BAREKENG: Jurnal Ilmu Matematika dan Terapan
March 2022 Volume 16 Issue 1 Page 121–128
P-ISSN: 1978-7227 E-ISSN: 2615-3017
https://doi.org/10.30598/barekengvol16iss1pp121-128

PRIVACY-PRESERVING REAL TIME TRACING SYSTEM FOR COVID-19 PATIENT USING GPS TECHNOLOGY

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Abstract. *The new normal condition in Indonesia does not mean that Indonesia is completely free from infection with the Covid 19 virus. Individuals exposed to the Covid 19 virus have symptoms like mild, moderate, to severe condition. Most individuals who have mild symptoms are self isolating at their home until tested negative for the Covid 19 virus. The impact of Covid 19 has led to an increase in the use of gadgets to access all the information needed. The purpose of this study is to provide information regarding patients infected with Covid 19 in a certain area through a tracing application. The application can help public to find out how many individuals are infected with Covid 19 in the surrounding environment by prioritizing privacy-preserving in a real time. The method used in this study is a combination of graph theory and GPS tracing system on a gadget. The initial stage of this study was carried out through tracing Covid 19 patients based on their position of residence. The final stage of the study was carried out using a graph approach based on distance and percentage of transmission. The result of this study obtained privacy-preserving real-time tracing with the predicted precentage of Covid 19 transmission susceptibility within the scope of danger or vulnerability, quite safe, and secure. Furthermore, individuals can take precautions by maintaining a safe distance.*

Keywords: *tracing, real time, privacy-preserving, graph, gps.*

Article info:

Submitted: 14th November 2021 *Accepted: 5th February 2022*

How to cite this article:
N. L. Azizah and U. Indahyanti, "PRIVACY-PRESERVING REAL TIME TRACING SYSTEM FOR COVID-19 PATIENT USING GPS TECHNOLOGY", *BAREKENG: J. Il. Mat. & Ter.*, vol. 16, iss. 1, pp. 121-128, Mar 2022.

1. INTRODUCTION

The number of patients who are self-isolating due to exposure to the Covid-19 virus in Indonesia has made many people more alert. The urgency of this research is to increase the efficiency of using mobile tracing applications on patients infected with Covid-19 by predicting personal susceptibility to contracting Covid-19. The method stages start from tracking patients infected with Cvid-19 based on the position of residence, then predicting it through a mathematical model. In predicting susceptibility modeling for contracting Covid-19, there are many variables that determine whether or not a person is susceptible to Covid-19 transmission, this depends on the distance of the individual doing the tracing, GPS accuracy, prediction model, and other variables that influence, such as immunity [1]. The positive cases of Covid-19 experienced by each patient showed different symptoms ranging from asymptomatic, mild cases, moderate cases, even severe and critical cases. Patients with asymptomatic, mild, and moderate symptoms are advice to self-isolate at home. In previous studies, many mobile and web-based applications were produced to provide information on the whereabouts of patients infected with Covid-19 in the surrounding environment based on map of the patient's location via Bluetooth or GPS on their gadgets [2]. Based on the survey and data obtained, users are not satisfied with the application that has been developed for tracking Covid-19 patients, because it is still in the form of information on the number of confirmed patients [3]. This research was made considering the importance of contact tracing for confirmed Covid-19 patients. The advantage of using GPS tracking is that individuals can find out how many patients or individuals are infected with Covid-19 through their respective gadgets without having to be in the direct or close proximity. In addition, the advantage is that the privacy data of patients infected with Covid-19 are not published so that it is safe in accordance with medical regulations [4].

This real time and anonymous tracking are very safe to determine the position of patients infected with Covid-19 without having to expose their identities. The prediction of vulnerabilities generated in the application is expected to help the public in controlling their health through predictions that have been generated on the application record. Predictions are related to time series mathematical models, one of which predictions are presented through sequential data [5]. Previous research has shown that confirmation of the Covid-19 virus occurring in limited areas such as cruise ships, nursing homes, school environments and dormitories has a high transmission rate with a limited model that has been mathematically modeled [6]. In the research that has been done previously, namely the "Vulnerability Prediction Model Using Mobile Tracking in Patients Infected with Covid-19" discuss a mathematical model regarding the problem of predicting vulnerability in patients infected with Covid-19 using gadgets [1]. Meanwhile, in 2021 there will be research related to the title "Predicting Personal Vulnerability to Covid-19 Using Graph Approach" [3] and [4] which discusses the vulnerability prediction model using a graph approach. This research is a continuation of the research that has been done previously, namely the combination of time series data, graphs, and GPS systems. In this study, a model with adjustable parameters will be formed so that it becomes complex. In Calculating time series data, graphs and GPS systems on gadgets, a distance concept related to graphs is needed, including the concept of graph labeling. The following in Figure 1 is an example of graph labeling on a fan graph F_5 [7].

