9 772723 437005

Institut Teknologi Telkom Surabaya
Ketintang Str. No. 156, Surabaya, 60231,
East Java, Indonesia
E-mail: complete@ittelkom-sby.ac.id;
Web: journal.ittelkom-sby.ac.id/complete

COMPLETE | Journal of Computer, Electronic, and Telecommunication | Vol. 1 No. 1 July 2020

COMPLETE

Journal of Computer, Electronic, and Telecommunication

Vol. 1 No. 1 July 2020

JURNAL

KEMAJUAN TEKNIK KOMPUTER, ELEKTRO, & TELEKOMUNIKASI

ISSN: 2723-4371 E-ISSN: 2723-5912

ITTelkom Surabaya
Solution for The Nation

Website: journal.ittelkom-sby.ac.id/complete | E-mail: complete@ittelkom-sby.ac.id

EDITORIAL TEAM

Journal of Computer, Electronic, and Telecommunication

Faculty of Electrical Engineering - Institut Teknologi Telkom Surabaya

Ketintang Str. No. 156, Surabaya, 60231, East Java, Indonesia

Phone. +6285 234852155; E-mail: complete@ittelkom-sby.ac.id;

Web: journal.ittelkom-sby.ac.id/complete

TABLE OF CONTENTS

ABOUT THE JOURNAL

COMPLETE : Journal of Computer, Electronic, and Telecommunication is an official journal of Faculty Electrical Engineering, Institut Teknologi Telkom Surabaya. It publishes research or review articles in the field of Computer, Electronic, and Telecommunication technology. This journal provides platform for research lecturers, the reviewer, practitioners, industry, and observers across Indonesia and overseas to promote, share, and discuss new issues and development of technology. Scope of the journal include :

- Technology utilization of maritime resources
- Strengthening infrastructure maritime
- Technology and management safety transportation
- Industrial strengthening technology transportation
- Supporting infrastructure and transportation system
- Operational efficiency
- Electronics Technology
- Telecommunication Technology
- Computer Technology
- System Security
- Advanced Robotics Technology
- Technology and disaster management
- Advanced Power Electronics
- Application of Power System
- Renewable Energy
- Chips Technology
- Smart IoT Devices
- 5G Technology and Ecosystems
- Technology and management environment

COMPLETE published twice a year. Editors invite research lecturers, the reviewer, practitioners, industry, and observers to contribute to this journal. The language used in the form of Indonesian and English. All accepted manuscripts will receive individual digital object identifier (DOI) and indexed by Google Scholar (On Processing). The online PDF version of the journal is open access from journal.ittelkom-sby.ac.id/complete. Subscription of the hard copy can be requested by email to complete@ittelkom-sby.ac.id.

PREFACE

Welcome to the Journal of Computer, Electronic, and Telecommunication, Vol. 1, Issue No. 1. It is my privilege and pleasure to present the second volume of this peer-reviewed journal, the first published journal under Institut Teknologi Telkom Surabaya. The aim of this journal is to accommodate the results of research publications through journals, from national to worldwide, as part of continuous improvement.

As the chairman of COMPLETE, I would like to thank many people who supported to this journal, especially Research and Community Service Units (LPPM) Institut Teknologi Telkom Surabaya. Furthermore, as the editor in chief, I would like to extend my sincere thanks to all members of the editorial and the advisory boards from Institut Teknologi Telkom Surabaya, whose service, dedication, and commitment have made the creation of this journal possible. We work together trying to continuously improve the quality and excellence of articles published.

It is our hope that COMPLETE could deliver valuable and interesting information and stimulate further research to the telecommunications, electrical, and computer engineering communities throughout the world.

Surabaya, July 2020

Editor of Journal

COMPLETE
Journal of Computer, Electronic, and Telecommunication
ISSN 2723-4371, E-ISSN 2723-5912
doi.org/10.52435/complete.v1i1.43

Design Configuration of Water Quality Monitoring System in Surabaya

Anifatul Faricha [1], Dimas Adiputra [2*], Isa Hafidz[3], Moch. Iskandar Riansyah[4], Lora Khaula Amifia[5], Moch. Fauzan Rasyid[6], Moch. Bagus Indrastata[7], Abdulloh Hamid Nushfi[8]

[1-8] Department of Electrical Engineering, Faculty of Electrical Engineering, Institut Teknologi Telkom Surabaya, Jawa Timur, Indonesia; adimas@ittelkom-sby.ac.id
* Correspondence: adimas@ittelkom-sby.ac.id or faricha@ittelkom-sby.ac.id

Abstract: Water have been important needs for human life in many sectors such as in industry, agriculture, and household that its quality must be conserved so is in Surabaya city. The quality of water could influence the quality of human life directly, thus it is important to have an integrated water quality monitoring system. Information regarding water quality monitoring such as pH, dissolved oxygen, turbidity, and conductivity were collected to produce a periodic decision for controlling, analyzing, and fixing the condition of the water. This paper proposed a design configuration of water quality monitoring system for tap water in Surabaya. First, a comparison study of water quality monitoring technology in terms of area, parameter, and methodology from the previous researchers is presented. From the study, the design configuration of water quality monitoring system to be implemented in Surabaya is concluded. The data collection method is better to be done by using Internet of Things (IoT) technology where it is possible to do multiple data type and multiple point real-time data collection throughout the water distribution network remotely.

Keywords: Water quality monitoring; area; parameter; methodology; internet of things; data collection; real-time; remote; distribution network; Surabaya.

1. Introduction

The world enters industry 4.0 era where the information exchange became so fast due to the internet interference. The growth of industry development becomes faster which also increased the production rate. Although, high production rate was good for the industry, the increment of waste from the production need to be further considered. The waste might affect the water resource such as decreasing the water quality [1]. Low water quality was not safe to be used as drinking water and potentially harmful for public health. Therefore, the water quality needs to be monitored so it can be evaluated to ensure the public health [2].

In order to conserve the water quality, several researches on water quality monitoring had been done conventionally. For instance, samples were collected from several sites then transported to laboratory for further test and analysis. This method was clearly no efficient, which take times and high cost [3]. Further action was necessary if the water quality was low. However, it would not relevant anymore because the time between sample collection and analysis results was too long. Real time and remote monitoring was demanded so fast action could be taken to overcome the reduction of water quality [4] and this can be achieved by implementing Internet of Things (IoT) in water quality monitoring [5].

The IoT connects many entities for exchanging information between them such as utensils, vehicle, appliances, and any kind of tools or machine with embedded sensors and communication

software through the internet. Nowadays, the IoT concept has been implemented in many aspects of daily life such as industry, government, household, weather forecast, traffic monitoring, smart farm, and even the water quality monitoring [4]. The IoT utilize a storage system which is based on cloud which enable multiple access from any authorized user anywhere and anytime they are connected to the internet. Therefore, by implementing the IoT, the water quality monitoring surely can be done in real time, moreover in remote area also.

Although, the real-time and remote water quality monitoring is important, it has not been considered yet in Surabaya especially the tap water. This paper will discuss about water quality monitoring in terms of monitoring area in section 2, parameter in section 3, and methodology in section 4. The discussions are based on articles found in the Web of Science by using key word "Water Quality Monitoring IoT" and "Water Quality Monitoring Online". Then, the findings were concluded in section 5 to decide suitable design configuration of water quality monitoring in Surabaya especially for tap water (PDAM) in section 6.

2. Water Quality Monitoring Area

Water covers more than 60% of the earth area. However, not all the water on the earth is used for daily living. It was not necessary to do water monitoring in all water area on earth, except in the area where the water is used for daily living. From the previous research, the water has been monitored in strategic area such as in medical environment [6], industrial environment [7], agriculture [8], aquaculture [9], disaster prone area [10], pipe network [11] and sewage [2], catchment area [1], household [12] and drinking water supply [13] as shown in Figure 1. In this section, each of the water monitoring area is further discussed.

Figure 1. Water quality monitoring area.

The water monitoring in medical environment and industrial environment has not been done for the tap water, but rather chemical solution. It is not that the medical and industrial does not use tap water in their daily routine. However, the main concern of liquid in that area was not the tap water, but another liquid such as chemical solution which directly contribute to the area. For instance, in medical environment, the IV content monitoring in a saline bag [6] and chemical content such as calcium threshold in a solution which unnecessary for medicine [14]. On the other hand, the viscosity of an oil is necessary to be monitored in industrial environment because the oil was used regularly for the machinery [7].

Agriculture [15], aquaculture [16], and disaster prone [10] area can be categorized as one area

category of water monitoring. In these areas, it was important to monitor the water especially the necessary amount of water which was used for irrigation [17]. Too less water was not good for the plant in a farm, however, too much water was dangerous for the plant life. In some cases, the water content for watering the plant was also monitored to make sure the plant grows well. As for the disaster- prone area, the water was monitored as an indicator for early notification of disaster such as flood [10].

Another area necessary to be monitored was the tap water distribution area such as the catchment area or water resource area [4, 18], the pipe network itself [19, 20], and the sewage [21]. In these three areas, all the water quality must be guaranteed to be good. Clearly, the water quality in the catchment area such as river bank, lake, and fountain must be good before starting distribution [22]. As the water quality in the pipe network in underground [23] must be guaranteed to prevent quality reduced due to the pipe network issue such as rusty pipe and so on [24]. The water quality in sewage was also needed to be monitored because it was usually hazardous for the environment [21]. To determine the water quality, it was necessary to consider multiple sensor [25, 26] which could work independently and remotely [5] in real time application [27]. This is where the IoT took place in the monitoring system.

Last but not least, the water quality has been monitored near to us which were in household [16] and drinking water area [28]. The household water or tap water as well as drinking water were monitored because the tap water is used directly by the end-user, thus the quality assurance is necessary [21]. The household water can be monitored in the water tank and pipe network [29] inside the house which could be imagined as small version of water distribution network [30]. As for the drinking water, the monitoring could be done in water dispenser before the water reach the glass [5].

3. Water Quality Monitoring Parameter

Several parameters have been considered in water monitoring, such as Fluid Level [6], Viscosity [7], Water Needs [15, 17], Leakage [23, 24], Volatile Organic Compounds (VOC) [4, 28], Environment Parameter (temperature, humidity, pollution) [25, 16], and Water Quality Parameter (pH, oxygen, turbidity, conductivity, mineral content) [5, 21] as shown in Figure 2. Not all the mentioned parameter directly related to water quality monitoring. Also, depends on the monitoring purposes, the monitoring could only consider one parameter or multiple parameter.

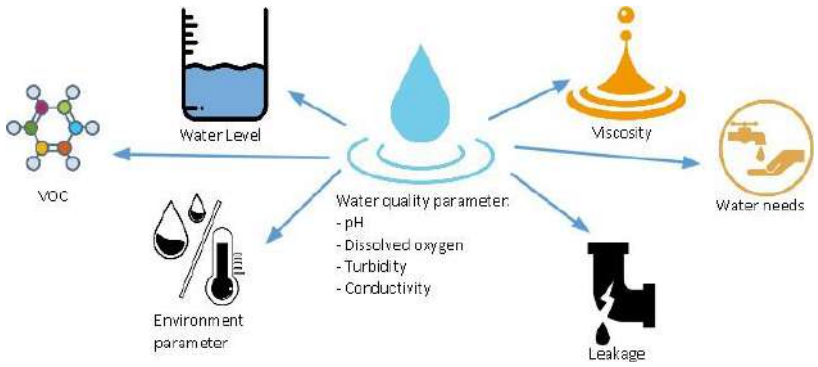


Figure 2. Water quality monitoring parameter

Fluid level and viscosity were the considered parameter in medical and industrial environment. Both these parameters did not relate to water quality monitoring, but rather a solution quality monitoring. For instance, the content of IV saline bag was necessary to be monitored for early notification when the IV was running out [6]. The mineral content in a solution was monitored because there might be some toxic mineral or unwanted mineral included. The solution which was contaminated with unnecessary mineral might not suitable for patient's consumption [14]. On the other hand, the viscosity of an oil was monitored to ensure the industrial machine could work optimally by using the monitored oil as a grease [7].

The plant water needs to be fulfilled, however the needs are not necessary to be fulfilled every time. Therefore, the water needs for plant are considered parameter to be monitored in agriculture area [8, 15] which was determined by using external information such as the temperature surrounding the plant and internal information such as the leaf temperature [8]. The water needs speak about the water volume which has similarity to water usage. However, the term of water usage was usually used for household area [30]. The water usages were monitored for bill efficiency and usually combined with electricity monitoring [12]. Although, both these parameters are not directly related to the water quality parameter, it can still be considered to support the water quality monitoring system.

Leakage was a common problem found in water distribution network which usually use pipe as the distribution medium. The investigation of leakage was conducted by using vibration signal (acoustic, radio, spectrogram) which could be modeled as leakage type, pipe pressure, and current season as presented in [11, 23]. Flow meter also can be used to detect the leakage in house pipe network, however without the ability to pinpoint the leakage location [20]. To enable the location detection, several points of measurement need to be considered in the pipe network. Similar to water usage and water needs, the leakage is not a water quality parameter, but can be considered as supporting parameter in water quality monitoring system.

Through all various water conditions and anthropogenic pressure, the quality of water can be affected by other chemical substances. The water may contain chemical compound such as Volatile Organic Carbon (VOC). It could be measured using spectrometer to see the UV absorbance of the water [13]. In another researches, impedance analyzer was used to collect information of vary impedance of a water due to VOC. It would be dangerous if by any change the VOC or even microbial inside the water was the one that affect health aspect of living creature [27]. The VOC amount in the water is necessary to be monitored in real time and remotely to ensure the water quality. Thus, early notification of microbial re-growth can be obtained as early as possible.

In some researches, the environment parameters such as temperature, humidity, and pollution are included together with VOC in water monitoring system for assessing the water quality [1, 2, 25]. Previous researches have addressed pH, dissolved oxygen, turbidity, and conductivity specifically for water quality parameter [9, 18, 27]. The reported water quality parameter is suitable with the parameter mentioned in standard IS 10500:1991. Another additional information that could be considered in water quality monitoring was the nutrient content as reported in [5]. Combining all the parameter to be considered in water quality monitoring, the water quality can be guaranteed and moreover the abnormality can be quick assessed due to vast amount of data available.

4. Water Quality Monitoring methodology

In doing the water quality monitoring, several methodologies have been conducted by previous researcher. In this paper, the methodologies were categorized based on measurement type and monitoring type. Based on measurement type, the methodologies are divided into direct measurement [1] and indirect measurement [4]. Then, based on monitoring type, the methodologies are divided into offline monitoring [24], online monitoring [8, 13], and remote-online monitoring [9, 29]. Illustration of water quality monitoring methodology is shown in Figure 3.

Figure 3. Water quality monitoring methodology

The direct measurement means the parameter to measure the water quality were measured using the respective sensor. For instance, the temperature was measured using temperature sensor [31] and water pH was measured using pH sensor [9]. On the other hand, indirect measurement was conducted using sensor which was different with the measured parameter, thus a model was needed to obtain the measurement result. For instance, the leaking was measured using acoustic sensor. To locate the leakage, propagation model of the acoustic signal was derived to pinpoint the location of the leakage [11, 19, 20, 23].

Depends on the monitoring type, the water monitoring methodologies are divided into offline, online, and remote-online monitoring methods. The offline monitoring methods were the conventional way to monitor the water quality which was not suggested anymore [15, 24]. Online monitoring was a promising method to monitor the water quality. Any detected abnormality for instance, leakage in the network could be known right away, thus further action could be taken to fix the abnormality [4, 29, 30]. In addition, the online monitoring that can be done remotely was the most suggested method, thus called as remote-online monitoring. These methodologies enabled an online monitoring in a remote area notably the catchment area [5, 18, 25] and buried pipe network [23, 24] which can be done easily by IoT [22]. Some of the previous works also consider multiple point measurement instead of single point measurement to enable abnormality prediction and analysis using model [20, 24] or even artificial intelligence [23]. For instance, water contaminant detection in several point in a house pipe network to analyze the contaminant distribution [28]. In some research, the monitoring was done in several point with different way such as local point measurement, airborne measurement, and satellite [27]. In another research, multiple point measurement was used to obtained different information to produce satisfying hot water in terms of energy usage and water temperature [31].

5. Discussion

In this paper, several aspects regarding water quality monitoring had been discussed in terms of area, parameter, and methodology. Table 1 shows the summary of water quality monitoring. Most

of the previous works pay attention to do water quality monitoring in catchment area [4, 25], household area [16, 29] and drinking water [5, 28]. This is because the main function of the water itself which is to be consumed by living creatures.

The leakage monitoring in pipe network also has high attention because it affects the water resource and distribution [23, 24]. Other than that, the water monitoring can be seen in agriculture for the plant water [8, 15] and in aquaculture for the environment condition [9, 16]. The parameter which was being measured to assess the water quality were pH, dissolve oxygen, turbidity, conductivity (EC), and mineral content. This is suitable with parameter mentioned in drinking water standard IS 10500:1991. In some cases, the environment parameter such as temperature and humidity were considered for luxury application such as home water heater [31]. The volatile organic compounds (VOC) were also necessary to be measured because it affected the long-term health although it was not acutely toxic [2, 28]. Water usages and leaking monitoring was necessary to be monitored for ensuring the high- quality water was well distributed [23, 24]. As for fluid level and viscosity, it was not considered for water quality monitoring as its application was for chemical solution in medical andindustrial application [6, 7, 14].

There were lots of parameter to be considered in doing the water quality monitoring. Therefore, the IoT methodology was the most prominent method to be implemented [26]. That was because it could realize an integrated water quality monitoring by combining many kinds of respective sensor, thus build a sensor network to collect data for assessing the water quality in real time [14]. The IoT also provided a remote-online monitoring, therefore the monitoring could take place in a remote area such as in a catchment area [27]. Moreover, multiple point measurement could also be implemented using this IoT method. Various type of data could be collected, thus opened the possibility of machine learning to develop a decision-making process for pin pointing the abnormality location and determining anecessary action due to abnormality [5, 28].

6. Proposed Design Configuration

The previous researches pay close attention to real-time and remote water quality data collection using sensor network through internet (IoT) real- time and remote data collection. The data is then can be used for analysis such as water quality classification, abnormality location, and further action due to the abnormality accordingly using machine learning method. This section explains the proposed design configuration for water quality monitoring in Surabaya as shown in Figure 4.

The proposed system has multiple point of data collection such as module A, module B, and module C. At least, there are three data collection points such as at the source, along the distribution network, and at the sink. It is expected from multiple data collection point that more information can be obtained, thus better water quality classification and abnormality location analysis can be conducted. In each module, there are sensors such as pH, oxygen, turbidity, conductivity sensors, and flow meter sensors. Data from the sensors are sent to the cloud server. This information is then can be accessed by authorized personal on their smartphone or personal computer anywhere and anytime they were connected to the internet.

Table 1. Summary of water quality monitoring research

References	Monitoring		
	Area	Parameter	Methodology
6	Medical environment	Fluid level	Indirect measurement, remote-online using IoT.
14		Mineral content	
7	Industrial environment	Viscosity	Indirect measurement, online
15	Agriculture	Water needs/ water usages	Indirect measurement, offline
8			Indirect measurement, online
17			Indirect measurement, remote-online using IoT
9, 16	Aquaculture	pH, oxygen, turbidity, conductivity, temperature, VOC	Direct measurement, remote-online using IoT
14	Disaster prone area	Water level	Direct measurement, remote-online using IoT.
11, 20, 24	Pipe network	Leakage	Indirect measurement, offline
23			Indirect measurement, remote-online using IoT
19			Direct measurement, offline
21, 26			Direct measurement, remote-online using IoT
2	Sewage	VOC	Direct measurement, online monitoring
21		pH, oxygen, turbidity, conductivity	Direct measurement, remote-online using IoT
4	Catchment area	VOC	Indirect measurement, remote-online using IoT
1, 25		Temperature, humidity, pollution	Direct measurement, remote-online using IoT
27		pH, oxygen, turbidity, conductivity.	Direct measurement, online
18, 5, 22			Direct measurement, remote-online using IoT

29	Household	Leakage	Indirect measurement,
			remote-online using IoT
12, 30		Water needs/water usages	Direct measurement, remote-online
16, 31		Temperature, humidity, pollution	using IoT
13	Drinking water	VOC	Indirect measurement, online
28			Direct measurement, online
21		Leakage	Direct measurement, remote-online
5		pH, oxygen, turbidity, conductivity	using IoT

Figure 5 shows the proposed module of water quality system monitoring. There are two chambers inside the module box namely lower and upper chamber. On the lower chamber, there is a pipe that goes outside the module box which can be installed directly to the water distribution network and sink pipe. It can also be put float on a water tank at the source point with the help of

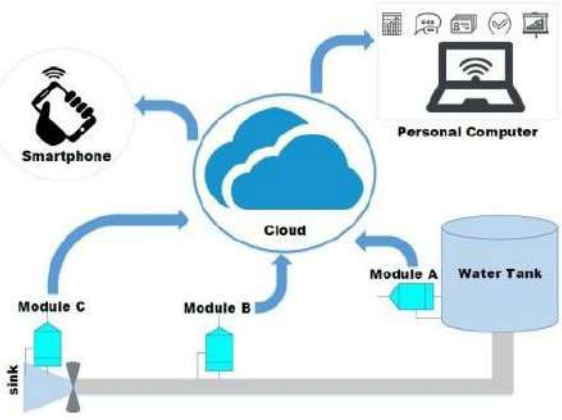


Figure 4. Proposed design configuration of water quality monitoring in Surabaya.

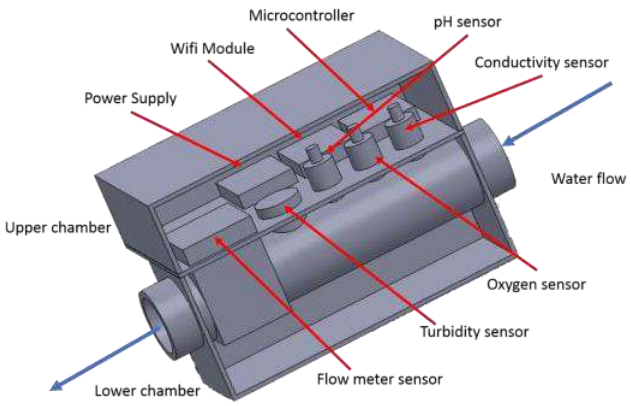


Figure 5. Proposed water quality monitoring module. The module architecture (a); module installed on a water tank (b); module installed on a pipe network (c).

weight and buoy. The sensors are installed to pierce the pipe structure thus it can collect the water quality data. On the upper chamber, there are power supply, microcontroller, and circuit for reading and sending the data from sensors. Lastly, there was also a wifi module for data communication between the module and the cloud.

7. Conclusion

In this paper, preliminary study to decide design configuration for water quality monitoring in Surabaya is presented. Comparison study on water quality monitoring has been conducted in terms of monitoring area, monitoring parameter, and monitoring methodology. Based on the previous researches and future trends suggestion in previous sections, the combination of water quality parameter (pH, oxygen, turbidity, conductivity, VOC), leakage, water usage, are necessary to monitor the tap water quality in Surabaya. Thus, in the proposed monitoring module, there are pH sensor, conductivity sensor, turbidity sensor, and flow meter sensor to obtain that information. Monitoring module are proposed to be installed in multiple point of measurement namely source, network distribution, and sink. By doing this, it is expected that many information can be obtained to conduct water quality and abnormality, and location analysis. The modules are connected using IoT technology, so it can communicate with the cloud server for data storage and authorized personal for a decision. The next step is to develop the module and capture the water quality data of tap water in Surabaya.

Acknowledgments: The authors would like to express gratitude to Institut Teknologi Telkom Surabaya for the funding support in doing this research articles under Dana Bantuan Penelitian dan Pengabdian Masyarakat Institut Teknologi Telkom Surabaya 2019.

