Knowledge growth and development: internet of things (IoT) research, 2006–2018

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ABSTRACT

The term "Internet of Things" first appeared in publication paper since 2006, describing the paradigm of evolution concept that brought about by the presence of internet technology (Vermesan and Friess, 2015) which is very important in contemporary circumstances. This study conducted an in-depth analysis of the research material written on 26420 papers which focused on the published Internet of Things (IoT) research, starting from the firstly year IoT keyword appeared in 2006 until 2018. The selected paper is a combination of various disciplines and publications which are all indexed by Scopus wherein the article discusses IoT. IoT articles are classified using key attributes in sequence: the methodology used, general knowledge and applied concepts, and various general exploration topics. By using the Scientometrics method, this method will group the overall terms that appear frequently from the Scopus paper database according to keywords, titles, and abstracts. The resulting data is then studied to understand and distinguish trends that occur in the time span along with the general characteristics of the paper, in the mathematics visual scheme. All various issues that are considered in the paper's methodology selection, their studied and services innovations, and continuing discoveries on the characteristics, concepts, and processes applied to IoT success. Although it only involves scopus indexed paper, this study found a remarkable increase in the number of articles on IoT in each category of the paper. This study also reveals the direction of the regular discipline of knowledge. The use of the Scientometrics method makes the analysis able to focus on the movement of characteristics and IoT themes to researcher's direction that has not found at this time, as a comprehensive guide to further research and industry strategy that is more directed on concepts that support the 4th industrial revolution.

1. Introduction

The entire study in the paper between 2006 and 2018 carries a record of 8510 journal papers and 16775 conference proceeding papers that discuss the Internet of Things. The article Internet of Things starts from the following three conference papers (Adelmann et al., 2006; Bernard, 2006; Rammig et al., 2006) published in 2006 even though there is only one paper that explicitly uses the internet of things sentence in its title, while the other two mention it in the abstract. Then there were only two conference papers in 2007 (Muensch et al., 2007; Thiesse et al., 2007), and became increased to six papers in 2008 (Elrharbi and Peppin, 2008; Frenken and Spiess, 2008; Gronbæk and Telenor, 2008; Kong et al., 2008; Nyman et al., 2008; Wu, 2008) until the time of writing this paper at the end of 2018 there were a total of 25285 published papers. Developments in the early three years of the Internet of Things research, all types of paper documents in the form of conference papers that contain technical applications in connecting real-world objects to virtual information using computing system mobility, for example, mobile phones or handheld PDAs, by instilling an introduction to reading algorithms barcode or RFID to start IoT for the future better (Adelmann et al., 2006) which later developed into a variety of big things to date. The percentage of occurrence in the initial three years is 6.2 × 10^-4% can be considered as a very less significant value in the development of knowledge. The graph data in Fig. 1 indicate IoT began to be interested in being investigated since 2010 with a large number of researches (total 119) then continuing with developments multiplying times each year until this paper was made.

The research area of the Internet of Things in recent years has experienced growth and development in an interdisciplinary manner. Various papers are written very massive, and reach various concepts and fields of knowledge ranging from technology, applied engineering, economics, business, strategy, industry, management, etc. This becomes a confusion in understanding the direction of the development of the IoT knowledge.

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Besides this, IoT brings many dimensions of disruptive to many things for humans and nature such as physical disruption in terms of work, cyber-space disruptions that make human work deprived and faced with various new complexities when carrying out their routine activities and tasks, disruption of data through mastery of information generated by big data which causes many opportunities for new knowledge to emerge and new creative intelligent environments greatly changes the current conditions (Ammirato et al., 2018), including interfering with many everyday business processes both the specifications of people, their abilities and routine tasks, which are directed towards benefits characterized by high speed and interconnection.

Most of the research is written on the applied scale of technology in using IoT, run as something that facilitates human life in certain fields, including how IoT helps improve business capabilities, and recent research analyzes how data obtained from IoT devices can benefit various aspects. But looking at the disruptive level that spreads across all industrial areas (so-called revolution) and becomes a topic that is widely discussed in the future through the 4th industrial revolution scheme. It is a gap to write a science thinking flow as a foundation that addresses this IoT growth and development that can be used by researchers, developers and industries. The direction of the development of IoT is expected to be easier to understand, how the character and habits of the problem occur, and various methods and tools used by researchers related to the knowledge domain and industry.

The purpose of this paper is to explore the theoretical core of the IoT. This paper discusses the research questions as follows:

RQ1. How does the core knowledge of the field of the Internet of Things evolve through time?

RQ2. What are the most influential industries in the Internet of Things knowledge field?

RQ3. What are the substance methods or tools used in the Internet of Things research?

The research approach is an in-depth literature analysis using Scientometrics technique with a comprehensive information visualization technology in the entire journal paper and conference paper mentioned above. In order to process large-scale documents, we need a tool for software and data visualization technology that is capable of handling large amounts of scientific literature data. VOSviewer is used which has a special function for mining text that can be used to build, visualize and explore bibliometric maps of keywords taken from a large collection of scientific literature that presented in various ways, through keyword repeat mapping, which can provide visualization of results through various bibliometric indicators (Jin and Ji, 2018; Sajovic et al., 2018; Youngblood and Lahti, 2018) by interpreting a mathematic scheme in the linked-circular theme and progressive average year, so that research and trends in certain fields can be more clearly demonstrated. In addition to contributing to the more clearly found portrayals of various fields, an additional qualitative analysis was also conducted to bridge the gap between the IoT and various findings of scientific disciplines related to research content.

The structure of the paper is communicated as follows in sequence: starting with the background, this paper presents IoT research to the present, identifying research gaps and motivations to overcome them through answers to defined research questions. The methodology section explains the sequence of stages of obtaining material and methods, analysis of repetition of keywords and clusters, classification of data, and analysis of results. The following subsections show IoT evolution followed by presentations of the five largest fundamental themes of the group area and related knowledge disciplines, to further identify the state-of-the-art field of the IoT. The end result is a conclusion as an outlook from the IoT and the future of the work area. The writing of the sub-section of the paper further shows the evolution of IoT in the disciplinary group of knowledge and a description of the overall main character in the field of industry, then identifying what details the various methods and tools in implementing the concept of the IoT. We also report an approach to the thinking process of scientists in formulating their IoT research as a sequential flow of state-of-the-art concepts. The end result is a conclusion as an outlook from the IoT and the future of the work area.

2. Methodology

This study answers the research questions stated in the introduction by applying quantitative literature review using Scientometrics Analysis based on the bibliometric techniques on keywords, abstracts, and titles.

In order to get a comprehensive dataset, our data sources are generated from the results of Scopus database queries, with an advanced search using the ‘IoT’ AND ‘Internet of Things’ search phrases that found in Titles, Abstracts and Paper Keywords.

To make the dataset obtained relevantly and to avoid invalid documents, a set of criteria needs to be defined. Following are the methods used to include/remove documents from the analysis dataset:

- Only admit paper indexed by Scopus, with document type: conference paper, article and article in press; Emit other types of documents such as a book, chapter book, editorial, letter, note, review, and short survey;
- Admit papers written in English;
- Eliminate duplication, and data formatted incorrectly on each dataset item;
- Admit paper from the entire year and publisher;

The study uses a VOSviewer software tool based on co-citation to produce any term map based on co-occurrence data that is processed based on the title, keyword and abstract from the dataset provided, where the conditions specified are terms with the number of occurrences >10 times (configuration set). This tool displays an analysis of bibliometric maps of paper that are processed in detail. Then the research uses the VOSviewer software tool to create a paper map based on co-citation to produce any term map based on co-occurrence data that is processed
based on the title, keyword, and abstract of the entered dataset, where the conditions specified are in with the number of occurrences > 10 times. This tool displays the bibliometric map analysis of the entire paper processed in detail (van Eck and Waltman, 2010) and as an analytical method for mapping science that is able to identify knowledge of useful terms from data, networks, and maps (Sajovic et al., 2018).

