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COMPARATIVE ANALYSIS OF VINCENTY AND GEODESIC METHOD APPROACHES IN MEASURING THE DISTANCE BETWEEN SUBDISTRICT OFFICES IN SALATIGA CITY

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Abstract. *Salatiga city has four subdistrict offices, namely Argomulyo Subdistrict, Sidorejo Subdistrict, Sidomukti Subdistrict, and Tingkir Subdistrict. In this study, a comparative analysis of the distance between subdistrict offices in Salatiga city was conducted using the Vincenty method and Geodesic method with distance obtained from Google Maps. The data is the geographical coordinates of the Earth's surface (latitude and longitude) obtained from Google Earth. The results showed that both Vincenty and Geodesic methods compared with Google Maps calculation results between 95% -105%, so it can be said to be good. The geodesic method gives relatively better results than the Vincenty method because it has an average percentage of 99.58 %. In comparison, the Vincenty method has an average percentage of 99.48 %. However, the results obtained still use relatively fewer data.*

Keywords: *Google Earth, Google Maps, Vincenty Method and Geodesic Method.*

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1. INTRODUCTION

Salatiga City is one of the cities included in the area of Central Java Province. It is limited to several villages included in the Semarang Regency area. Salatiga City is divided into 4 subdistricts, namely Argomulyo subdistrict, Sidorejo subdistrict, Sidomukti subdistrict, and Tingkir subdistrict, with a total area of 56.78 km^2. The area of Argomulyo subdistrict is 18.53 km^2, Sidorejo subdistrict is 16.24 km^2, Sidomukti subdistrict is 11.46 km^2, Tingkir subdistrict is 10.55 km^2[1]. Each subdistrict will be led by a subdistrict head and divided into several subdistricts and villages. Each subdistrict will have a subdistrict office located in its respective area. Through the subdistrict office, the community can take care of permits such as Police Records Certificate (SKCK), UMK (Micro and Small Business) permits, and domicile certificates. In this era of technology and information, there are many ways to determine the value of the distance between a location. By utilizing the service facilities owned by Google Maps and Google Earth, the distance between one subdistrict and another subdistrict located in Salatiga City can be seen.

Google Earth and Google Maps are free mapping services developed by Google. Google Earth is a service that provides information about maps and their ins and outs [2]. Map images produced by Google Earth are taken from several combinations of sources, such as aerial photography, satellite images, and GIS (Geographical Information System) processing by Google in 2007. In addition, there are several other features of Google Maps, such as displaying travel directions, finding locations, displaying world maps, satellite photos, road density, the topography of a place, and street view. In addition to using Google Earth and Google Maps services, according to Huber et al., in their research entitled Calculate Travel Time and Distance with Openstreetmap Data Using the Open Source Routing Machine (OSRM) [3], to calculate the distance and travel time between two points can use the command Open Source Routing Machine (OSRM) and OpenStreetMap. The advantage of OSRM and OpenStreetMap is that it allows users to make unlimited requests independent of the internet, and the results can be replicated at any time. In addition to Xia's research entitled Design of Remote Real-Time Positioning Method for Long-Distance Running under Wireless Network Technology [4], the researcher proposes using wireless-based technology for positioning long-distance running in real-time by combining PLS (Partial Least Squares), Isomaps, and MDS principles.

The application of the Vincenty and Geodesic Methods using Google Earth and Google Maps services has been carried out by several researchers, such as the research by Karney entitled Algorithms for geodesics [5]. According to researchers, using geodesic algorithms in ellipsoid calculations provides accurate values, strong solutions, and quick for the problem of inverse geodesic, differential, and integral geodesic to be calculated. Hung's research entitled Development of a Document Classification Method by Using Geodesic Distance to Calculate Similarity of Documents [6], explains that the use of the internet today provides opportunities for people to access human knowledge quickly and easily through various ways such as web pages, networks social and digital libraries. Researchers have challenges in representing, storing, sorting, and classifying documents by presenting a new approach to text classification based on semi-supervised machine learning and SVM (Support Vector Machine). Setiawan et al.'s research, entitled Using Google Maps and Spherical Quadrilateral Approach Method for Land Area Measurement [7], presents a way to determine the measurement of the area of the province of DIY and Central Java by using the Spherical Quadrilateral method approach, which will be compared with the quadrilateral approach method with a coordinate system UTM (Universal Transverse Mercator). In Crane et al.'s research, entitled A Survey of Algorithms for Geodesic Paths and Distances [8], the researchers explain that numerical computation of the shortest path or geodesic in curved domains, as well as geodesic related to distance, appears in various applications across digital geometry processing, scientific computing, computer graphics, and computer vision. Compared to Euclidean distance calculations, these tasks are complicated due to the influence of curvature on the shortest path's behavior and the fact that the domain representation itself may be an approximation. Despite the difficulty of this problem, the recent literature has developed a wide variety of sophisticated methods that allow rapid querying of geodesic information, even on relatively large models. This survey reviews the main categories of approaches to calculating geodesic paths and distances, highlighting common themes and opportunities for future improvement. Windarni et al.'s research, entitled Determination of Land Area with the Circle Approach Method Based on Google Earth and GADM for the Semarang Regency Region [9], use Google Earth data and the GADM database to obtain the boundaries of each subdistrict in the form of latitude and longitude coordinates and researchers also study how to obtain the area of a subdistrict in Semarang Regency by applying the circle approach method and the Karney polygon method. Trettner et al.'s research, entitled Geodesic Distance Computation via Virtual Source Propagation [10], presents a practical, efficient and versatile approach for calculating geodesic distance estimates. The method is designed for triangle meshes, with a set of point sources on the surface. The researcher also features extensions for geometric inputs, including triangle soups and point clouds.