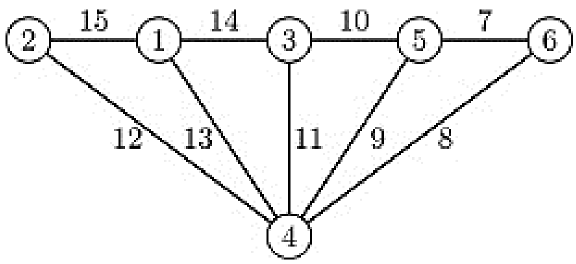

Figure 1. Labeling graph F_5

In the distance of 1 meter, there are several individuals who have confirmed Covid-19 then at a distance of 2 meters there are mode individuals who have confirm Covid-19, so only close distance are included in the prediction model, while for distances that are not close together, distance is still taken the shortest path [3].

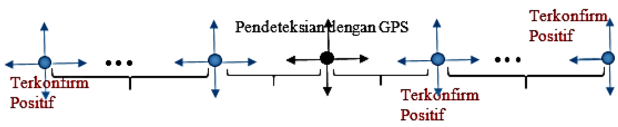

Figure 2. Graph Models if $n = 1$

2. RESEARCH METHODS

The research method is carried out by combining the prediction model using the graph method, time series data on the exponential model, and the GPS system on the user's mobile or gadget. The stage of this research included:

1. Data collection stage
   Data collection is done by taking primary and secondary data. Primary data was obtained from experiments conducted directly at the time of the study, while secondary data was obtained from data generated from journals and ministry websites.

2. Observation and model design
   Observations were made by comparing the previous research and the current research. GPS has the disadvantage of not being able to access a distance that is too close **[8]**, so it is necessary to determine the minimum distance that can be accessed or can be stored by the device/gadgets used. In addition, the difference in memory capacity on the gadget also determines the accuracy of the research, so the minimum tracing distance that can be used in this study is 1 meter. Time series data related to the time at which $\boldsymbol{r}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}$ and $\boldsymbol{K}$ show the average growth (person/day), symptomatic effects, and differentiation. If $\boldsymbol{\alpha} = \mathbf{1}$, it becomes a differential equation whose solution looks like the following equation **[9]** :

$$y(t) = \frac{K}{\left(1 + \alpha \exp\left(-r(t - t_m)\right)^{1/\alpha}\right)} \quad (1)$$

   By using differential equations [10]:

$$\frac{dI}{dt} = \beta I \frac{S}{N} - \gamma I \quad (2)$$

$$\frac{dS}{dt} = -\beta I \frac{S}{N} \quad (3)$$

$$\frac{dR}{dt} = \gamma I \quad (4)$$

   And merging with the graph model used is the shortest path using graph labeling with the following lemmas and theorems [11] :
   Lemma 1. If a graph (p,q) is a labeling super (a,d)-edge anti-magic then [12]:

$$d \leq \frac{2p + q - 5}{q - 1} \quad (5)$$

   While on the other hand, the maximum possible value of the largest side weight is by adding up the two largest point labels (p - 1) and p with one of the largest edges (p + q), so obtain that: $(p - 1) + (p + q) + p = 3p + q - 1$. as a result:

$$a + (q - 1)d \leq 3p + q - 1$$

$$d \leq \frac{p + q - 1 - (p + 4)}{q - 1}$$

$$d \leq \frac{2p + q - 5}{q - 1} \quad (6)$$

3. Observation and model weighted graph design
   The design of this system aims to form a mathematical model with the help of a graph model on a GPS sensor detection tool with several assumptions that have the same purpose, including signal GPS categorized as a graph with a node as the sensor of smartphone.

$x_n(k) = x_1[t] + x_2[t] + x_3[t] + \cdots + x_n[t]$
For $n = 1$, where r is the number of individuals confirmed Covid-19 and by combining the models, we get a prediction model for $n = 1$ [13].

3. RESULTS AND DISCUSSION

In this study, the flutter framework was used. Flutter was chosen to support the design because it is a flexible framework. Flutter also has tools that ca be used to write code using the Kotlin language, so access to sensors is greater. Flutter can also be used in applications for android and IOS systems. Flutter consist of android application and database server. Available applications include the Java Development Kit (JDK), Android Studio, Flutter SDK, Text Editor [14].