The results of this bibliometric analysis result in trending items in the form of research terms that run within the span of the research marked by the number of occurrences and average years of publication, this answers the research question one about how does the core knowledge of the field of the Internet of Things evolve through time (RQ1); the results are then processed to answer the research question two about what are the most influential industries in the Internet of Things knowledge field (RQ2) in order to produce any industry influenced by the Internet of Things. Fig. 2 shows the research methodology.

At the end of Fig. 2, data segregation is carried out in order to have benefits in answering research questions. The core knowledge that moves the IoT research period will be related to certain technological fields that are automatically marked based on the labels that appear according to the tools used. Segregation in terms of industry is the most influential through the results of manually defining all data found with label-to-industry mapping. Segregation to get the method used in the article, obtained by redefining certain attributes of each industry in Scopus database search, through various articles according to each industry obtained then examined about what methods and tools are used by researchers (manual and automatic segregation).

3. Study area

Scopus has indexed 469 publishers around the world who have published papers that write a variety of knowledge about IoT, in Fig. 3, there are 20 top publishers, including 3 of the most active ones, namely IEEE, MDPI AG and Elsevier B.V. IEEE publishers produce most research publications, and they furthermore have issued 80 standards, 45 ongoing projects, including the most famous is IEEE P2413 (Draft Standard for the Architectural Framework for the IoT), and also has its own research Working Group that focuses on the field of IoT (IEEE Standards Association, 2018), this is different from MDPI AG and Elsevier B.V which only play a role in publishing journal papers and IoT conference papers.

The topic of IoT research involves various industries, which are considered disruptive and threats to various sectors because of the presence of internet technology that confirms changes in business patterns, humans in work, communication, transportation, factories, etc. that replace human functions, or significantly change values corporate chain through defining various new business models. It is increasingly scattered and increasing in quantity, this is in line with the development of knowledge which is characterized by irregular developments.

Through VOSviewer tools we find various studies of researchers who move according to the times and conditions that are considered the most hits in time, so that it is expected to map a very large and complex research trend so that models can show the development of successive research and to be able to see what IoT potential that is in the future. Through Fig. 4, the pattern of analysis of research trends from 2006 to 2018 is shown with different years colors, the occurrence increasing of research terms will be displayed with a larger diameter circle size.

This research we classify various industries which are considered very intensive involving IoT in their business model. The number of industries found is in line with the emergence of research attention in the industrial sector, whether driven by industry needs or researchers' proposals due to the suitability of IoT technical application to related industries. These finding industries can be categorized as mature in applying the 4th industrial revolution concept in their operation where IoT is one of the key elements.

Labels or terms that are found are presented as a combination of the words and sentences that are most widely used by researchers in the period 2006–2018 which recur more than 10 times (according to the configuration set) in the title, keyword, and abstract of all existing research. Total repetition is calculated in the Occurrence column, which displays information on how many terms appear in all the research papers. Average score explains the average of all years of publication found in various years, this indicates the weight of the year distribution which is the quantitative average of the term emerged.

All terms involving industry are displayed, excluded from the telecommunications and ICT industry because both are considered not influenced by IoT and are even the basic industry providers of IoT products themselves (such as vendor service connectivity and various
sensor devices as IoT solutions). This study found various industrial sectors that involved or were affected by IoT intensively as shown in Table 1.

4. Results & discussion

Data derived from Table 1 is further processed to categorize paper related to certain industrial sectors. Found seven industries affected by the IoT starting from the most to the least influential as follows: Manufacturing, Agriculture, Public Service, Health, Electronics, Energy, and Mining.

4.1. Growth and development of the IoT industry

4.1.1. Industry 1: manufacturing

In this study, IoT looks very influential in the manufacturing industry.
sector, as shown in Fig. 5, research activities in this field are very intensive and always high throughout the year, this is in line with the 4th industrial revolution that is running throughout the world. Starting from the German government which initiated the term Industrie 4.0 in 2011 in the manufacturing industry sector using the term IoT (Industrial IoT) through the 4th industrial revolution, which strongly emphasized IoT integration into manufacturing operations and communication between many objects (Kiel et al., 2017). This characterizes the digital connections of industrial manufacturing processes that produce fully intelligent, connected and autonomous plants.

### Table 1

| Label/Term            | weight | <Occur-rences> | score | Avg. pub.year | Industry Sector |
|-----------------------|--------|----------------|-------|---------------|----------------|
| logistic              | 420    | 2014.8         |       |               | All Industry   |
| agricultural product  | 107    | 2014.8         |       |               | Agriculture    |
| iot industry          | 57     | 2015.3         |       |               | All Industry   |
| supply chain          | 126    | 2015.4         |       |               | All Industry   |
| management            | 33     | 2015.5         |       |               | Agriculture    |
| agricultural production | 54  | 2015.5        |       |               | Agriculture    |
| decision support      | 54     | 2015.7         |       |               | All Industry   |
| intelligent           | 173    | 2015.7         |       |               | Public Service |
| transportation system | 18     | 2015.7         |       |               | Public Service |
| electric vehicle      | 96     | 2015.8         |       |               | Electronics    |
| production process    | 100    | 2015.9         |       |               | Manufacturing  |
| automotive industry   | 34     | 2015.9         |       |               | Manufacturing  |
| campus                | 128    | 2016.1         |       |               | Public Service |
| bus                   | 222    | 2016.1         |       |               | Manufacturing  |
| mining                | 392    | 2016.2         |       |               | Mining         |
| manufacturing industry| 73     | 2016.2         |       |               | Manufacturing  |
| agriculture           | 625    | 2016.3         |       |               | Agriculture    |
| school                | 146    | 2016.5         |       |               | Public Service |
| manufacturing         | 511    | 2016.5         |       |               | Manufacturing  |
| health care           | 298    | 2016.5         |       |               | Health         |
| smart industry        | 36     | 2016.5         |       |               | Manufacturing  |
| robot                 | 466    | 2016.5         |       |               | Electronics    |
| education             | 327    | 2016.6         |       |               | Public Service |
| electronic            | 408    | 2016.6         |       |               | Electronics    |
| industrial process    | 53     | 2016.6         |       |               | Manufacturing  |
| hospital              | 328    | 2016.6         |       |               | Health         |
| industrial control    | 52     | 2016.6         |       |               | Manufacturing  |
| system                | 102    | 2016.8         |       |               | Public Service |
| electricity           | 144    | 2016.6         |       |               | Energy         |
| city                  | 3365   | 2016.6         |       |               | Public Service |
| farm                  | 197    | 2016.7         |       |               | Agriculture    |
| electronics           | 74     | 2016.7         |       |               | Electronics    |
| healthcare            | 875    | 2016.7         |       |               | Health         |
| factory               | 212    | 2016.7         |       |               | Manufacturing  |
| production line       | 52     | 2016.7         |       |               | Manufacturing  |
| traffic management    | 95     | 2016.7         |       |               | Public Service |
| microcontroller       | 430    | 2016.8         |       |               | Electronics    |
| battery               | 850    | 2016.8         |       |               | Energy         |
| transportation system | 102    | 2016.8         |       |               | Public Service |
| healthcare service    | 171    | 2016.8         |       |               | Health         |
| plant                 | 330    | 2016.8         |       |               | Agriculture    |
| farming               | 141    | 2016.8         |       |               | Agriculture    |
| precision agriculture | 89     | 2016.8         |       |               | Agriculture    |
| healthcare system     | 292    | 2016.8         |       |               | Manufacturing  |
| manufacturing system  | 123    | 2016.9         |       |               | Manufacturing  |
| gas                   | 114    | 2016.9         |       |               | Energy         |
| water                 | 508    | 2016.9         |       |               | Public Service |
| production system     | 119    | 2017.0         |       |               | Manufacturing  |
| medicine              | 151    | 2017.0         |       |               | Health         |
| medical data          | 59     | 2017.0         |       |               | Health         |
| wearable              | 209    | 2017.0         |       |               | Electronics    |
| smart manufacturing   | 99     | 2017.0         |       |               | Manufacturing  |
| gas sensor            | 74     | 2017.0         |       |               | Energy         |
| farmer                | 271    | 2017.1         |       |               | Agriculture    |
| smart factory         | 203    | 2017.1         |       |               | Manufacturing  |
| solar energy          | 36     | 2017.1         |       |               | Energy         |
| irrigation system     | 89     | 2017.1         |       |               | Agriculture    |
| healthcare industry   | 59     | 2017.2         |       |               | Health         |
| smart agriculture     | 76     | 2017.2         |       |               | Agriculture    |
| machinery             | 447    | 2017.3         |       |               | Manufacturing  |

