Research Article

Excel as an Aid to Find Parametric Arc Length in Complex Graph for Undergraduate Students

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Abstract: This study uses a method using excel to figure out if the graph function of Excel trendline is a liable function to aid in calculating parametric arc length for undergraduate students learning parametric equations and parametric graphs. Since there are not many software out there that are easily obtainable by students to use as a reference for them to tackle complex graph where it's function is complicated and hard to obtain. Namely, functions that have a high power or complex combination of trigonometric functions. This method uses the Excel's trendline function within the software to get the mathematical functions and also the graph by only using data obtain via hand drawn graph of a map route. The data then can be manipulated within excel into several segments to make out easier graph for use in calculation of parametric arc length. With this method many students and professionals that needs to find the parametric arc length of a graph can use the method as a substituted or an alternative to calculate parametric arc length using only excel. Furthermore, this method have the potential to be commercialize into being use as a way to engage students into understanding parametric concept more interactively since it can be use in real life by having them make their own graph of their surrounding and extrapolating them into using excel.

Keywords: excel, aid, parametric length.

1. INTRODUCTION

Over the decade Microsoft have continuously reinventing and upgrading their line up of computer software. One of these software that we all know is Excel, the software that made it's debut in the year 1985. It is a spreadsheet application that allows people to make data table and use mathematical inputs to organize the data. Albeit, Excel is not usually well used amongst students and professionals when it comes to graphing complex functions. Most of them opt to use more advanced and high performing software which incorporate Computer Algebra System (CAS) into the software. Although Excel is not well equip with advanced mathematical functions that are needed for advance maths all the functions it currently has is enough to help people who use it to get amazing results. In

this research we have tried to use the Excel's trendline function as an aid to help calculate parametric arc length in complex graph.

The method used only Excel and a reference picture of the set graph that is to be use to calculate the arc length. In this research we use a map of a driving route from a residential area to the front gate of UITM Shah Alam. The map used is obtain from google map and is only used as a reference to make out the outline for the set graph. Since we are trying to figure out the arc length of the graph of the complex function. If we try to graph the map into a graphing software it will take a considerable amount of time and might also be complicated since we do not know any of the functions of the set graph. The only data that we have is the time intervals between several point within the route itself. Hence by using Excel we are able to get al the prerequisites requirement to use in calculating the parametric arc length, namely the function of x(t) and y(t).

Furthermore, this research also have potential to be commercialize as a teaching method for parametric equations. This is because the method enables people to use it as an interactive way to find functions of a graph in real life without using complex software. People can try to graph out many types of patterns and obtain all the information from it with the software that is currently within a buttons click. This will perpetually increase understanding in math with the masses and also mounting a more sustainable way learning especially in the field of Science Technology Engineering and Math (STEM).

Moving on this research also incorporate the use of several equations within the known fields of Physics and Math to try and give a more solid foundation to the tested method. The equations that will be used are in the sub category of parametric equation in Math, which is:-

$$L = \int_{\alpha}^{\beta} \sqrt{[f'(t)]^2 + [g'(t)]^2} \, dt$$

There is also the use of an equation in physics that is from the subcategory of linear motion which is:-

$$v = u + at \qquad (1)$$
$$s = \tfrac{1}{2}(u + v)t \qquad (2)$$
$$s = ut + \tfrac{1}{2}at^2 \qquad (3)$$
$$v^2 = u^2 + 2as \qquad (4)$$
$$s = vt - \tfrac{1}{2}at^2 \qquad (5)$$

$$V = \frac{\Delta x}{\Delta t}$$

The above equations are both important to try and verify the findings that will further be discuss in this research paper. Both part of this equation are related in finding the acceleration, a and velocity, v of the moving car used in data collecting part of the research.

Finally, this paper will also provide the method of finding the result needed in th research, tabulation of data, calculation and also show any error in the findings. There will also be an in depth discussion of the result yielded within this research, with also adding what should be further done in the future to make appropriate advancements in the method for better results.

2. METHOD & MATERIAL

First of all, the materials needed to fulfil the method are a map route of a targeted length to be calculated, Microsoft Excel software (preferably no later than 2019) and graph paper. For the calculation part it could either be done by hand or by using any integral and derivative calculator. The map route that will be use can be source from any geographical sources, for this research we choose to reference the map route from google maps. This is because, google maps allows us to see the time estimation for the route taken, although this is at the mercy of the time of day and also depending on the amount of traffic on the route. Other notable maps that can be used as reference are of any mapping system that uses Global Positioning System (GPS) such as the WAZE application. For the software used which is Microsoft Excel, this can be access via any computer of digital electronics appliances that can operate it. Finally the graph paper that will be used can be of any type and also any scale. In case of this research we have chosen to use the scale for every 2cm will be 1km.