Based on the above background, the researcher wants to use Google Earth and Google Maps mapping services to calculate the distance between one subdistrict office and another in Salatiga City by applying the Vincenty Method and the Geodesic Method. The author uses R software in solving problems, especially to calculate the distance of each point generated by Google Earth in the form of latitude and longitude coordinates by applying the Vincenty Method and the Geodesic Method. Software R is a programming language intended to handle statistical computing and facilitate the presentation in the graphical form [11]. The packages contained in the R software are open source or free. R can be used to handle GIS, image processing, machine learning, and big data.

2. RESEARCH METHOD

2.1 Research Flow Schematic

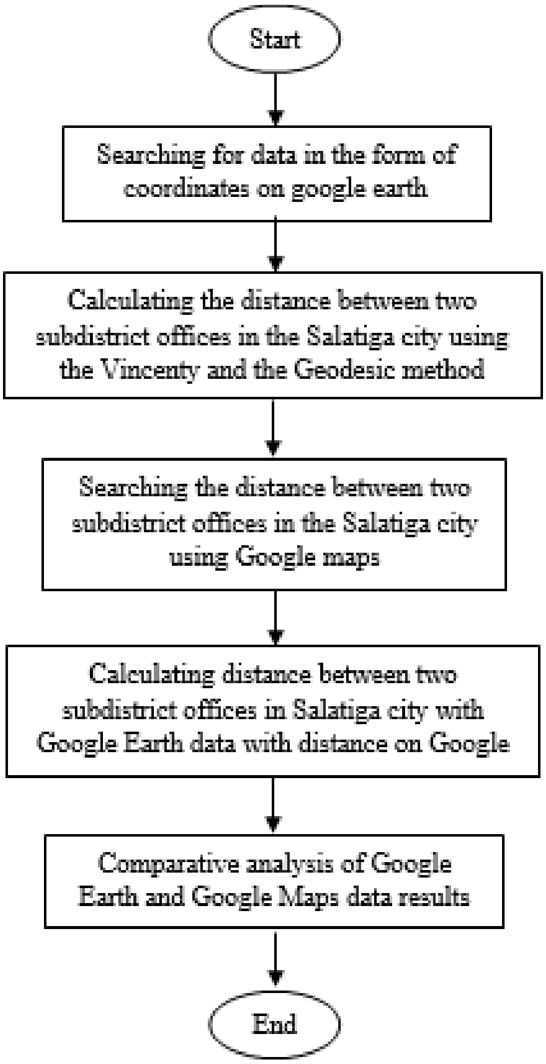


Figure 1. Research Flow Schematic

Figure 1 is a schematic of the research flow that will be carried out by researchers which will be explained as follows:

1. Search Data on Google Earth

Searching data on Google Earth utilizes latitude and longitude coordinates by creating a new project that contains the initial subdistrict office points with the destination subdistrict office points, then proceeds to create route points that have previously been adjusted to the routes found on Google Maps seen in Figure 2. In this study, there are four subdistrict offices located in Salatiga City, so the total calculation of distance search between subdistricts in Salatiga city is 6.

