion
From the bibliometric analysis carried out, the conclusion certified that there were five main clusters in research on microcontrollers. In addition, it was also discovered that sensors, algorithms, voltage, and power continued to dominate research on microcontrollers. On the other hand, research that showed the relationship between sun and microcontrollers was still lacking. Also, through bibliometric analysis, this research is advantageous for depicting a comprehensive research framework and allowing future scientists to focus more on rarely explored specific topics.

Acknowledgment
This study was supported by Penelitian Kebijakan FMIPA Universitas Negeri Surabaya 2021.

References
[1] Trevennor A 2012 *Practical AVR microcontroller* (Berkeley, CA: Apress)
[2] Al Dhaher A H G 2001 *Microprocess. Microsys.* 25 317
[3] Al Dhaher A H G 2004 *Int. J. Eng. Educ.* 20 52
[4] Vincent E and Godswill O 2018 *Researchjournali’s J. Comput. Sci.* 5 1
[5] Kelemen M, Prada E, Klemenova T, Mikova L, Virgala I, and Liptak T 2015 *Appl. Mech. Mater.* 816 248
[6] Hsiung S C 1992 *Research and Development of Microcontroller Experiment Instructional Units and Their Effectiveness with Industrial Technology, Electronic Technology, and Electrical Engineering Technology Majors Retrospective Theses and Dissertation 1003* (USA: Iowa State University)
[7] Guven Y, Cosgun E, Kocaoglu S, Gezici H, and Yilmazlar E 2017 *Res. Inventy Int. J. Eng. Sci.* 6 38
[8] Shi Y, Qiu G, and Wang N 2020 Basic microcontroller use for measurement and control *Introduction to Biosystem Engineering* eds Holden N M, Wolfe M L, Ogejo J A and Cummins E J (USA: American Society of Agricultural and Biological Engineers and Virginia Tech Publishing)
[9] Shi J, Miao W, and Si H 2019 *Sustain.* 11 988
[10] Han J, Kang H, Kim M, and Kwon G H 2020 *J. Biomed. Inform.* 109 103516
[11] Herdianto R, Windyaningrum N, Masruroh B, and Setawan M A 2021 *Belantika Pendidik.* 4 44
[12] Hamidah I, Sriyana, and Hudha M N 2020 *Indones. J. Sci. Technol.* 5 209
[13] Klapka O and Slaby A 2018 Visual analysis of search results in Scopus database *Digital Libraries for Open Knowledge TPDL 2018 (Lecture Notes in Computer Sciences vol 11057)* eds Mendez E, Crestani F, Ribeiro C, David G and Lopes J (Switzerland: Springer Nature) p 340
[14] Van Eck N J and Waltman L 2011 *ISSI Newsol.* 7 50
[15] Efendi D N, Irwandani, Anggraini W, Jatmiko A, Rahmayanti H, Ichsan I Z, and Rahman M M 2010 *J. Phys. Conf. Ser.* 1796 012096
[16] González-Zamar M D, Abad-Segura E, Vázquez-Can E, and López-Meneses E 2020 *Electron.* 9 1246
[17] Van Eck N J and Waltman L 2010 *Scientometr.* 84 523
[18] Chen X, Chen J, Wu D, Xie Y, and Li J 2016 *Procedia Comput. Sci.* 91 547
[19] De Moraes L L and Kafure I 2020 *RDBCJ: Digit. J. Libr. Inf. Sci.* 18 e020016
[20] Kabir E, Kumar P, Kumar S, Adelodun A A, and Kim K-H 2018 *Renew. Sust. Energ. Rev.* 82 894
[21] David T M, Rizol P M S R, Machado M A G, and Buccieri G P 2020 *Heliyon* 6 e04452