Moving on to fully help explain the method used on this research it will follow this flowchart below to help conceptualize the method more simply, we will also go on further detail based on this flowchart.
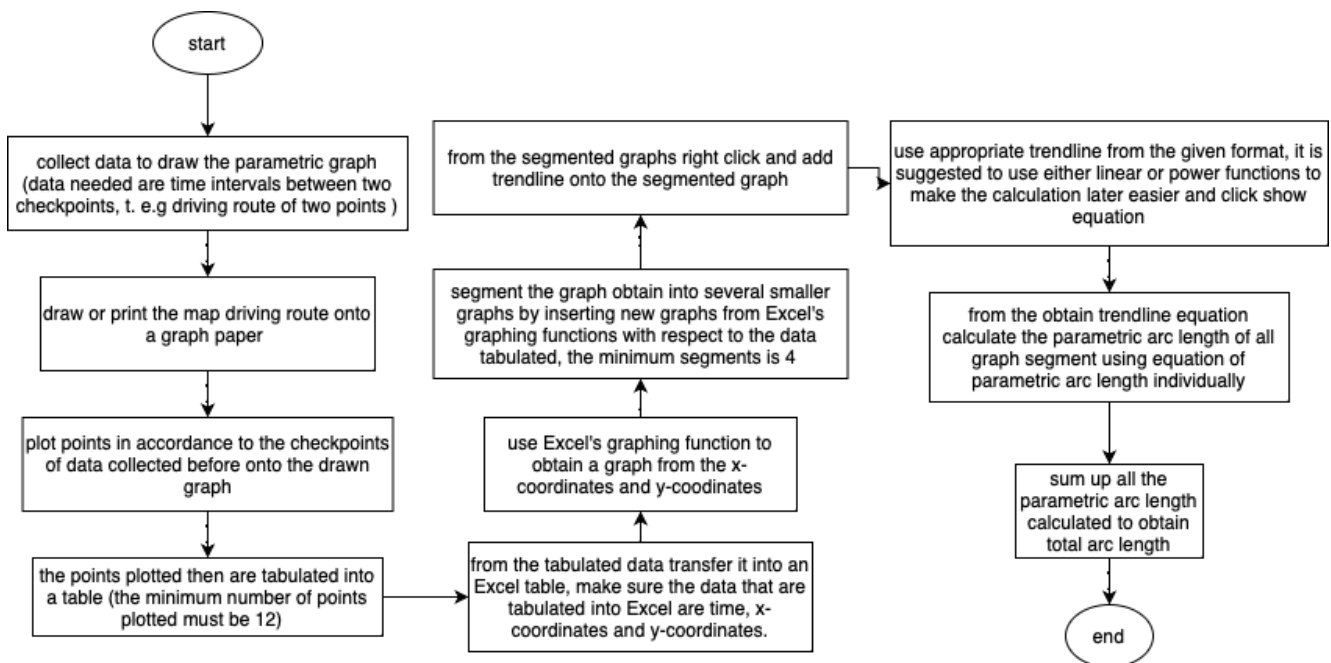

Figure 2.1 flowchart of the method

From the flowchart the first step for the method is to collect data of the driving route which is the target of this research which is to calculate the parametric arc length. We start collecting data by first picking the two points that we want to calculate the length of. In this case we chose to calculate the length between a residential area of this street Jalan Qamari U5/109a, Bandar Pinggiran Subang to the front gate of UITM Shah Alam. After picking the route we will go to google maps to look at the route and set the points at which we will record the time taken to reach the points. This is the first step which can be seen from the flowchart. The time intervals between the points will the time variable in this research.

Then after obtaining the data for time interval we will move on to the next step which is to hand drawn the map route onto a graph paper. This step can be either hand drawing the route of printing it with the map already in a graph. After tracing the map route onto the graph paper make sure to scale the graphed route. The scale that we chosen is 2cm : 1km, the scale depends on the graph

made. After that plot all the points of time interval from the collected data of time before onto the drawn graph, the minimum number of points for time interval is 12.
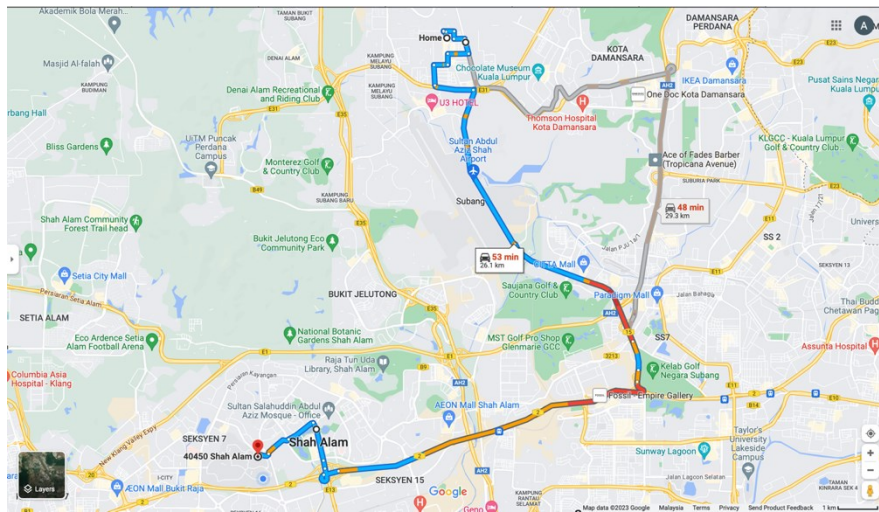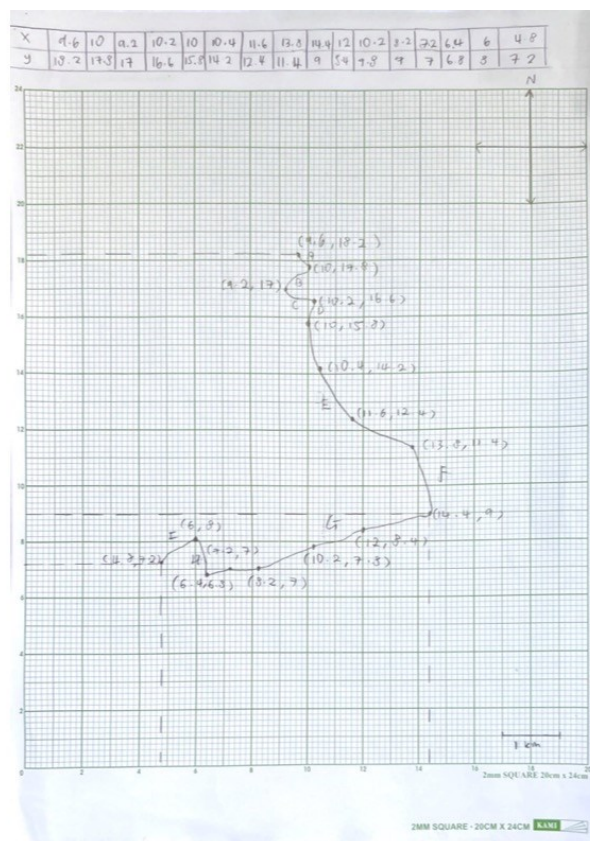