### 4.1.2. Industry 2: agriculture

The second industry sector that is most influenced by IoT is the agricultural sector where the IoT has recently been applied in agrarian countries, as stated by (Mushtaq, 2018; Srilakshmi et al., 2018) this is driven because IoT contributes significantly to socio-economic growth, Increasing Productivity, Reducing Costs and Optimizing time for farmers in particular, and also this sector produces a basic need that has a great effect on a country in general where its development is strongly influenced by how is the government's strategy (Saragh et al., 2018).

### 4.1.3. Industry 3: public service

Due to IoT technology ability to connect many services through the internet with the ability of sensor devices and monitoring to be spread everywhere, many researchers are implementing their IoT applications in the sector of intelligent Public Service industry (Hoon et al., 2013; Díaz-díaz, Muñoz and Pérez-gonzález, 2017; Trilles et al., 2017), those are found in this study included intelligent transportation system, smart campus, smart school, general education, city, traffic management, transportation system and water.

### 4.1.4. Industry 4: electronics

The electronic industry sector which is much influenced by the presence of IoT, all those found are electric vehicles, robots, electronics, electronics, microcontrollers, and wearables. Actually, these findings are product technologies that have long existed, but through IoT now developed with a variety of new capabilities, such as being able to have sensors on the environment, then be able to connect and exchange information with each other through an internet connection.

### 4.1.5. Industry 5: health

This health industry sector is one of the biggest influenced by IoT, the sector is a new IoT product in health services which includes labels found in it such as Health care, hospital, healthcare, healthcare service, healthcare system, medicine, medical data, healthcare industry. Services that involve IoT such as health condition sensors and historical records that study a person's health condition with qualitative analysis, as well as a human health monitoring tool.

### 4.1.6. Industry 6: energy

The Energy Industry Sector, including chemistry which is much influenced by the presence of IoT found, is labeled electricity, battery, gas, sensor gas and solar energy.

### 4.1.7. Industry 7: mining

The mining industry sector which is much influenced by the existence of IoT, which is found is mining in the form of data mining labels, which is an advanced Information Technology (IT) industry. There are several other industrial labels that are classified as widely used and are considered to have an IoT influence, namely logistics, IoT industry, supply chain management, decision support which are classified as operating management devices which in this study are categorized as all industries.

The manufacturing industry is the most mature sector in the application of the IoT concept with a large amount of research in this sector, this is reasonable because the 4th industrial revolution framework has emerged earlier and is very underlined about smart manufacturing, causing a lot of research to focus on this sector before moving to various industries others. Then the agriculture industry, researchers are very interested in this field because of the high opportunity for socio-economics, the rapid application of IoT techniques, and also land and plant objects involved in having very low applied risks. So that in terms of applied risk, very low risk is also the reason why the Public Service Industry is heavily influenced by IoT, as applies to the manufacturing sector. Then the electronics industry functions as a supporting tool that makes it easy for humans to access IoT services directly or IoT as a daily life support tool used by humans such as electric vehicles and wearable.
The passage of time, research has begun to shift a lot and reveal about the Hospital and Health care industry, even since 2016 this health topic is a new subject. Due to its application has a high risk because it is related to humans, but it can be interpreted that the level of IoT technology advancement has been quite mature since the time of the emerges at the time of the arrival of technology despite the very high level of risk to be applied. The future of research looks at the energy and chemistry industry as an important prospect in subsequent scientific research, this is not only a necessity because the more renewable energy, but also the presence of batteries is an important character of IoT energy availability to work so that ubiquitous can be easier to happen. Recent researchers are also very interested in conducting research related to data mining, the emergence of IoT which has resulted in the accumulation of very large data both offline and online into their own needs for analytic and then take advantage of the data for various interests of certain stakeholders.

4.2. IoT main character for industry

The development of IoT knowledge is very much and continues to be increasingly in demand by scientists and industry, it is because of the ability of IoT to connect many devices to be able to communicate with each other and enter information through the internet as delivered by (Kaur et al., 2018) even with a variety of different (heterogeneous) devices that can carry certain functions or benefits (Chan, 2015). Based on its function then IoT has a role, among others identity, track and traceability, and authentication (Liu et al., 2017), then traceability and visibility (Meng et al., 2017). Other perceptions that are not much different from industries perceptive (Zhang et al., 2018) outlining the benefits of IoT is to promote information progress in real-time monitoring, traceability, tracking, transparency, and interaction, which was then comprehensively elaborated by (Zhang et al., 2016) as real-time traceability, visibility, and interoperability in production planning, execution, and control.

This study found that there are four main things that are the main characteristics of IoT for industrial organizations (1) Traceability, (2) Visibility, (3) Interoperability and (4) Interaction. Whereas the role outside the industrial organization through the presence of IoT is included in green and eco-friendly process management (Al-Turjman, 2018), and IoT is also able to mitigate energy and green computing consumption (Mohiaddin and Almogren, 2019).

The development of IoT does not always bring positive things as discussed above, some negative things and problems are found related to the journey of IoT research and need to be considered by researchers including: technical or technological problems from IoT itself, industrial problems and businesses that require IoT solutions, problems in terms of IoT framework, problems when adopting and redesigning the current process, and problems after applying IoT. IoT design techniques have very poor communication latency problems and communication overhead (Jutila, 2016; Praveen Kumar and Babu, 2017; Al-Turjman, 2018) including the cost of remote wireless communication which is relatively expensive on some devices (Lv et al., 2016) which requires the right stage of device selection based on function and price. Including the limitations of the device in producing certain other variables needed such as “how much power is used” (Han et al., 2018). Overall the presence of the development of IoT is very fast, so in general, this IoT is difficult in terms of standardization as delivered (Tervonen, 2018). In order to achieve a good IoT system implementation (Fortino et al., 2017a) have a suggestion that developers may use IoT simulations based on either agent or network approach, which allows designers to validate their design choices and unfold unexpected conduct before the actual deployment.