References

1. Fang, S., Xu, L. Da, Zhu, Y., Ahati, J., Pei, H., Yan, J., & Liu, Z. (2014). An integrated system for regional environmental monitoring and management based on internet of things. IEEE Transactions on Industrial Informatics, 10(2), 1596–1605. http://doi.org/10.1109/TII.2014.2302638
2. Wu, C., Liu, W., Jiang, J., Wang, Y., Hou, K., & Li, H. (2019). An in-source helical membrane inlet single photon ionization time-of-flight mass spectrometer for automatic monitoring of trace VOCs in water. Talanta, 192, 46–51. http://doi.org/10.1016/j.talanta.2018.09.013
3. Henny Gusril. (2016). Studi Kualitas Air Minum PDAM di Kota Duri Riau. Jurnal Geografi, 8(2), 190-196. https://doi.org/10.24114/jg.v8i2.5783
4. Khan, R., Khan, S. U., Zaheer, R., & Khan, S. (2012). Future internet: The internet of things architecture, possible applications and key challenges. Proceedings - 10th International Conference on Frontiers of Information Technology, FIT 2012, 257–260. http://doi.org/10.1109/FIT.2012.53
5. Chang, N. Bin, Imen, S., & Vannah, B. (2015). Remote sensing for monitoring surface water quality status and ecosystem state in relation to the nutrient cycle: A 40-year perspective. Critical Reviews in Environmental Science and Technology, 45(2), 101–166. http://doi.org/10.1080/10643389.2013.829981
6. Ray, P. P., & Thapa, N. (2018). A systematic review on real- time automated measurement of IV fluid level: Status and challenges. Measurement: Journal of the International Measurement Confederation,

129(September 2017), 343– 348. http://doi.org/10.1016/j.measurement.2018.07.046

7. Wang, G., Wang, Q., & Li, F. (2018). A U-shape shear horizontal waveguide sensor for on-line monitoring of liquid viscosity. Sensors and Actuators, A: Physical, 284, 35–41. http://doi.org/10.1016/j.sna.2018.10.017
8. Daskalakis, S. N., Goussetis, G., Assimonis, S. D., Tentzeris, M. M., & Georgiadis, A. (2018). A uW Backscatter-Morse- Leaf Sensor for Low-Power Agricultural Wireless Sensor Networks. IEEE Sensors Journal, 18(19), 7889–7898. http://doi.org/10.1109/JSEN.2018.2861431
9. Vijayakumar, N., & Ramya, R. (2015). The Real Time Monitoring of Water Quality in IoT Environment. IEEE Sponsored 2nd International Conference on Innovations in Information,Embedded and Communication Systems (ICIIECS)2015.
10. Perumal, T., Sulaiman, M. N., & Leong, C. Y. (2016). Internet of Things (IoT) enabled water monitoring system. 2015 IEEE 4th Global Conference on Consumer Electronics, GCCE 2015, 86–87. http://doi.org/10.1109/GCCE.2015.7398710
11. Hunaidi, O., & Chu, W. T. (1999). Acoustical characteristics of leak signals in plastic water distribution pipes. Applied Acoustics, 58(3), 235–254. http://doi.org/10.1016/S0003- 682X(99)00013-4
12. Chen, H., Wu, C., Huang, W., Wu, Y., & Xiong, N. (2018). Design and application of system with dual-control of water and electricity based on wireless sensor network and video recognition technology. International Journal of Distributed Sensor Networks, 14(9). http://doi.org/10.1177/1550147718795951
13. Asheri-Arnon, T., Ezra, S., & Fishbain, B. (2018). Contamination Detection of Water with Varying Routine Backgrounds by UV-Spectrophotometry. Journal of Water Resources Planning and Management, 144(9), 4018056. http://doi.org/10.1061/(ASCE)WR.1943-5452.0000965
14. Yuan, Y., Feng, S., Alahi, M., Nag, A., Afsarimanesh, N., Zhang, H., & He, S. (2018). Development of an Internet of Things Based Electrochemical Microfluidic System for Free Calcium Detection. Applied Sciences, 8(8), 1357. http://doi.org/10.3390/app8081357
15. Adeyemi, O., Grove, I., Peets, S., Domun, Y., & Norton, T. (2018). Dynamic modelling of lettuce transpiration for water status monitoring. Computers and Electronics in Agriculture, 155(September), 50–57. http://doi.org/10.1016/j.compag.2018.10.008
16. Shixian, Z., & Rui, X. (2018). Research and development of water quality online monitoring system based on Internet of things technology. Desalination and Water Treatment, 122, 25–29. http://doi.org/10.5004/dwt.2018.22586
17. TongKe, F. (2013). Smart Agriculture Based on Cloud Computing and IOT. Journal of Convergence Information Technology, 8(2), 210–216. http://doi.org/10.4156/jcit.vol8.issue2.26
18. Esakki, B., Ganesan, S., Mathiyazhagan,S., Ramasubramanian, K., Gnanasekaran, B., Son, B., Choi, J. S. (2018). Design of amphibious vehicle for unmanned mission in water quality monitoring using internet of things. Sensors (Switzerland), 18(10). http://doi.org/10.3390/s18103318
19. Ahadi, M., & Bakhtiar, M. S. (2010). Leak detection in water-filled plastic pipes through the application of tuned wavelet transforms to Acoustic Emission signals. Applied Acoustics, 71(7), 634–639. http://doi.org/10.1016/j.apacoust.2010.02.006
20. Poulakis, Z., Valougeorgis, D., & Papadimitriou, C. (2003). Leakage detection in water pipe networks using a Bayesian probabilistic framework. Probabilistic Engineering Mechanics, 18(4), 315–327. http://doi.org/10.1016/S0266- 8920(03)00045-6
21. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT) A vision, architectural elements, and future directions. Future Generation Computer Systems, 63(3), 16–18. http://doi.org/10.1016/j.future.2013.01.010

22. Silva Girão, P., Postolache, O., & Pereira, J. D. (2014). Wireless sensor network-based solution for environmental monitoring: water quality assessment case study. IET Science, Measurement & Technology, 8(6), 610–616. http://doi.org/10.1049/iet-smt.2013.0136
23. Yamaguchi, Y., Fujino, Y., Katsuda, H., Nakano, M., Fukumoto, H., Teruhi, S., … Yoshino, S. (2018). Underground Infrastructure Management System using Internet of Things Wireless Transmission Technology. IEICE Transactions on Electronics, E101.C(10), 727–733. http://doi.org/10.1587/transele.E101.C.727
24. Muggleton, J. M., Brennan, M. J., & Pinnington, R. J. (2003). Wavenumber prediction of waves in buried pipes for water leak detection. Journal of Sound and Vibration, 249(5), 939– 954. http://doi.org/10.1006/jsvi.2001.3881
25. Simi, M., Member, S., Stojanovi, G. M., & Manjakkal, L. (2016). Multi-Sensor System for Remote Environmental (Air and Water) QualityMonitoring. 2016 24th Telecommunications Forum (TELFOR), 5–8. http://doi.org/10.1109/TELFOR.2016.7818711
26. Saravanan, K., Anusuya, E., Kumar, R., & Son, L. H. (2018). Real-time water quality monitoring using Internet of Things in SCADA. Environmental Monitoring and Assessment, 190(9). http://doi.org/10.1007/s10661-018-6914-x
27. Meyer, A. M., Klein, C., Fünfrocken, E., Kautenburger, R., & Beck, H. P. (2019). Real-time monitoring of water quality to identify pollution pathways in small and middle scale rivers. Science of the Total Environment, 651, 2323–2333. http://doi.org/10.1016/j.scitotenv.2018.10.069
28. Buysschaert, B., Vermijs, L., Naka, A., Boon, N., & De Gusseme, B. (2018). Online flow cytometric monitoring of microbial water quality in a full-scale water treatment plant. Npj Clean Water, 1(1), 16. http://doi.org/10.1038/s41545- 018-0017-7
29. Schultz, W., Javey, S., & Sorokina, A. (2018). Smart Water Meters and Data Analytics Decrease Wasted Water Due to Leaks. Journal - American Water Works Association, 110(11), E24–E30. http://doi.org/10.1002/awwa.1124
30. Koo, D., Piratla, K., & Matthews, C. J. (2015). Towards Sustainable Water Supply: Schematic Development of Big Data Collection Using Internet of Things (IoT). Procedia Engineering, 118, 489–497. http://doi.org/10.1016/j.proeng.2015.08.465
31. Sean Dieter, T. K., Nagender Kumar, S., & Subhas Chandra, M. (2013). Towards the Implementation of IoT for Environmental Condition Monitoring in Homes. IEEE Sensors Journal, 13(10), 67–69. http://doi.org/10.1109/JSEN.2013.2263379.

COMPLETE
Journal of Computer, Electronic, and Telecommunication
ISSN 2723-4371, E-ISSN 2723-5912
doi.org/10.52435/complete.v1i1.44

5G Vehicular Network for Smart Vehicles in Smart City: A Review

Hamzah U. Mustakim

Institut Teknologi Telkom Surabaya hamzah@ittelkom-sby.ac.id;
arekpanjen@gmail.com

Abstract: Smart vehicles is one of the innovation that can be used to increase the effectiveness of traffic in smart city as urban area and in the highway. In its development, smart vehicles not only require mobile communication services to ensure safety but also multimedia services for the passengers. These services must be integrated on intelligent transportation system. 5G vehicular network technology provides data communication services for intelligent transportation system via macrocells and smallcells to support smart vehicles which can drive at a maximum speed of 500Km/hour with multimedia services for passengers with data rates reaching the Gbps level. This paper will review 5G network architecture and emerging technologies that enabling vehicular network for smart vehicles in smart city.

Keywords: smart vehicles, smart city, 5G, microcell, smallcell, network, intelligent transportation system.

1. Introduction

Smart city is an innovation that developed in the last ten years by utilizing sensors, actuators, cloud technology as data and information centers connected to broadband communication networks. The concept of smart city will produce a variety of new service scenarios for the community so that it can change the style and way of life of people [1] and increase economic growth [10].

As a smart city enabler technology, 5G networks providing broadband communication services are the key technology that must be in place to serve data communication traffic from sensors to the cloud. There are three main scenarios in the 5G service: Enhanced Mobile Broadband (eMBB) for multimedia and mobile communication, then Ultra Reliable and Low Latency Communications (URLLC) can be used for transportation services and Massive Machine Type Communications (mMTC) for Internet of Things (IoT) applications that use many devices such as sensors and actuators. Development of 5G wireless technology will make cites smarter and more connected with smart items, smart vehicles and infrastructure (roads, buildings, etc.).

According to Colistra [2], in 2050, the global population is approaching 10 billion with a percentage of 70% being urban people. The concept of smart city is part of a new mechanism to build and organize the city and the environment within it with a variety of integrated internet connectivity to prepare for the future and a better quality of life.

In the 21st century, the concept of smart city can be translated into several main components which include smart economy, governance, society, science, technology, community life and the environment [4]. Smart cities are urban areas where there are various sectors that work together to achieve sustainable results through real-time information analysis by sharing specific information and operational technology systems [6]. The goal of the government to implement smart city is to improve operational effectiveness in meeting services to the public by utilizing technology and for the purpose of making decisions quickly and accurately in real-time [5]. Because of that we need a

system that can integrate the main components and their derivatives, namely: smart house, smart vehicle, intelligent transportation system and others. Especially for smart vehicles, the development of this system leads to intelligent automobile systems or autonomous vehicles that are designed to work like the human brain [7]. The core of Smart vehicle is the internet of vehicle, which is an application of Internet of Things (IoT) technology in intelligent transportation system (ITS) [15], that lead to the development of vehicle to everything (V2X) including vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to pedestrian (V2P), vehicle to road (V2R) and vehicle to network (V2N) which require ultra high reliability [16].

2. Vehicle to Everything Communication

Vehicle to everything (V2X) communication is a technology and standard that enable a vehicle to communicate and interact with the user, road, infrastructure, pedestrian and network is shown in Figure 1 [19] [22].

2.1 Vehicle to Vehicle Communication

V2V communication services is designed for connected and autonomous vehicle need continuous access to vehicle's sensors to support advanced trajectory planning and high speed maneuver [20]. There are two trajectory planning schemes in V2V communication, first sort-term trajectory planning which is using data from its vehicle's sensor and long-term trajectory planning which is using another vehicles and infrastructure around. Therefor a connected vehicle can take dynamic decision safely depend on traffic situation [21].

2.2 Vehicle to Pedestrian Communication

V2P communication is aiming to improve the safety of pedestrians using cellular technology on smart phone. All of connected vehicles, cyclists and pedestrian will send information including speed, location and direction to the cloud server. These data is used to determine safety and hazard situation warning messages such as vehicle collision.

Figure 1. Kind of technologies for vehicle to everything communication [19].

2.3 Vehicle to Infrasrukture Communication

The main purpose of V2I is sharing information and data bidirectionally to the side road components such as traffic lights, street light, parking area, traffic camera, RFID, etc. the components that required by V2I communication are vehicle on-board unit (OBU), roadside unit (RSU) and safe communication channel. OBU is a radio transceiver for dedicated short range communication (DSRC) system, GPS, and provide communication with RSU. RSU made data transfer and message management to the vehicles.

2.4 Intra Vehicle Communication

Intra vehicle communication facilitating data transmission between vehicle components and vehicle sensors. This communication is important to make sure safety driving such as driver sensor which monitor driver condition and another vehicle sensors that monitor tire condition and braking system. These communication via wireless interconnection and ethernet.

3. Vehicle Networking Communication Standards

Development of smart vehicle network is based on all of networking system rather than one system including cellular system, short range communication system, WLAN, and satellite communication system. From these overall systems we can compose to be three core elements [15]: • Node: It is a vehicle network terminal element that used to collect and transmit data on vehicle, road, traffic and vehicle owner including GPS, On-board diagnostics (OBD), sensor, RFID, etc.

- Local Network: The network technology that used in a environment for traffic and roads to fulfil the requirements for vehicle communication.
- Internet of Things: A important component to built intelligent transportation system.

3.1 Dedicated Short Range Communication.

Dedicated Short Range Communication (DSRC) or IEEE 802.11p is a ad-hoc network for vehicle communication. A wireless access in vehicular environment which have good performance on delay while transmitting data in order to avoid vehicles collision [15] [17].

3.2 Cellular Communication

With large scale coverage area of Radio Access Network (RAN), Cellular communication technology has important role for machine to machine communication (M2M) as V2V application. 3GPP had defined standard communication for V2X based cellular network called C-V2X based 4G LTE (Figure 2) and future 5G. C-V2X will be good complement with DSRC technology [18].

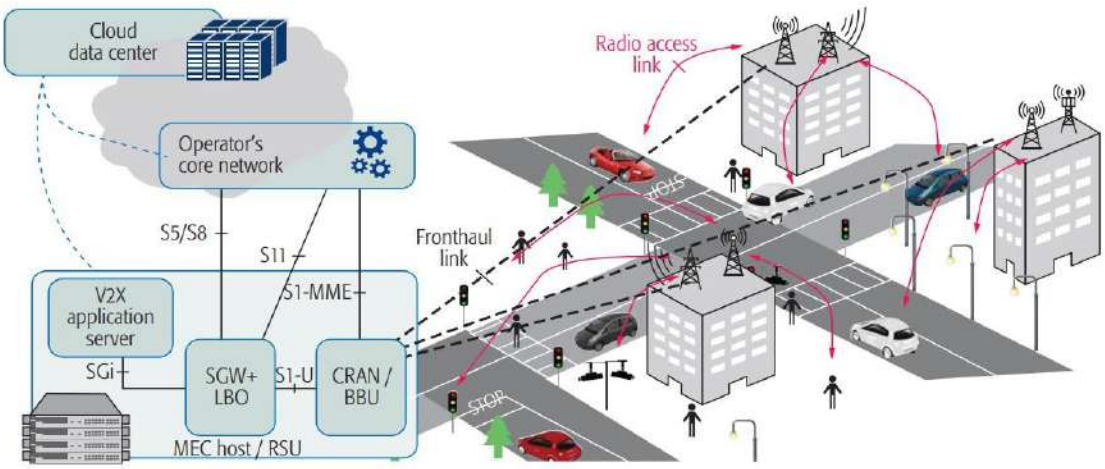


Figure 2. C-V2X based 4G network [18].

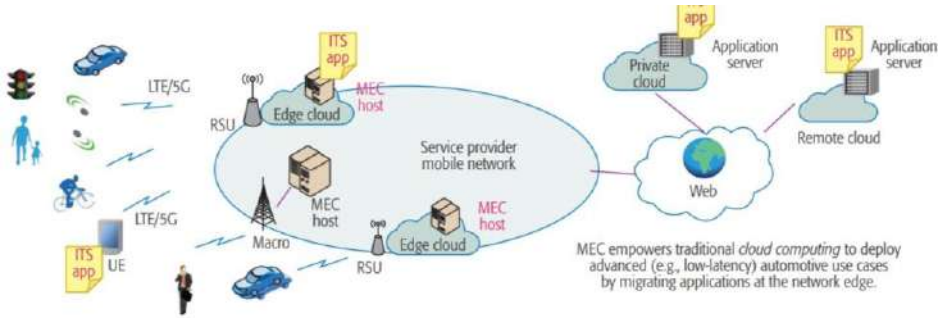


Figure 3. 5G network with MEC [18].

3.3 Vehicle Ad-hoc Network

Vehicle Ad-hoc Network (VANET) is a combination between DSRC and cellular technology or IEEE 802.11p within 4G LTE, that called LTE-V2X, support high speed mobility, reliable communication and better security level. LTE-V2X will use 802.11p frequency band for direct communication and have inertial navigation device that maintain positioning accuracy without GPS.

4. 5G Vehicullar Network

There are three main scenarios in the 5G service, one of them is a service scenario used in data and multimedia communication applications with the main performance parameters at a data rate reaching up to 20Gbps on donwlink and 10Gbps at uplink [8]. The advantage of 5G technology is the ability to integrate and interconnect with existing networks using network function virtualization (NFV). The vehicullar network architecture in smart city services uses a centralized cloud system, distributed cloud and mobile cloud (Figure 3). In this network architecture there is the fog computing node that can provide mobile services for smart vehicles and multi-media applications for passenger. Part of the core of this architecture is the Visualization Plane Infrastructure which allows the formation of network visualization and function visualization [10].

Distributed clouds witch located at the edge of network infrastructure is called multi access edge computing (MEC) technology. The main purpose of MEC is fulfill low latency and high bandwidth requirements. As we mentioned above that vehicular communication require high level reliability (99.99%) to maintain connection V2X [16].

Radio Access Network (RAN) technology which used for smart cars can be microcell, smallcell or microcell. For the use of microcell, you can use light poles on the side of the road with the advantage of being able to save infrastructure. The use of mmWave can significantly increase bandwidth and data rates. Smallcells are currently being developed using sensor technology and light emitting diodes (LEDs) [11]. Another thing to note is the 5G network can work at 4G network using non-stand alon scheme. To provide Gbps bit rate the use of fiber optic cable on the transport network, especially on the fronthaul which functions to send signals from the base band processing unit (BBU) to the antenna [13] [14]. Direct communication for V2V and V2I is called PC5 interface. PC5 using direct channel that not required 5G base station (gNB).

5. Conclusions

The primary purposes of V2X communication technology is to improve driving safety and optimizing traffic in smart city. To achive that purposes required high reliability communication which can delivered by orchestration cellular technologi, 802.11p, DSRC, and utilization of MEC on 5G network technology. For the future research we need performance analysis (including troughput and hanover parameter) for each network which used in 5G vehicular network.

References

1. E. Oproiu, M. Iordache, C. Patachia, C. Costea and I. Marghescu, "Development and implementation of a Smart City Use Case in a 5G mobile network's operator," 2017 25th Telecommunication Forum (TELFOR), Belgrade, 2017.
2. J. Colistra, "The Evolving Architecture of Smart Cities," 2018 IEEE International Smart Cities Conference (ISC2), Kansas City, MO, USA, 2018.
3. C. Colman-Meixner et al., "Deploying a Novel 5G-Enabled Architecture on City Infrastructure for UltraHigh Definition and Immersive Media Production and Broadcasting," in IEEE Transactions on Broadcasting, vol. 65, no. 2, pp. 392-403, June 2019.
4. E. Mardacany, "Smart cities characteristics: importance of buit environments components," IET Conference on Future Intelligent Cities, London, 2014.
5. M. Abu-Matar and R. Mizouni, "Variability Modeling for Smart City Reference Architectures," 2018 IEEE International Smart Cities Conference (ISC2), Kansas City, MO, USA, 2018.
6. Gartner, Inc., "Market Guide for Smart City Operations Management Platforms and Ecosystems", 2015.
7. M. Karaduman and H. Eren, "Smart driving in smart city," 2017 5th International Istanbul Smart Grid and Cities Congress and Fair (ICSG), Istanbul, 2017.
8. Afif Osseiran, "5G Mobile and Wireless Communications Technology", Cambridge University Press, 2016.
9. M. A. Habibi, M. Nasimi, B. Han and H. D. Schotten, "A Comprehensive Survey of RAN Architectures Toward 5G Mobile Communication System," in IEEE Access, vol. 7, pp. 70371-70421, 2019.
10. A. Karadimce and N. Marina, "Smart Mobile City Services in the 5G Era," 2018 10th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), Moscow, Russia, 2018.
11. B. Gholampooryazdi, H. Hämmäinen, S. Vijay and A. Savisalo, "Scenario planning for 5G light poles in smart cities," 2017 Internet of Things Business Models, Users, and Networks, Copenhagen, 2017.
12. IMT Vision, "Framework and overall objectives of the future development of IMT for 2020 and beyond", 2015.
13. P. T. Dat, A. Kanno, N. Yamamoto and T. Kawanishi, "Seamless Convergence of Fiber and Wireless Systems for 5G and Beyond Networks," in Journal of Lightwave Technology, vol. 37, no. 2, pp. 592-605, 15 Jan.15, 2019.
14. K. Zeb, X. Zhang and Z. Lu, "High Capacity Mode Division Multiplexing Based MIMO Enabled All-Optical Analog Millimeter-Wave Over Fiber Fronthaul Architecture for 5G and Beyond," in IEEE Access, vol. 7, pp. 89522-89533, 2019.
15. Y. Yang and K. Hua, "Emerging Technologies for 5G-Enabled Vehicular Networks," in IEEE Access, vol. 7, pp. 181117-181141, 2019.
16. D. Garcia-Roger et al., "5G Functional Architecture and Signaling Enhancements to Support Path Management for eV2X," in IEEE Access, vol. 7, pp. 20484-20498, 2019.
17. Chang K H. Wireless communications for vehicular safety[J]. IEEE Wireless Communications, 2015, 22(1): 6-7.
18. F. Giust et al., "Multi-Access Edge Computing: The Driver Behind the Wheel of 5G-Connected Cars," in IEEE Communications Standards Magazine, vol. 2, no. 3, pp. 66-73, SEPTEMBER 2018.
19. H. Ullah, N. Gopalakrishnan Nair, A. Moore, C. Nugent, P. Muschamp and M. Cuevas, "5G Communication: An Overview of Vehicle-to-Everything, Drones, and Healthcare Use-Cases," in IEEE Access, vol. 7, pp. 37251-37268, 2019.
20. I. Mavromatis, A. Tassi, R. J. Piechocki, and A. Nix, ''Efficient V2V communication scheme for 5G mmWave hyper-connected CAVs,'' in Proc. IEEE Int. Conf. Commun., May 2018, pp. 1–6.
21. N. Lu, N. Cheng, N. Zhang, X. Shen, and J. W. Mark, ''Connected vehicles: Solutions and challenges,'' IEEE Internet Things J., vol. 1, no. 4, p 5G Evolution: A View on 5G Cellular Technology Beyond 3GPP Release 15 p. 289–299, Aug. 2014.

COMPLETE
Journal of Computer, Electronic, and Telecommunication
ISSN 2723-4371, E-ISSN 2723-5912
doi.org/10.52435/complete.v1i1.47

Energy Consumption Data Analysis: Indonesia Perspective

Wahyu Andy Prastyabudi [1]* and Isa Hafidz [2]

[1] Department of Industrial Engineering, Institut Teknologi Telkom Surabaya; wahyu.andy@ittelkom-sby.ac.id
[2] Department of Electrical Engineering, Institut Teknologi Telkom Surabaya; isa@ ittelkom-sby.ac.id
* Correspondence: wahyu.andy@ittelkom-sby.ac.id;

Abstract: Energy consumption has been increasingly affected by many factors such as population growth, energy price, etc. This paper utilizes data analysis to examine energy consumption data and its correlation to GDP growth, particularly in the case of Indonesia. The data observed in this study comprises a record from 1961-2018. An exploratory data analysis was employed to comprehend the features of the data, while beforehand a pre-processing and testing were conducted to prepare the data. Data visualization was built then a Spearman correlation rank was also performed to see the association among variables. The result shows that energy consumption is dominated by fossil generated energy i.e. oil, coal, gas. Meanwhile, renewable energy was started to use since early 2000 with a huge leap of consumption on solar energy. The result of correlation ranking indicates that the energy consumption and GPD growth have no significant association as the rank value is negative and the p-value is greater than the chosen significance level. Moreover, Indonesia has the opportunity to switch to geothermal energy which contributes 3.6% to the national energy supply.

Keywords: energy; data analysis; GDP

1. Introduction

Energy has been always an issue to be encountered by many countries including Indonesia. As the fossil energy sources have decreased rapidly while its consumption is soaring gradually, there is a need to look forward the energy security and at the same time maintaining the consumption efficiency. Energy security is a such condition of energy availability secured and affordable for relatively a long period not being affected by the regional nor international fluctuation [1]. Global Energy Institute reported in the International Index of Energy Security Risk 2020, that the world will require the amount of energy 31% larger in 2040 than we produce today [2]. The report shows that Indonesia is classified as a large energy user group at ninth place among 25 countries.