Figure 2.2 reference map route and graph drawn

Scanned with CamScanner

Figure 2.3 graph drawn

After drawing and plotting all point on the graph, the next step is to tabulate the data for x-axis and y-axis for the point of time interval. This tabulated data will then be transferred into Excel spreadsheet. In excel make the table having columns for time t, x-axis x, and y-axis y. Then by using Excel graphing function graph out the x and y data to get a graph in Excel. To do this simply select the tables containing data for x-axis and y-axis, then click insert graph and select the style accordingly. Then from the graph obtain segment it into several parts, the minimum number of parts is 4. It is advised to have more segments for easier calculations. Following this to get segmented graph simply select the part of the graph that is wanted to be segmented from the data table then repeat the process to insert a graph. Repeat it until all segments of the graph are made.

Then, from the segmented graphs select the right click onto it and select add trendline to obtained the graph function. For this hover the mouse on the line of the graph and right click with your mouse. Then select trendline and continue to pick the types of functions available, we suggest to pick either linear of power functions because it will have an easier time when doing calculations. But depending on the segmented graph you have made pick accordingly. Lastly click on display equation, this show the equation of the graph that you have segmented. Repeat this process for all the remaining segments of graphs made.
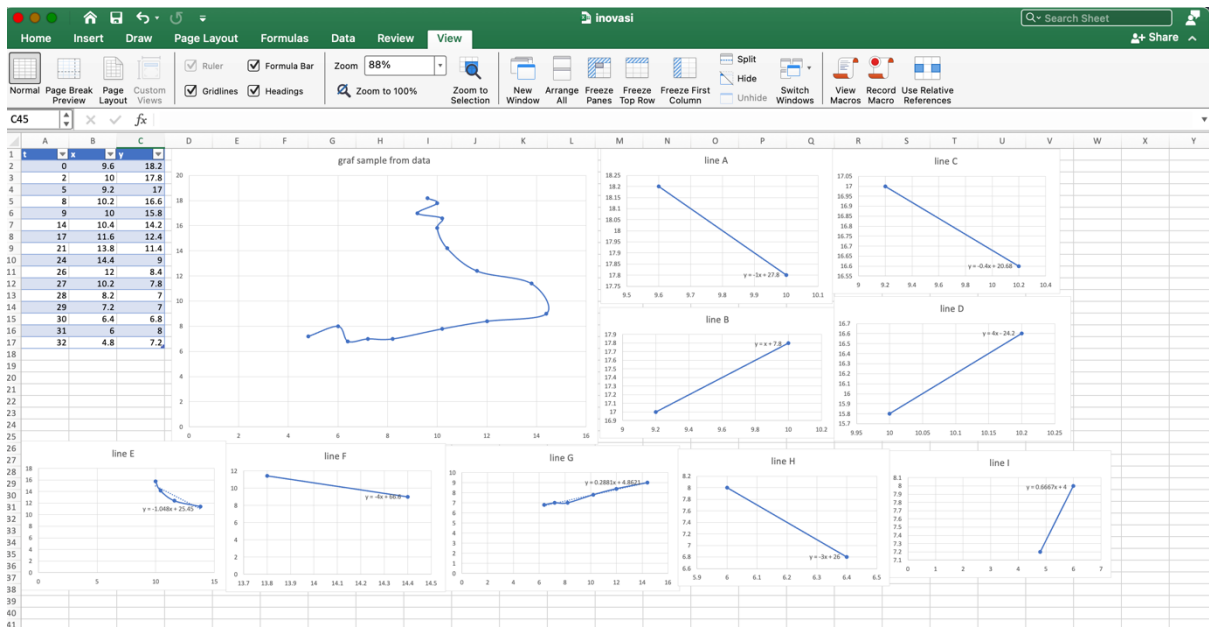

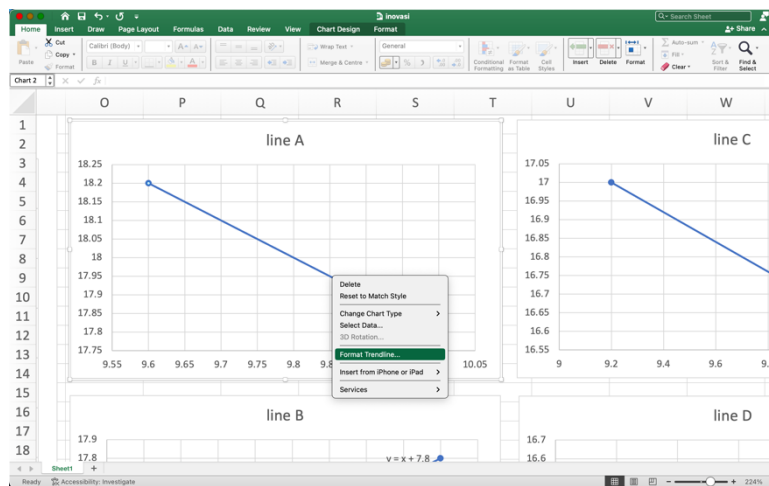Figure 2.3 graph from data table, segmented graph, and equation obtain from trendline function