If given a distance of $x = 1$, then there are several individuals who have been exposed to the Covid-19 virus, and for example $x = 2$, there are several individuals who have been exposed to the Covid-19 virus, then only the closest distance is used to predict the model, while for distances that are not close together, it will be taken the shortest path (shortest path) with graph theory. In Figure 3 shows a graph on the Covid-19 tracking system through the application.

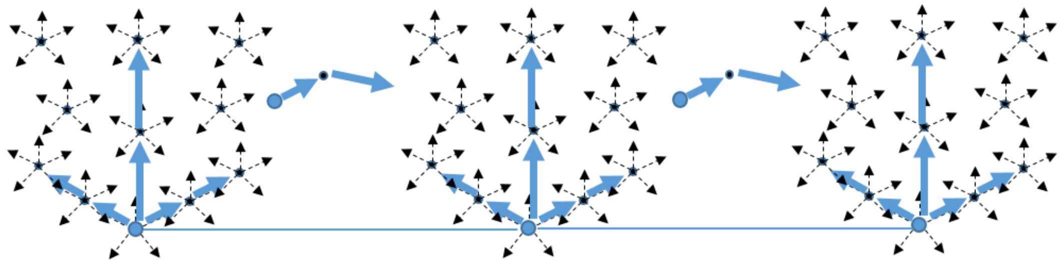

Figure 3. Corona Virus Tracing Graph Model

It is assumed that the GPS sensor can also transmit and receive signals from and to the confirm positif corona virus signals in all directions.

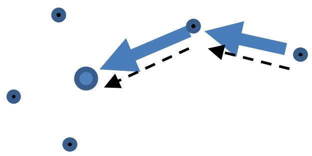

Figure 4. Route Transmission

The graphs in Figure 3 and Figure 4 have similarities with the path graph P_n and the path graph P_m which in general can be described as graph P_n [15]. The graph in figure 3 also shows a combination of the path graph P_n and the star graph S_m with the following theorem :

Teorema 1 :

If $P_n \odot P_m$ become Corona graph from path graph P_n and path graph P_m with $n, m \geq 4$, then vertex coloring edge is weighted with graph $P_n \odot P_m$ is $\mu(P_n \odot P_m) = 2$

Teorema 2 :

If $P_n \odot S_m$ become Corona graph from path graph P_n dan star graph S with $n, m \geq 4$, then vertex coloring edge is weighted with graph $P_n \odot P_m$ is $\mu(P_n \odot P_m) = 2$

$$x_n(t) = \begin{cases} 2 & if \;\; t = x_{ij}, for \; j = 1, m, 1 \leq i \leq n \\ 3 & if \;\; t = x_{ij}, for \; j = even, m, 2 \leq j \leq m-1, 1 \leq i \leq n \\ 4 & if \;\; t = x_{ij}, for \; j = odd, m, 2 \leq j \leq m-1, 1 \leq i \leq n \end{cases}$$

If the level of personal or individual vulnerability is written with the symbol k (00%) which can be calculated based on the relationship between variables, distance, and the number of patients exposed, as calculated below :

$$(Pk) = \frac{100n_{(k,n)}\delta\left(\sum_{k=1,n=1}^{n}\frac{1}{x_n(k)}\right)\left(\sum_{n=1,k=1}^{n}x_n(k)\right)}{n} \tag{7}$$

with
$x_n(k) = x_1[t] + x_2[t] + x_3[t] + \cdots + x_n[t]$

JIf $n = 1$, with r adalah individuals confirm Covid-19 virus with the combination models, we can predict for $n = 1$, as a follows :

$$x_n(t) = \begin{cases} 1 & if\ t = x_{ij}, for\ j = 1, m, 1 \leq i \leq n \\ 2\ if\ t = x_{ij}, for\ j = even, m, 2 \leq j \leq m-1, 1 \leq i \leq n \\ 5\ if\ t = x_{ij}, for\ j = odd, m, 2 \leq j \leq m-1, 1 \leq i \leq n \end{cases}$$

If $n = 2$, with r is individual who was confirmed Covid-19 virus with the combination model, we have the model of prediction from , $2 \leq j \leq m-1, 1 \leq i \leq n$, as follows:
$x_n(t) = 2$ if $t = x_{ij}, for\ j = even, m, 2 \leq j \leq m-1, 1 \leq i \leq n$

If $n = 3$, with r is individual who was confirmed Covid-19 virus with the combination model, we have the model of prediction from , $2\ for\ j = odd, m, 2 \leq j \leq m-1, 1 \leq i \leq n$, as follows:
$x_n(t) = 2$ if $t = x_{ij}, for\ j = odd, m, 2 \leq j \leq m-1, 1 \leq i \leq n$