By 2050, the demand of energy in Indonesia is expected to reach the average of 4.9% growth every year, in case of business as usual scenario is applied [3]. Population growth, economic growth, energy price, and development of technology are those among factors that affected the energy demand [3]. On the other hand, the growth of GDP may also be driven by the amount of energy consumption to boost up the industrial and economic activities. Thus, it is necessary to oversee the rate of energy consumption meanwhile the energy conservation program is carried out.

This study particularly attempts to unfold the correlation between energy consumption and GDP. The energy consumption data of Indonesia and the data of GDP growth were deserved to assess further by intention to give a broader view on how Indonesia spend most of their energy. Moreover, it may lead to provide insights for the government so that they are able to formulate an appropriate regulation. Exploratory data analysis approach was employed to analyze the data by which beforehand was pre-processed to prepare the data. Shapiro-Wilk test was performed to examine the

data distribution while another test so-called Spearman rank correlation was conducted as well to find out the relationship among observed variables.

In the recent study, we found some literature that investigates the energy consumption data for various objectives. Fatai et al. (2004) discussed the application of co-integration analysis, i.e. Granger causality, to study the relationship between energy consumption data and GDP using a case study in New Zealand, Australia, and four Asian countries including Indonesia [4]. It is highlighted in their study that there was a unidirectional link from energy to income, particularly in Indonesia. The same method was employed in a paper by Lise and Montfort whereas the study was specifically performed to analyze the energy consumption in Turkey [5]. In addition, another method to elucidate the relationship between energy and GDP is using panel data analysis approach by which it observes time-series cross sectional data [6], [7].

To complement those studies, this paper asserts the use of graphical representation to explore the salient features of energy consumption and GDP data. The paper is, then, organized into four sections. In addition to this introduction, Section 2 will discuss about the data and methods to analyze them by means of data exploratory analysis. In Section 3, the result of data analysis is presented. Spearman rank correlation was employed to show the association between the energy consumption and the GDP. Meanwhile, the Section 4 discusses the results.

2. Materials and Methods

2.1. Data

The data utilized in this study is available online taken from the website of world bank and British Petroleum (BP). From the world bank we collected the GDP data which comprises the record of country's GDP growth per capita from 1965-2017 [8]. Meanwhile, the energy consumption data provided by BP comprises annual data available from 1961-2018 [9]. The data contains energy consumption which can be categorized into two by its sources, i.e. non-renewable energy (oil, coal, gas, nuclear) and renewable energy (hydropower, wind, solar, others).

2.1. Methods

2.1.1. Data Pre-Processing

Prior to harness the data for analytical purpose, the data is required to undergo a pre-processing. We filtered out the data, both GDP and energy consumption data, from Indonesia only as we only concern to analyze the data from this country in the present study. Then, both data were combined by intersecting its year vector values. So that the merged data has the same series of period. We also removed non-essential part of the data, particularly in the energy consumption data, we eliminated the column nuclear as Indonesia has not yet owned nuclear power.

2.1.2. Testing

Once the pre-processing data completed, the following stage is to conduct statistical testing, thus we can choose the appropriate means to analyze the data. Herein, we conduct Shapiro-Wilk test (see equation 1) to examine the normality of data.

$$W = \frac{(\sum_{i=1}^{n} a_i x_i)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (1)$$

The null hypothesis (H_0) assumed that the data is normally distributed. Otherwise, the alternative hypothesis (H_1) assumed that the data does not follow normal distribution. If the test result indicates *p*-value is less than the chosen alpha level, then the null hypothesis is rejected, and the alternative hypothesis is accepted. Thereby, we can be evidently confident that the data tested are not normally distributed. On the other hand, if the *p*-value is greater than the chosen alpha level, then the null hypothesis is accepted and reject the alternative hypothesis by which we can conclude that the data came from a normally distributed population.

Another statistical test that we conduct herein is Spearman rank correlation coefficient which measures the association between two observed variables *X* (independent variable) and *Y* (dependent variable). This rank, denoted as r_s, can be computed as follows:

$$r_s = 1 - \frac{6}{n(n^2-1)}\sum_{i=1}^{n} d_i^2 \quad (2)$$

where d_i is the deviation between the ranks assigned to x_i and y_i with the number of n pairs of data. The rank value (r_s) will range from -1 to +1 which indicates the direction of association of both variables. If the rank value r_s is equal to zero, it may be inferred that there is no tendency of those variables to be correlated. In addition, if the *p*-value is smaller than the chosen alpha level it means the correlation is considered to be significant.

2.1.3. Data Analysis Procedure

In order to gain understanding of the data including their relationship, an exploratory data analysis (EDA) approach was performed. This method was introduced by John W. Tukey by which it tries to look the data from as many aspects as possible [10]. Hence, we may be able to probe the underlying features reside in the data. The EDA offers an advantage as there is no model to be considered, rather it emphasizes the data visualization to comprehend its characteristics.

Numerous studies have employed EDA method to carry out analysis regarding the energy consumption data. Filipovic et al. studied about energy security index using EDA approach to determine a new index considering economic, environmental, political, and social dimensions [11]. Their observed 28 EU countries for ten years period of energy security index data. The study found that GDP per capita greatly affects the country's energy security. Another study by Baker and Rylatt (2008) tried to improve the prediction of energy demand by analyzing annual energy consumption data [12]. Meanwhile, Tyralis et al. used EDA to understand the time series electrical energy demand data and building a forecasting model [13].

In this study, analysis was performed by observing the statistical descriptive summary to see the range of energy consumption of each source. Thereafter, we can easily categorize the data which has a closed band of the amount of energy. The following step was to visualize the data using boxplot and time series line chart. Thus, it is possible to compare each energy source's statistical value, e.g median, maximum, and minimum. By means of time series line chart, we may examine the movement and trend over the period. The Spearman correlation rank test was performed to examine the associations between energy consumption, at each source, and the GDP. Finally, a correlogram correlation matrices was built to visualize the association of each variables.

3. Results

3.1. Data testing

The energy consumption data contains 5,066 records by which after cutting off to observe the data from Indonesia, we obtain 54 records. In the meantime, the GDP data by Indonesia only contains about 57 records whereas the raw data has 11,315 records. Since the energy consumption data and GDP data has the different range of period, both data are then intersected and obtained 54 records which range from the year of 1965-2017.

In order to test the normality of each data, Shapiro-Wilk test was performed using $\alpha = 0.05$ and **Table 1** below shows the test result. As shown from the table, most of the data do not follow the normal distribution as its *p*-value is less than the given α value, except for the Wind and Other data that closely follow the normal distribution. In addition, the energy consumption data has been classified into three different groups according to its consumption level. The first group contains the data of energy consumption produced by oil, coal, and gas whereby they produce the biggest energy consumption with average more than 150 terawatt-hours. The second group consists of the energy consumption data produced by hydropower and other sources with both have roughly the same

median to 17 terawatt-hours. Meanwhile, the energy consumption data produced by wind and solar which almost share the same median of 0.01 terawatt-hours are put together into the third group.

Table 1. Shapiro-Wilk normality test for each energy consumption by its source

Variables	W	p-value
Oil	0.91104	0.0007855
Coal	0.74532	3.117e-08
Gas	0.87809	6.268e-05
Hydropower	0.90803	0.0006137
Solar	0.73971	0.002674
Wind	0.83857	0.05568
Other	0.93561	0.08551
GDP	0.67043	1.233e-09

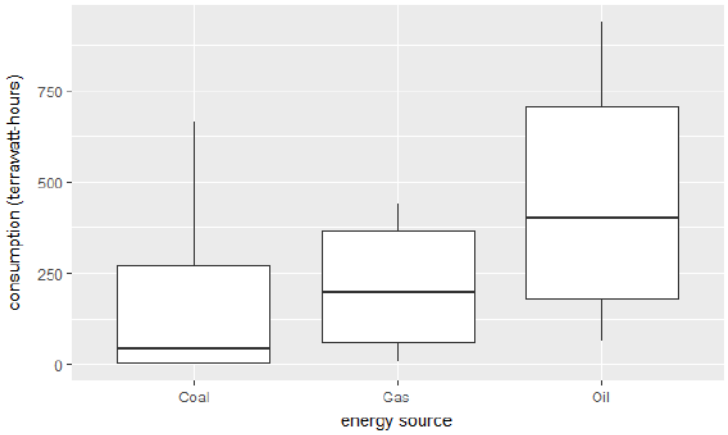


Figure 1. Box plot of energy consumption produced by oil, coal, and gas

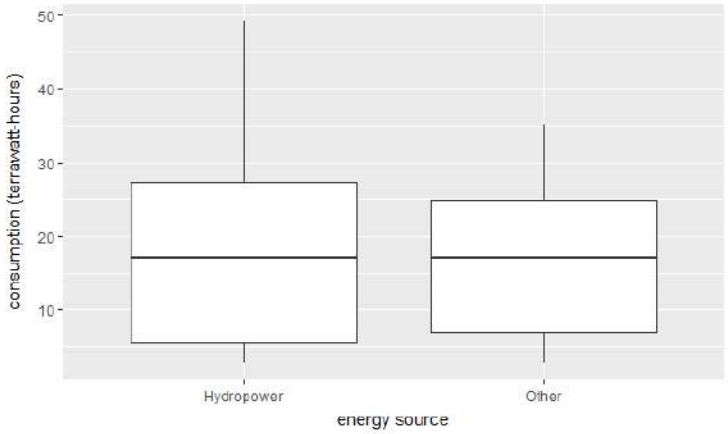


Figure 2. Box plot of energy consumption produced by hydropower and other sources

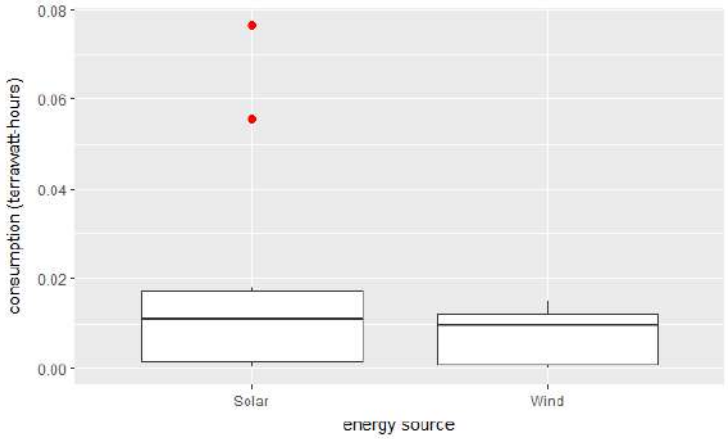


Figure 3. Box plot of energy consumption produced by solar and wind

3.2. Exploratory data analysis

Figure 1 presents the statistical summary of energy consumption data produced by oil, coal, and gas. During the period energy produced by oil has a lot of usages compared to other sources by which it is confirmed by the median surpass the other two data. On the other hand, however, the energy consumption produced by oil has also more variability. The figure also reveals that the coal data and gas data have relatively similar variability, however the coal data has more skewness to the right. Over the period, the energy consumption produced by the coal has been surpass the gas and nearly reach the 0.75 percentile of the oil data.

Figure 2 summarizes the statistical features of energy consumption data produced by hydropower and other sources. Both data share the quite identical median that is 17 terawatt-hours, however, the hydropower data has more variability and its maximum value is higher as well than the other sources do. Moreover, **Figure 3** depicts the statistical summary of the rest group data that is energy consumption produced by solar and wind. Both data has relatively low energy consumption under 0.02 terawatt-hours and the wind data has more skewness to the left.

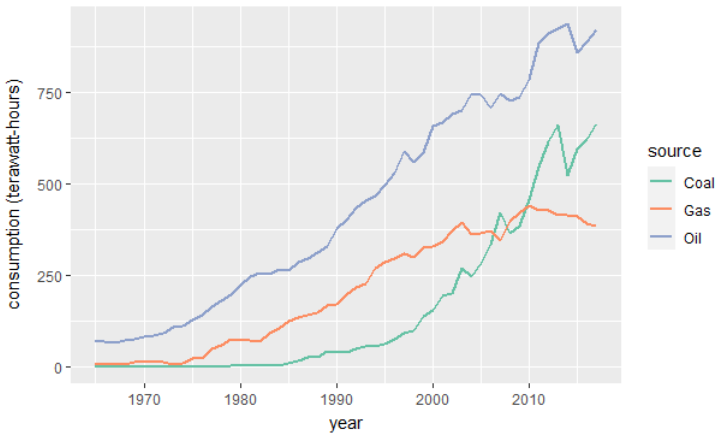


Figure 4. Energy consumption of the first group per year during 1965-2017

Figure 4 depicts the change of energy consumption produced by oil, coal, and gas. Meanwhile, **Figure 5** and **Figure 6** show the change of energy consumption in the second and third group, respectively. The consumption of most of energy sources are soaring over period. The energy consumption from coal has surpassed the gas by the year of 2010. In the meantime, energy generated by hydropower was utilized relatively low during 15 years in early period. Then, the consumption increased rapidly by 1985 and fluctuated after 1990. On the other hand, the utilization of other

renewable energy was begun at 1990 with relatively low variance, however, the usage yet lower than those produced by hydropower. In fact, it is shown that the cultivation of renewable energy from solar and wind was just started at 2007. Apparently, the consumption from wind energy was somehow quite low under 0.02 terawatt over the period. From **Figure 6**, it is also shown that the usage of solar energy was escalate incisively since 2015.

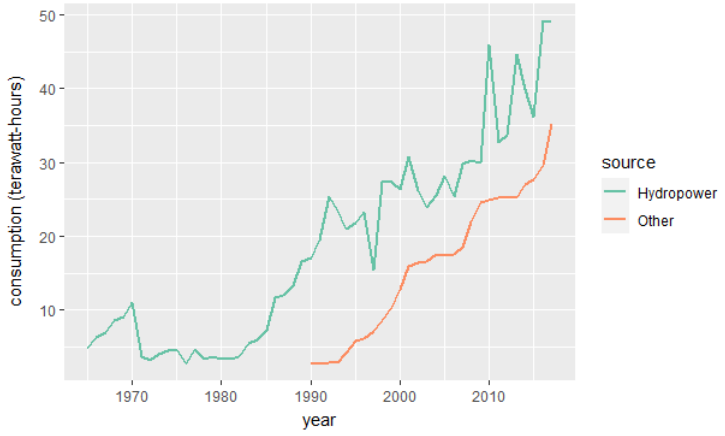


Figure 5. Energy consumption data of the second group during 1965-2017

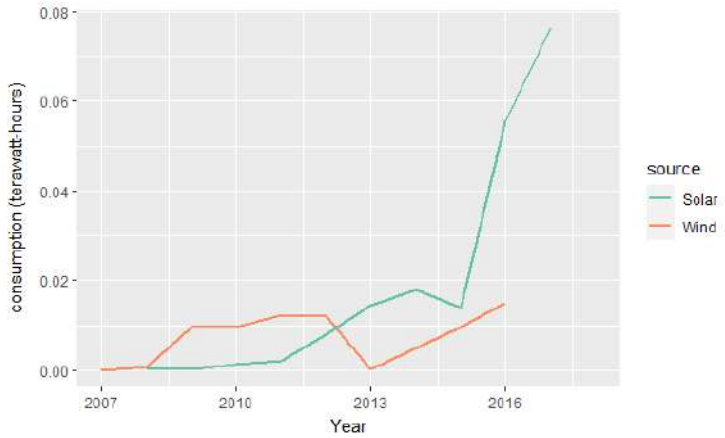


Figure 6. Energy consumption data of the third group during 2007-2017

Considering the growth of GDP along with the energy consumption over the period, a bubble chart visualization is presented in **Figure 7, Figure 8,** and **Figure 9** for each group of energy sources, respectively. The bubble size represents the amount of energy consumption in terawatt-hours. Note that each chart is depicted an outlier of the GDP in an extremely condition which occurred in crisis period 1998 with only -14.34% growth of GDP. It is shown from **Figure 7** and **Figure 8** that the amount of energy consumption relatively getting increased since 1990, though there was still no implication in a positive way to the growth of GDP. In addition, **Figure 9** reveals another outlier of GDP growth with only about 3.2% that occurred in 2009. The energy consumption from solar increased gradually since 2013. Meanwhile, the energy consumption produced by wind was vacant at 2014 and 2017 as no bubble shown in the figure.

Figure 7. Change of energy consumption (oil, gas, coal) and GPD over period 1965-2017

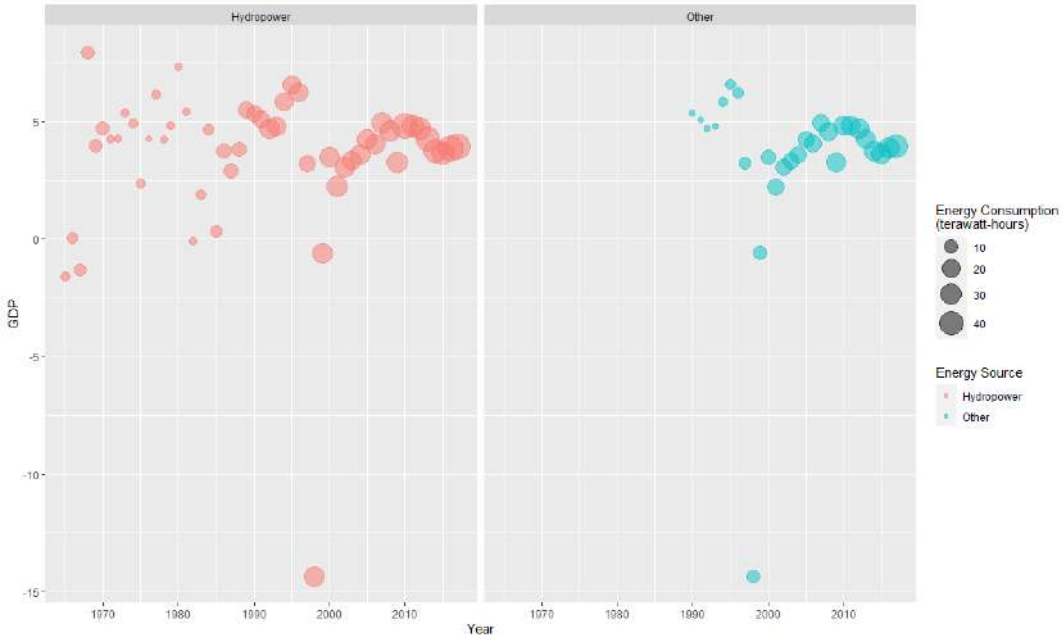


Figure 8. Change of energy consumption (hydropower and other) and GPD over period 1965-2017

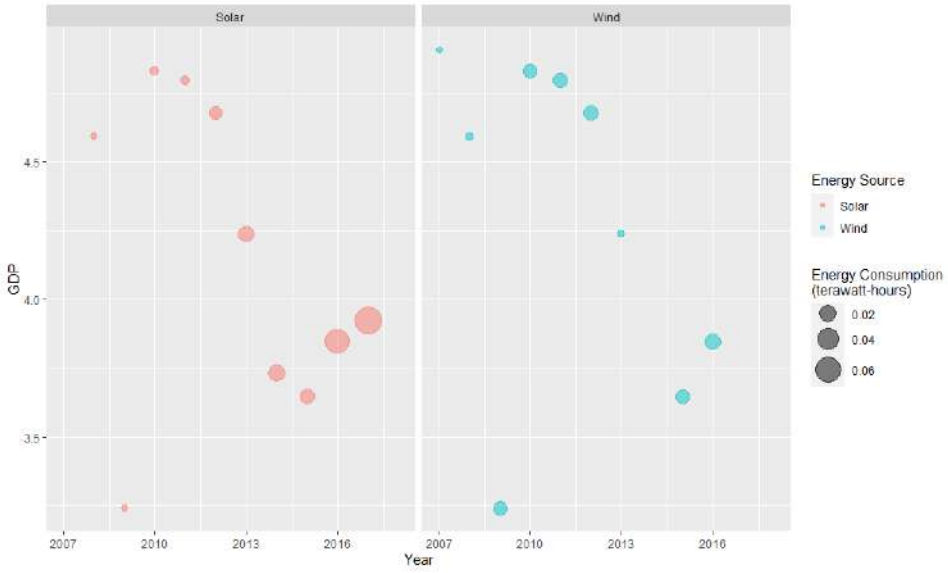


Figure 9. Change of energy consumption (solar and wind) and GPD over period 2007-2017

3.3. Correlation between GDP and energy consumption

Herein, the association of GDP and energy consumption by means of Spearman correlation rank. The data was divided, for the sake of simplicity, into three groups. The first group comprises the energy consumption data of oil, gas, coal, and hydropower by which the usage period was started at the same year. The second group consist the data of energy powered by solar and wind by which the usage of these power was started relatively the similar period since 2007. Thus, the observed GDP growth was tailored to the same period by 2007. The third data is left only for the energy consumption of other generated power as it was firstly utilized at 1990 which had the different period to the other sources.

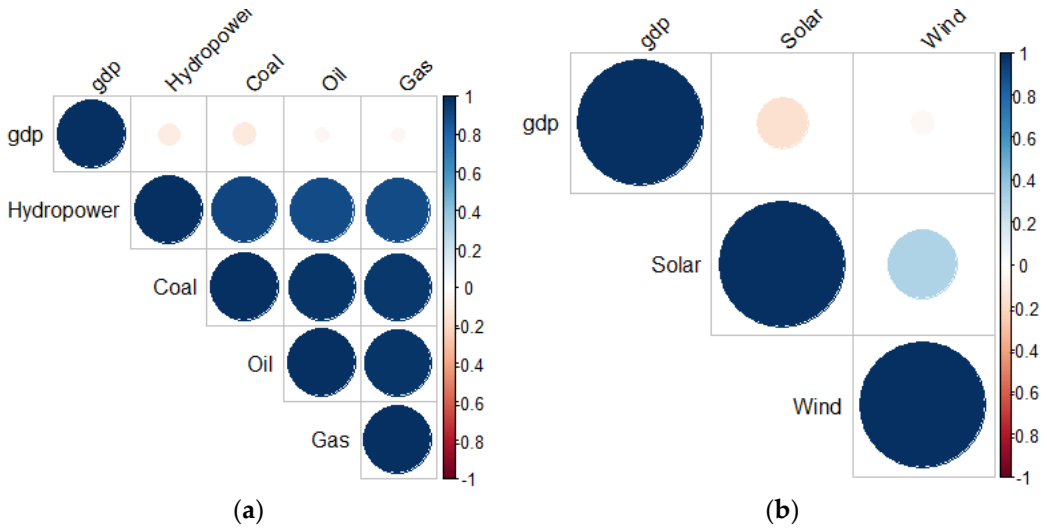


Figure 10. Correlogram of energy consumption and GDP. (a) The correlation matrices between GDP and energy consumption produced by oil, gas, coal, and hydropower. (b) The correlation matrices between GDP and energy consumption produced by solar and wind.

Table 2 and
Table 3 show the correlation rank for the first and second group, respectively. As depicted from the tables that the correlation between GDP and most of energy sources has negative association. In addition, the correlation rank between the consumption of other powered energy and GPD yields the rank $r = -0.2364$. **Figure 10** illustrates the correlogram matrices which visualize the result of correlation rank in **Table 2** and **Table 3** into figure (a) and (b), respectively. Positive correlation is indicated by the blue color, otherwise the negative correlation is indicated by the red color. Meanwhile, the color intensity and the size of circle imply the proportion of the correlation coefficient value. As we can see that the consumption energy generated by wind and gas are the highest rank while the solar energy is the lowest rank. The p-value (see **Table 4**), by which larger than the significant level (alpha) 0.05, also indicates that correlation between energy consumption and GDP growth is considered as insignificant.

Table 2. Spearman correlation rank of GDP and energy consumption produced by oil, gas, coal, and hydropower

	Oil	**Gas**	**Coal**	**Hydropower**	**GDP**
Oil	1.0	0.9797	0.9726	0.8941	-0.0420
Gas	0.9797	1.0	0.9639	0.8903	-0.0411
Coal	0.9726	0.9639	1.0	0.9159	-0.1151
Hydropower	0.8941	0.8903	0.9159	1.0	-0.1098
GDP	-0.0420	-0.0411	-0.1151	-0.1098	1.0

Table 3. Spearman correlation rank of GDP and energy consumption produced by solar and wind

	Solar	**Wind**	**GDP**
Solar	1.0	0.3072	-0.1676
Wind	0.3072	1.0	-0.0359
GDP	-0.1676	-0.0359	1.0

Table 4. p-value of Spearman correlation test

Energy source/GDP	**p-value**
Oil	0.7647
Gas	0.7700
Coal	0.4116
Hydropower	0.4333
Solar	0.6914
Wind	0.9327
Other	0.2248

4. Conclusion

The paper discusses pertaining energy consumption in Indonesia during the period between 1965 and 2017. As well as trying to unfold the relationship of energy consumption and the growth of GDP. The energy consumption data examined in this study was divided by its sources into seven i.e. oil, gas, coal, hydropower, solar, wind, and other. An exploratory data analysis approach was employed to reveal the features of the data. The method emphasizes on the graphical representation analysis. Two testing were conducted prior to the analysis i.e. Shapiro-Wilk test and Spearman correlation rank.