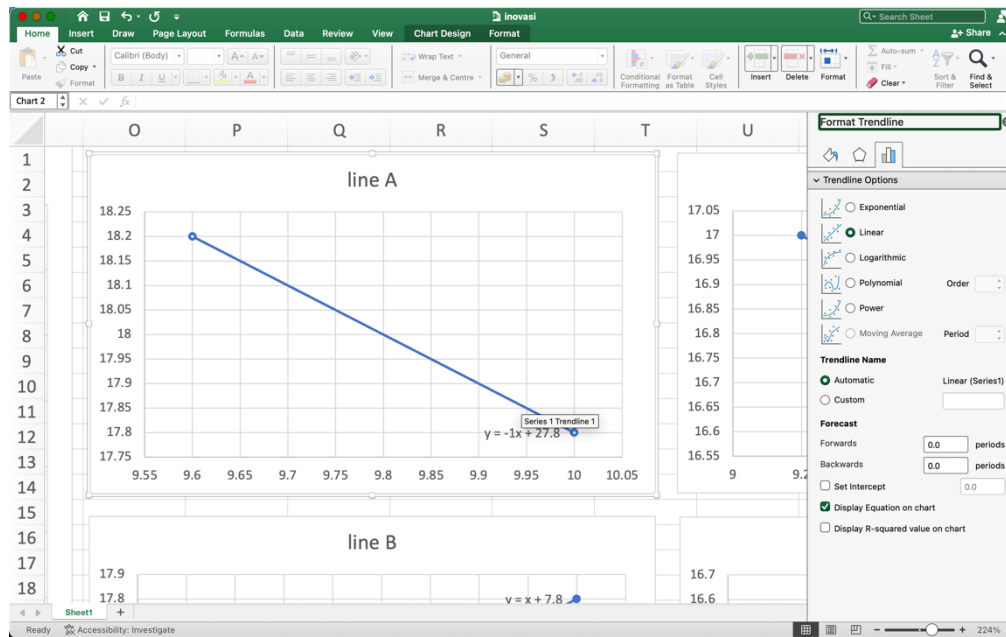Figure 2.4 how to get trendline function

Figure 2.5 trendline function

Finally, after obtaining all the equation needed for the calculation from Excel it is time to calculate the parametric arc length of the route. For this part we can either do it by hand or use an integral and derivative calculator. Firstly, the equation that is needed for this process is the equation of parametric arc length which is $L = \int_A^B \sqrt{(f'(t))^2 + (g'(t))^2}\,dt$. From this equation we can manipulate the equation obtain from the graph to suit our calculation. In this case we know that the equation obtain is in the form of $y = mx + c$ since this form is obtain when either x(t) is applied into y(t) or vice versa. This means we can get the equation that we need which is both x(t) and y(t). to get this we simply let one variable to time t. Hence we can say that when x = t, then $y = mx + c$ will become in terms of t rather that x. this will get us the functions of x with respect to t, x(t) and also function of y with respect to time, y(t). from the new function that we obtain we can then insert it according to the equation of parametric arc length mention earlier. In this case we need to integrate both function of x and y with respect to time, or simply say $\frac{dy}{dt}$ and $\frac{dx}{dt}$. For this we can do simple differentiation by hand or by using a derivative calculator to get the value. After that we will place the differentiated functions into the equation before for parametric arc length to get the length parametrically. This process needs to be repeated for all the remaining equations from all the graph. Since all the process will be similar for all the segments of the graph we can assume that for all the graph t = x, then solve for y using the method presented before. After finishing that we will add up all the length values to get the total length of the graph made. The final value obtained should be rescale according to the scale chosen before with the hand drawn graph to get the value in kilometres, km.

3. FINDINGS

For the findings in this research we will show the calculation done from the collected data based on the graph made on excel. The calculation provided will follow the equations previously mentioned, with several other calculations to be use as comparative analysis for better understanding on the result obtained. There will also be the table for the collected data and also the graph made in excel.

3.1 table of data collected

Table 1. table of findings

Time, t	x-axis	y-axis
0	9.6	18.2
2	10	17.8
5	9.2	17
8	10.2	16.6
9	10	15.8
14	10.4	14.2
17	11.6	12.4
21	13.8	11.4
24	14.4	9
26	12	8.4
27	10.2	7.8
28	8.2	7
29	7.2	7
30	6.4	6.8
31	6	8
32	4.8	7.2