4.2.1. Problem came from the business needs that feasible be supported by IoT

- Agri-crisis occurs due to rain and poor climatic conditions, so farmers suffer from severe scarcity and have difficulty recovering from drought. IoT is a technology that serves as a solution to this problem (Srilakshmi et al., 2018). To do air quality tracking carried out only at the macro level, detailed hyper-local data is difficult to obtain because of the lack of sensors that collect information (Meinert et al., 2018). In addition, the relationship between weather, plants, and pests can negatively affect plant productivity and profitability (Moon et al., 2018)
- Problems in urban areas such as traffic jams, environmental contamination, limited natural resources (Paruchuri and Rajesh, 2018). Problems due to lack or absence of detection systems in the city (Díaz-díaz, Muñoz and Pérez-gonzález, 2017)
- Every authority (government) is required to know the pattern of citizen estimation for public service design and optimization goals, taken from a large number of passenger digital transaction records, this is the scope of researchers in IoT-driven urban computing applications (Weng et al., 2018)
- Changes in current manufacturing technology that require monitoring devices that support the distribution of sensors and high-speed wireless networks (Zhao et al., 2015), including manufacturing inspections in industry (Li et al., 2018b), and difficulties in planning production logistics (PL) which increases due to uncertainty and dynamic production environment (Huang et al., 2019)
- Difficulty in building optimization that covers the entire production process (Liu et al., 2017) and how IoT can help activate the optimal composition of services (Li et al., 2018c)

4.2.2. Problem came from the current IoT framework.

- The framework is currently limited by the constraints of communication latency, fixed bandwidth, coverage, and uneven computing
resources, therefore the framework is difficult to adapt to the emergence of IoToT demands or requirements (Li et al., 2018d).

- Not complete in calculating the factors that cause common problems that occur at this time in the system of Production Logistic - PL such as the following: distribution accuracy and low efficiency, lack of flexibility and responsiveness, and inconsistencies between distribution and production (Huang et al., 2019).

- IoToT is easy to hack and difficult to survive from various cyber-attacks (Falcon et al., 2018).

- IoToT has a large variety of devices, with different technologies and protocols. This brings its own disadvantages, so IoToT is very low in terms of interoperability, security, scalability, efficiency or reliability (Trilles et al., 2017) including poor throughput running simultaneously (Al-Turjman, 2018).

- How to integrate production and logistics into a smart control system such as its ability to identify exceptions, self-organizing configurations, and self-adaptive collaboration (Zhang et al., 2018).

- Constant interactions that occur between machines, between humans, between humans and machines and the complexity of information from certain problems that arise will result in difficulties in exchange and sharing. Fundamental construction can lead to mutual understanding and awareness of the organizational information structure between users and agents (Hao et al., 2015).

- The superiority of IPv6 topology is also very concerned now to be used in implementing IoToT in the future, where IPv6 can establish locative conditions on the Internet that are applicable and actually, due to IP distribution between objects that are not uniform at this time (Kleineberg and Helbing, 2017). In the IPv6 Internet topology, each node (device) represents the Autonomous System, this is a very perfect IoToT concept to run.

4.2.3. Problem came when adopting IoT and redesigning the current process.

- Analyzing the current situation: before redesigning, the reengineering team needs to gain a better understanding of the chosen current process, paying attention to how badly it operates (bad or problematic processes), critical issues that affect performance, and a set of instructions for IoT adoption and redesign processes (Wolfs, 2017; Ammirato et al., 2018).

- Intensively understand ecological conditions at a fundamental level, the speed of communication, including information on certain distances to local servers (Keswani et al., 2018).

- How is worker satisfaction and how long the adaptation is needed to be competent in carrying out new activities (Ammirato et al., 2018).

- It is always difficult for designers to analyze and validate performance efficiently and effectively when it is associated with limited professional knowledge and there are black-box models (Zheng et al., 2018).

4.2.4. Problem after IoT is applied.

- With a manual approach to the amount of available system information and expert assumptions, it still poses difficulties in validating for experts to understand the system (Falco et al., 2018). Thus, the accumulation of data has a limitation, which presents a situation of large amounts of data but contains little information. So that data mining technology emerges; as an important tool in the acquisition of knowledge from the manufacturing environment (Liu et al., 2017).

- Applications must be able to find ways to obtain data (from the client side in it sensor-program code), to be stored reliably in large numbers and in a scalable way (digesting data in the database with all its difficulties), to transform that data into a which makes it possible to access them with analytical purposes then present them in a dashboard view (Lengyel et al., 2015).

- Sensors have poor sensory detectors, many physical parameters that cannot be detected, such as various things on dirty surfaces, mirrors or shadows, including positions that are slightly misaligned (Adelmann et al., 2006; Zhang et al., 2012).

- Various interconnected devices are difficult to maintain (maintenance) (Wolfs, 2017).

- Raw sensor data contains a lot of noise, is heterogeneous, and has high dimensions, which comes with a lot of complexity and computational difficulties in extracting high-quality results in a real-time manner (Vermesan and Friess, 2015).

4.3. A variety of research methods and tools, in the implementation of the concept of the internet of things

Researchers view IoT as an important research opportunity to solve various industrial problems, as the main character of IoT described in section B. Researcher can use several operational models in developing conventional industrial notation towards IoT services, which assist in verification and execution so that they can use the right tools as explained by (Fortino et al., 2017b). The growth of knowledge then combines science and technology into certain research methods that are applied through stages that focus on defining one of the four layers of IoT technology architecture as a domain of research knowledge: (1) the "Application and Service" layer, or (2) the "Platform" Architecture layer, also called data and knowledge, or (3) "Communication" Architecture layer, or (4) "Physical" Architecture layer called sensor or actuator (Meng et al., 2017), these are then processed to answer research questions three about what are the substance methods or tools used in the Internet of Things research (RQ3) in order to produce the substance methods or tools used in the IoT research.

All research begins with the phenomenon of business/industrial needs which are then faced with the willingness of IoT technology features so that they (researchers) look for novelty research with the help of methods based on appropriate science, as new discoveries into several context solutions, in the form of architecture own or combined technology, industrial technical application, or as a new context of knowledge from industrial management that is supported by IoT functions such as analysis of available real-time data. The researcher thinking process is shown in Fig. 6. The researcher processed the data through the bibliographic method for the entire 2006 IoT study until the end of 2018, obtained by finding IoT in the seven main industries in section A displayed in Tables 2, 3, and 4 where several terms (labels) were found that corresponded to each IoT technology used, described in each year the appearance of research. Through a comprehensive search of various studies with IoT keywords, industry and methods used by researchers; hence a variety of research methods are obtained which are considered to have a significant impact on research on the development of knowledge and strategic development and include impacts on the industry. Then these results are elaborated on the knowledge domain column according to emerging terms and components of basic IoT technology architecture which are ideas from the technical focus of research and development of science, as shown in Tables 5, 6, 7, 8, 9, and 10.

In traditional manufacturing industries, there are limitations to sensor technology, with many physical parameters unable to be detected, especially the need for long-term dynamic and real-time monitoring (Zhang et al., 2012). In today's modern industry there are several new terms that describe future industry concepts, such as Manufacturing 2.0, Internet Industry, Smart Factory, 4th industrial revolution and IIoT (Riel et al., 2017; Meng et al., 2018).

The broad topic of IoT research for 4th industrial revolution in the manufacturing area as mentioned in Table 5 is about connecting all components in manufacturing systems using various sensor systems, Cyber-Physical Systems (CPS) through the IoT concept, where activity data from all components can be real-time collected and monitored, to
provide a smart response to various problems that may arise in the factory, including the results of real-time analysis obtained from cloud computing and big data (Tsai and Lu, 2018).

Specific IoT research topics for 4th industrial revolution provide opportunities for smart manufacturing in terms of real-time traceability, visibility and interoperability in production planning, implementation and control (Zhang et al., 2016), flexibility in systems, monitoring, and adaptation to change manufacturing needs (Kumar, 2018), besides that reliability is also an important research topic in other IoT applications and cloud environments (Xiao et al., 2018).