The testing result of normality test indicates that most of the data did not follow normal distribution. Hence, to figure out the association between energy consumption and GDP growth Spearman correlation rank was employed. The result implies that in general energy consumption is increasing gradually despite its source. In regard of renewable energy, Indonesia uses a numerous amount of energy generated by solar power since 2015 with a huge leap on the following year. On the other hand, the result of correlation test implies there was no significant relationship between energy consumption and GDP growth indicated by the negative rank value. Notwithstanding, as the growth of energy consumption, moreover, the energy reserve is decreasing. It is expected that, in case of Indonesia, the reservation of oil, gas, and coal reserve will last at 2024, 2052, and 2091, respectively [1]. Hence, to maintain the energy security index Indonesia needs to switch to the alternative renewable energy, such as geothermal energy which contributes 3.6% to the national energy supply [14].

References

1. R. E. Caraka, "Simulasi Kalkulator Energi Baru Terbarukan (EBT) Guna Memenuhi Ketahanan Energi di Indonesia," *Stat. J. Theor. Stat. Its Appl.*, vol. 16, no. 2, pp. 77–88, 2016.
2. U.S. Chamber of Commerce, "International Index of Energy Security Risk: 2020 Edition," 2020. Accessed: May 11, 2020. [Online]. Available: https://www.globalenergyinstitute.org/international-index-energy-security-risk-2020-edition.
3. D. E. Nasional, "Indonesia energy outlook 2016," *Jkt. Sekr. Jenderal Dewan Energi Nas.*, 2016.
4. K. Fatai, L. Oxley, and F. G. Scrimgeour, "Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, The Philippines and Thailand," *Math. Comput. Simul.*, vol. 64, no. 3–4, pp. 431–445, 2004.
5. W. Lise and K. Van Montfort, "Energy consumption and GDP in Turkey: Is there a co-integration relationship?," *Energy Econ.*, vol. 29, no. 6, pp. 1166–1178, 2007.
6. B.-N. Huang, M. J. Hwang, and C. W. Yang, "Causal relationship between energy consumption and GDP growth revisited: a dynamic panel data approach," *Ecol. Econ.*, vol. 67, no. 1, pp. 41–54, 2008.
7. C.-C. Lee and C.-P. Chang, "Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data," *Resour. Energy Econ.*, vol. 30, no. 1, pp. 50–65, 2008.
8. World Bank, "GDP per capita growth (annual %)." https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG (accessed May 11, 2020).
9. BP Global, "Statistical Review of World Energy," *BP global*. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (accessed May 11, 2020).
10. S. Morgenthaler, "Exploratory data analysis," *Wiley Interdiscip. Rev. Comput. Stat.*, vol. 1, no. 1, pp. 33–44, 2009.
11. S. Filipović, M. Radovanović, and V. Golušin, "Macroeconomic and political aspects of energy security–Exploratory data analysis," *Renew. Sustain. Energy Rev.*, vol. 97, pp. 428–435, 2018.
12. K. J. Baker and R. M. Rylatt, "Improving the prediction of UK domestic energy-demand using annual consumption-data," *Appl. Energy*, vol. 85, no. 6, pp. 475–482, 2008.
13. H. Tyralis, G. Karakatsanis, K. Tzouka, and N. Mamassis, "Exploratory data analysis of the electrical energy demand in the time domain in Greece," *Energy*, vol. 134, pp. 902–918, 2017.
14. S. Setiawan, "Energi panas bumi dalam kerangka MP3EI: Analisis terhadap prospek, kendala, dan dukungan kebijakan," *J. Ekon. Dan Pembang.*, vol. 20, no. 1, pp. 1–28, 2012.

COMPLETE
Journal of Computer, Electronic, and Telecommunication
ISSN 2723-4371, E-ISSN 2723-5912
doi.org/10.52435/complete.v1i1.15

Analisis Performa *Reference Signal Received Power* Akibat Rugi-Rugi Propagasi Pada Frekuensi 2300 MHz Dengan Model Okumura

Sandryones Palinggi [1], Aan Saputra [2]

[1] Institut Teknologi Bandung; 23217112@std.stei.itb.ac.id
[2] Telkom University; aansaputra30@gmail.com
* Correspondence: sandryones@gmail.com; Tel.: +62-8586-005-0332 (S.P)

Abstract: Teknologi seluler, terutama 4G-LTE, telah berkembang ke arah yang jauh lebih canggih. Teknologi 4G-LTE merupakan kelanjutan dari teknologi sebelumnya yang disebut 3G. Dalam penelitian ini, perhitungan kekuatan sinyal kemudian digunakan untuk menghitung kerugian yang terjadi pada frekuensi 2300 MHz di sepanjang Jalan Cihampelas Bandung, yang memiliki panjang lintasan 2.7 Km. Metode penelitian yang digunakan adalah metode kuantitatif yang menggunakan data primer hasil pengukuran, kemudian membandingkannya dengan metode empiris dalam bentuk perhitungan ideal. Perhitungan di lingkungan *outdoor* menggunakan Model Okumura dengan mempertimbangkan topologi maupun rugi-rugi propagasi di sepanjang Jalan Cihampelas Bandung seperti *Skywalk* Cihampelas dan bangunan bertingkat. Hasil penelitian ini dinyatakan dalam bentuk tabel dan grafik dengan menggunakan Matlab sehingga mudah untuk menarik hasil analisis dari penelitian yang dilakukan, yang mana diketahui bahwa rugi-rugi propagasi yang terjadi mempengaruhi *Reference Signal Received Power* dari jaringan komunikasi seluler berbasis teknologi 4G-LTE.

Keywords: *Reference Signal Received Power*, Rugi-Rugi Propagasi, Model Okumura, Lingkungan *Outdoor*, 4G-LTE

1. Pendahuluan

Bidang telekomunikasi telah banyak mengalami perkembangan yang sangat signifikan. Penerapan teknologi khususnya telekomunikasi telah merambah ke segala bidang. Teknologi 4G-LTE merupakan teknologi seluler terbaru dan telah digunakan secara massal dengan mengandalkan kecepatan yang melebihi teknologi 3G. Dalam banyak kasus, 4G-LTE telah memberikan manfaat yang besar dalam membantu terselesainya sebuah pekerjaan.

Salah satu segmen pekerjaan yang mengandalkan kecepatan akses 4G-LTE adalah transportasi online. Sebagai bentuk pekerjaan yang berbasis pada layanan, transportasi online sangat bergantung pada akses internet dalam memenuhi layanan *customer*. Demikian pula *customer*, memerlukan hal yang serupa.

Dengan kepadatan trafik data di kawasan yang ramai, kecepatan akses data begitu penting, khususnya di area yang diklasifikasikan sebagai wilayah *urban*. Sebuah akses data dengan

mengandalkan kecepatan maupun kestabilan *connectivity* jaringan, tidak akan lepas dari rugi-rugi propagasi yang terjadi di sepanjang lintasan yang menghubungkan antara UE (*User Equipment*) dan *e-NodeB* (eNB). Perlu dilakukan perhitungan khususnya terhadap wilayah yang memiliki tingkat kepadatan tinggi, baik dari segi trafik lalu lintas, maupun kepadatan pengguna jaringan komunikasi.

Dalam paper ini, dilakukan perhitungan rugi-rugi yang terjadi pada frekuensi 2300 MHz sepanjang Jalan Cihampelas, dimana tingkat kepadatan trafik baik dari segi UE sebagai pengguna layanan *broadband* maupun pengguna lalu lintas sebagai *user mobile* yang melintas di sepanjang area yang diteliti. Jalan Cihampelas memiliki profil yang tepat dalam mengukur rugi-rugi propagasi dengan panjang lintasan mencapai 2.7 Km.

Tujuan dari penelitian ini adalah melakukan perhitungan dengan menggunakan model Okumura dalam menghitung RSRP (*Reference Signal Received Power*) yaitu kuat sinyal 4G-LTE yang diterima oleh *user* dalam frekuensi tertentu. Adapun hasil dari penelitian ini, kemudian dijabarkan dalam bentuk Tabel dan Grafik *Scattering* sehingga memudahkan dalam melakukan identifikasi terhadap performa jaringan 4G-LTE yang terjadi di sepanjang lintasan.

2. Propagasi Seluler 4G

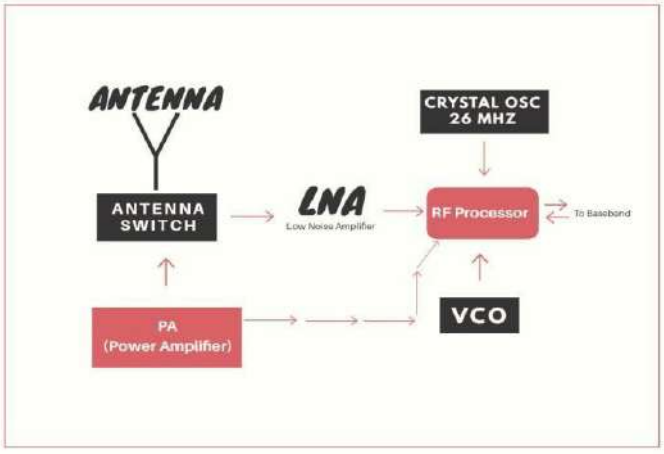
2.1. Propagasi Seluler

Sistem telepon seluler terbagi menjadi 3 (tiga) bagian, yaitu sistem radio, sistem komunikasi telepon dan sistem pemrograman. Sistem komunikasi radio dan telepon terdiri dari sirkuit elektronik pasif dan aktif. Telepon seluler adalah perangkat elektronik yang sangat umum digunakan di masyarakat saat ini dengan wilayah operasi pita UHF (*Ultra High Frequency*), 800 hingga 1900 MHz (*Mega Hertz*). Untuk level yang lebih tinggi, frekuensi yang digunakan adalah 2300 MHz. Rentang frekuensi ini dikategorikan sebagai rentang frekuensi tinggi dan telah diatur oleh semua negara di dunia. [3][4][6]

Pemilihan antena yang baik dapat meningkatkan kinerja sistem secara keseluruhan karena antena dapat berfungsi sebagai penguat untuk pengirim dan penerima. Secara umum, tingkat penerimaan sinyal pada suatu titik dirumuskan:

$$P_{Rx} = P_{Tx} + 2G - FSL \quad (1)$$

$$FSL(dB) = -67.55 + 20logf(MHz) + 20logD(cm) \quad (2)$$



Gambar 1. Blok Diagram VCO [3][4]

2.2. Model Rugi-Rugi Lintasan

Penggunaan model lintasan dengan Model Okumura dalam penelitian ini menggunakan frekuensi di atas 1500 MHz. Model Okumura merupakan salah satu model yang paling sering digunakan dalam menghitung atau memprediksikan kekuatan sinyal di area *urban*. Model jenis ini sangat cocok dalam melakukan perhitungan dengan rentang frekuensi dari 150 MHz sampai 1920 MHz pada jarak 1 Km sampai 100 Km dengan ketinggian antena berkisar 30 meter hingga 1000 meter. Namun, walau demikian, model Okumura masih relevan digunakan hingga pada frekuensi 3000 MHz. [5]

Dalam melakukan penelitian ini, beberapa variabel dipertahankan seperti *median attenuation relative to free space* (A_{mu}), tinggi efektif antena Tx (h_{te}), dan tinggi efektif antena Rx (h_{re}). Semua variabel yang digunakan dalam melakukan penelitian ini telah disesuaikan kondisi profil *outdoor* di sepanjang Jalan Cihampelas Bandung.

Dengan menggunakan rentang frekuensi tersebut, maka dengan demikian frekuensi 2300 MHz dapat dihitung dengan menggunakan pemodelan sebagai berikut : [2]

$$L_{Urban} = 43.3 + 33.9logf - 13.82logh_b - ah_m + (44.9 - 6.55logh_b)\ log_d + C_m \text{ [dB]} \quad (3)$$

dimana f = frekuensi kerja (MHz), h_b = tinggi efektif antena *transmitter* (BTS/eNB) sekitar 30 - 200 meter, h_m = tinggi efektif antena *receiver* (*unit mobile*) sekitar 1 - 10 meter, d = jarak antara Tx - Rx (Km) ah_m = faktor koreksi untuk tinggi efektif antena unit *mobile*. Pemodelan dengan menggunakan Persamaan 3, masih dianggap relevan mengingat penelitian ini menggunakan tipe area *urban*.

$$L_{50}(dB) = L_F + A_{mu}(f, d) - G(h_{te}) - G(h_{re}) - G_{AREA} \quad (4)$$

Pada Persamaan 4, L_{50} merupakan nilai median dari *path loss*, L_f merupakan *free space loss* atau rugi-rugi propagasi ruang bebas, A_{mu} merupakan *median attenuation relative to free space*, G(h_{te}) merupakan *base station antenna heigh gain factor*, G(h_{re}) *mobile antenna heigh gain factor*, dan G_{AREA} merupakan gain dari tipe lingkungan *outdoor*. [5]

Selain menggunakan Persamaan 4, model Okumura menggunakan beberapa Persamaan yang digunakan untuk menghitung secara presisi. Adapun Persamaan yang dimaksud, dijabarkan dalam Persamaan 5, Persamaan 6, dan Persamaan 7.

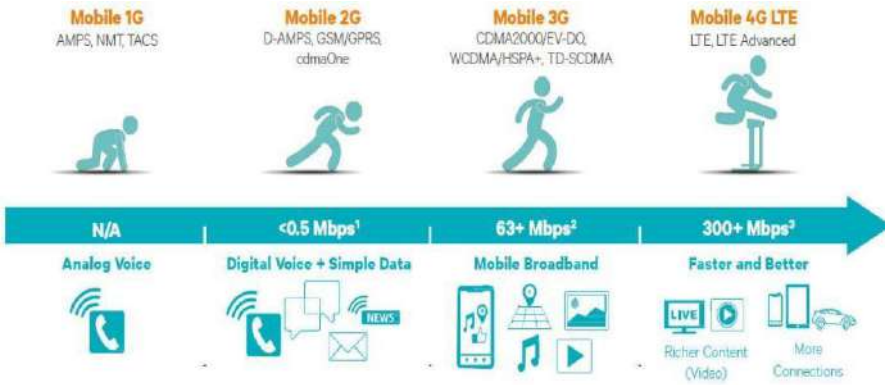
$$G(h_{te}) = 20 \log \left(\frac{h_{te}}{200}\right) 1000m > h_{te} > 30m \quad (5)$$

$$G(h_{re}) = 10\log \left(\frac{h_{re}}{3}\right) h_{re} \leq 30_m \quad (6)$$

$$G(h_{re}) = 20\log \left(\frac{h_{re}}{3}\right) 10m > h_{re} > 3m \quad (7)$$

2.3. Teknologi Seluler 4G

Layanan *mobile broadband* terus berkembang seiring dengan meningkatnya mobilitas masyarakat dalam beraktivitas serta kebutuhan layanan internet. Berbagai teknologi seluler terus dikembangkan mulai dari GSM/GPRS/EDGE, UMTS/HSPA, dan teknologi LTE. LTE adalah standar terbaru dalam



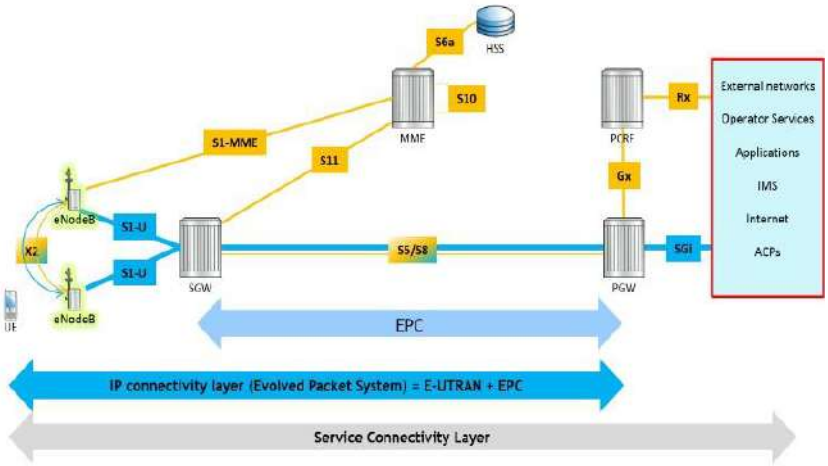
Gambar 2. *Roadmap* Teknologi Seluler [8]

teknologi jaringan seluler dibandingkan GSM/EDGE dan UMTS/HSPA. LTE adalah sebuah nama baru dari layanan yang mempunyai kemampuan tinggi dalam sistem komunikasi bergerak yang merupakan langkah menuju generasi ke-4 dari teknologi radio yang dirancang untuk meningkatkan kapasitas dan kecepatan jaringan telepon *mobile*. LTE adalah suatu proyek dalam *Third Generation Partnership Project* (3GPP). [7]

Pada Gambar 2 dapat dilihat bahwa LTE merupakan evolusi dari jaringan seluler yang dipersiapkan untuk teknologi 4G. Keuntungan utama dengan LTE adalah *throughput* yang tinggi, *latency* yang rendah, FDD dan TDD pada platform yang sama, peningkatan pengalaman pelanggan dan arsitektur sederhana yang mengakibatkan biaya operasional yang rendah. LTE juga akan mendukung sel dengan teknologi jaringan yang lebih lama seperti GSM, CDMAOne, WCDMA/UMTS, dan CDMA2000. Banyak fasilitas yang didapat sehingga perlu untuk *upgrade* 3G UMTS ke teknologi komunikasi *mobile* 4G-LTE, yang pada dasarnya adalah sebuah sistem *mobile broadband* dengan peningkatan layanan multimedia. [2]

2.4. Arsitektur 4G

Arsitektur jaringan LTE dirancang untuk tujuan mendukung trafik *packet switching* dengan mobilitas tinggi, QoS (*Quality of Service*), dan *latency* yang kecil. Pendekatan *packet switching* ini memperbolehkan semua layanan termasuk layanan *voice* menggunakan koneksi paket. Oleh karena itu pada arsitektur jaringan LTE dirancang sesederhana mungkin, yaitu hanya terdiri dari dua *node* yaitu eNB dan MME/GW (*Mobility Management Entity/Gateway*). Semua *interface* jaringan pada LTE adalah berbasis IP (*Internet Protocol*). eNB saling terkoneksi dengan *interface* X2 dan terhubung dengan MME/SGW melalui *interface* S1. Pada LTE terdapat 2 *logical gateway*, yaitu S-GW (*Serving Gateway*) dan P-GW (*Packet Data Network Gateway*). S-GW bertugas untuk melanjutkan dan menerima paket ke dan dari eNB yang melayani UE. P-GW menyediakan *interface* dengan jaringan PDN (*Packet Data Network*), seperti internet dan IMS. Selain itu P-GW juga melakukan beberapa fungsi lainnya, seperti alokasi alamat, *packet filtering*, dan *routing*. Jaringan LTE yang disebut sebagai SAE (*System Architecture Evolution*) hanya terdiri atas dua bagian, yaitu EPC (*Evolved Packet Core*) dan E-UTRAN (*Evolved UMTS Terrestrial Radio Access Network*). [2]



Gambar 3. Arsitektur Jaringan 4G-LTE [7]

Gambar 4. Profil Jalan Cihampelas Bandung dengan Citra Satelit

3. Metoda Penelitian

Metoda penelitian yang digunakan dalam penelitian ini adalah metoda kuantitatif dimana menggunakan data primer hasil pengukuran, lalu membandingkannya dengan metode empiris dalam bentuk perhitungan ideal. Hasil perbandingan tersebut dinyatakan dalam bentuk Tabel dan Grafik dengan menggunakan Matlab sehingga memudahkan dalam penarikan hasil analisis dari penelitian yang dilakukan.

Pengambilan sampel dilakukan secara berurutan, berdasarkan lokasi yang telah ditentukan. Pengukuran kekuatan sinyal yang didapatkan kemudian direkam secara numerik dan digunakan sebagai data pembanding antara perhitungan ideal dan hasil data pengukuran. Dari perbandingan antara keduanya, dapat menggambarkan secara jelas performa RSRP 4G-LTE yang diakibatkan oleh rugi-rugi propagasi yang terjadi di daerah pengambilan data pengukuran.

4. Hasil Penelitian dan Analisis

Lokasi pengambilan data pengukuran adalah sepanjang Jalan Cihampelas Bandung, dengan panjang total adalah 2.7 Km. Pengambilan data, dibagi menjadi 10 titik pengambilan sampel data pengukuran dimana tiap titik lokasinya berjarak ± 270 meter dihitung dari titik 0 meter. Kondisi lalu lintas di Jalan Cihampelas Bandung pada saat pengambilan sampel data pengukuran dalam kondisi

Tabel 1. Lokasi Titik Pengambilan Sampel Data Pengukuran

Jarak (Meter)	Lokasi Pengambilan Sampel Data Pengukuran
0	Pos Polisi Gandok
270	Depan Old Skull *Barber Shop*
540	Depan Mazda Cihampelas
810	Depan Graha Maranatha Cihampelas
1080	Depan ATM Bank BRI Cihampelas / ATM Bank Permata Cihampelas
1350	Depan Jalan Masuk Ciwalk Mall
1620	Depan Indomaret Cihampelas 122
1890	Dibawah Jembatan Layang Pasteur
2160	Depan Cihampelas Motor
2430	Depan Eiger Adventure *Store* (Putar Balik Lalu Lintas)
2700	Depan Lampu Merah Perempatan Jalan Padjajaran (Putar Balik Lalu Lintas)

lancar tanpa adanya kemacetan. Secara jelas, dapat dilihat pada Gambar 5 memperlihatkan rute lokasi penelitian di Jalan Cihampelas menggunakan citra satelit. Adapun titik lokasi tempat pengambilan sampel data pengukuran dapat ditunjukkan pada Tabel 1 dimana jumlah titik pengambilan data adalah 11 lokasi sehingga menghasilkan jumlah data yang sama.

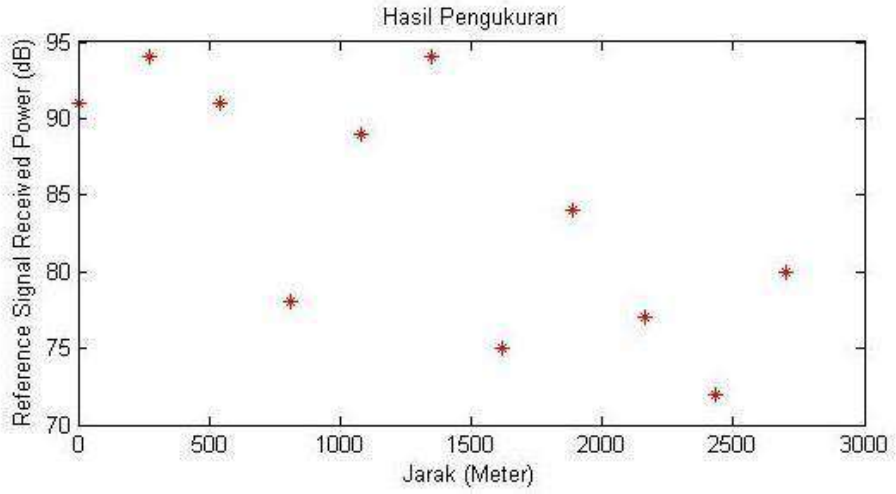
Dalam pengambilan data, telepon seluler digunakan untuk menangkap RSRP 4G-LTE yang dihasilkan dari eNB terdekat dan bersifat sebagai *receive only*. Perangkat telepon seluler tersebut ditanam sebuah perangkat lunak bernama *Network Signal Info Lite*. Perangkat lunak ini berfungsi untuk mengukur RSRP 4G-LTE dari eNB dan meng-*capture* data tersebut. Untuk mendapatkan hasil yang stabil, perangkat telepon didiamkan di lokasi titik yang telah ditentukan selama 5-10 menit. Nilai rata-rata terbanyak kemudian dicatat sebagai sampel data valid untuk dianalisa.

Lingkungan *outdoor* tempat pengambilan sampel data pengukuran, memiliki profil yang disekitarnya memiliki gedung-gedung yang rata-rata memiliki ketinggian mencapai 2 sampai 3 lantai. Selain itu, terdapat pula *Skywalk* di Jalan Cihampelas dengan tinggi 4.6 meter, lebar 9 meter, dan panjang 450 meter. Walaupun profil ruangan *outdoor* tempat pengambilan sampel data pengukuran kebanyakan memiliki profil *line of sight*, keberadaan *Skywalk* dapat menghalangi sinyal yang sampai ke perangkat walau tidak signifikan secara *real-time*. Adapun hasil sampel data yang didapatkan, dapat ditunjukkan seperti pada Tabel 2.