3.2 graph made within Excel
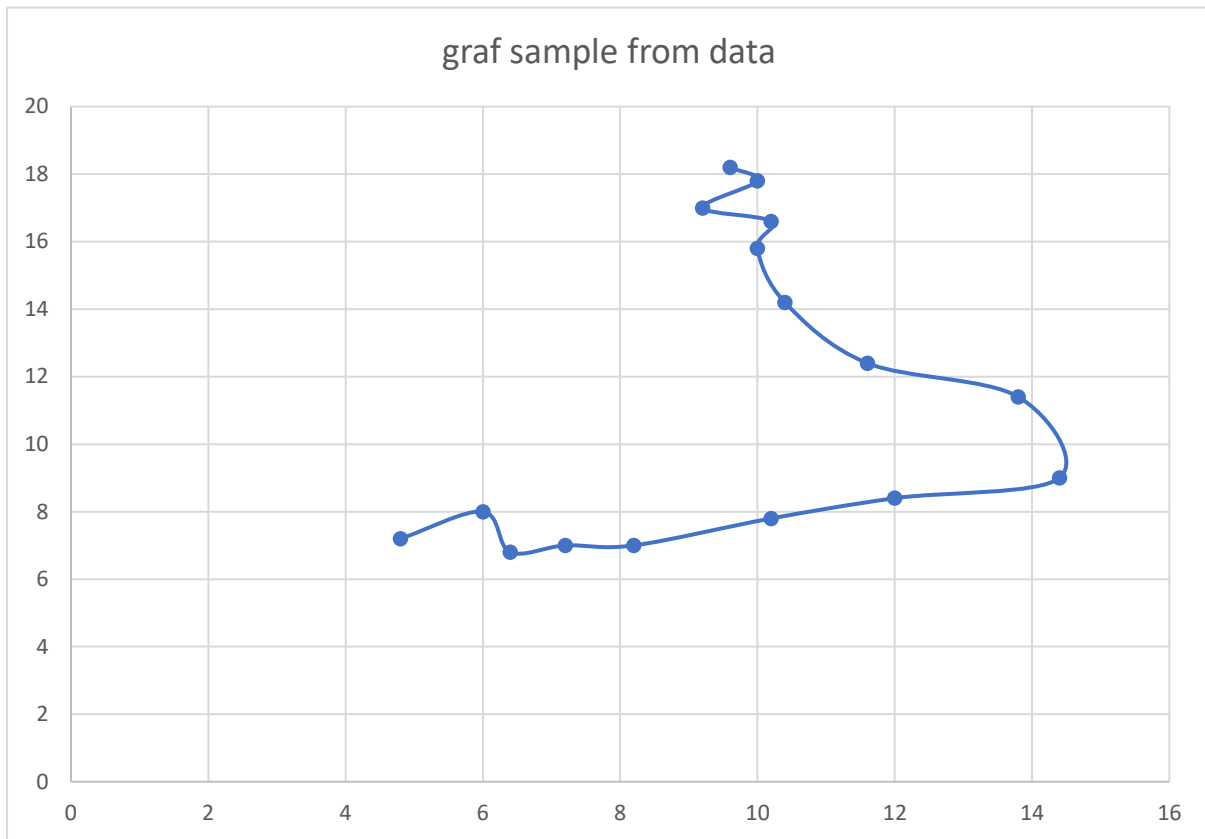
Figure 3.1 graph of the map route
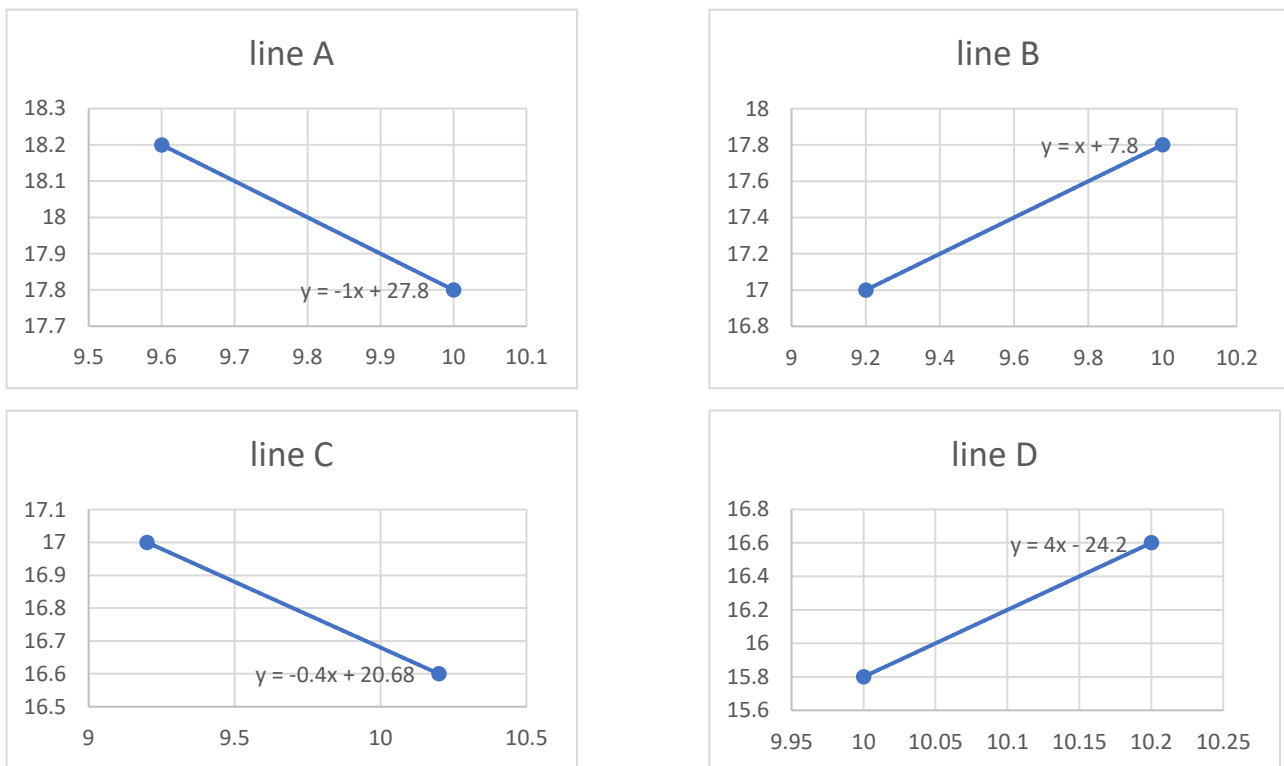
Figure 3.2 segment of the graph line A,B,C and D
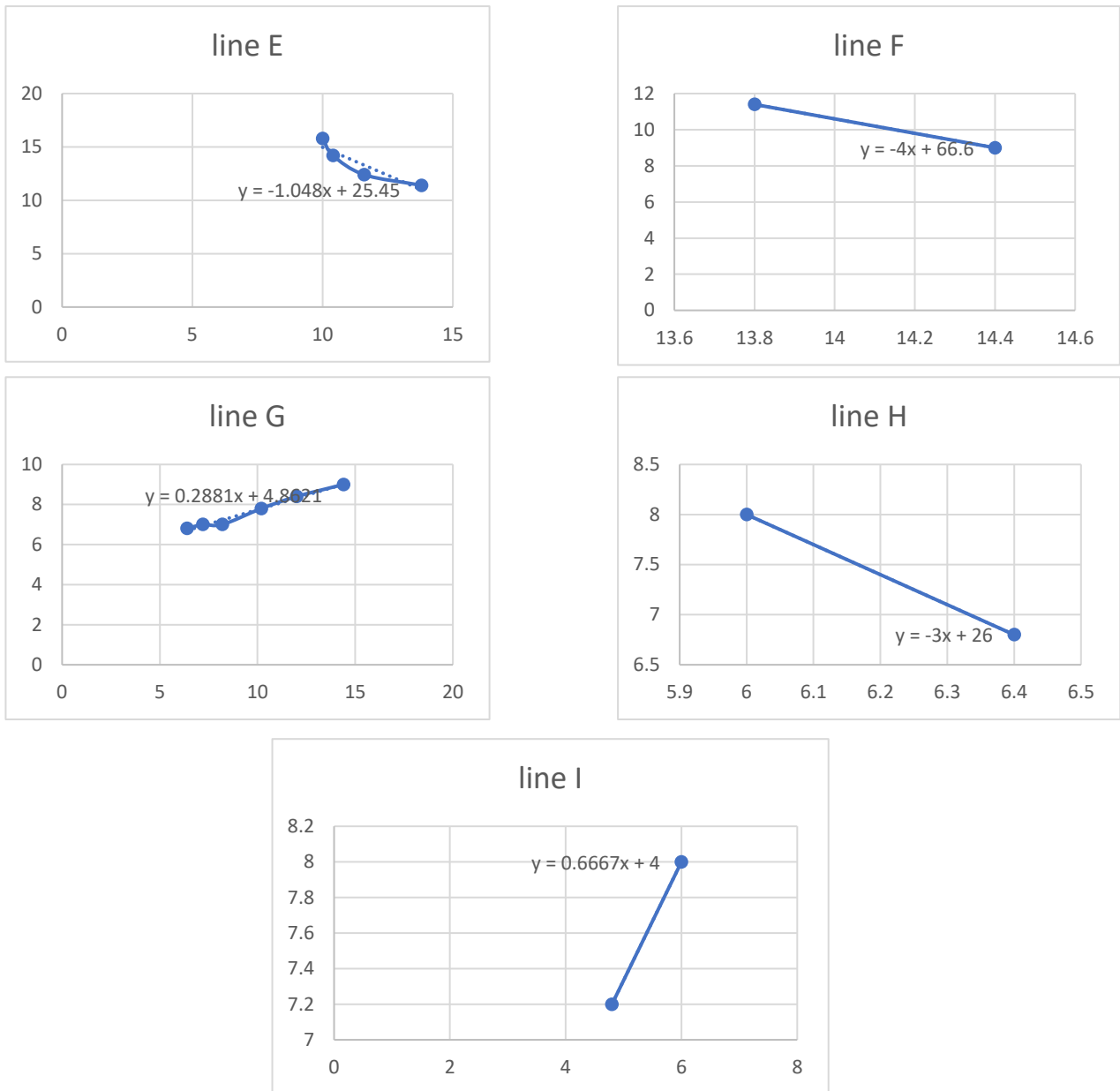
Figure 3.3 segment of the graph line E,F,G,H and I