It can be conclude that for $n = t$, the distance will be based on the time series (t) in other words $x_1[t] + x_2[t] + x_3[t] + \cdots + x_n[t]$will be inversely proportional to the exponential time and number of individuals exposed, as follows:

$$\delta = \alpha\beta\gamma K\left(\frac{(x_1[t] + x_2[t] + x_3[t] + \cdots + x_n[t])}{\left(1 + \alpha\exp(-r(t - t_m))^{1/\alpha}\right)n}\right) \tag{8}$$

The model used in analyzing Covid-19 implements a variable that is initiated by the name susceptible (S), individuals but have not been infected are devided into two, namely individuals who have been diagnosed with positive confirmed Covid-19 (E_i), and individuals who have not been diagnosed with confirmed positive Covid-19 and in Indonesia terms are OTG (Asymptomatic People E_n), isolated individuals (W), infected individuals who can transmit and have not been dignosed with Covid-19 (I), recovered individuals (R), and individuals who die from disease Covid-19 (D) and N is the total population. The value compartement diagram for the parameteres is presented as follows :

Table 1. The Relationship Between Individuals who are Confirm to be Covid-19 if $x = 1$

Distance	**Result**					
Jarak ($\boldsymbol{x_1}$)	1	2	3	4	5	6
Delta ($\boldsymbol{\delta}$)	0,5	0,5	0,5	0,5	0,5	0,5

For $x = 2$,

Table 2. The Relationship Between Individuals who are Confirm to be Covid-19 if $x = 2$

DISTANCE	**RESULT**					
JARAK ($\boldsymbol{x_1}$)	10	10	20	20	30	30
JARAK ($\boldsymbol{x_2}$)	10	20	20	30	30	40
DELTA ($\boldsymbol{\delta}$)	0,6	0,9	1,2	1,5	1,8	2,1

For $x = 3$,

Table 3. The Relationship Between Individuals who are Confirm to be Covid-19 if $x = 3$

DISTANCE	**RESULT**					
DISTANCE ($\boldsymbol{x_1}$)	1	1	1	2	2	3
DISTANCE ($\boldsymbol{x_2}$)	1	1	2	2	3	3
DISTANCE($\boldsymbol{x_3}$)	1	2	2	2	3	3
DELTA ($\boldsymbol{\delta}$)	0,7	0,933333	1,166667	1,4	1,866667	2,1

For $x > 3$,

Table 4. The Correlation between the Number of Individuals Exposed whie $x > 3$

PERCENTAGE OF INDIVIDUAL VULNERABILITY (%)							
PERSONAL AMOUNT (n)	Result						Character
$n(1)$	50	25	16,67	12,5	10	8,33	Safe
$n(2)$	60	45	30	25	20	17,5	Safe
$n(3)$	70	58,3333	46,66667	35	27,2222	23,3333	Safe
$n(4)$	80	60	40	33.3333	26,66667	23,33333	Modertae
$n(5)$	90	61,71429	36	32.5	24	22,23529	Vulnerable

4. CONCLUSIONS

Based on the results of the research obtained, prediction of personal vulnerability are obtained which are influenced by various factors, according to GPS mobile tracking, including some factors.

1. Prediction of vulnerability using GPS mobile tracking, produce a model in the form of an exponential function. This model is based on GPS distance data with reduced accuracy if the detected distance is less than 10 km, so a delta variable is needed.
2. Based on the calculation result, it is initiated that the prediction of personal vulnerability occurs in the initiation of predictions in the form of vulnerability occurs in the initiation of prediction in the form of vulnerable, moderately vulnerable, and safe.
3. In this research, it is said to be vulnerable if at safe distance $x = 1$ and there are $n \geq 5$ people exposed
4. The result of this vulnerability prediction are influenced by many variables, including personal distance $x_n(k,t)$ with patients infected with Covid-19, GPS accuracy ($\propto$), movement (β), and personal immunity
5. The result of this susceptibility are influenced by several variables including is the average GPS transmission, is recovery from individuals who do isolation, K is latent individuals who can transmit the virus.
6. This research is limited to the use of GPS with respect to distance, and minimizes the error of other related variables.

AKNOWLEDGEMENT

Thank you to the Universitas Muhammadiyah Sidoarjo (UMSIDA) for providing the opportunity to participate in the research of Muhammadiyah (RISETMU). Thank you for Hibah RISETMU Batch V grant program which has supported the research funding process in the 2021-2022 academic year.

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