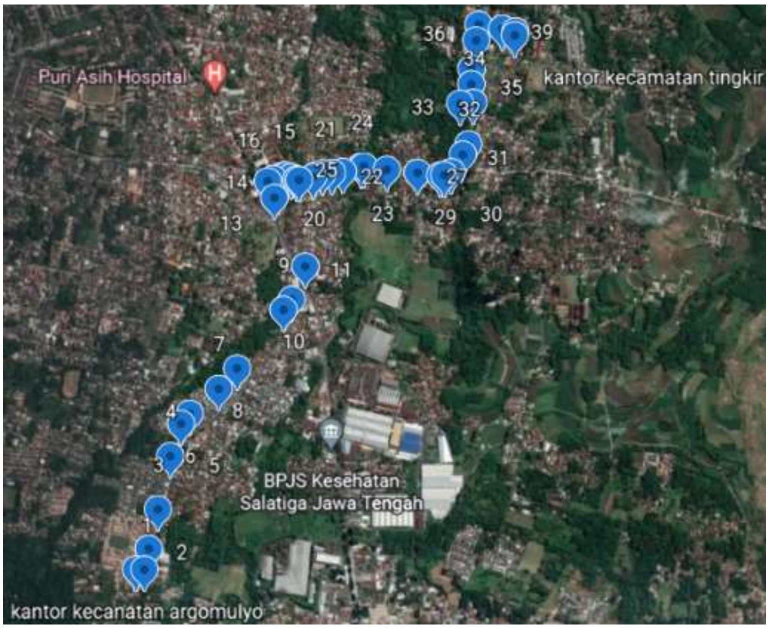


Figure 2. Initial Route Point of Argomulyo subdistrict Office with Tingkir Subdistrict Office on Google Earth.

2. Search Data on Google Maps

   Searching for data on Google Maps is the same as searching for data found on Google Earth. The total distance search calculation for each subdistrict is 6 between subdistrict offices. The difference in searching data on Google Maps is that researchers only need to enter the route of the starting point of the subdistrict office and the destination of the subdistrict office. Google Maps will automatically display the route that can be passed along with the distance of the location, which can be seen in Figure 3.

3. Data Processing

   After getting data from Google Earth in the form of route points made in the form of latitude and longitude coordinates, it can be seen the distance of each point using the Vincenty Method and the Geodesic Method using the R software.

4. Data Analysis

   The last stage is the data analysis stage. At this stage, an analysis of the distance results generated by Google Earth using the Vincenty Method and the Geodesic Method was carried out, along with the distance results generated by Google Maps.

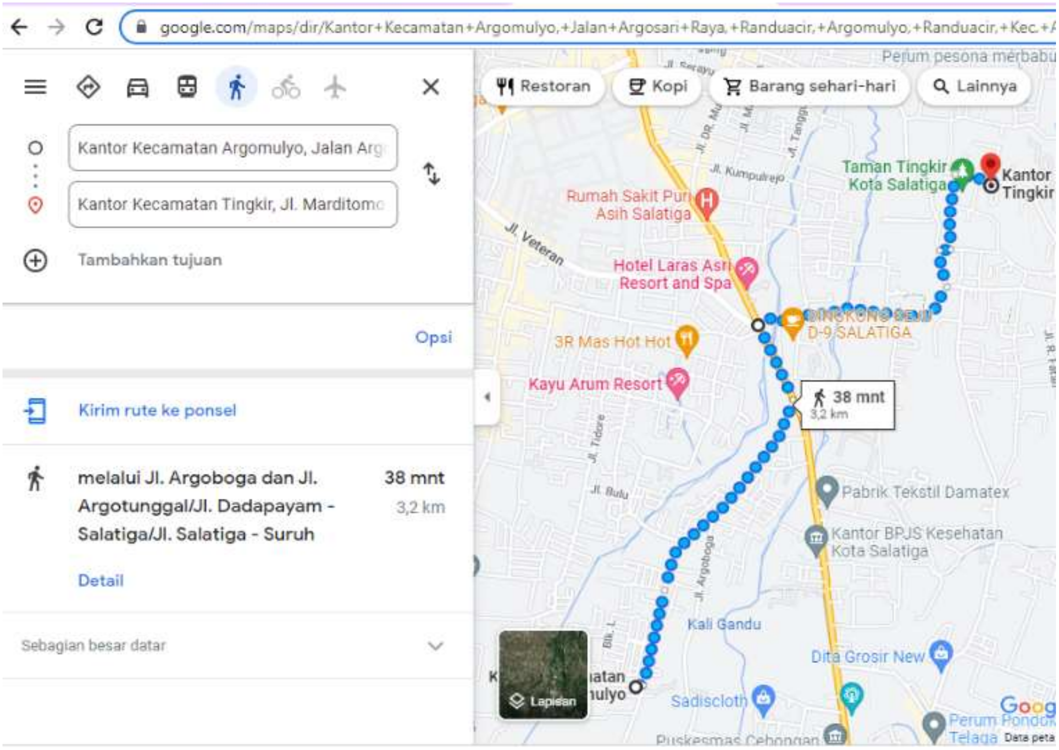


Figure 3. The starting point of the Argomulyo subdistrict Office with the Destination Point of the Tingkir subdistrict Office on Google Maps.