3.3 list of all the equation to used in the calculations

There are nine equations in total, this is because we have segmented the original graph into nine segments. The list of equations are as follows :-

A. $y = -x + 27.8$
B. $y = x + 7.8$
C. $y = -0.4x + 20.68$
D. $y = 4x - 24.2$
E. $y = -1.048x + 25.45$……E1 used as main equation
F. $y = -4x + 66.6$
G. $y = 0.2881x + 4.8623$……G2 used as main equation
H. $y = -3x + 26$
I. $y = 0.6667x + 4$

this is the next equations that will also be used for comparative analysis later on :-

    A. $y = 0.4417x^2 - 11.606x + 87.463$, E2

    B. $y = 0.0066x^3 + 0.2118x^2 - 1.8841x + 11.95$, G2

The equations shown are all obtain via the trendline function within Excel's list of useable functions. All the equations are in the form of parametric equations that have combined x(t) and y(t) into an equation. There will also be several equations derived from physics that will also be used to further explain the effectiveness of this method. The equations that will be used is from the linear motions equation. This is to find relative speed, v and also relative acceleration.

3.4 list of all the calculation done in this research

For the calculation processes it can be done either manually or by using a calculator software. Depending on the method chosen the answer will be the same. For this research we have opt to use a calculator software to fasten the processes, since we will be repeating the calculations for several times to get the parametric arc length of each graphs. Also for the calculation of the length it also to be noted that we will assume such that t = x since we only have the combined equation of the arc n the graph segment hence with this we will obtained the functions of x(t) and y(t).

$$t = x, and \ \frac{dx}{dt} = 1$$

This function of x(t) will be used for all the segments

For line A, $y = -x + 27.8$

$$y = -x + 27.8, t = x. Then \ y = -t + 27.8$$

$$first, \frac{dy}{dt} = -1$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2} \ dt = \int_0^2 \sqrt{(1)^2 + (-1)^2 dt} = \sqrt{2} \times (2 - 0) = 2^{\frac{3}{2}}$$