IoT implementation is considered to provide various benefits in supporting manufacturing operation's internal processes or activities, such as optimization of production logistics in utilizing the real-time data generated by the IoT (Huang et al., 2019). Other benefits include smart energy management that significantly saves operational expenses and minimizes total product completion time (Rubaeiee and Yildirim, 2018), detect product defects (Li et al., 2018b), ultimately increasing profitability and production efficiency (Zhang et al., 2018). In terms of R & D operations, IoT technology is able to bridge the gap between humans and technology that can be used for interactive innovation (Wang and Hsieh, 2017).

In terms of technical application, research (Liu et al., 2017) provides an important framework for companies that already have high technology potential and then want to activate IoT, through IoT-enabled intelligent assembly systems for mechanical products (IIASMP), through their research questions as following: (1). How to encode current manufacturing resources, through data parsing, exchange, processing, and sharing? (2). How to capture massive data from heterogeneous devices then transfer and integrate it? (3). What methodology is appropriate for value-added information for the company's management decision-making process? (4). How to achieve optimization from the current manufacturing process.

Research in the agricultural area is largely directed at analyzing sensor utilization through the Wireless Sensor Network (WSN) system which is actually not IoT, even though this WSN application is part of

| Table 2 | Mapping research on technology architecture (2006–2015). |
|-------|-------------------------------------------------|
| label | IoT Technology | Weight <Occurrences> | Score <Avg. pub. year> |
| RFID technology | Physical | 269 | 2014.2 |
| RFID network | Physical | 42 | 2014.6 |
| Application system | Application | 75 | 2014.7 |
| Next generation network | Communication | 37 | 2014.8 |
| RFID system | Physical | 233 | 2014.9 |
| Low power wireless personal area networks | Communication | 39 | 2014.9 |
| Zigbee technology | Communication | 40 | 2015.1 |
| Service platform | Platform | 178 | 2015.1 |
| Passive RFID tag | Physical | 39 | 2015.1 |
| RFID reader | Physical | 114 | 2015.3 |
| Zigbee network | Communication | 53 | 2015.3 |
| WSN application | Application | 46 | 2015.5 |
| Actuator network | Communication | 84 | 2015.5 |
| Personal area network | Communication | 78 | 2015.5 |
| Sensor technology | Physical | 178 | 2015.6 |
| Open platform | Platform | 41 | 2015.6 |
| Middleware solution | Platform | 72 | 2015.6 |
| NFC | Communication | 201 | 2015.7 |
| Constrained application | Application | 144 | 2015.7 |
| 6LoWPAN network | Communication | 72 | 2015.7 |
| Zigbee | Communication | 434 | 2015.7 |
| Ad hoc network | Communication | 102 | 2015.7 |
| Network node | Communication | 131 | 2015.8 |
| Electric vehicle | Physical | 96 | 2015.8 |
| Middleware platform | Platform | 68 | 2015.8 |
| Wireless sensor network | Physical | 2224 | 2015.8 |
| Application development | Application | 151 | 2015.8 |
| Wireless sensor node | Physical | 143 | 2015.9 |
| Network environment | Communication | 139 | 2015.9 |

Fig. 6. The IoT research thinking process.
building an IoT solution. WSN research is conducted throughout the World for precision agricultural purposes (Sawant et al., 2017), requiring many improvements in the fields of communication, data distribution, and real-time component analysis to make dynamic decisions. For example, IoT wireless sensor environment development that is able to accurately analyze soil and environmental parameters used in agricultural activities to predict air demand in a timely manner (Keswani et al., 2018), including management of agricultural production, with case studies in solar greenhouses (Kang et al., 2018).

Other research uses the concept of IoT through smarter, more complex farming, looking at opportunities through plant and land data supported by sensors, so that embedded sensors are expected to be used for crop yield prediction, crop classification, soil classification, weather prediction, and crop prediction with using decision-making systems on existing IoT components such as the IoT Gateway and IoT Service platforms integrated in the system to provide smart plant growth solutions for farmers (Patil and R, 2017), other studies focus on diverse agricultural data that need to be stored efficiently and beneficial (Moon et al., 2018).

Research on IoT applications for public services is currently associated with the usual use of the Internet to communicate with other devices to achieve certain benefits in urban areas, this is supported by the development of today's critical infrastructure that is 'smarter' and more dependent on highly specialized computers called industrial control system (ICS) (Falco et al., 2018). Benefits are obtained through the use of approval, sensing and information functions for everyday human activities. According to (Jiang and Liu, 2018), research on the IoT area can be carried out on the following three main aspects (1) How to recognize data transmission objects and technology. (2) Data communication technology, which is about how to act on data and technology. (3) Understanding and adaptation of historical data of IoT device users based on data and reasoning.

Recognizing objects and data transmission technology in the concept of public services is closely related to infrastructure and how to control it, such as CCTV, electricity network, air network and transportation network security (Falco et al., 2018), real-time garbage collection scheduling based on certain conditions (Jiang and Liu, 2018), management of public parking spaces by developing urban parking management cloud platforms (Kong et al., 2018), fire security and monitoring (Naidu Are et al., 2018).

Understanding data transmission communication technology in the

| Table 3 (continued) |
|---------------------|
| label | IoT Architecture Technology | Weight <Occurrences> | Score <Avg. pub. year> |
| Application layer | Application | 62 | 2016.8 |
| Network lifetime | Communication | 273 | 2016.8 |
| Network resource | Communication | 139 | 2016.8 |
| Android | Platform | 171 | 2016.8 |
| Smart city application | Application | 137 | 2016.8 |
| Diverse application | Application | 46 | 2016.8 |
| Sensor value | Physical | 44 | 2016.8 |
| Healthcare application | Application | 135 | 2016.8 |
| Camera | Physical | 551 | 2016.8 |
| Connected vehicle | Physical | 53 | 2016.8 |
| Temperature sensor | Physical | 143 | 2016.9 |
| Network capacity | Communication | 64 | 2016.9 |
| Network simulator | Communication | 57 | 2016.9 |
| Board | Physical | 501 | 2016.9 |
| Network traffic | Communication | 161 | 2016.9 |
| Sensors data | Physical | 49 | 2016.9 |
| Analytic | Platform | 641 | 2016.9 |
| Opportunistic network | Communication | 49 | 2016.9 |
| Big data analytic | Platform | 210 | 2016.9 |
| Surveillance camera | Physical | 56 | 2016.9 |
| Single board computer | Physical | 73 | 2016.9 |
| Analytical model | Platform | 111 | 2016.9 |
| IoT sensor node | Physical | 38 | 2016.9 |