Jika dilihat dari Gambar 5, RSRP 4G-LTE yang berada di sepanjang Jalan Cihampelas, masuk dalam kategori RSRP 4G-LTE yang *excellent*. Berdasarkan klasifikasi kekuatan sinyal dari perangkat lunak yang digunakan, kategori indikator RSRP terbagi atas 4, yaitu buruk, sedang, baik, dan sangat baik. RSRP 4G-LTE antara -140 dB sampai -116 dB, masuk dalam kategori indikator buruk. RSRP 4G-LTE antara -115 dB sampai -106 dB, masuk dalam kategori indikator sedang. RSRP 4G-LTE antara -105 dB sampai -96 dB, masuk dalam kategori indikator baik. Sedangkan RSRP 4G-LTE antara -95 dB sampai -44 dB, masuk kategori indikator sangat baik. Untuk level RSRP 4G-LTE, semakin mendekati

Tabel 2. RSRP 4G-LTE Berdasarkan Lokasi / Hasil Data Pengukuran

Jarak (Meter)	Lokasi ke-N	RSRP (dB)
0	0	91
270	1	94
540	2	91
810	3	78
1080	4	89
1350	5	94
1620	6	75
1890	7	84
2160	8	77
2430	9	72
2700	10	80



Gambar 5. Distribusi RSRP 4G-LTE Hasil Pengukuran

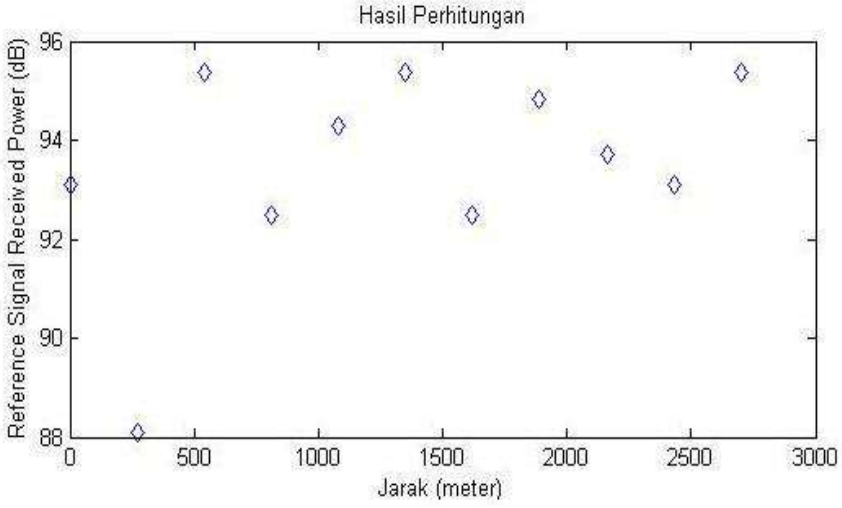
nilai -44 dB, maka level RSRP 4G-LTE untuk wilayah tersebut akan semakin baik. Layanan Operator Seluler yang digunakan adalah Indosat Ooredoo untuk memberikan variabel yang berbeda di masing-masing Provider Seluler. Jika dijabarkan dalam bentuk grafik, RSRP 4G-LTE hasil pengambilan sampel data pengukuran sepanjang Jalan Cihampelas, dapat ditunjukkan pada Gambar 5.

Dalam melakukan perhitungan, beberapa variabel turut dimasukkan seperti redaman pada manusia yang mencapai 3.5 dBm, redaman dedaunan dan kayu (pohon), redaman dinding yang mencapai 13 dB, redaman metal yang mencapai 26 dB, redaman almunium di sekitar pengambilan data sampel pengukuran yang mencapai 20.4 dB dan redaman lantai yang mencapai 10 dB. Selain dari redaman furniture di sekitar daerah pengambilan sampel pengukuran. Redaman hujan diabaikan dikarenakan pengambilan data sampel pengukuran dilakukan dalam kondisi cuaca yang cerah. Redaman hujan dapat mencapai 30.5 dB per kilometer persegi di atas frekuensi 10 GHz pada sistem seluler [3][4]. Dengan menggunakan Persamaan 2, Persamaan 3, Persamaan 4, Persamaan 5, Persamaan 6, dan Persamaan 7, maka didapatkan hasil perhitungan yang dijabarkan dalam Tabel 3.

Secara lengkap dapat dijabarkan dalam bentuk *scattering* dalam Gambar 6 tentang Hasil Perhitungan. Untuk memudahkan dalam melakukan perbandingan, Tabel 4 menunjukkan Hasil Pengukuran dan Hasil Perhitungan. Adapun dalam Tabel 4, mengacu pada Tabel 3 dan Tabel 4. Berdasarkan pada Tabel 4, maka dapat digambarkan dalam Gambar 7 dan Gambar 8 tentang perbandingan Hasil Pengukuran dan Hasil Perhitungan dengan menggunakan Model Okumura. Adapun hasilnya diperlihatkan pada Gambar 7 dan Gambar 8.

Tabel 3. Hasil Perhitungan RSRP 4G-LTE dengan Model Okumura

Frekuensi	***d* T_x ke R_x (m)**	***H_{te}* (m)**	***H_{re}* (m)**	**RSRP (dB)**
2300	25	30	1.5	93.10
	18	30	1.5	88.08
	29	30	1.5	95.37
	24	30	1.5	92.48
	27	30	1.5	94.28
	29	30	1.5	95.37
	24	30	1.5	92.48
	28	30	1.5	94.84
	26	30	1.5	93.70
	25	30	1.5	93.10
	29	30	1.5	95.37



Gambar 6. Distribusi RSRP Hasil Perhitungan

Tabel 4. Perbandingan RSRP 4G-LTE antara Hasil Pengukuran dan Hasil Perhitungan

Lokasi ke-N	Hasil Pengukuran (dB)	Hasil Perhitungan (dB)
0	91	93.10
1	94	88.08
2	91	95.37
3	78	92.48
4	89	94.28
5	94	95.37
6	75	92.48
7	84	94.84
8	77	93.70
9	72	93.10
10	80	95.37

Gambar 7. Distribusi Perbandingan RSRP 4G-LTE antara Hasil Pengukuran dan Hasil Perhitungan

5. Kesimpulan

Dari hasil penelitian yang dilakukan, dapat diambil simpulan sebagai berikut :

- Hasil Pengukuran RSRP 4G-LTE di lokasi yang telah ditentukan berada pada *range* -72 dB sampai -94 dB. Sedangkan Hasil Perhitungan dengan memperhitungkan redaman yang terjadi menggunakan Model Okumura berada pada *range* -88.08 dB sampai -95.37 dB.
- Hasil Pengukuran maupun Hasil Perhitungan dengan Model Okumura, masing-masing dalam kategori level RSRP 4G-LTE yang sangat baik sepanjang Jalan Cihampelas Bandung. Dengan demikian semakin kecil rugi-rugi propagasi, maka level RSRP 4G-LTE yang diterima oleh *user* semakin mendekati baik.
- RSRP 4G-LTE di Jalan Cihampelas Bandung dengan panjang lintasan adalah 2.7 Km, dimana RSRP 4G-LTE telah terdistribusi dengan baik oleh pihak Operator Seluler tanpa adanya

fluktuasi yang signifikan yang mungkin diakibatkan oleh rugi-rugi propagasi sehingga dapat mempengaruhi kekuatan sinyal seluler.

Referensi

1. de Toledo, A.F., & Turkmani, A.M. *Propagation into and within at 900, 1800, 2300 MHz*. University of Liverpool, Department of Electrical Engineering and Electronics. ISSN: 1090-3038. 1992.
2. Nugroho, Daniel A., & Aryanta, Dwi. *Perancangan Simulator Pemodelan Prediksi Redaman Propagasi Outdoor pada Sistem Komunikasi Seluler*. TELKA: Jurnal Telekomunikasi, Elektronika, Komputasi, dan Kontrol. Vol.4, No.2, November 2018, pp. 150-161. ISSN (e): 2540-9123. ISSN (p): 2502-1982.
3. Palinggi, Sandryones., & Iskandar. *Indoor Propagation Environmental Profile Analysis at 2300 MHz*. 2019 IEEE 5th International Conference on Wireless and Telematics (ICWT), Page 72, July 2019. Electronic ISBN: 978-1-7281-4796-3. USB ISBN: 978-1-7281-4795-6. DOI: 10.1109/ICWT47785.2019.8978222.
4. Palinggi, Sandryones., et al. *Estimasi Lokasi Pengguna Telepon Seluler GSM pada Lingkungan Indoor*. CENTIVE: Conference of Electrical Engineering, Telematics, Industrial Technology, and Creative Media. Vol.2, No.1, November 2019, pp. 215-223. ISBN: 978-602-53004-0-0.
5. Rappaport, S. Theodore. *Wireless Communication: Principle and Practice, 2nd Ed*. New York: Pearson Education International. 2002.
6. Razak, Irawati. *Estimasi Lokasi Robust Indoor pada Sistem Komunikasi Wireless*. Institut Teknologi Sepuluh Nopember (ITS). 2006.
7. Sridhar, Kamakshi. *Introduction to Evolved Packet Core (EPC): EPC Elements, Protocols and Procedures*. Alcatel-Lucent. 2012. Unpublished.
8. Wahadin, Amrul. *Drive Test & Optimize 4G Network*. Modul Training Edutech Solution. 2019. Unpublished.

COMPLETE
Journal of Computer, Electronic, and Telecommunication
ISSN 2723-4371, E-ISSN 2723-5912
doi.org/10.52435/complete.v1i1.49

Analisa Kesalahan Trajektori dan Algoritma Solusi Invers pada Robot Lengan Berdasarkan Jaringan QACA-RBF

Ardiansyah Al Farouq [1], Presto Fani [2], Muhammad Yanuar Muhaimin [3]

[1] Teknik Komputer, Fakultas Teknik Elektro, Institut Teknologi Telkom Surabaya; alfarouq01@gmail.com
[2] Teknik Elektronika, D4 Teknik Elektronika, Politeknik Elektronika Surabaya; dipres@gmail.com
[3] Teknik Komputer, Fakultas Teknik Elektro, Institut Teknologi Telkom Surabaya; yanuardanu19@gmail.com

Abstrak: Dalam rangka meningkatkan akurasi posisi dan trajektori dari robot lengan UR5, algoritma solusi invers pada robot lengan berdasarkan jaringan QACA-RBF diajukan. Desain algoritma ini menggunakan model prediksi melalui jaringan saraf dan menggunakan algoritma koloni semut kuantum untuk mengoptimalkan bobot keluarannya. Dalam memecahkan masalah ini, algoritma koloni semut kuantum memiliki presisi konvergen yang rendah dan mudah jatuh ke dalam solusi local optimal dalam algoritma solusi invers dari derajat kebebasan pada robot lengan, maka peningkatan pengukuran seperti local optimasi dan batas maksimum minimum feromon dan variasi dibutuhkan. Dengan membandingkan hasil simulasi dari hasil simulasi robot lengan UR5 dan hasil simulasi berdasarkan jaringan saraf ACA, QACA, dan RBF untuk mendapatkan posisi dan gerak trajektori pada titik ruang dengan kepresisian disetiap algoritma. Dengan skema tersebut agar dapat membuktikan kelayakan algotirma jaringan QACA-RBF.

Keywords: robot lengan; algoritma; trajektori; QACA; ACA.

1. Pendahuluan

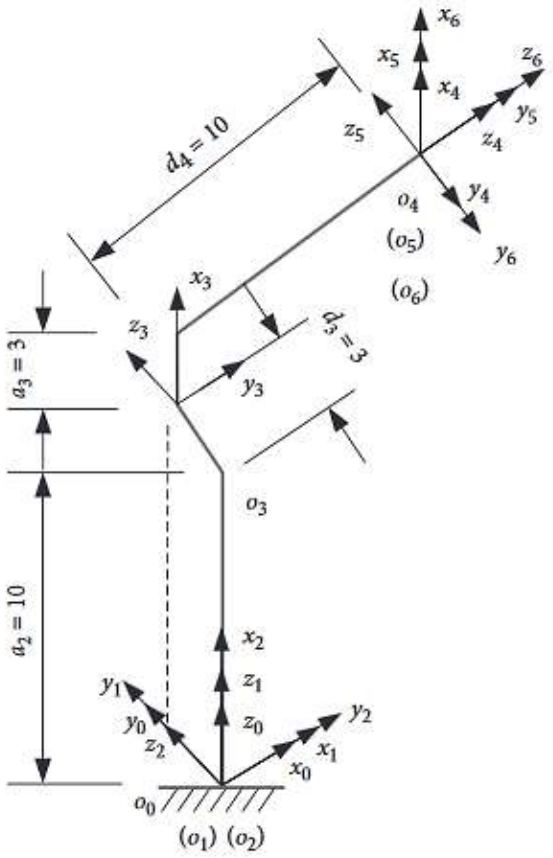
Pada desain manufaktur moderen saat ini, robot lengan adalah perangkat elektromekanis terintegrasi yang sangat dibutuhkan. Robot lengan yang dibahas disini menggunakan robot lengan UR5. Pada dasar teori dinamika dan kinematika, keakuratan solusi invers adalah faktor penentu untuk akurasi dan efisiensi perencanaan trejektori pada robot lengan.

Solusi invers dari robot lengan UR5 adalah dasar dari trejektori robot lengan. Persamaan solusi invers memiliki karakteristik dimensi dan nonlinier yang tinggi, solusinya kompleks, dan sulit untuk menemukan solusi yang akurat. Solusi invers tradisional dapat secara kasar dibagi menjadi metode aljabar [1-6] dan metode geometris [7-9] sudah jarang digunakan karena hasil yang buruk. Dalam metode iteratif numerik yang lebih populer pada tahap ini [10-13], evolusi, bionik dan simulasi, jaringan saraf, dan algoritma lainnya adalah algoritma kecerdasan yang umum digunakan [14-16]. Meskipun metode ini telah mencapai hasil yang luar biasa, mereka masih tidak memuaskan dan terbatas dalam hal akurasi. Oleh sebab itu, maka perlu dieksplorasi lebih lanjut dan ditingkatkan.

Dalam algoritma kecerdasan, jaringan saraf RBF adalah algoritma yang sangat penting, yang dapat mendekati fungsi nonlinier dalam kepresisian. Beberapa peneliti telah menyadari pentingnya jaringan saraf dan menggunakannya untuk memecahkan solusi invers dari robot lengan untuk mendapatkan efek dan kepresisian yang relative ideal [17-19]. Dalam makalah ini, sebuah algoritma yang didasarkan pada jaringan QACA-RBF(peningkatan algoritma koloni semut) diusulkan untuk mengoptimalkan beban keluaran dari koloni semut kuantum yang ditingkatkan, kemudian hasil yang baik diperoleh.

2. Model Mekanikal Lengan UR5

Mekanikal lengan UR5 yang digunakan memiliki enam derajat kebebasan. Permasalah forward kinematics nya telah diselesaikan dan lengan UR5 menggunakan sistem model parameter DH yang ditunjukkan pada Gambar 1[20-21].



Gambar 1: lengan UR5 menggunakan sistem model parameter DH.

Dari Gambar 1 dapat terlihat bahwa matrik konversi koordinat dari manipulator di sistem koordinat akhir *joint* relatif pada sistem koordinat dasarnya adalah

$$ {}^{0}_{1}T = {}^{0}_{1}T\,{}^{1}_{2}T\,{}^{2}_{3}T\,{}^{3}_{4}T\,{}^{4}_{5}T\,{}^{5}_{6}T = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (1) $$

$[p_x, p_y, p_z]$ pada matrik ini merepresentasikan posisi dari bagian akhir manipulator pada sistem koordinat dasar. Sudut RPY Euler dapat dijelaskan dengan rumus berikut[21-23]:

$$ a = \arctan(a_y, a_x), \qquad (2) $$

$$ \beta = \arctan(a_x \cos a + a_y \sin a\,, a_z), \qquad (3) $$

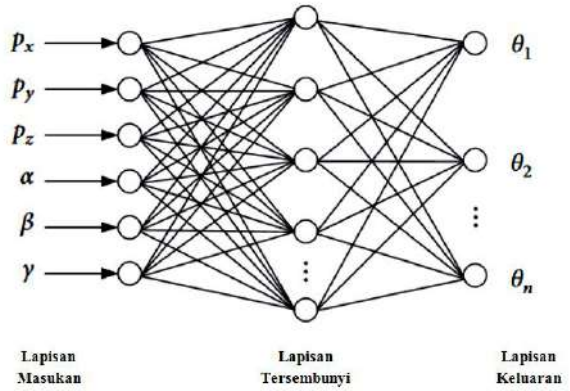
$$ \gamma = \arctan(-n_x \sin a + n_y \cos a\,, o_y \cos a - o_x \sin a) \qquad (4) $$

Dari rumus tersebut maka dapat dilihat karena variabel dalam persamaan (1) adalah semua fungsi dari sudut *joint* θ_i, posisi akhir dari $p = [p_x, p_y, p_z, \alpha, \beta, \gamma]$dapat diperoleh dalam permasalahan penentuan θ_i.

3. Permodelan Prediksi dari Solusi Invers Berdasarkan Jaringan QACA-RBF

Dalam menemukan solusi invers dari robot lengan, model prediksi dari jaringan saraf dibuat. Untuk meningkatkan akurasi solusi invers, nilai bobot keluaran dioptimalkan dengan meningkatkan algoritma koloni semut kuantum, sehingga kesalahan antara keluarannya dengan keluaran aktualnya diminimalkan.

RBF adalah salah satu algoritma pembelajaran jaringan saraf. Struktur pada jaringan saraf RBF terdapat lapisan masukan, lapisan tersembunyi (hidden layer, dan lapisan keluaran.



Gambar 2: Jaringan saraf RBF

Pada Gambar 2 menunjukkan diagram struktur dari jaringan saraf RBF manipulator dari n-dof [20]. Pada Gambar 2 tersebut diasumsikan bahwa masukan dari jaringan saraf RBF adalah posisi akhir pada variabel $x = [p_x, p_y, p_z, \alpha, \beta, \gamma]^T$, dan variabel keluaran adalah solusi invers dari robot lengan bahwa n adalah sudut joint, $y = [\theta_1, \theta_2, \dots, \theta_j, \dots, \theta_n]^T \epsilon R^n$, dimana y adalah vector dimensi ke n, dan hubungan antara x dan y adalah:

$$y_n = \sum_{i=1}^{k} \omega_{ij} \exp\left(-\frac{1}{2\sigma^2}\|x_k - c_i\|^2\right), 2 < n, \quad (5)$$

Dimana

$$x_k = [p_x^k, p_y^k, p_z^k, \alpha^k, \beta^k, \gamma^k]^T,$$
$$c_i = [c_{1i}, c_{2i}, \dots, c_{hi},], \quad (6)$$

Dimana x_k adalah parameter masukkan sampel k. c_i adalah pusat simpul dari fungsi lapisan tersembunyi ke-i. h adalah jumlah simpul. ω_{ij} adalah bobot dari lapisan implisit ke lapisan keluaran. y_n adalah keluaran sebenarnya dari sudut kebebasan ke-n. σ adalah variasi dari fungsi lapisan tersembunyi.

Algoritma Koloni Semut Kuantum / *Quantum Ant Colony Optimization Algorithm* (QACA) adalah Sebuah sistem yang memungkinkan semua semut untuk menerapkan metode pengkodean bit kuantum dan pembaruan. Pada metode tersebut jumlah populasinya relative kecil, kinerja algoritmanya relative tinggi, dan tingkat konvergensinya cepat.

Dalam penelitian ini, jaringan saraf QACA dan RBF digabungkan untuk saling melengkapi satu sama lain dan memanfaatkan sepenuhnya kemampuan optimalisasi yang efisien dari koloni semut kuantum, dan langkah langkah peningkatan yang direncanakan untuk membentuk algoritma solusi invers dari mekanik robot lengan pada jaringan QACA-RBF.

4. Percobaan Simulasi dan Analisa Kesalahan dari Manipulator UR5

Pada bagian ini terdiri dari dua sub bab yang membahas tentang algoritma prediksi dan kesalahan trajaktori gerakan dari metode yang digunakan.

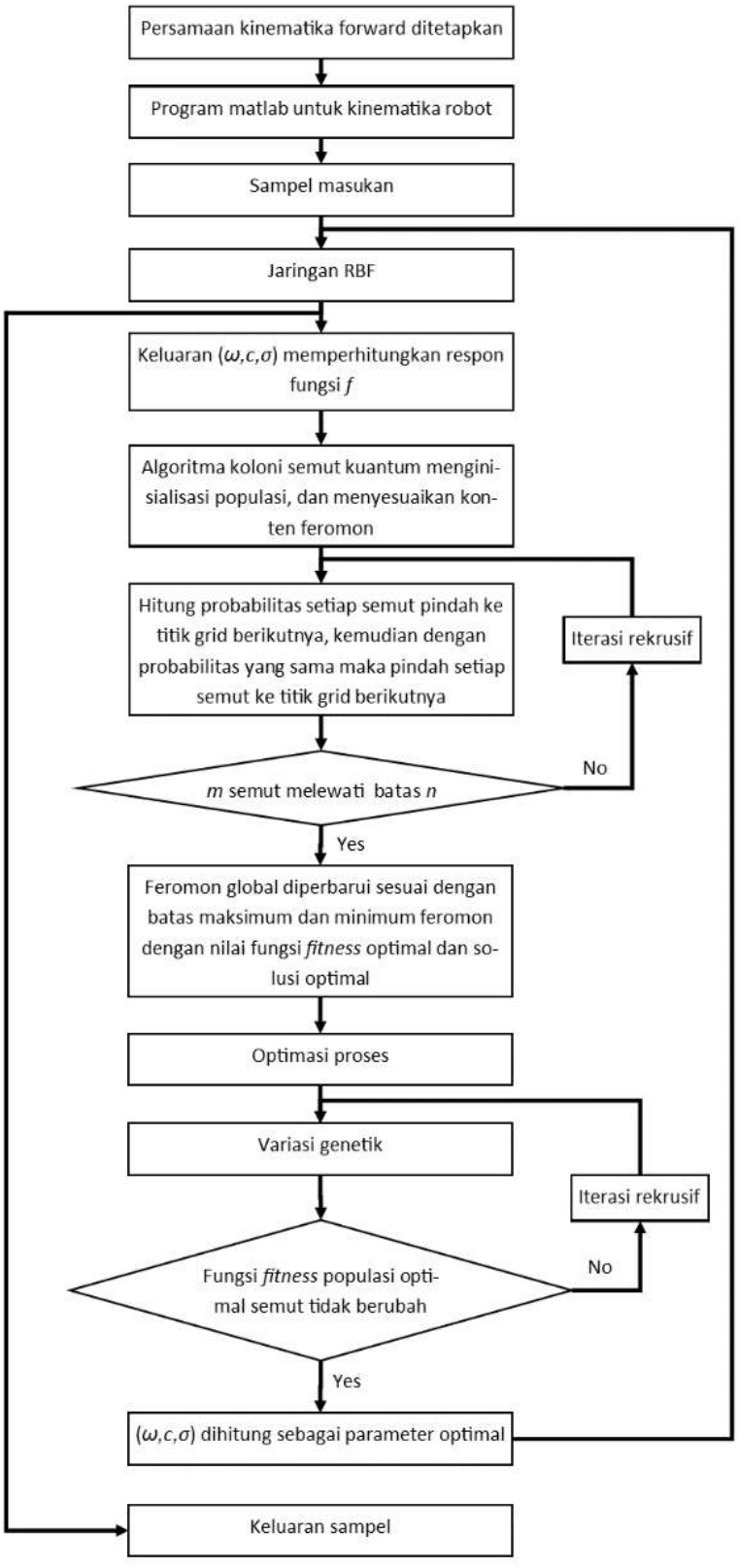
4.1 Pembentukan Permodelan Prediksi untuk Solusi Invers Robot Lengan UR5

Pada bagian percobaan ini dilakukan dengan robot lengan UR5. Kemudian didapatkan secara acak 8000 titik disekitar robot lengan UR5 dan 1000 titik dipilih sebagai sampel pelatihan. Setelah normalisasi, parameter masukan dari jaringan RBF dibentuk, seperti $x = \left[p_x', p_y', p_z', \alpha', \beta', \gamma'\right]^T$.