For line **B**, $y = x + 7.8$

$$y = x + 7.8, t = x. Then \ y = t + 7.8$$

$$first, \frac{dy}{dt} = 1$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2} \ dt = \int_2^5 \sqrt{(1)^2 + (1)^2 dt} = \sqrt{2} \times (5 - 2) = 3\sqrt{2}$$

For line **C**, $y = -0.4x + 20.68$

$$y = -0.4x + 20.68, t = x. Then\ y = -0.4t + 20.68$$

$$first, \frac{dy}{dt} = -0.4$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_5^8 \sqrt{(1)^2 + (-0.4)^2 dt} = \frac{\sqrt{29}}{5} \times (8-5) = \frac{3\sqrt{29}}{5}$$

For line **D**, $y = 4x - 24.2$

$$y = 4x - 24.2, t = x. Then\ y = 4t - 24.2$$

$$first, \frac{dy}{dt} = 4$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (4)^2 dt} = \sqrt{5} \times (9-8) = \sqrt{17}$$

For line E1, $y = -1.048x + 25.45$

$$y = -1.048x + 25.45, t = x. Then\ y = -1.048t + 25.45$$

$$first, \frac{dy}{dt} = -1.048$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (-1.048)^2 dt} = 17.38$$

For line E2, $y = 0.4417x^2 - 11.606x + 87.463$

$$y = 0.4417x^2 - 11.606x + 87.463, t = x. Then\ y = 0.4417t^2 - 11.606t + 87.463$$

$$first, \frac{dy}{dt} = \frac{4417t - 58030}{5000}$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (\frac{4417t - 58030}{5000})^2 dt} = 38.05$$

For line F, $y = -4x + 66.6$

$$y = -4x + 66.6, t = x. Then\ y = -4t + 66.6$$

$$first, \frac{dy}{dt} = -4$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (-4)^2 dt} = 12.37$$

For line G1, $y = 0.2881x + 4.8623$

$$y = 0.2881x + 4.8623, t = x. Then\ y = 0.2881t + 4.8623$$

$$first, \frac{dy}{dt} = 0.2881$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (0.2881)^2 dt} = 14.68$$

For line G2, $y = 0.0066x^3 + 0.2118x^2 - 1.8841x + 11.95$

$$y = 0.0066x^3 + 0.2118x^2 - 1.8841x + 11.9, t = x. Then\ y = 0.0066t^3 + 0.2118t^2 - 1.8841t + 11.9$$

$$first, \frac{dy}{dt} = \frac{198t^2 - 4236t + 18841}{10000}$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (\frac{198t^2 - 4236t + 18841}{10000})^2 dt} = 30.28$$

For line H, $y = -3x + 26$

$$y = -3x + 26, t = x. Then\ y = -3t + 26$$

$$first, \frac{dy}{dt} = -3$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (-3)^2 dt} = 3.16$$

For line I, $y = 0.6667x + 4$

$$y = 0.6667x + 4, t = x. Then\ y = 0.6667t + 4$$

$$first, \frac{dy}{dt} = 0.6667$$

$$L = \int_a^b \sqrt{(\frac{dy}{dt})^2 + (\frac{dx}{dt})^2}\ dt = \int_8^9 \sqrt{(1)^2 + (0.6667)^2 dt} = 1.201$$

For the total length of the parametric arc is the sum of all the graph segments. This means that for this we need to apply the formula, $\sum A + B + C + D + E + F + G + H + I$. Hence with this we will get the total sum.

- For the sum using E1 and G1 we will get,

$$L = \sum A + B + C + D + E + F + G + H + I \approx 63.23cm$$

- For the sum using E2 and G2 we will get,

$$L = \sum A + B + C + D + E + F + G + H + I \approx 99.50 cm$$

Both of the sum are in units of centimetres and should be change according to the scale that we have set from the hand drawn graph which is 2cm : 1km. This will give us the total length of the parametric arc for sum using E1 and G1, 31.615km and for the one using E2 and G2, 49.75km respectively.

Moving on, the next part is the calculation for the cars velocity and acceleration. For this part we can use the equation of velocity, v which is change of distant over time. We will also use the equation for acceleration, a which is change of velocity over time. This calculations are to estimate the length of segments to further be discuss later on.

$$v = \frac{x}{t}, a = \frac{v}{t}$$

From the data taken before on the time interval of the point plotted on the graph the average velocity of the car is 90km/h. hence using that with the amount of time per interval we get for line A is 3km and we can also apply this to all other segment for such line B is 4.5km and so on. For acceleration it is mainly used to measure the acceleration or declaration of the car for such that the difference between different point of interval will get different acceleration.

3.5 list of all the calculation for error done in this research

Calculation for error is done to look for any deviations within the calculation with the real life data. In this research we have calculated the error between experimental data and also real life data which is the length of the parametric arc. The equations for this theoretical value minus the real value over real value times 100%.

$$percentage\ error = \frac{theoritical\ value - original\ value}{original\ value}\ (100\%)$$

$$percentage\ error = \frac{31.62 - 26.1}{26.1}\ (100\%) = 21.13\%$$

This value is for when using E1 and G1

$$percentage\ error = \frac{99.5 - 26.1}{26.1}\ (100\%) = 281.23\%$$

This value is for when using E2 and G2

4. DISCUSSION

4.1 explanation on findings

For the discussion part of this research we will review back on what findings we have obtain from the calculations and also explain the reasoning behind how we obtain the final answer. Since there are also deviation within the final answer and the original length, we will also address this.

To look back on the result from the graph we can see that the graph made with a reference to the map is more of a mixed of curves. This can be interpreted to such we can assume that the graph will have a very complex function. The reason it has this complexity to it is because the curves itself is not in a shape that we normally would fine. An average graph that we will usually encounter are either in the several that have simple functions such as a linear, power, logarithmic, exponential and more. This type of graph would usually have a simple shape either being wavelike or just a curve. Since the graph obtain does not meet this requirement we will need to segment it hence the nine segments gotten from the original graph. This step is simply done to simplify the function for the set graph and in turn will ease the calculation.