| Table 3 |
|---------|
| label | IoT Architecture Technology | Weight <Occurrences> | Score <Avg. pub. year> |
| Global network | Communication | 68 | 2016.0 |
| e-Health application | Application | 47 | 2016.0 |
| Sensor system | Physical | 127 | 2016.0 |
| Wireless sensor networks | Physical | 68 | 2016.0 |
| Mobile ad hoc network | Communication | 55 | 2016.0 |
| Application programming interface | Application | 56 | 2016.1 |
| Constrained network | Communication | 49 | 2016.1 |
| Application developer | Application | 91 | 2016.1 |
| Network service | Communication | 80 | 2016.1 |
| Network topology | Communication | 193 | 2016.1 |
| Heterogeneous network | Communication | 197 | 2016.1 |
| IoT middleware | Platform | 115 | 2016.1 |
| GPS | Physical | 209 | 2016.1 |
| Wireless communication network | Communication | 38 | 2016.1 |
| Network coding | Communication | 62 | 2016.1 |
| Network architecture | Communication | 333 | 2016.2 |
| Network management | Communication | 76 | 2016.2 |
| Medical sensor | Physical | 44 | 2016.2 |
| Cloud database | Platform | 40 | 2016.2 |
| Network security | Communication | 75 | 2016.2 |
| Network size | Communication | 35 | 2016.2 |
| Network virtualization | Communication | 45 | 2016.2 |
| Sensor node | Physical | 1141 | 2016.2 |
| Application protocol | Application | 130 | 2016.2 |
| Information centric networking | Communication | 109 | 2016.3 |
| LTE network | Communication | 69 | 2016.3 |
| Network load | Communication | 46 | 2016.3 |
| Mobile network | Communication | 246 | 2016.4 |
| Body sensor network | Physical | 53 | 2016.4 |
| Web application | Application | 158 | 2016.4 |
| Vehicular network | Communication | 59 | 2016.4 |
| Loney network | Communication | 216 | 2016.4 |
| Wireless local area network | Communication | 54 | 2016.4 |
| Medical application | Application | 63 | 2016.4 |
| Network device | Communication | 95 | 2016.4 |
| Access network | Communication | 183 | 2016.5 |
| Network performance | Communication | 227 | 2016.5 |
| Large scale network | Communication | 56 | 2016.5 |
| Wireless network | Communication | 667 | 2016.5 |
| Bluetooth | Communication | 273 | 2016.5 |
| Wireless mesh network | Communication | 39 | 2016.5 |
| Data networking | Communication | 98 | 2016.5 |
| Predictive analytic | Platform | 40 | 2016.5 |
| LTE | Communication | 478 | 2016.5 |
| Wi-Fi | Communication | 303 | 2016.5 |
| Vehicular ad hoc network | Communication | 65 | 2016.5 |
| Network parameter | Communication | 37 | 2016.6 |
| Network throughput | Communication | 78 | 2016.6 |
| Vehicle | Physical | 1735 | 2016.6 |
| Multiple sensor | Physical | 73 | 2016.6 |
| Mobile sensor | Physical | 39 | 2016.6 |
| Core network | Communication | 77 | 2016.6 |
| Home network | Communication | 79 | 2016.6 |
| Network congestion | Communication | 60 | 2016.6 |
| Mesh network | Communication | 67 | 2016.6 |
| Wearable sensor | Physical | 98 | 2016.6 |
| Wireless body area network | Communication | 60 | 2016.7 |
| Wi-Fi | Communication | 313 | 2016.7 |
| Bluetooth low energy | Communication | 292 | 2016.7 |
| Humidity sensor | Physical | 57 | 2016.7 |
| Cellular network | Communication | 320 | 2016.7 |
| Large network | Communication | 33 | 2016.7 |
concept of public communication, for example (Al-Turjman, 2018) that uses IoT hybrid sensing communication for smart cities, which facilitates the involvement of heterogeneous traffic flows in network sensors so that it can be used for simultaneous users with various needs.

Regarding the understanding and adapting the historical data for IoT device users, for example the Intelligent/Smart and Connected Transportation System (ICTS) understands the preferences and demands of actual passenger behavior collected passively from IoT devices to reduce passenger transit chains using information enrichment and probabilistic inference approaches (Weng et al., 2018).

Table 4
Mapping research on technology architecture (2017).

| label                              | IoT Architecture Technology | Weight Occurrence | Score Avg pub year |
|-----------------------------------|-----------------------------|-------------------|--------------------|
| Network bandwidth                 | Communication               | 60                | 2017.0             |
| Network operator                  | Communication               | 84                | 2017.0             |
| Analytical result                 | Platform                    | 52                | 2017.0             |
| Wearable                          | Physical                    | 209               | 2017.0             |
| Android application               | Application                 | 104               | 2017.0             |
| Gas sensor                        | Physical                    | 74                | 2017.0             |
| Arduino board                     | Physical                    | 54                | 2017.0             |
| Software defined networking       | Communication               | 113               | 2017.0             |
| Motion sensor                     | Physical                    | 41                | 2017.0             |
| 5G system                         | Communication               | 50                | 2017.0             |
| Industrial IoT application        | Application                 | 34                | 2017.1             |
| Things network                    | Communication               | 88                | 2017.1             |
| Big data analytics                | Platform                    | 43                | 2017.1             |
| IoT network                       | Communication               | 1208              | 2017.1             |
| Network function                  | Communication               | 60                | 2017.1             |
| Raspberry Pi                      | Physical                    | 489               | 2017.1             |
| Data analytic                     | Platform                    | 298               | 2017.1             |
| Arduino                          | Physical                    | 156               | 2017.2             |
| Wi-Fi network                     | Communication               | 47                | 2017.2             |
| Biosensor                        | Physical                    | 57                | 2017.2             |
| Network condition                 | Communication               | 55                | 2017.2             |
| 5G technology                     | Communication               | 50                | 2017.2             |
| Edge network                      | Communication               | 52                | 2017.2             |
| Network edge                      | Communication               | 163               | 2017.2             |
| Raspberry                        | Physical                    | 38                | 2017.2             |
| Wearable technology               | Physical                    | 59                | 2017.3             |
| Sigfox                           | Communication               | 72                | 2017.3             |
| 5G network                        | Communication               | 209               | 2017.3             |
| Ultrasonic sensor                 | Physical                    | 53                | 2017.3             |
| Network function                  | Communication               | 48                | 2017.3             |
| Lora technology                   | Communication               | 34                | 2017.4             |
| NB IoT system                     | Communication               | 53                | 2017.4             |
| Unmanned aerial vehicle           | Physical                    | 79                | 2017.4             |
| IoT applications                  | Application                 | 150               | 2017.4             |
| Low power wide area network       | Communication               | 129               | 2017.4             |
| Wi-Fi module                      | Communication               | 46                | 2017.5             |
| Lora                             | Communication               | 326               | 2017.5             |
| NB IoT                           | Communication               | 329               | 2017.5             |
| Arduino uno                       | Physical                    | 38                | 2017.5             |
| Lora network                      | Communication               | 38                | 2017.5             |
| Low power wide area networks      | Communication               | 47                | 2017.5             |
| Loranav                          | Communication               | 191               | 2017.6             |
| UAV                              | Physical                    | 193               | 2017.6             |
| PIR sensor                        | Physical                    | 33                | 2017.7             |

Table 5
Growth of IoT knowledge on Manufacture.

| Research                          | Domain Knowledge                          | Method/Tools                              | Industry               |
|-----------------------------------|-------------------------------------------|-------------------------------------------|------------------------|
| (Areez et al., 2018)              | Physical IoT                              | A resonance method based on square-patch antennas | Manufacture            |
| (Huang et al., 2019)             | Production Logistics                      | Ant Colony algorithm                       | Manufacture            |
| (Kumar, 2018)                    | Smart Manufacturing                        | Flexibility in systems, monitoring, and adaptation to changing needs | Manufacture            |
| (Lee et al., 2018)               | Smart Manufacturing                        | A light-weight Demand                      | Manufacture            |
| (Li et al., 2018b)               | Smart industry                             | AI Method (Deep Learning) to detect the defects of the products | Manufacture            |
| (Li et al., 2018c)               | Cloud Manufacturing                        | EK-Oriented genetic algorithm (EK-GA) for the large-scale IoT service composition | Manufacture            |
| (Liu et al., 2017)               | IoT-enabled Intelligent                     | Assembly System (IASSMP)                   | Manufacture            |
| (Meng et al., 2018)              | Adaptive Manufacturing                     | Manufacturing (MRBAs)                      | Manufacture            |
| (Na et al., 2018)                | Smart Manufacturing                        | Maximum Weight                             | Manufacture            |
| (Riel et al., 2017)             | System                                     | Independent Set (MWIS)                     | Manufacture            |
| (Rubaiie and Yildirim, 2018)     | Energy-aware                               | Ant Colony algorithm                       | Manufacture            |
| (Wang et al., 2018b)             | Human-centered design factors for the design of interactive clothing | Kanezi Evaluation method | Manufacture            |
| (Wang and Haib, 2017)            | Smart eyewear industry                     | Quality Function Development (QFD) to recognize the specific IoT development potential | Manufacture            |
| (Xiao et al., 2018)             | Fabrication of logic circuits              | Bayesian Network (BN) method, and Probabilistic Transfer-Matrix (PTM) model | Manufacture            |
| (Zhang et al., 2012)            | Cloud Manufacturing                        | Fiber Bragg Grating perception network | Manufacture            |
| (Zhang et al., 2018)            | Methodology of smart production            | Smart Production (Logistics Systems (SPLS) | Manufacture            |
| (Zhang et al., 2018)            | Real-Time Production                        | Performance Analysis and Exception Diagnosis Model (PAEDM) | Manufacture            |
| (Tsai and Lu, 2018)             | Production planning and control            | Activity-Based Costing (ABC) and Theory of Constraints (TOC) | Manufacture            |