2.2 Vincenty Distance

Vincenty formula is used in geodesy to calculate the distance between two points on the earth's surface, which is assumed to be an ellipsoid [12]. For example, there are 2 points (A and B), $A\ (\Phi 1,\ L1)$ and $B\ (\Phi 2,\ L2)$. Given the coordinates of two points ($\Phi 1, L1$) and ($\Phi 2, L2$), inverse problem finding azimuth $\alpha 1$, $\alpha 2$, and the ellipsoidal distance s. Then, $U1$, $U2$, and L are calculated, and the initial value $\lambda = L$ is set. Then, iteratively evaluate the following equation until λ close to zero,

$$sin\sigma = \sqrt{(cosU_2 \sin\lambda)^2 + (cosU_1 \sin U_2 - \sin U_1 \cos U_2\, cos\lambda)^2} \tag{4}$$

$$cos\sigma = \sin U_1 \sin U_2 + cosU_1 cosU_2 cos\,\lambda \tag{5}$$

$$\sigma = \arctan \frac{sin\sigma}{cos\sigma} \tag{6}$$

$$sin \propto = \frac{cosU_1 cosU_2 sin\lambda}{sin\sigma} \tag{7}$$

$$\cos(2\sigma m) = cos\sigma - \frac{2sinU_1 sinU_2}{cos2\propto} \tag{8}$$

$$C = \frac{f}{16} cos^2 \propto [4 + f(4 - 3cos^2 \propto)] \tag{9}$$

$$\lambda = \mathrm{L}(1 - \mathrm{C})\ \mathrm{f} \sin \propto \{\sigma + \mathrm{C}\ \sin\sigma[\cos(2\sigma m) + \mathrm{C}\ \cos\sigma(-1 + 2cos^2(2\sigma m))]\} \tag{10}$$

When λ has converged to the desired level of accuracy (10^{-12} corresponds to about 0.06 mm), evaluate the following:

$$U_2 = cos^2 \propto (\frac{a2 - b2}{b2}) \tag{11}$$

$$A = 1 + \left(\frac{u2}{16384}\right)\{4096 + u2[-768 + u2(320 - 175\ u2)\} \tag{12}$$

$$B = \left(\frac{u2}{1024}\right)\{256 + u2[-128 + u2(74 - 47\ u2)\} \tag{13}$$

$$\Delta\sigma = B\ sin\sigma\ \{\cos(2\sigma m) + \frac{1}{4}B[cos\sigma\big(-1 + 2cos^2(2\sigma m)\big) - \frac{b}{6}\cos\,(2\sigma m)(-3 + 4sin^2\sigma)(-3 + 4cos^2(2\sigma m))]\} \tag{14}$$

$$s = bA(\sigma - \Delta\sigma) \tag{15}$$

$$\propto 1 = archtan\,(\frac{cosU_2 sin\lambda}{cosU_1 \sin U_2 - sinU_1 cosU_2 cos\lambda}) \tag{16}$$

$$\propto 2 = archtan\,(\frac{cosU_1 sin\lambda}{-sinU_1 \cos U_2 + cosU_1 sinU_2 cos\lambda}) \tag{17}$$

where,

a : The length of the semi-major axis of the ellipsoid (radius at the equator) (6378137.0 meters),

f : Flattening the ellipsoid (1/298.25722356),

b : $(1-f)\,a$: The length of the semi-minor axis of the ellipsoid (radius at the poles) (6356752.314245 meters),