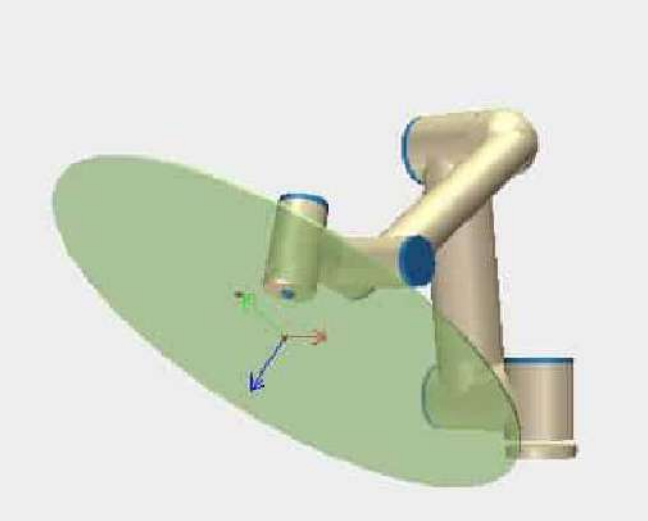
Sedangkan untuk mendapatkan parameter keluaran dari jaringan RBF, sudut joint harus dinormalisasi seperti $y = [\theta_1', \theta_2', \theta_3', \theta_4', \theta_5', \theta_6']$. Berdasarkan dari itu, maka prediksi model dari 6 masukan 6 keluaran dengan algoritma solusi invers berdasarkan jaringan QACA dibangun, pelatihan data pada permodelan prediksi berdasarkan pada 1000 titik yang sudah ditentukan sebelumnya.

4.2 Analisa Kesalahan pada Trajektori Gerakan

Pada Gambar 3 adalah end effector robot lengan UR5 yang disimulasikan dengan GAZEBO ROS. Untuk dapat menganalisa kesalahan trajektori pada kurva trajektori yang telah diketahui panjangnya dan dipilih secara merata 30 titik sebagai deskripsi trajektorinya. Posisi 30 titik tersebut dihitung menggunakan persamaan (1)-(4) untuk mendapatkan nilai $p_x, p_y, p_z, \alpha, \beta,$ dan γ. Kemudian mendapatkan 30 set yang sesuai didapat dari hasil invers yang diketahui $\theta_1', \theta_2', \theta_3', \theta_4', \theta_5', \theta_6',$ yang mana set tersebut akan digunakan sebagai titik referensi untuk analisis kesalahan trajektori. 30 titik yang sudah dipilih pada trajektori tersebut digunakan sebagai masukan. Setelah algoritma solusi invers berbasis pada jaringan QACA-RBF dihitung dan dinormalisasikan, maka nilai 30 set nilai keluaran yang diprediksi diperoleh. Untuk dapat mengevaluasi efek prediksi secara onjektif, maka digunakan indeks kesalahan absolut.



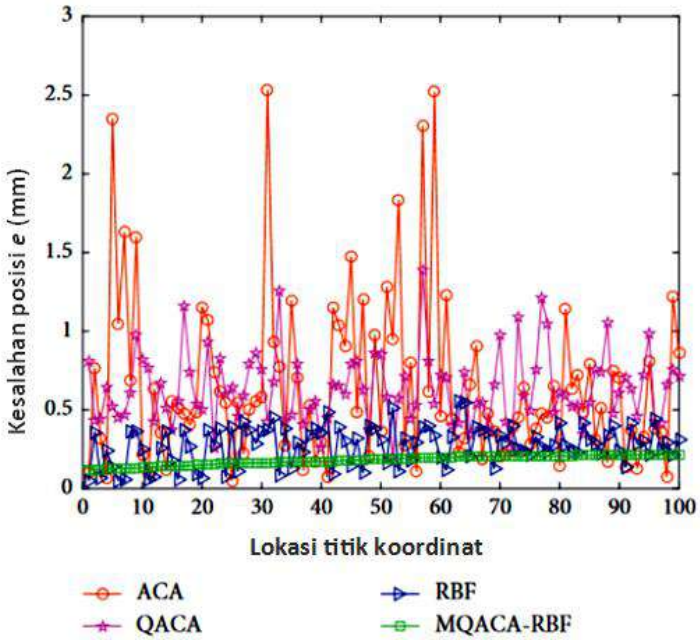
Gambar 2. Algoritma QACA-BRF untuk flowchart invers kinematic



Gambar 3. E*nd effector* robot lengan UR5

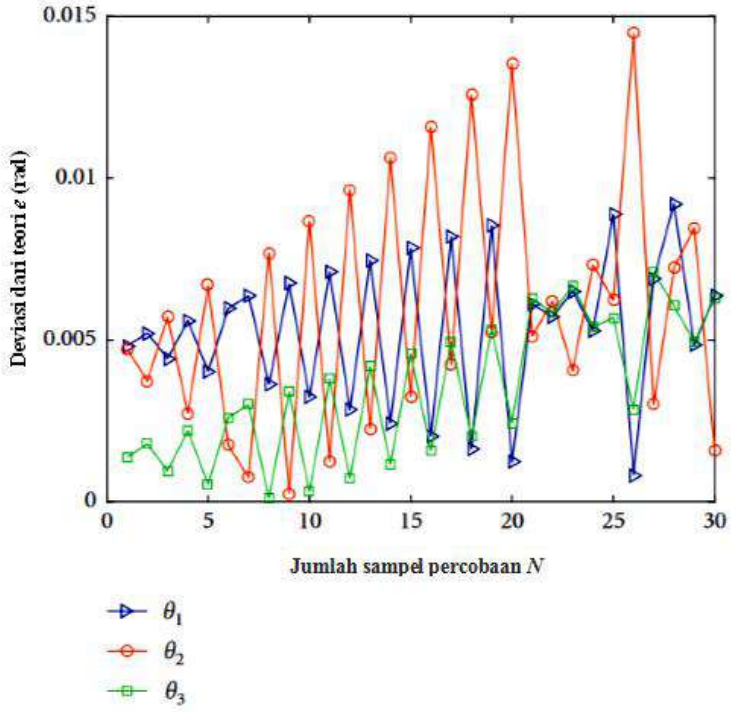
Tabel 1. DH Parameter pada trajektori robot lengan

Joint i	$a_{i-n}(mm)$	$a_{i-n}(mm)$	$a_{i-n}(°)$	θi (°)
1	0	0	0	-160 ~ 160
2	0	0	-95	-225 ~ 45
3	10	3	0	-45 ~ 225
4	3	10	-95	-110 ~ 170
5	0	0	95	-100 ~ 100
6	0	0	-95	-266 ~ 266

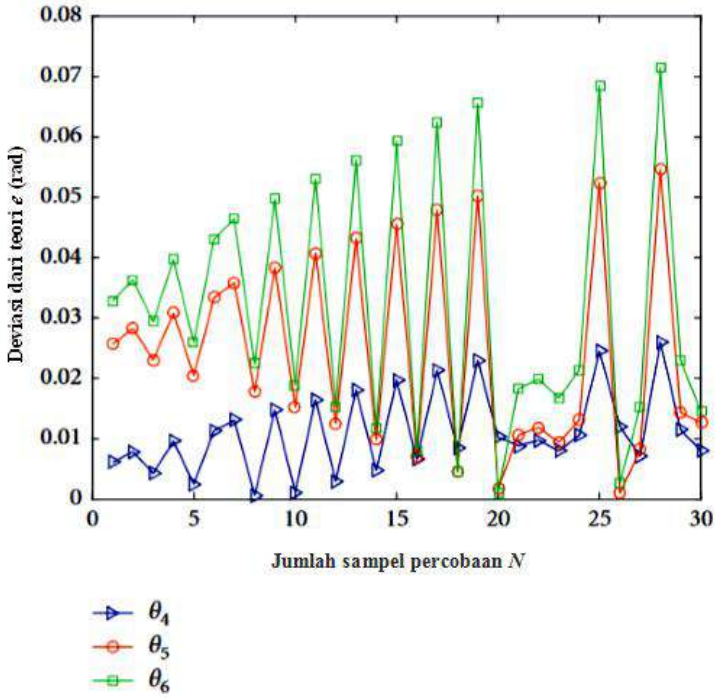


Gambar 5. Perbandingan kesalahan posisi ACA, QACA, RBF, QACA-RBF

Pada gambar 7 dan 8 adalah nilai prediksi solusi invers dari 30 set dari sudut joint θ_1 hingga ke θ_6 yang sudah sesuai dengan 30 titik yang telah dipilihkemudian dibandingkan dengan kesalahan absolut nyatanya.



Gambar 7. Kesalahan absolut dari sudut joint θ_1, θ_2 dan θ_3



Gambar 8. Kesalahan absolut dari sudut joint θ_4, θ_5 dan θ_6

Kesimpulan

Pada penelitian ini, manipulator yang menggunakan algoritma solusi invers yang didasari dengan jaringan QACA-RBF yang ditulis membuktikan bahwa metode ini efektif mencampurkan jaringan saraf RBF dan algoritma QACA. Metode tersebut juga memberikan keuntungan pada masing-masing algoritma. Kemudian dari percobaan simulasi trajektori dan simulasi kesalahan posisi membuktikan bahwa algoritma solusi invers menggunakan jaringan QACA-RBF lebih baik dibandingkan menggunakan algoritma solusi invers yang berbasis pada ACA, QACA, dan RBF karena kesalahan posisi masing-masing meningkat menjadi 3.89%, 6.19% dan 0.76%.

Referensi

1. Venanzi, Stefano, and Vincenzo Parenti-Castelli. "A new technique for clearance influence analysis in spatial mechanisms." (2005): 446-455.
2. Pizzolato, C., et al. "Real-time inverse kinematics and inverse dynamics for lower limb applications using OpenSim." *Computer methods in biomechanics and biomedical engineering* 20.4 (2017): 436-445.
3. Ananthanarayanan, Hariharan, and Raúl Ordóñez. "Real-time inverse kinematics of redundant manipulator using a hybrid (analytical and numerical) method." *2013 16th International Conference on Advanced Robotics (ICAR)*. IEEE, 2013.
4. Schröder, Matthias, et al. "Real-time hand tracking using synergistic inverse kinematics." *2014 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 2014.
5. Husty, Manfred L., Martin Pfurner, and Hans-Peter Schröcker. "A new and efficient algorithm for the inverse kinematics of a general serial 6R manipulator." *Mechanism and machine theory* 42.1 (2007): 66-81.
6. Kucuk, Serdar, and Zafer Bingul. "Inverse kinematics solutions for industrial robot manipulators with offset wrists." *Applied Mathematical Modelling* 38.7-8 (2014): 1983-1999.
7. Richter, Charles, Adam Bry, and Nicholas Roy. "Polynomial trajectory planning for aggressive quadrotor flight in dense indoor environments." *Robotics Research*. Springer, Cham, 2016. 649-666.
8. de Jesús Rubio, José, Enrique García, and Jaime Pacheco. "Trajectory planning and collisions detector for robotic arms." *Neural Computing and Applications* 21.8 (2012): 2105-2114.
9. Hao, Wong Guan, Yap Yee Leck, and Lim Chot Hun. "6-DOF PC-Based Robotic Arm (PC-ROBOARM) with efficient trajectory planning and speed control." *2011 4th International Conference on Mechatronics (ICOM)*. IEEE, 2011.
10. Antonelli, Gianluca, Stefano Chiaverini, and Giuseppe Fusco. "A new on-line algorithm for inverse kinematics of robot manipulators ensuring path tracking capability under joint limits." *IEEE Transactions on Robotics and Automation* 19.1 (2003): 162-167.
11. Bayro-Corrochano, Eduardo, and Julio Zamora-Esquivel. "Differential and inverse kinematics of robot devices using conformal geometric algebra." *Robotica* 25.1 (2007): 43-61.
12. Zamora-Esquivel, Julio, and Eduardo Bayro-Corrochano. "Robot perception and handling actions using the conformal geometric algebra framework." *Advances in applied Clifford algebras* 20.3-4 (2010): 959-990.
13. Pesonen, Janne, and Krister OE Henriksson. "Polymer conformations in internal (polyspherical) coordinates." *Journal of computational chemistry* 31.9 (2010): 1873-1881.
14. Tan, G. Z., and W. B. Li. "Design of ant algorithm-based optimal PID controller and its application to intelligent artificial leg." *Zhongnan Daxue Xuebao(Ziran Kexue Ban)/J. Cent. South Univ.(Sci. Technol.)(China)(China)* 35.1 (2004): 91-96.
15. Chen, Gang, et al. "Obstacle avoidance path planning of manipulator based on speed correction term." *Control and Decision* 1.30 (2015): 156-160.
16. Hong, Xie, et al. "Inverse kinematics solution method based on multi-subgroup hierarchical hybrid of differential algorithm and chaotic particle swarm optimization." *Journal of Electronic Measurement and Instrumentation* 10 (2015): 7.
17. Dash, K. K., et al. "A neural network based inverse kinematic problem." *2011 IEEE Recent Advances in Intelligent Computational Systems*. IEEE, 2011.

18. KöKer, RaşIt. "A genetic algorithm approach to a neural-network-based inverse kinematics solution of robotic manipulators based on error minimization." *Information Sciences* 222 (2013): 528-543.
19. Duka, Adrian-Vasile. "Neural network based inverse kinematics solution for trajectory tracking of a robotic arm." *Procedia Technology* 12.1 (2014): 20-27.
20. Pau, James WL, Shane SQ Xie, and Andrew J. Pullan. "Neuromuscular interfacing: Establishing an EMG-driven model for the human elbow joint." *IEEE Transactions on biomedical engineering* 59.9 (2012): 2586-2593.
21. Bin, He, Liu Wen Zhen, and Lv Hai Feng. "The kinematics model of a two-wheeled self-balancing autonomous mobile robot and its simulation." *2010 Second International Conference on Computer Engineering and Applications*. Vol. 2. IEEE, 2010.

COMPLETE
Journal of Computer, Electronic, and Telecommunication
ISSN 2723-4371, E-ISSN 2723-5912
doi.org/10.52435/complete.v1i1.51

Investigasi Parameter *Epoch* Pada Arsitektur ResNet-50 Untuk Klasifikasi Pornografi

Faiz Nashrullah [1], Suryo Adhi Wibowo [2]* dan Gelar Budiman [3]

[1] Telkom University; faissme@student.telkomuniversity.ac.id
[2] Telkom University; suryoadhiwibowo@telkomuniversity.ac.id
[3] Telkom University; gelarbudiman@telkomuniversity.ac.id
* Korespondensi: suryoadhiwibowo@telkomuniversity.ac.id; Tel.: +6282145143639

Abstrak: Kemajuan teknologi informasi yang cepat dan tak terkontrol membuat berbagai konten negatif seperti pornografi dapat dengan mudah diakses. Konten pornografi terbukti dapat menyebabkan berbagai permasalahan terutama pada generasi muda. Beberapa pengembangan metode untuk pendeteksian pornografi telah dilakukan namun masih terkendala pada keterbatasan karakteristik data masukan. Pada penelitian kali ini dikembangkan sistem pendeteksi konten pornografi berbasis klasifikasi menggunakan *Convolutional Neural Network* (CNN) dengan arsitektur ResNet-50 untuk mengatasi permasalahan sebelumnya. Dalam proses perancangan model sistem, diterapkan berbagai konfigurasi *epoch* dan didapatkan bahwa performa dari sistem memiliki kecenderungan untuk meningkat seiring dengan pertambahan *epoch*. Performa terbaik diraih oleh sistem pada konfigurasi *epoch* 60 dengan akurasi 91,033%.

Kata kunci: CNN; ResNet-50; ResNet; Klasifikasi; *Hyperparameter*; *Epoch*

1. Pendahuluan

Kemajuan teknologi yang sangat pesat terutama dalam teknologi penyebaran informasi terkhusus internet, memberikan aksesibilitas yang mudah dan cepat kepada semua orang. Keuntungan tersebut dapat memberikan dampak yang buruk jika terjadi penyalahgunaan yang dilakukan oleh beberapa pihak dengan cara menyebarkan konten negatif, salah satunya pornografi. Tidak dapat dipungkiri bahwa konten pornografi memiliki persebaran yang sangat masif dan cepat di internet. Definisi dari pornografi adalah materi yang menciptakan pikiran seksual, berisi gambar eksplisit atau deskripsi tindakan seksual yang melibatkan alat kelamin [1]. Pornografi dapat menimbulkan kecanduan dan terdapat ulasan dari berbagai penelitian [2] yang menunjukkan bahwa pornografi dapat mengganggu kesehatan perkembangan seksual pada anak modern.

Menanggapi permasalahan tersebut, diperlukan metode deteksi atau *filtering* terhadap konten pornografi, yang kemudian dapat dikembangkan menjadi piranti lunak penangkal pornografi, serta bisa diterapkan di berbagai *platform*. Dalam masa awal penelitian tentang konten pornografi, Basilio *et al* [3] menggunakan metode *thresholding* untuk membuat metode pendeteksi citra pornografi dengan memperhatikan banyaknya komposisi kulit dalam suatu citra. Tetapi penentuan konten pornografi yang mengacu pada komposisi warna kulit memiliki tingkat akurasi yang rendah jika *background* dari objek dalam citra mempunyai komposisi warna yang serupa dengan kulit asli manusia, bisa disebut juga dengan *noise*. Tidak semua warna kulit juga dapat terdeteksi dikarenakan hanya warna kulit yang berada di antara ketentuan *threshold* saja yang terdeteksi. Karena itu metode yang dirancang [3] tidak terlalu cocok untuk menangani data dengan *noise* yang banyak sehingga terbatas dalam segi karakteristik citra pornografi yang dapat terdeteksi.

Berdasar penelitian yang telah dilakukan sebelumnya, pada penelitian ini dikembangkan sebuah metode klasifikasi untuk mendeteksi suatu citra pornografi dengan menggunakan metode *Convolutional Neural Network* (CNN) yang merupakan salah satu contoh *deep learning*. Penerapan

berbagai metode *deep learning* mulai digunakan untuk melakukan klasifikasi citra ataupun berbagai pengolahan video berbasis *computer vision* [4]–[7]. CNN sendiri mengadopsi cara kerja dan memiliki struktur tiruan dari neuron otak manusia. Dengan model struktur tersebut, CNN mampu melakukan ekstraksi fitur dari citra secara lebih mendetail, serta CNN dapat menyimpan dan menjadikan acuan hasil pembelajaran yang telah dilakukan dengan adanya parameter *weight* dan *bias* di dalam arsitekturnya. Dengan konsep tersebut CNN dapat menerima *input* citra dengan karakteristik lebih umum atau dengan banyak *noise* sekalipun.

Struktur CNN secara umum disusun oleh tiga komponen utama *layer*, yaitu *convolutional layer*, *pooling layer* dan *full connection layer* [8]. Ketiga *layer* tersebut dapat dikombinasikan sesuai dengan tujuan dan kebutuhan, sehingga tercipta berbagai arsitektur dari CNN dengan keunggulannya masing-masing. Pada penelitian ini, sistem klasifikasi dibuat dengan menggunakan ResNet-50 [9] sebagai model arsitektur dari CNN. ResNet-50 memiliki konsep *shortcut connection* yang mencegah sistem dari kehilangan banyak informasi selama *training* dilakukan. Sistem klasifikasi yang dibuat dalam penelitian ini ditujukan untuk dapat mendeteksi apakah suatu gambar yang menjadi *input* dalam sistem merupakan pornografi atau bukan.

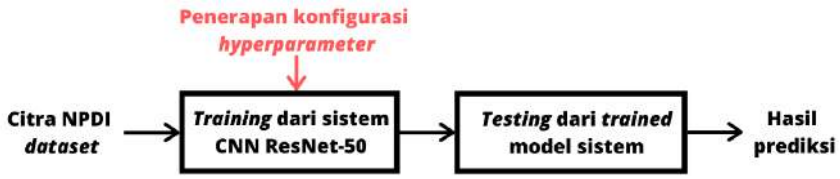
Dalam penelitian ini dilakukan investigasi dari pengaruh penerapan konfigurasi *hypeparameter epoch* ke dalam arsitektur yang dibuat untuk sistem klasifikasi pornografi. *Epoch* adalah suatu kondisi ketika seluruh *dataset* yang menjadi masukan model sistem telah selesai melewati seluruh neural network secara *forward propagation* dan *back propagation* dalam 1 kali putaran [10]. Diharapkan berdasarkan hasil percobaan yang dilakukan, dapat diketahui pengaruh penerapan konfigurasi *epoch* terhadap akurasi yang didapatkan sistem klasifikasi.

2. Bahan dan Metode

Penelitian yang dilakukan diawali dengan merancang sebuah sistem klasifikasi gambar pornografi menggunakan CNN dengan ResNet-50 sebagai arsitekturnya. Dalam perancangan yang dilakukan, NPDI *dataset* [11] dipilih menjadi data citra masukan untuk proses *training* dan *testing* dari percobaan yang dilakukan. Sebelum dilakukan proses *training*, *hyperparameter* seperti *epoch*, *learning rate*, dan *batch size* diatur terlebih dahulu. Secara umum garis besar dari perancangan sistem ditunjukkan oleh Gambar 1.

2.1 NPDI *dataset*

Pada penelitian kali ini digunakan NPDI *dataset* [11] sebagai data masukan untuk sistem yang dirancang. NPDI *dataset* berisikan video yang berdurasi hampir 80 jam yang terdiri dari 400 video pornografi dan 400 video non-pornografi. Untuk keperluan *data preprocessing*, video dalam *dataset* tersebut diekstrak menggunakan STOIK *Video Converter* dan menghasilkan 16727 *frames* yang sudah dipilih dari total semua frames ekstraksi. Konten dalam *dataset* ini juga terdiri dari variasi berbagai macam etnis di dalamnya. Dari total keseluruhan *frames* yang diekstrak, hanya digunakan sebagian *dataset* dan kemudian dilakukan augmentasi pada *dataset* tersebut sehingga total didapatkan 15000 *frames* atau citra untuk keperluan penelitian ini. *Dataset* NPDI diorganisir sesuai yang tertera pada Tabel 1 dan Gambar 2 merupakan *preview* dari citra NPDI *dataset*.



Gambar 1. Diagram garis besar perancangan sistem.

Tabel 1. Sistematika pembagian data.

Kelas	Data Latih	Data Validasi	Data Uji
Pornografi	6000	600	1500
Non-Pornografi	6000	600	1500

Gambar 2. *Preview* dari NPDI *dataset* [11].

2.2 *Convolutional Neural Network*

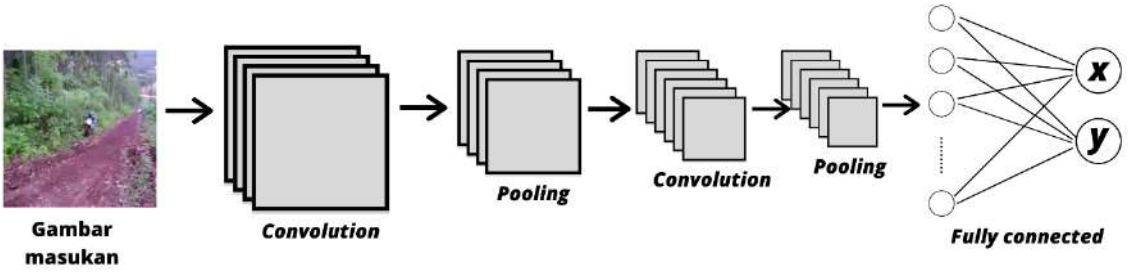
Secara garis besar, struktur dari CNN terdiri dari 3 macam *layer* penyusun utama yaitu, *convolutional layer*, *pooling layer*, dan *fully connection* atau *fully connected* layer. Struktur pada arsitektur CNN biasanya terdiri dari berbagai tingkatan kedalaman *network* yang tiap-tiap struktur merepresentasikan fitur tersendiri [8]. Pada *convolutional layer* dilakukan proses konvolusi untuk mengekstrak fitur-fitur yang terdapat pada citra, proses konvolusi secara sederhana dirumuskan dalam persamaan 1,

$$h(x) = f(x) * g(x), \tag{1}$$

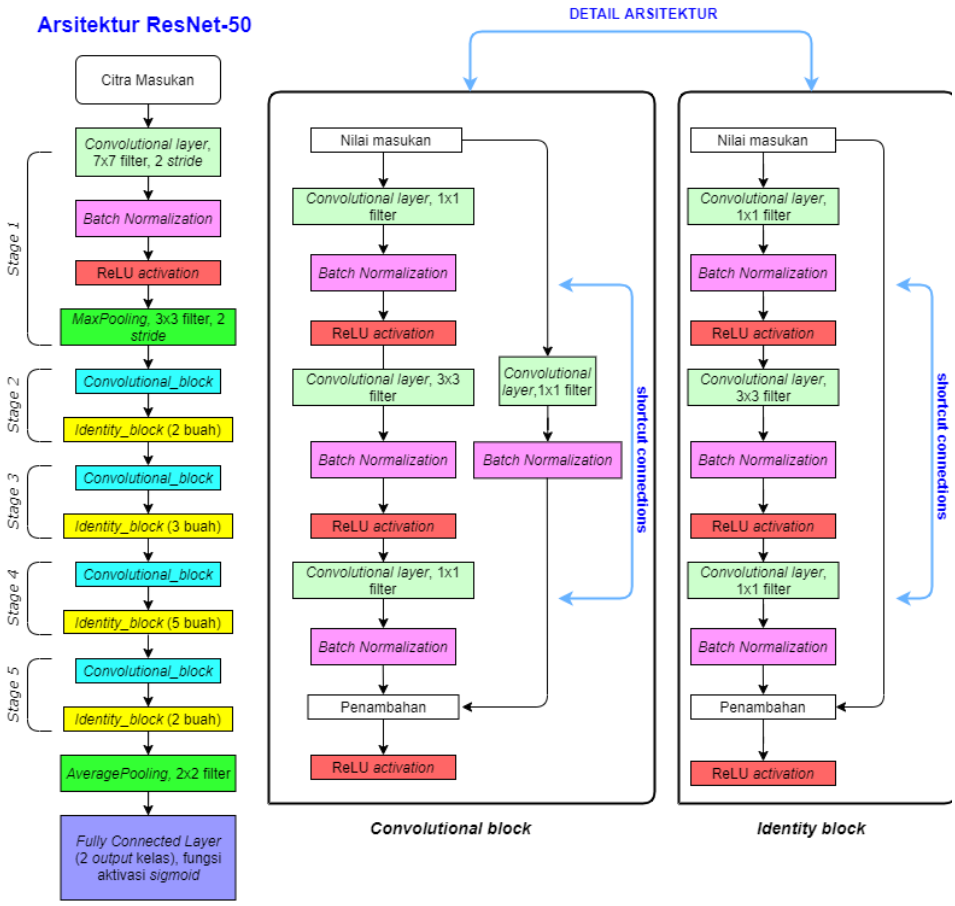
dari persamaan 1, $h(x)$ adalah *output* matriks hasil konvolusi atau dapat disebut *feature map*, $f(x)$ adalah matriks dari citra *input* dan $g(x)$ adalah *kernel* atau filter. Setelah konvolusi selesai dilakukan, kemudian *feature map* keluaran tersebut direduksi dengan menggunakan *pooling layer*. Terakhir setelah melewati proses konvolusi dan *pooling*, nilai-nilai hasil perhitungan *layer* sebelumnya diteruskan ke *fully connected layer* untuk dilakukan proses prediksi guna menghasilkan *output* kelas. Arsitektur CNN secara umum ditampilkan pada Gambar 3.