one of the most important barriers to practical application (Chen et al., 2018) because powering electronics is a big challenge using battery technology with power limited. As research is conducted on circuit design methods to improve the efficiency of charging to energy storage devices (Pyo et al., 2019), then triboelectric nanogenerator (TENG) research based on triboelectrification and electostatic induction make energy harvesting technology simple, cost-effective, and versatile (Liu et al., 2018a).

There is also a flexible Electronic concept, which requires information to be distributed on whatever surface we need, where development is highly demanded the IoT, this case associated with robot technology and
Recent research is now beginning to focus on the growth of IoT knowledge on various domains. Table 6 illustrates the growth of IoT knowledge on Agriculture, Table 7 on Public Service, and Table 8 on Electronics.

Table 6: Growth of IoT knowledge on Agriculture.

| Research             | Domain Knowledge | Method/Tools                  | Industry |
|----------------------|------------------|-------------------------------|----------|
| Kang et al., 2018    | Smart Agriculture| Agricultural cyber-physical-social system (CPSS) | Agriculture |
| Khewani et al., 2018 | Smart irrigation control scheme | Neural network | Agriculture |
| Moon et al., 2018    | Predictive weather on IoT platform | Low loss compression based on FWH and DCT | Agriculture |
| Nalajala et al., 2017| Communication IoT | Monitoring and control of greenhouse | Agriculture |
| Palit and R., 2017   | Communication and platform IoT | Kalman filter (KF) | Agriculture |
| Savant et al., 2017  | Physical IoT | Adaptation framework | Agriculture |

Table 7: Growth of IoT knowledge on Public Service.

| Research             | Domain Knowledge | Method/Tools                  | Industry |
|----------------------|------------------|-------------------------------|----------|
| Al-Turjman, 2018     | Application and Service IoT | Hybrid Collaborative Path Finder (HCPF) | Public Service |
| Naidu et al., 2018   | Application and Service IoT | Fire IoT sensors | Public Service |
| Tolco et al., 2018   | Communication IoT | Automated attack generation based on artificial intelligence techniques | Public Service |
| Jiang and Liu, 2018  | Application and Service IoT | Solid waste transportation scheduling | Public Service |
| Kong et al., 2018    | Application and Service IoT | Parking space sharing and allocation problem | Public Service |
| Weng et al., 2018    | Passengers' closed transit chains | Information enrichment and probabilistic inference | Public Service |

Table 8: Growth of IoT knowledge on Electronics.

| Research             | Domain Knowledge | Method/Tools                  | Industry |
|----------------------|------------------|-------------------------------|----------|
| Chen et al., 2018    | Physical IoT | Crumpled morphology onto the gold thin film using macro control | Electronics |
| Jouzan et al., 2018  | Physical IoT | Electrolyte-gated field-effect transistors (EGFETs) based on inorganic materials | Electronics |
| Kumar and Gandhi, 2017| Communication IoT | Transport layer security (TLS) protocol | Electronics |
| Liu et al., 2018a    | Phisical IoT | Flexible temperature sensors | Electronics |
| Pyo et al., 2019     | Physical IoT | Triboelectric nanogenerators (TENGs) | Electronics |
| Razafimandimbily et al., 2019 | Communication IoT | Neuro-Dominating Set algorithm (NDS) | Electronics |
| Salomon and Meissner, 2015 | Phisical IoT | Monte Carlo simulations | Electronics |

Table 9: Growth of IoT knowledge on Health.

| Research             | Domain Knowledge | Method/Tools                  | Industry |
|----------------------|------------------|-------------------------------|----------|
| Chai et al., 2018    | Application and Service IoT | Plan-Do-Study-Act method | Health |
| Chukka and Kumar, 2018| Application and Service IoT | IoT-Enabled ECG | Health |
| Ezhoveny et al., 2018 | Application and Service IoT | Telemetry system | Health |
| Kaur et al., 2018    | Application and Service IoT | Vector machine and artificial neural network classifiers | Health |
| Kim and Chung, 2017  | Application and Service IoT | Knowledge-based | Health |
| Kim and Kim, 2018    | Application and Service IoT | Crowdsourcing | Health |
| Li et al., 2018a     | Application and Service IoT | (a,k)-anonymity model | Health |
| McRae et al., 2016   | Application and Service IoT | Machine learning | Health |
| Santhoshi and Thirugnanam, 2016 | Application and Service IoT | Fall detection scheme using ambient sensors | Health |
| Sarkar et al., 2017  | Application and Service IoT | Blind cloud framework | Health |
| Wang et al., 2018c   | Application and Service IoT | The Mann-Whitney test or t-test | Health |
| Xie et al., 2018     | Platform IoT | Knowledge in linked open data | Health |

architecture to combine primitive information into collective intelligence (Salmon and Meissner, 2015).

The research on the Health area, there is a paradigm shift from traditional and IoT-based medical field cases, where doctors now have to pay more attention to the patient's raw medical records, then directly in making medical advice, conclusions or diagnoses from their experience using the hospital information system (HIS). The IoT-based HIS is distributed by scattered devices such as tablet computers, personal digital assistants that are used as automatic analyzers, or other massive and informative medical devices (Xie et al., 2018) and the possibility of a diagnosis can be made by a doctor elsewhere when the doctor has time for special patients, so the diagnosis can be more precise.

IoT research in the health sector, it is important to pay attention to various attributes of health information such as the service provider profession, task discussion room, devices used, expert support, and various personal medical data (Kim and Kim, 2018). Various medical data can be obtained by utilizing IoT devices that are in our daily lives, such as jam, health tape, scale, TV, lights, and door lock (Kaur et al., 2018), or various types of related sensors used such as smart accelerometers, gyroscope, pulse oximeter, RBG camera, camera Kinect, micro cellphone, PIR, RFID, smart tiles, etc., where these sensors are integrated with IoT technology (Santhoshi and Thirugnanam, 2016) and all these sensors can support, personal health records and self-diagnoses (Kim and Chung, 2017), for example, IoT to monitor human physiological conditions indefinitely, so doctors examine their patients remotely such as monitoring using brain safety research obtained through sensors (Kaur et al., 2018).

IoT research in the energy sector largely relies on energy efficiency that can be applied to a wide variety of fields with the benefits brought by IoT, both in internal IoT devices that require energy to run (usually batteries or solar panels), as well as external use of resources large-scale energy such as power-networks that are helped by IoT in reducing unnecessary or inefficient energy. The basic idea of the various studies is IoT that is able to complement network connectivity and computing capabilities to various physical devices.

Smart-grid is a sub-function of the smart city today, its research has become an evolution in managing electricity demand that is large to be managed, smart and economical, in the Heterogeneous Network.
conditioners) communicate over the network using smart meters and suppliers with smart decisions about energy use/production in real time. Electricity meters are connected to the Internet to provide consumers and adjust to changes in user demand. This is supported by IoT where growth of IoT knowledge on energy.