Φ_1, Φ_2 : point latitude,

U_1 : arctan $((1-f)\tan \Phi_1)$,

U_2 : arctan $((1-f)\tan \Phi_2)$,

L : $L_2 - L_1$: The difference in longitude of two points,

λ_1, λ_2 : The longitude of the points on the additional sphere,

α_1, α_2 : Forward azimuth at points,

α : Azimut at the equator,

S : Ellipsoidal distance between two points,

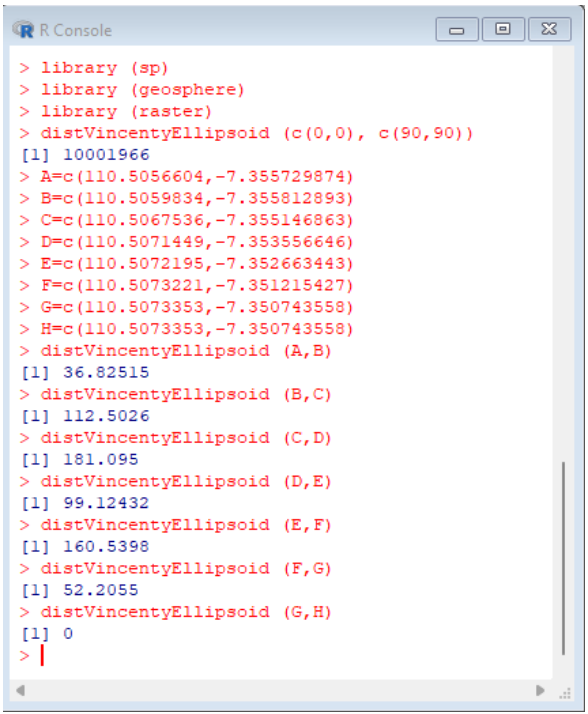
σ : The length of the arc between the points on the additional sphere.

Table 1 contains the coordinates in the form of latitude and longitude for the initial route points for the Argomulyo subdistrict office and the Tingkir subdistrict office using Google Earth services. It was obtained 46 route points symbolized by the letters A to TT. To find the distance of each point using the Vincenty Method, the researcher uses a tool in the form of software R. The calculation formula can be seen in Figure 4. For example, if we want to calculate the distance of the route points from points A, B, C, D, E, F, G, and H, the distance between AB is 36.83 m, BC is 112.50 m, CD is 181.10 m, DE is 99.12 m, EF is 160.54 m, FG is 52.21 m, and GH is 0.00 m.

Table 1. Initial Route Point Argomulyo subdistrict Office with Tingkir Subdistrict Office Using Google Earth

Points	*Latitude*	*Longtitude*	Metode Vincenty	Metode Geodesic
A	110.5056604	-7.355729874		
B	110.5059834	-7.355812893	36.83 m	36.83 m
C	110.5067536	-7.355146863	112.50 m	112.50 m
D	110.5071449	-7.353556646	181.10 m	181.10 m
E	110.5072195	-7.352663443	99.12 m	99.12 m
F	110.5073221	-7.351215427	160.54 m	160.54 m
G	110.5073353	-7.350743558	52.21 m	52.21 m
H	110.5073353	-7.350743558	0.00 m	0.00 m
I	110.5075833	-7.350847086	29.68 m	29.68 m
J	110.5087503	-7.349702628	180.61 m	180.61 m
K	110.5091064	-7.349275127	61.49 m	61.49 m
L	110.5095832	-7.349088736	56.54 m	56.54 m
M	110.5106206	-7.347284677	230.06 m	230.06 m
N	110.5107715	-7.346597606	77.79 m	77.79 m
O	110.5109362	-7.345714421	99.35 m	99.35 m