2.3 ResNet-50

ResNet-50 [9] merupakan salah satu arsitektur dari CNN yang memperkenalkan sebuah konsep baru yaitu *shortcut connections*. Munculnya konsep *shortcut connections* yang ada pada arsitektur ResNet-50 memiliki keterkaitan dengan *vanishing gradient problem* yang terjadi ketika usaha memperdalam struktur suatu *network* dilakukan. Bagaimanapun memperdalam suatu *network* dengan tujuan meningkatkan performansinya tidak bisa dilakukan hanya dengan cara menumpuk *layer*. Semakin dalam suatu *network* dapat memunculkan *vanishing gradient problem* yang bisa membuat *gradient* menjadi sangat kecil yang berakibat pada menurunnya performansi atau akurasi [9].



Gambar 3. Arsitektur CNN secara umum.



Gambar 4. Diagram blok arsitektur ResNet-50.

Karena itu ResNet memperkenalkan konsep *shortcut connections* dan dalam konsep ini fitur yang merupakan input dari layer sebelumnya juga dijadikan sebagai input terhadap output dari layer tersebut. Cara ini dilakukan sebagai solusi untuk meminimalisir hilangnya fitur-fitur penting pada saat proses konvolusi. Secara keseluruhan ResNet-50 terdiri dari 5 *stage* proses konvolusi yang kemudian dilanjutkan *average pooling* dan diakhiri dengan *fully connected layer* sebagai *layer* prediksi. Gambar 4 merupakan diagram blok susunan dari arsitektur ResNet-50 dalam penelitian ini.

Terdapat perbedaan antara arsitektur ResNet-50 yang digunakan dalam penelitian ini dengan arsitektur aslinya [9]. Hal ini dikarenakan terdapat sedikit modifikasi yang dilakukan untuk menyesuaikan dengan kebutuhan sistem klasifikasi. Modifikasi yang dilakukan antara lain:

- Mengganti jumlah *output* pada *fully connected layer* dari 1000 kelas menjadi 2 kelas.
- Mengganti fungsi aktivasi pada *fully connected layer* dari *softmax* menjadi *sigmoid*.

2.3.1 Proses *Training* ResNet-50

Training dilakukan untuk membentuk model dari ResNet-50 yang kemudian digunakan sebagai sistem klasifikasi. Sebelum *training* dijalankan, terdapat beberapa konfigurasi *hyperparameter* yang harus diatur terlebih dahulu. *Hyperparameter* yang dikonfigurasi antara lain, *learning rate*, *batch size* dan 5 macam konfigurasi *epoch* untuk keperluan investigasi, tertera pada Tabel 2.

Tabel 2. Konfigurasi *hyperparameter*.

Learning rate	*Batch Size*	*Epoch*
0.001	32	20, 40, 60, 80, 100

Sesuai Tabel 2, proses *training* dibagi menjadi 5 tahapan *epoch* dimulai dari 20 sampai dengan 100. Tahap pertama dilakukan proses *load dataset* NPDI sebanyak 12000 citra ke dalam sistem sebagai data masukan untuk *training*. Dikarenakan jumlah *sample* data cukup besar, selanjutnya citra 3 dimensi tersebut diperkecil menjadi resolusi 64×64 agar komputasi dapat berjalan lebih cepat. Terdapat dua kelas dari *dataset* yang dijadikan *input* dalam proses *training*, yaitu pornografi dan non-pornografi. Selanjutnya proses ekstraksi fitur dilakukan dari *stage* 1 sampai dengan 5.

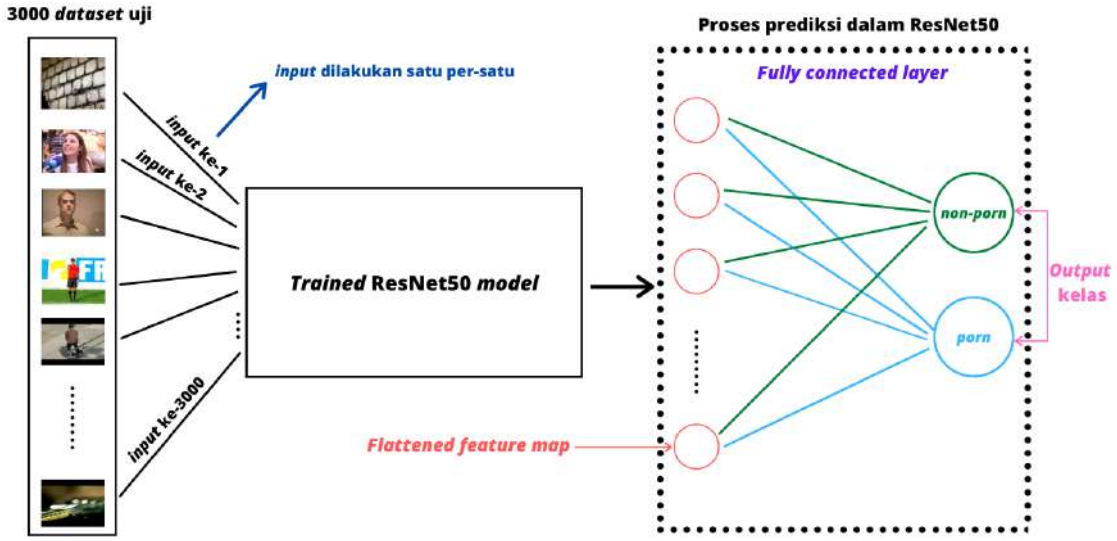
Pada *stage 1* citra dikonvolusi oleh *convolutional layer* dengan ukuran filter 7×7 dan *stride* 2. Konvolusi tersebut menghasilkan *feature map* yang kemudian dinormalisasi oleh *Batch Normalization*. Normalisasi yang dilakukan bertujuan untuk membuat nilai-nilai *output* dari *layer* sebelumnya yang sangat bervariasi menjadi 1 skala yang sama, hal ini dapat mempercepat proses *training* karena beban komputasi berkurang. Hasil dari normalisasi selanjutnya masuk ke *layer* aktivasi, didalamnya terdapat ReLU atau *Rectified Linear Unit activation function* yang digunakan untuk membuat hasil dari ekstraksi fitur menjadi *non-linear*. Selanjutnya nilai keluaran dari fungsi aktivasi direduksi oleh *maxpooling layer* sebelum diteruskan pada *stage* 2.

Diantara *stage* 2 sampai dengan *stage* 5, proses ekstraksi fitur dilakukan oleh kombinasi susunan antara *convolutional block* dan *identity block*. Pada blok-blok tersebut, citra mengalami pereduksian dan peningkatan dimensi. Hal ini disebabkan oleh tipe arsitektur pada kedua blok tersebut terdiri dari tiga tahapan konvolusi dengan ukuran filter 1×1, 3×3 dan 1×1. Tipe arsitektur blok seperti ini dikenal dengan sebutan *'bottleneck'* dan ditujukan untuk menghemat waktu komputasi. Setelah proses ekstraksi fitur selesai kemudian *feature map* diproses ke dalam *fully connected layer* untuk melakukan proses prediksi dibantu dengan fungsi aktivasi *sigmoid*. Total keseluruhan parameter *training* yang dihasilkan ketika melakukan *training* adalah 23,589,761 parameter.

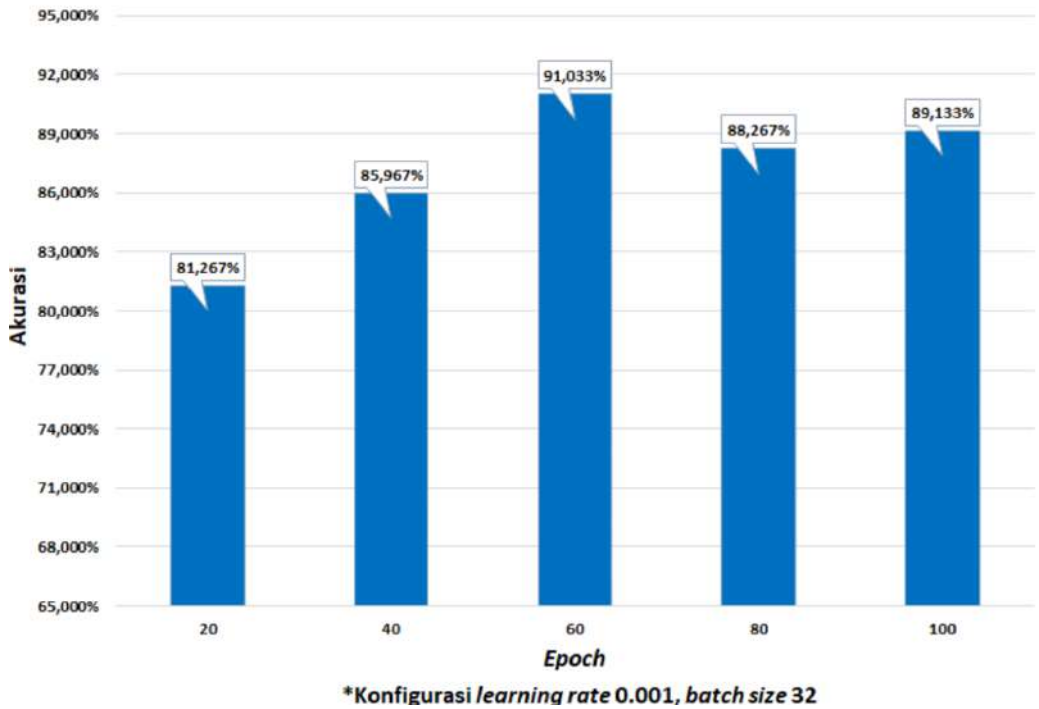
3. Hasil

Untuk menguji model sistem yang sudah dilatih pada tahap sebelumnya, dilakukan eksperimen pengetesan sistem terhadap 3000 citra *dataset* uji. Keseluruhan citra *dataset* uji dipilih secara acak agar mampu merepresentasikan seluruh karakteristik citra yang terdapat dalam NPDI *dataset*. Jika digambarkan, proses pengujian yang dilakukan untuk mendapatkan hasil performa sistem dapat dilihat pada Gambar 5.

Sebanyak 3000 *dataset* yang menjadi masukkan untuk sistem secara satu-persatu di *load* ke sistem. Lalu dilakukan proses prediksi dengan menggunakan model sistem ResNet-50 yang telah dilatih. Setelah mengalami proses ekstraksi fitur dengan bantuan *convolutional layer* dan *pooling layer*, nilai-nilai ekstraksi tersebut kemudian dirubah dimensinya menggunakan fungsi *flattening* agar bisa di proses ke *fully connected layer*. Dalam *fully connected layer* dilakukan proses prediksi yang menempatkan suatu citra masukan ke dalam kategori kelas tertentu. Hasil keseluruhan dari proses prediksi yang dijalankan tertera pada Gambar 6.



Gambar 5. Skema pengujian sistem.



Gambar 6. Hasil pengujian model dengan penerapan konfigurasi *epoch*.

Dari grafik hasil pengujian dapat dilihat jika keseluruhan dari 5 konfigurasi *epoch* menghasilkan akurasi diatas 80%. Seiring bertambahnya jumlah *epoch* dimulai dari *epoch* ke-20, 40 dan 60, akurasi klasifikasi yang dihasilkan oleh sistem cenderung mengalami kenaikan yang signifikan mulai dari 81,267%, 85,967% dan 91,033%. Tetapi ketika konfigurasi jumlah *epoch* bertambah dari 60 ke-80, akurasi klasifikasi yang dihasilkan turun sebesar 2,766% menjadi 88,267%. Pada konfigurasi *epoch* ke-100 atau yang terakhir, akurasi dari model mengalami sedikit peningkatan dibandingkan akurasi pada *epoch* ke-80, yaitu menjadi 89,133%. Dari keseluruhan hasil yang didapatkan dari eksperimen, akurasi terbaik diraih pada konfigurasi *epoch* 60 dengan hasil 91,033% dan terburuk pada *epoch* 20 dengan hasil 81,267%.

4. Diskusi

Mengacu pada hasil eksperimen yang didapat pada eksperimen yang tertera dalam Gambar 5. Akurasi dari sistem klasifikasi yang dibuat mengalami tren peningkatan seiring dengan pertambahan jumlah *epoch*. Tetapi terjadi sedikit fluktuasi akurasi, tepatnya pada *epoch* 60 performa akurasi dari sistem meningkat drastis yang kemudian turun lagi pada pertambahan *epoch* selanjutnya. Jika menilik secara teori, seiring bertambahnya nilai *epoch* maka performa dari sistem yang dirancang juga semakin meningkat dikarenakan sistem lebih mampu menggeneralisir data berdasarkan *update* dari *weight* dan *bias* atau pembelajaran yang sudah dilakukan pada *epoch* sebelumnya.

Fluktuasi nilai seperti ini terjadi karena sistem mengalami *overfitting* yang menyebabkan pada beberapa kondisi tertentu sistem tidak dapat menggeneralisir atau memprediksi data dengan baik. *Overfitting* yang terjadi dikarenakan jumlah dari *dataset* yang digunakan masih kurang atau belum mencapai jumlah yang sesuai. *Overfitting* juga dimungkinkan terjadi dikarenakan karakteristik *dataset* untuk kelas non-pornografi yang terdapat dalam NPDI *dataset* terlalu mudah untuk di prediksi, sehingga pendistribusian nilai saat proses *training* menjadi tidak seimbang.

Tidak ada acuan pasti dalam menentukan nilai *epoch* yang ingin diterapkan, hal ini terkait dengan konvergensi dari *neural network* yang dilatih. Suatu model dapat dikatakan konvergen jika dalam proses *training* yang dilakukan sudah tidak terdapat lagi peningkatan performa yang signifikan, hal ini bisa dilihat dari parameter *loss* saat *training*. Jika nilai *loss* selama *training* sudah tidak mengalami penurunan secara signifikan seiring pertambahan *epoch*, maka hal tersebut dapat menjadi pertanda bahwa model telah mencapai konvergensi dan sebaiknya penambahan jumlah *epoch* atau proses *training* dihentikan. Tetapi selama performa dari sistem masih mengalami tren kenaikan yang signifikan, maka penambahan jumlah *epoch* masih dimungkinkan sehingga proses *training* masih bisa dilanjutkan.

Kesimpulan

Berdasarkan hasil yang telah didapat dari eksperimen, dapat disimpulkan bahwa peran *epoch* sangat penting dalam mempengaruhi performa dari sistem klasifikasi CNN dengan ResNet-50 yang dirancang. Seiring meningkatnya jumlah *epoch* didapatkan tren naik dari performansi sistem, dikarenakan sistem mampu menggeneralisir data lebih baik berkat pembelajaran yang dilakukan pada *epoch* sebelumnya. Tetapi fluktuasi nilai masih mungkin terjadi dikarenakan *overfitting* yang dialami sistem. Sangat disarankan untuk penelitian selanjutnya agar dapat meningkatkan jumlah *epoch* latih dan menambah dari segi kuantitas maupun karakteristik *dataset* masukan sistem. Diharapkan, penelitian ini dapat dijadikan acuan untuk pengembangan metode ataupun piranti lunak yang dapat meminimalisir dampak negatif dari pornografi.

Terkait dengan riset kedepan yang dikerjakan akan berfokus mengenai pengaruh konfigurasi *learning rate* terhadap performansi klasifikasi citra pornografi dengan menggunakan ResNet-50. Serta terdapat rencana riset *optional* untuk mencari pengaruh modifikasi arsitektur, terutama dalam susunan dan jumlah *layer* ResNet-50 terhadap performa klasifikasi pornografi.

Kontribusi Penulis: konseptualisasi, F.N. and S.A.O.; metodologi, F.N.,G.B.; piranti lunak, F.N.; validasi, F.N., S.A.O. dan G.B.; analisis formal, F.N.; investigasi, F.N., S.A.O.; sumber, S.A.O., G.B.; kurasi data, F.N.; penulisan— persiapan *draft* asli, F.N.; penulisan—peninjauan dan penyuntingan, S.A.O., G.B.; visualisasi, F.N.; pimpinan, F.N., S.A.O.; administrasi proyek, S.A.O., G.B.; akuisisi dana, F.N.

Referensi

1. R. C. Reid, D. S. Li, R. Gilliland, J. A. Stein, and T. Fong, “Reliability, validity, and psychometric

development of the pornography consumption inventory in a sample of hypersexual men," *J. Sex Marital Ther.*, vol. 37, no. 5, pp. 359–385, 2011, doi: 10.1080/0092623X.2011.607047.

2. E. W. Owens, R. J. Behun, J. C. Manning, and R. C. Reid, "The Impact of Internet Pornography on Adolescents: A Review of the Research," *Sexual Addiction and Compulsivity*. 2012, doi: 10.1080/10720162.2012.660431.
3. J. A. M. Basilio, G. A. Torres, G. S. Pérez, L. K. T. Medina, and H. M. P. Meana, "Explicit image detection using YCbCr space color model as skin detection," 2011. https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=79958723400&origin=inward
4. S. A. Wibowo, H. Lee, E. K. Kim, and S. Kim, "Convolutional Shallow Features for Performance Improvement of Histogram of Oriented Gradients in Visual Object Tracking," *Math. Probl. Eng.*, vol. 2017, 2017, doi: 10.1155/2017/6329864.
5. S. A. Wibowo, H. Lee, E. K. Kim, and S. Kim, "Collaborative Learning based on Convolutional Features and Correlation Filter for Visual Tracking," *Int. J. Control. Autom. Syst.*, vol. 16, no. 1, pp. 335–349, 2018, doi: 10.1007/s12555-017-0062-x.
6. A. Wiranata, S. A. Wibowo, R. Patmasari, F. T. Elektro, and U. Telkom, "Region-Based Convolutional Neural Network Untuk Deteksi Kendaraan Region-Based Convolutional Neural Networks." https://openlibrary.telkomuniversity.ac.id/home/catalog/id/149659/slug/analisis-performansi-region-based-convolutional-neural-network-untuk-deteksi-kendaraan.html
7. A. Y. Nasirudin, S. A. Wibowo, and R. Purnamasari, "Analisis Parameter Performansi Pada Pengenalan Objek Berbasis Region-Convolutional Neural Network Performance Parameter Analysis For Region-Convolutional Neural Network Based Object Recognition", PP.28.https://openlibrary.telkomuniversity.ac.id/home /catalog/id/149655/slug/analisis parameter performansi-pada-pengenalan-objek-berbasis-region-convolutional-neural- network.html
8. K. Zhou, L. Zhuo, Z. Geng, J. Zhang, and X. G. Li, "Convolutional neural networks based pornographic image classification," *Proc. - 2016 IEEE 2nd Int. Conf. Multimed. Big Data, BigMM 2016*, pp. 206–209, 2016, doi: 10.1109/BigMM.2016.29.
9. K. He, X. Zhang, S. Ren, and J. Sun, "Deep residual learning for image recognition," *Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit.*, vol. 2016-Decem, pp. 770–778, 2016, doi: 10.1109/CVPR.2016.90.
10. S. Sharma, "Epoch vs Batch Size vs Iterations - Towards Data Science," *Medium*, 2017. https://towardsdatascience.com/epoch-vs-iterations-vs-batch-size-4dfb9c7ce9c9 (accessed Jun. 26, 2020).
11. S. Avila, N. Thome, M. Cord, E. Valle, and A. De A. Araújo, "Pooling in image representation: The visual codeword point of view," *Comput. Vis. Image Underst.*, 2013, doi: 10.1016/j.cviu.2012.09.007.

COMPLETE
Journal of Computer, Electronic, and Telecommunication
ISSN 2723-4371, E-ISSN 2723-5912
doi.org/10.52435/complete.v1i1.48

The Comparative Study for Predicting Disease Outbreak

Anifatul Faricha [1]*, M. Achirul Nanda[2], Siti Maghfirotul Ulyah[3], Ni'matut Tamimah[4], Enny Indasyah[5], Robin Addwiyansyah Alvaro Samrat[6]

[1] Electrical Engineering Department, Institut Teknologi Telkom Surabaya, 60231, Jawa Timur, Indonesia; faricha@ittelkom-sby.ac.id
[2] Doctoral Alumni of Agricultural Engineering Science Department, Faculty of Agricultural Engineering and Technology, IPB University, Bogor 16680, West Java, Indonesia; m.achirulnanda@gmail.com
[3] Departement of Mathematics, Universitas Airlangga, 60115, Surabaya, Jawa Timur, Indonesia; maghfirotul.ulyah@fst.unair.ac.id
[4] Teknik Permesinan Kapal, Politeknik Perkapalan Negeri Surabaya, 60111, Surabaya, Jawa Timur, Indonesia; nimatuttamimah@ppns.ac.id
[5] Departemen Teknik Elektro Otomasi, Fakultas Vokasi, Institut Teknologi Sepuluh Nopember, 60111, Surabaya, Jawa Timur, Indonesia; enny_indasyah@its.ac.id
[6] Electrical Engineering Department, Institut Teknologi Telkom Surabaya, 60231, Jawa Timur, Indonesia.
* Correspondence: faricha@ittelkom-sby.ac.id or anifatulfaricha@gmail.com

Abstract: As the global pandemic caused by coronavirus disease is spread massively in Indonesia, proper predictive modeling is required to represent the prediction of disease outbreak. This study presents the comparative predictive modeling for predicting disease outbreak using two models i.e., optimizable support vector machine (SVM) and optimizable gaussian process regression (GPR). The dataset used in this study contains three cases i.e., positive cases, recovered cases, and death cases. The dataset at each case is divided into training dataset for the training process and external validation dataset for the validation process. Based on the training process and validation process, the root mean square error (RMSE) at positive cases, recovered cases, and death cases using optimizable GPR is substantially more effective for prediction than the optimizable SVM. According to the result performance, by applying optimizable GPR, the training process has the average RMSE of 19.54 and the validation process has the average RMSE of 15.85.

Keywords: Dataset; Optimizable GPR; Optimizable SVM.

1. Introduction

The coronavirus pandemic or COVID-19 pandemic is the ongoing pandemic which caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first outbreak was identified in December 2019 in Wuhan, China [1]. The outbreak of COVID-19 affects many sectors such as economy, logistics, transportations, etc. In Indonesia, the first case of COVID-19 was confirmed on 2 March 2020 and by 9 April 2020 was spread to all 34 provinces [2-4].