The idea of IoT research then continues to develop through the combination of co-citation offers a perspective on the work of the most influential and most productive industries in the IoT. The main research idea based on the business domain or technical derivability, which are crossed over among ideas. Based on the deductive way, a researcher can begin the process of sequential research thinking starting from the point of view of business and industrial needs as a broad-scale need. Then leading to the need for science and technology using certain tools and methods. Then based on IoT technology architecture that focuses on one or more applications, platforms, communications, and sensors. In the end, research involving the IoT system utilizes the main capabilities of each IoT device that has traces, views, operations and facilitates something.

### Table 10

| Research | Domain Knowledge | Method/Tools | Industry |
|----------|------------------|--------------|----------|
| (Boudekis et al., 2018) | Application and Service IoT | “Detect-Predict-Decide-Act” proactive decision principle | Energy |
| (Han et al., 2018) | Physical IoT | Ultra-low power (ULP) | Energy |
| (Jutila, 2016) | Communication IoT | VLSI circuits | Energy |
| (Liu et al., 2018b) | Physical IoT | Tag searching | Energy |
| (Mohiuddin and Almogren, 2019) | Platform IoT | Virtual Machine | Energy |
| (Praveen Kumar Reddy and Rajasekharababu, 2017) | Physical IoT | Gravitational Search Algorithm (GSA) and Artificial Bee Colony (ABC) algorithm | Energy |
| (Reddy and Babu, 2017) | Communication IoT | Fuzzy C-Means (FCM) clustering algorithm | Energy |
| (Rizwan and Rajasekharababu, 2016) | Platform IoT | DVFS (Dynamic Voltage and Frequency Scaling) | Energy |
| (Sun et al., 2018) | Platform IoT | Markov decision process. | Energy |
| (Wan et al., 2019) | Platform IoT | Q-learning algorithm and binary space partitioning (BSP) | Energy |
| (Li et al., 2018d) | Application and Service IoT | software-defined network (SDN) and edge computing (EC) | Energy |
| (Wang et al., 2018a) | Platform IoT | Offloading-assisted energy-balanced approach on IoT edge node relocation (CIC-OAERA), and CIC-based Direct Replacement Approach (CIC-DRA). | Energy |
| (Zhang et al., 2018) | production and logistics | production and logistics | Energy |
| (Cui et al., 2018) | Physical IoT | PRG | Energy |
| (Ge et al., 2017) | Platform IoT | Forum Alert Traffic Security (FATS) architecture | Energy |
| (Gupta et al, no date) | Communication IoT | taxonomy of various solutions | Energy |
| (Hao et al., 2015) | Physical IoT | Agent middleware technology | Energy |
| (Tervonen, 2018) | Physical IoT | Survey, business excellence and CogInfoCom | Energy |

infrastructure. Smart grid can automatically support electricity in the city and adjust to changes in user demand. This is supported by IoT where electricity meters are connected to the Internet to provide consumers/suppliers with smart decisions about energy use/production in real time. For example, smart home appliances (dishwashers, clothes, and air conditioners) communicate over the network using smart meters and electric machines to avoid peak times (Al-Turjman, 2018). The idea of IoT research then continues to develop through the integration of various infrastructure attributes such as hospitals, electricity networks, energy, transportation, food, air, etc. The idea of the researcher (Al-Turjman, 2018) with the “Agile IoT” method uses middleware signal processing to allow sensors in the infrastructure to be redesigned by applying ideas 1) Trying parallel communication methods, and 2) Feeling parallel mechanical parameters, to utilize the temperature sensor parameters for non-temperature measurements, such as fluid flow in a pipe (air, plant), ice buildup (transportation, energy, manufacturing), and mechanical doors (medicine storage cabinets in hospitals). “Green computing” method for energy use efficiency, where virtual machines replace idle physical servers into hibernation mode, thereby reducing power usage (Mohiuddin and Almogren, 2019).

Energy research in its own IoT internal devices, power consumption is a major concern for on-chip system designers, such as using ultra-low power VLSI (ULP) circuits that have benefited greatly from academia and industry as the most suitable technique for IoT devices (Han et al., 2018), a method with a combination of Optimal Secure Energy Conscious Protocol (OSEAP) and Improved Bacterial Foraging Optimization (IBFO) algorithm (Praveen Kumar Reddy and Rajasekharababu, 2017), resource allocation using the DVFS (Dynamic Voltage and Frequency Scaling) method and method optimal effective consolidation (Rizwan and Rajasekharababu, 2016).

#### 4.4. The thinking process on how scientists formulate IoT research

According to the systematic research survey result, it can be assumed there is a logically consistent of the scholar thinking process such framed in Fig. 6. The main research idea based on the business domain or technical derivability, which are crossed over among ideas. Based on the deductive way, a researcher can begin the process of sequential research thinking starting from the point of view of business and industrial needs as a broad-scale need. Then leading to the need for science and technology using certain tools and methods. Then based on IoT technology architecture that focuses on one or more applications, platforms, communications, and sensors. In the end, research involving the IoT system utilizes the main capabilities of each IoT device that has traces, views, operations and facilitates something.

#### 5. Conclusion

Paper made an important contribution, regarding the growth and development of the IoT in the following stages: First, applying a new research approach to all Scopus literature, reliable paper journals and proceedings from the beginning of 2006 until the end of 2018 without exception, as a dynamic representation of the growth of knowledge in the field to what are the main component themes. Second, exploring the field of the IoT with industry classification offers a comprehensive review. The combination of co-citation offers a perspective on the work of the most influential and most productive industries in the IoT. Third, this paper looks at Growth and Development of the IoT in Industry, about evaluating the problems that exist in defining needs, a technology that can be helped by the presence of IoT, problems when implementing IoT technology, until after the implementation of IoT. Fourth, this paper reaches out to thinking patterns from existing forms of research, by framing the thinking process of researchers.

This paper represents an overview of the field of IoT by combining two important perspectives - observing evolution and observing IoT directly on the most prominent themes in the Industrial sector and also as an accurate foundation for seeing new IoT business opportunities and research opportunity.

The most important factor that determines what is the most influential theme for researchers in the IoT found in this study are (1) the emergence of the 4th industrial revolution as an interesting topic for researchers because it has many novelties especially in large-scale industrial reforms manufacture, then (2) the broad opportunities and benefits of socio-economic research as shown by agriculture results in the result and analysis section A, and (3) considering how the level of risk from applying the research, such as those found in Hospital and healthcare industries which requires time for technological readiness.

Based on the perspective of researchers, how to start new research on IoT is how they need to focus on research gaps based on certain phenomena, but their research must be built on concepts about industry, methods, tools, technology, and functions as a deductive-scientific
approach. Research can also participate in following the trend that moves over time, where since the last two years research on hospitals, healthcare and energy has been widely researched and indicates that there will be many novels in this field.

There is a dependence on the time span of the dataset being studied, which allows for replication of the analysis in the future, at the same time period or in between, while the analysis of the next timeframe will produce different outcome lines. However, the overall study only processes Scopus indexed papers. There is a possibility that some papers that have significant scientific knowledge are excluded in research surveys, such as white paper from consulting firms, research companies, and government institutions, and IoT vendor companies. Therefore, this paper provides a good starting point for providing business solutions as well as dynamic literature reviews that are similar to other fields, or some explorations that are sub-sections of the IoT, for example, the results obtained can be further analyzed for positive roles and IoT negative in its application in the industry, what methods/tools are widely used, and so on.

Declarations

Author contribution statement

Muhammad Dachyar: Conceived and designed the experiments; Analyzed and interpreted the data.
Teuku Yuri M. Zagloel: Performed the experiments.
Lihardo Ranjaliba Saraghi: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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