Points	*Latitude*	*Longtitude*	Metode Vincenty	Metode Geodesic
P	110.511283	-7.343654346	231.02 m	231.02 m
Q	110.5104924	-7.342569274	148.39 m	148.39 m
R	110.5104402	-7.342771214	23.06 m	23.06 m
S	110.5103906	-7.342413447	39.94 m	39.94 m
T	110.5105653	-7.342349736	20.54 m	20.54 m
U	110.5109179	-7.34252357	43.42 m	43.42 m
V	110.5111468	-7.342719603	33.30 m	33.30 m
W	110.5114272	-7.342537938	36.91 m	36.91 m
X	110.511696	-7.342430078	31.99 m	31.99 m
Y	110.5119921	-7.34251874	34.13 m	34.13 m
Z	110.5125653	-7.342681877	65.81 m	65.81 m
AA	110.5124691	-7.342584041	15.16 m	15.16 m
BB	110.5131622	-7.342397585	79.26 m	79.26 m
CC	110.5133921	-7.342436371	25.74 m	25.74 m
DD	110.5139824	-7.342642745	69.06 m	69.06 m
EE	110.5149529	-7.342568037	107.47 m	107.47 m
FF	110.5154484	-7.342661389	55.68 m	55.68 m
GG	110.5158191	-7.342546948	42.84 m	42.84 m
HH	110.5162099	-7.342498688	43.48 m	43.48 m
II	110.5163658	-7.342390833	20.94 m	20.94 m
JJ	110.5172523	-7.341941563	109.77 m	109.77 m
KK	110.5172835	-7.340717224	135.45 m	135.45 m
LL	110.5171395	-7.340334149	45.25 m	45.25 m
MM	110.5171395	-7.340334149	0.00 m	0.00 m
NN	110.5171281	-7.339419839	101.12 m	101.12 m
OO	110.5169831	-7.339148249	34.04 m	34.04 m
PP	110.5169758	-7.338734059	45.81 m	45.81 m
QQ	110.5170206	-7.338393184	38.02 m	38.02 m
RR	110.5175441	-7.337703891	95.67 m	95.67 m
SS	110.5181437	-7.3372661	82.02 m	82.02 m
TT	110.5183208	-7.337333066	20.91 m	20.91 m
			3254.01 m	**3254.01 m**
	Total		**3.25 km**	**3.25 km**



```
R Console
> library (sp)
> library (geosphere)
> library (raster)
> distVincentyEllipsoid (c(0,0), c(90,90))
[1] 10001966
> A=c(110.5056604,-7.355729874)
> B=c(110.5059834,-7.355812893)
> C=c(110.5067536,-7.355146863)
> D=c(110.5071449,-7.353556646)
> E=c(110.5072195,-7.352663443)
> F=c(110.5073221,-7.351215427)
> G=c(110.5073353,-7.350743558)
> H=c(110.5073353,-7.350743558)
> distVincentyEllipsoid (A,B)
[1] 36.82515
> distVincentyEllipsoid (B,C)
[1] 112.5026
> distVincentyEllipsoid (C,D)
[1] 181.095
> distVincentyEllipsoid (D,E)
[1] 99.12432
> distVincentyEllipsoid (E,F)
[1] 160.5398
> distVincentyEllipsoid (F,G)
[1] 52.2055
> distVincentyEllipsoid (G,H)
[1] 0
>
```

Figure 4. Distance Calculation Using the Vincenty Method Based on the Initial Route Point of the Argomulyo subdistrict Office with the Tingkir Subdistrict Office in R Software

2.3 Geodesic Distance

The earth's shape can be modeled by a Cartesian plane or an ellipsoid. In this case, it is related to the quality of the approach. The shortest path between two points on the surface is called the geodesic. The concept of geodesic distance can be used in all fields, such as mathematics, mapping, surface partitioning, terrain navigation, and path planning [13]. The advantages of the geodesic approach are simplicity in implementation, performance, and accuracy. According to Physicopoulos [14], there are two main problems in geodesic: the direct problem in φ_1, s_{12}, α_1 and the inverse problem in φ_1, φ_2, λ_{12}. Researchers stated λ, φ, α, s longitude, latitude, azimuth, and distance on the respective ellipsoid. λ_1 is the longitude of the first point, and s_{12} is the distance between the first and second points. As can be seen in Figure 5, each problem is equivalent to the solution of the geodesic triangle N A B, given two sides and angles. N is the north pole, N A F and N B H are meridians, and A B is a geodesic with length s_{12}. *Longitude B* relative to A is λ_{12}, and latitudes *A* and *B* are φ_1 and φ_2. *E F H* is the equator with E and lies on the geodesic extension A B and α_0, α_1 and α_2 are the geodesic azimuths (in the forward direction) at E A B.

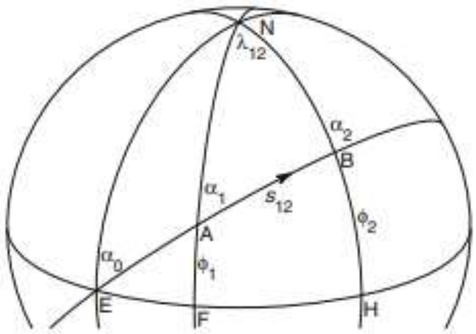


Figure 5. Ellipsoidal triangle N A B.

To find the distance of each route point using the Geodesic Method, the latitude and longitude coordinates can be seen in Table 1. The researcher uses a tool in the form of R software to calculate the distance of each route point by using a formula that can be seen in Figure 6. For example, suppose you want to calculate the distance of the route points from points A, B, C, D, E, F, G, and H. In that case, you will get the distance between AB of 36.83 m, BC of 112.50 m, CD of 181.10 m, DE of 99.12 m, EF of 160.54 m, FG of 52.21 m, and GH of 0.00 m. If we look at the results of the distance of the route points using both the Vincenty Method and the Geodesic Method, we have the same results.