According to the data of coronavirus cases released by the Indonesia Government, a predictive modeling is required to represent the data behavior of confirmed cases in Indonesia. This study presents the comparative predictive modeling using optimizable support vector machine (SVM) and optimizable gaussian process regression (GPR). The simulation was performed using Regression Learner Application in MATLAB 2020 (Trial version). The contents of this paper are organized as follows: section 2 discusses the materials and methods used in this study. Furthermore, section 3 demonstrates the results and verification analysis. Finally, we present our conclusions in section 4.

2. Materials and Methods

2.1 Materials

The dataset used in this study was taken from the confirmed coronavirus cases information in Indonesia presented by Indonesia Government and Worldometer [1-2]. The dataset includes three cases i.e., positive cases, recovered cases, and death cases. The positive cases are the cases of people actively infected by coronavirus. Furthermore, recovered cases include cases of recovered patients from coronavirus. Finally, the death cases are the total number of death cases due to coronavirus.

In this study, the dataset is divided into two parts i.e., training dataset for the training process and external validation dataset for the validation process. The training dataset includes all the positive cases, recovered cases, and death cases started from 2nd March 2020 to 30th April 2020. Whereas, the external validation dataset includes all the confirmed coronavirus cases in Indonesia started from 1st May 2020 to 12th May 2020.

2.2 Methods

To represent the model of confirmed coronavirus cases dataset in Indonesia, the predictive modeling is required. In this study, we used two models to predict the coronavirus disease outbreak in Indonesia i.e., SVM regression and gaussian process regression (GPR). The SVM Regression can be categorized as nonparametric technique because it depends on the kernel function selections [7]. Generally, SVM Regression can be written in Eq (1). Furthermore, the common equation of GPR is determined in Eq (2) [8-9].

$$f(x) = \sum_{n=1}^{N} (a_n - a_n^*) G(x_n, x) + b \tag{1}$$

Where: f(x) is response value (total cases), x is predictive value (number of day), N is the amount of dataset, a and a^* are the lagrange multiplier, G is kernel function, b is betha parameter.

$$P(y_i \mid f(x_i), x_i) \sim N(y_i \mid h(x_i)^T \beta + f(x_i), \sigma^2) \tag{2}$$

Where: $P(y_i \mid f(x_i), x_i)$ is density function, β is betha parameter, σ^2 is noise variance, h is explicit basis function.

In this study, the simulation was performed using Regression Learner Application in MATLAB 2020 (Trial version). In the Regression Learner Application in MATLAB, the optimizable SVM contains the selection of several kernel functions such as linear, quadratic, cubic, fine Gaussian, medium Gaussian, coarse Gaussian, etc [5]. Furthermore, the optimizable GPR includes selection of several kernel functions such as rational quadratic, squared exponential, mattern 5/2, exponential, etc [6]. Both the optimizable SVM and optimizable GPR use two processes to build the optimal predictive model i.e., training process and external validation process. The root mean square error (RMSE) and average RMSE are applied to evaluate the optimal predictive model performance [6].

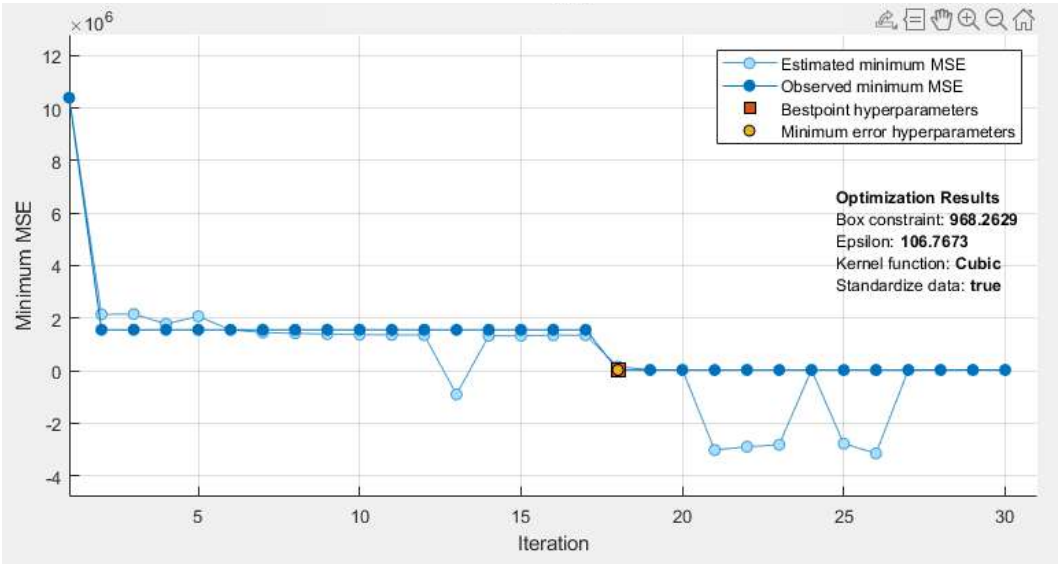
3. Results Analysis

There are two predictive models i.e, optimizable GPR and optimizable SVM used in this study which include two main processes i.e., training process and external validation process. Firstly, the training process by using training dataset, this process is used to find the best kernel function to obtain the optimal predictive model to represent the confirmed coronavirus cases in Indonesia.

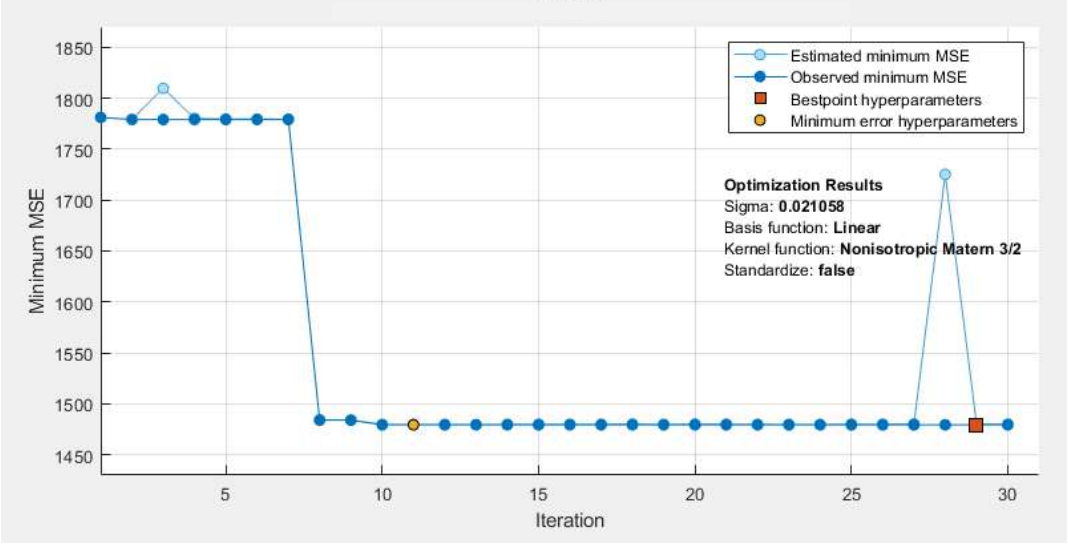
Furthermore, the external validation process includes the external validation dataset which used to verify the performance of the optimal predictive model obtained in the training process.

In the training process, the selection process to find the optimal predictive model for positive cases, recovered cases, and death cases are shown in Figure 3, Figure 4, and Figure 5 respectively. Using optimizable SVM, the best kernel function was achieved by cubic function for all confirmed coronavirus cases in Indonesia i.e, positive cases, recovered cases, and death cases. Furthermore, for optimizable GPR, the best kernel function was obtained by nonisotropic matern function for positive cases and isotropic matern function for recovered cases and death cases.

As explained in section of materials and methods, in this study, we used the training dataset from confirmed coronavirus cases in Indonesia started from 2nd March 2020 to 30th April 2020. Figure 6 shows the comparison of predictive modeling in the training process using optimizable SVM and optimizable GPR. According to Figure 6, it is clearly seen that the optimizable GPR is more able to represent the training dataset for positive cases, recovered cases, and death cases than optimizable SVM.

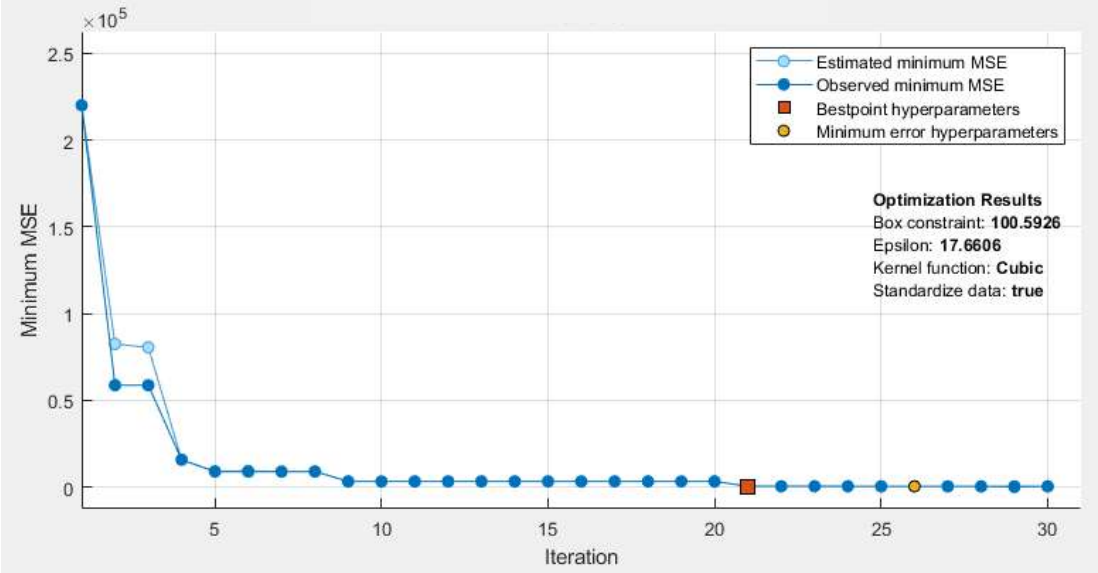


(a)

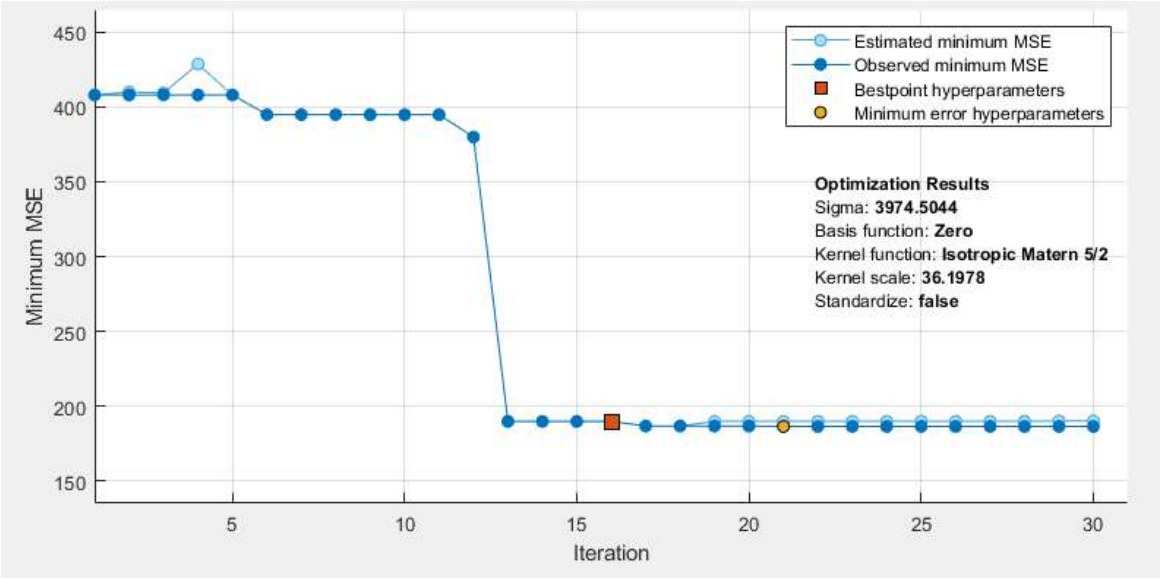


(b)

Figure 1 Searching for the optimal predictive model parameter for positive cases using: **(a)** Optimizable SVM; **(b)** Optimizable GPR.



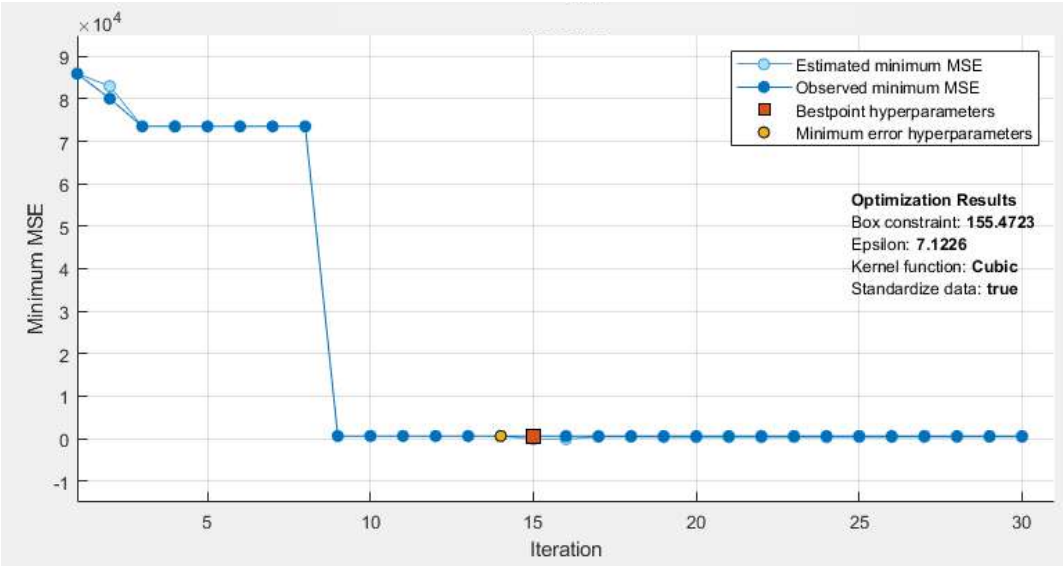
(a)



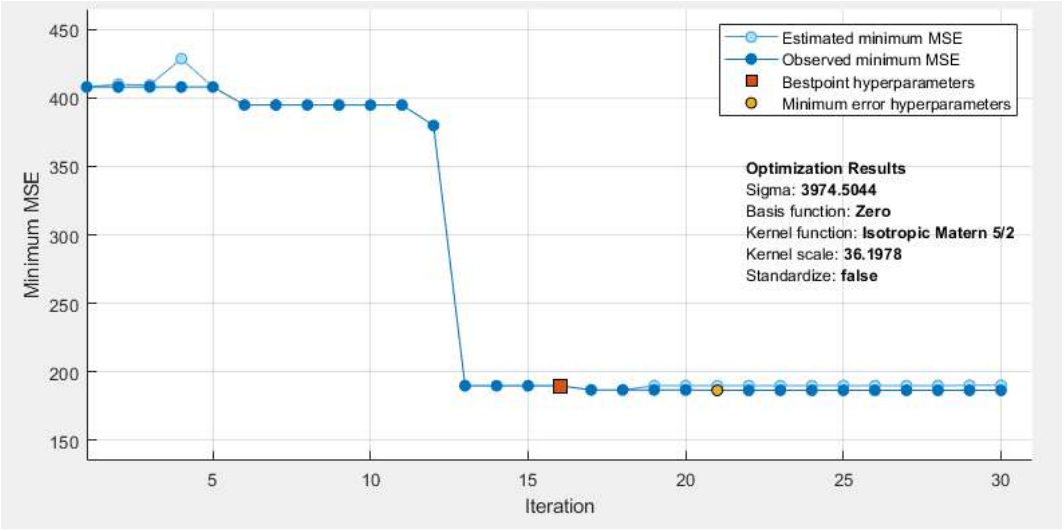
(b)

Figure 2 Searching for the optimal predictive model parameter for recovered cases using: **(a)** Optimizable SVM; **(b)** Optimizable GPR.

Table 1 shows the RMSE value of several cases using optimizable SVM and optimizable GPR in the training process. According to Table 1, optimizable GPR has lower RMSE value in positive cases, recovered cases, and death cases than optimizable SVM has. Therefore, the average RMSE produced by optimizable GPR is lower than produced by optimizable SVM i.e, 19.54. This result reveals that the optimizable GPR model has more favorable prediction capability than the optimizable SVM does.



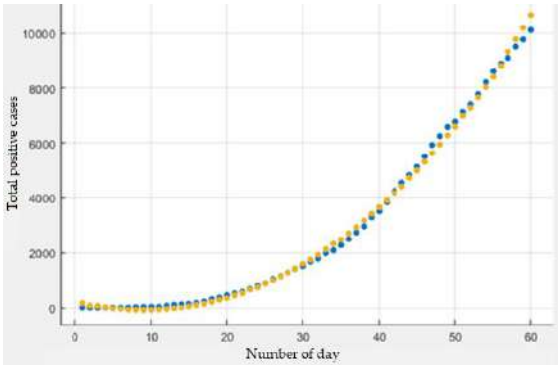
(a)



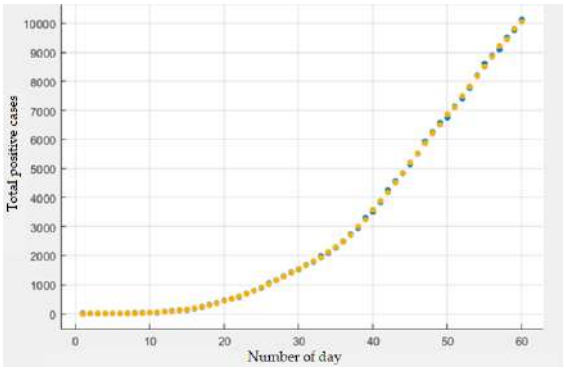
(b)

Figure 3 Searching for the optimal predictive model parameter for death cases using: **(a)** Optimizable SVM; **(b)** Optimizable GPR.

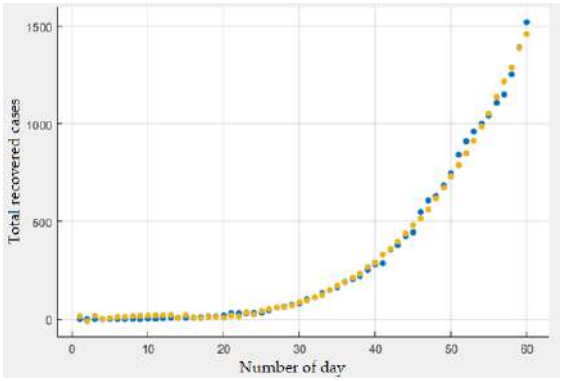
The external validation process was used for testing to assess the optimizable GPR and optimizable SVM performance. This study used the confirmed coronavirus cases in Indonesia started from 1st May 2020 to 12th May 2020 as external validation dataset. The RMSE value in the external validation process is shown by Table 2. According to Table 1 and Table 2, the average RMSE value achieved by optimizable GPR is more stable than obtained by optimizable SVM i.e., 19.54 and 15.85 for training and external validation process respectively. These results indicate that the optimizable GPR has more robust model than optimizable SVM.



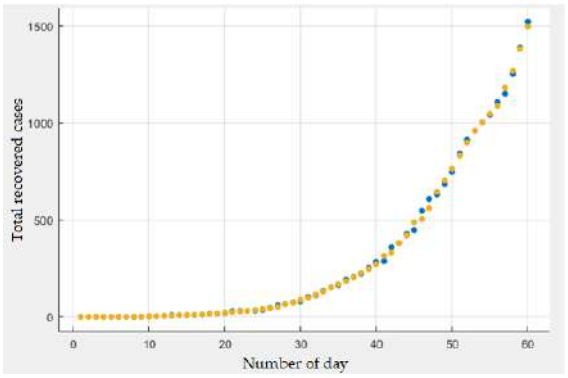
(a1)



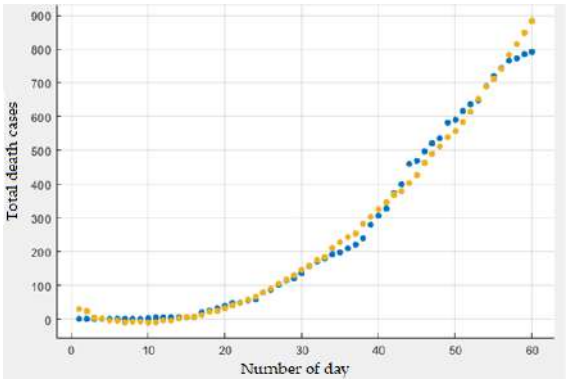
(a2)



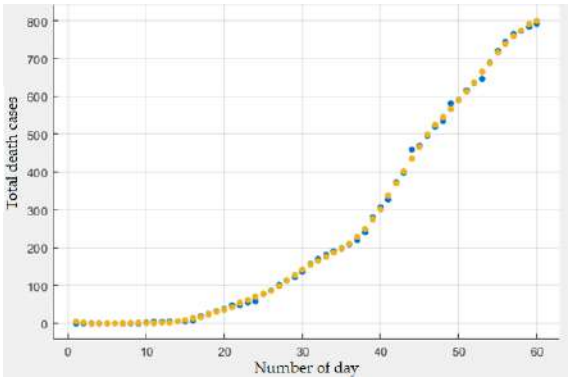
(b1)



(b2)



(c1)



(c2)

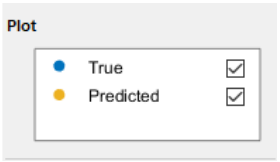


Figure 4 The prediction curve of disease outbreak at training process using optimizable SVM model for: (**a1**) Positive cases; (**b1**) Recovered cases; (**c1**) Death cases, and using optimizable GPR model for: (**a2**) Positive cases; (**b2**) Recovered cases; (**c2**) Death cases.

Table 1. The RMSE value at the training process

Method	RMSE			Average RMSE
	Positive cases	Recovered cases	Death cases	
Optimizable SVM	164.90	22.65	24.68	70.74
Optimizable GPR	38.46	13.77	6.40	19.54

Table 2. The RMSE value at the external validation process

Method	RMSE			Average RMSE
	Positive cases	Recovered cases	Death cases	
Optimizable SVM	31.75	11.04	14.21	19
Optimizable GPR	25.04	9.87	12.65	15.85

4. Conclusions

This study successfully demonstrated the optimal predictive model to predict the coronavirus disease outbreak in Indonesia which includes three cases i.e., positive cases, recovered cases, and death cases. The dataset of each case is divided into training dataset and external validation dataset. There are two model applied in this study i.e., optimizable support vector machine (SVM) and optimizable gaussian process regression (GPR). According to the training process, the optimizable SVM has average RMSE of 70.74 and optimizable GPR has average RMSE of 19.54. Furthermore, in the external validation process, the optimizable SVM and optimizable GPR have average RMSE of 19 and 15.85 respectively. This finding indicates that the optimizable GPR model is more suitable to represent dataset. Therefore, the future work will concern about using optimizable GPR model to predict the coronavirus disease outbreak in Indonesia by including the distribution of location coordinates (longitude and latitude) from infected people.

Author Contributions: Anifatul Faricha and M. Achirul Nanda; conceptualization, methodology, and formal analysis, Siti Maghfirotul Ulyah and Enny Indansyah; validation, review, and editing, M. Achirul Nanda and Ni'matut Tamimah, and Robin Addwiyansyah Alvaro Samrat; visualization and writing.

References

1. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. February 2020. 395 (10223): 497–506.
2. Coronavirus cases in Indonesia. Available: https://kawalcovid19.blob.core.windows.net/viz/statistik_harian.html (accessed on 12 May 2020).
3. Worldometer: coronavirus cases in Indonesia. Available: https://www.worldometers.infocoronavirus/country/indonesia (accessed on 12 May 2020).
4. COVID-19 Pandemic in Indonesia. Available: https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Indonesia (accessed on 12 May 2020).
5. Optimization in Regression Learner App. Available: https://www.mathworks.com/help/stats/hyperparameter-optimization-in-regression-learner-app.html (accessed on 12 May 2020).
6. Kernel function in Regression. Available: https://www.mathworks.com/help/stats/fitrkernel.html (accessed on 12 May 2020).
7. Vapnik, V. *The Nature of Statistical Learning Theory.* Springer, New York, 1995.
8. Nocedal, J. and S. J. Wright. *Numerical Optimization*, Second Edition. Springer Series in Operations Research, Springer Verlag, 2006.
9. Rasmussen, C. E. and C. K. I. Williams. Gaussian Processes for Machine Learning. MIT Press. Cambridge, Massachusetts, 2006.