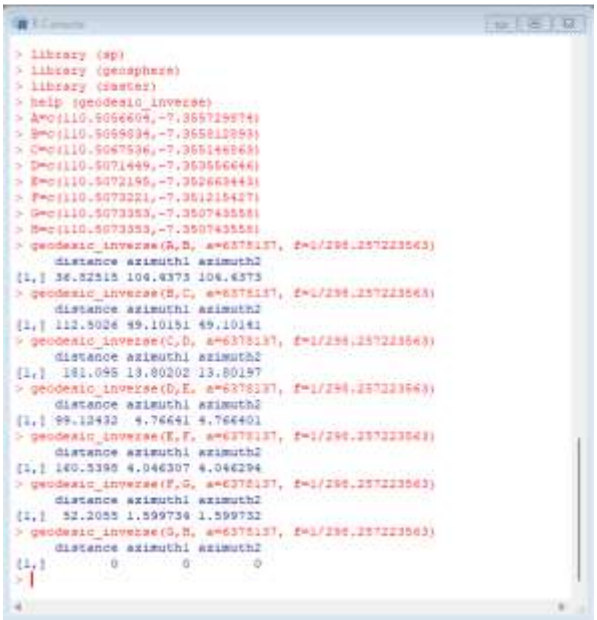


Figure 6. Distance Calculation Using Geodesic Method Based on Initial Route Point Argomulyo subdistrict Office with Tingkir Subdistrict Office in R Software.

3. RESULT AND DISCUSSION

Salatiga City is a city that has an altitude between 450-825m above sea level. The area of Salatiga City is divided into 4 subdistricts, 23 urban villages, 207 RW (hamlets), and 1119 RT (neighborhoods). The four subdistricts in Salatiga City are Argomulyo subdistrict, Sidorejo subdistrict, Sidomukti subdistrict, and Tingkir subdistrict. The subdistrict with the highest area contour is the Argomulyo subdistrict (680 masl), and the lowest area contour is the Sidorejo subdistrict (602 masl). Table 3 contains the addresses of each subdistrict office located in Salatiga City. After obtaining the address of each subdistrict office, the distance between each office will be calculated based on Google Earth's and Google Maps' services. The route points have been adjusted for the two services previously. It can be seen in Table 4. The distance between each subdistrict using the Google Maps service was calculated automatically. However, on Google Earth, we have to calculate the distance between each point, then add up all of them. The results of the calculation of Google Earth distances using the Vincenty Method and the Geodesic Method with Google Maps can be seen in Table 5. Google Earth services can also be used to determine the area. It is used in some studies, such as the Determining the Area of Regencies and Cities in Central Sulawesi Province Using the Polygon Method with Google Earth Assistance [15] and the Determination of Village Area in Semarang Regency Using the Circle Method [16]. Researchers used Google Maps and Google Earth services to calculate the area of all villages in Semarang Regency. Moreover, Paunsyah et al. used the Google Maps API service on GIS to determine the shortest path to social institutions in Tasikmalaya City. [17].

Table 3. Four Subdistrict Office Addresses in Salatiga City

District office	Subdistrict office address
Argomulyo Subdistrict Office	Jl. Argosari Raya, Randuacir, Argomulyo, Salatiga City, Central Java 50735, Indonesia
Sidorejo Subdistrict Office	Jl. Ki Penjawi No.19, Sidorejo Lor, Sidorejo, Salatiga City, Central Java 50714, Indonesia
Sidomukti Subdistrict Office	Jalan Hasanudin No.116B, Mangunsari, Sidomukti, Mangunsari, Sidomukti, Salatiga City, Central Java 50721, Indonesia
TingkirSubdistrict Office	Jl. Marditomo No.6, Sidorejo Kidul, Tingkir, Salatiga City, Central Java 50741, Indonesia

Table 4. Routes On Google Earth and Google Maps Services

<table>
<tr><th>Subdistrict office</th><th>Google Earth</th><th>Google Maps</th></tr>
<tr><td>Argomulyo and Sidomukti</td><td></td><td></td></tr>
<tr><td>Argomulyo and Sidorejo</td><td></td><td></td></tr>
<tr><td>Argomulyo and Tingkir</td><td></td><td></td></tr>
<tr><td>Sidomukti and Sidorejo</td><td></td><td></td></tr>
</table>

Subdistrict office	*Google Earth*	*Google Maps*
Sidomukti and Tingkir		
Sidorejo and Tingkir		

Table 5. Distance Calculation Results Based on Google Earth and Google Maps

District Office Distance	*Google Earth*		*Google Maps*
	Vincenty Method	Geodesic Method	
Argomulyo and Sidomukti	4.66 km	4.69 km	4.60 km
Argomulyo and Sidorejo	6.48 km	6.48 km	6.70 km
Argomulyo and Tingkir	3.25 km	3.25 km	3.20 km
Sidomukti and Sidorejo	6.40 km	6.32 km	6.32 km
Sidomukti and Tingkir	4.60 km	4.60 km	4.61 km
Sidorejo and Tingkir	5.30 km	5.52 km	5.50 km
Average	**5.13 km**	**5.14 km**	**5.13 km**

It can be seen in Table 6 that after obtaining the results of distance calculations based on Google Earth using the Vincenty Method and the Geodesic Method with Google Maps, calculations can be carried out to determine the percentage comparison of the two services. The results of the comparison of service usage on Google Earth using the Vincenty Method compared to Google Maps services have resulted above 95%, with the highest percentage being 101.56% and the lowest percentage being 96.01%. The percentage comparison of service usage on Google Earth using the Geodesic Method compared to the Google Maps service has results above 95%, with the highest percentage being 101.96% and the lowest percentage being 96.81%. Therefore, it can be stated that the results of distance calculations using Google Earth services using the Vincenty Method and the Geodesic Method, which are compared with the distance results generated automatically from the Google Maps service, have a good accuracy value because the percentage results of the distance between each office are between 95% and 105 %. However, the Geodesic method is relatively better than the Vincenty method. The formula for calculating the percentage of comparison can be searched with the following formula:

$$percentage = \frac{Distance\ Results\ from\ Google\ Earth\ Data}{Google\ Maps\ Distance} * 100\%$$

Table 6. Percentage Comparison of Google Earth Services (Vincenty Method and Geodesic Method) with Google Maps

Subdistrict Office Distance	Percentage Comparison of Google Earth Services with Google Maps	
	Vincenty Method on Google Earth with Google Maps	Geodesic Method on Google Earth with Google Maps
Argomulyo and Sidomukti	101.30 %	101.96 %
Argomulyo and Sidorejo	96.72 %	96.72 %
Argomulyo and Tingkir	101.56 %	101.56 %
Sidomukti and Sidorejo	101.27 %	101.27 %
Sidomukti and Tingkir	100 %	99.78 %
Sidorejo and Tingkir	96.01 %	96.18 %
Average	**99.49 %**	**99.58%**

In addition to using the Vincenty method, according to Coskun et al., the Haversine formula can also be used to calculate the distance between two points [18]. According to Hajar et al., the Haversine method is known to be accurate for calculating the distance between 2 points by calculating the length of a straight line between two points by considering a certain curvature of the earth [19]. In a study by Azdy et al., researchers used Google Maps services and the Haversine formula to find the distance between temporary shelters and the final waste processing site [20]. In this study, the results showed that the sequence of distances generated using the Haversine formula was the same as the order of distance traveled via Google Maps path. Many algorithms can handle distance problems, for example, the Vincenty and Haversine method. Both methods can be used to calculate the distance of a large circle. The Haversine method is widely used to calculate distances assuming the earth is spherical. Another advantage of the Haversine method is that it provides simpler calculations. In contrast, the Vincenty method calculates distances assuming the earth is an ellipsoid. The advantage of the Vincenty method is that it has a higher level of accuracy because it assumes the earth is an ellipsoid instead of a round shape.

In this study, researchers prefer to use the Vincenty method by assuming the earth's shape is not perfectly round but has an ellipsoid shape. The Vincenty method uses a relatively more complicated formula than the Haversine method. Likewise, the Geodesic method is more difficult to understand than the Vincenty method. Li et al. also explained that the geodesic algorithm is very complex [21].

The current research results show that the use of the Geodesic method is considered better than the Vincenty method. It can be seen in Table 5 as an example of the distance between the Argomulyo and Sidomukti subdistrict offices using the Vincenty Method of 4.66 km and the Geodesic Method of 4.69 km. The distance between the Argomulyo subdistrict office and the Sidorejo subdistrict office was 6.48 km using the Vincenty Method and the Geodesic Method. Then, the distance between the Argomulyo subdistrict office and the Tingkir subdistrict office is 3.25 km using the Vincenty Method and the Geodesic Method. If the average difference is calculated between the Vincenty Method and the Geodesic Method on Google Earth, the results are 5.13 km for the Vincenty Method and 5.14 km for the Geodesic Method.

4. CONCLUSION

It can be concluded from the results of this study that the use of the Geodesic Method is better than the Vincenty Method. Research is also still limited, using relatively little data to make conclusions. In further research, distance searches can be carried out with larger data, such as finding the distance of each subdistrict office in an area using Google Maps, Google Earth, or OpenStreetMap services by adding newer methods.

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