Moving on, the table that we obtain is to show corelation between the time variable with the axis data. This corelation is here because the graph obtain is a parametric graph. Because of this we use the parametric arc length equation to calculate the length of the curve, this equation has been stated before in both the introduction and the calculation section.

Next, is the reason why the segmented graphs have the equation that it has. The graph segment obtained is based on the trendline function, this means that the function is made with the format that is inside the trendline function. In the format we can select from different type of trendlines, since we would like to make calculation easier we chose the trendline format that have the best fit with the graph segment and also gives us a suitable equation to be use. Henceforth this is the reason why equation obtained from the graph segment is like that.

4.2 explanation on findings errors

There are two different equations for line E and G, which is E1,E2,G1 and G2. The difference is because the line E1 and G1 are a more simple function since it is only linear but on the other hand the line E2 and G2 are non linear, also they are quadratic and quartic function. This will show two different answers if integrated. Hence the different parametric arc length obtain from calculation. We can see that by using the line E1 and G1 will result in a smaller length but it is the opposite for when we use line E2 and G2. The difference is quit significant with a difference of 36.2 cm or 18.1 km deviation with scale to the graph based on the real life route. The deviation of length is due to the larger segment of line E2 and G2. To note that when using line E2 and G2 there is no segment for line H and I because the two line are already in line E2 and G2.

Furthermore, we can see that the final parametric arc length obtain via the calculation have some error to it. The error between the calculated value and the real value is 21.13% when using line E1 and G1, and 281.23% when using line E2 and G2. These error are obtain because there are different integrated values obtain, to also add that the trendline lines from the segment line E2 and G2 are not really close enough to the segments. This will contribute to increase in length calculated due to the inaccurate trendline place on the segmented graphs. This is also the reason for the percentage error of 21.13% in the value due to the slight inaccuracy of the trendline graphs. These slight difference in trendline graph on Excel will have an inevitable error due to the limited format of trendline in Excel. Hence to get a more accurate length the segment on the graphs needs to be increase since it is proven

that if there are more segment to the graph the result will become more accurate. This can be compared because the use of line E1,G1,E2 and G2. From these lines we see that when we use nine segments the error is 21.13% but when we use seven segment the error is 281.23%, this makes a trend that shows the more segment the graph is separated to the more accurate the calculated parametric arc length becomes. This is true because in mathematics we have see several graph made on the cartesian plane that follows this trend. It is known that whenever a graph is separated in rectangular shapes to an infinite number the area of the graph can be calculated, this is known as a concept of limit. Hence using appropriate assumption we can say that when using Excel to calculate parametric arc length the more segment we break the original graph into, the more accurate the calculated value will become. Albeit the more the segments the more time will be consumed to calculate it.

Moving on, we can also analysis the accuracy of the result calculated using simple physics. Since there are relationships between parametric equations in both physics and math. To further explain let us understand that in physics we can calculate the speed or velocity of an object by having it's distance dived by time taken to get to set distance. This is just a basic equation of speed, but of course there are more equation that can be use to measure this variable. For such using kinematics equation and applying Newtonian law will provide us with a plethora of equation to be used just to find velocity.

In this case we use velocity to estimate the distance taken by the car used to take the data for time variable in the graph. Let us assume the car is moving at a constant velocity with no acceleration and other forces acting upon it. This means we ignore drag and also other mechanical forces such as friction within the system of the car. We can get the distance of all the segments of the graph but for this let just find the distance for one. Stated before the line segment B yields a distance of 4.5 km when the car move with velocity of 90 km/h with all the limitation stated before. Comparing this with the calculated value we get which is $3\sqrt{2} = 4.24 \; cm$ or 2.12 km which get about half the value gotten from using velocity. This does look like it is a huge difference but bear in mind that the velocity calculation does not account for other things such as traffic, human error in driving, road condition and most importantly the route. The velocity only accounts for a straight line and does not account for any curves. But the velocity calculation provides us with better understanding on how the number should look like. We need to understand that the time variables all are taken at the mercy of the environment during the data collecting stage, hence this shows that the parametric arc length calculated can be more accurate if paired with distant measurement using velocity calculations. Mainly to compare and give us a somewhat grasp on what the value range should be like.

4.2 explanation on other findings errors

Finally, we will discuss on the other sources of error within this research. As we all know every experiment there is no absolute perfect result, this means that there is means of variance in the resulting findings with a reciprocating alignment with the data. From this research we have secluded some reasons on the errors made during the whole process of making this research.

Firstly, the most easily look upon reason is human error. This error is something that cannot be avoided and can only be reduced by means of repetitions or cross correction. From this research we say that this error can be track down during data collecting stage where the individual that is task with takin the time might mistakenly taken a small time difference. There also might be an error during graphing the hand drawn graph with the plotted points.

Secondly, we can say that there might be parallax error during data transfer when trying trace the plotted points on the hand drawn graph to a table. This miss tabulation can also be a source of error while using this method to calculate the parametric arc length of the graph.

Finally, there can be mechanical error within the process. This error might arise form the software used during the process of both calculating and making segments in Excel. This is because the trendline might look the same for two different trendline format but this will give different equations for the graph.

5. CONCLUSION

To conclude this research we can say that using Excel as an aid to calculate parametric arc length is a liable method to be used. This is because the method shown have proven to be useful to find equations for complex graphs but also is able to make use of a simple system that is provide by Microsoft Excel. This system focus more on simple math rather that complex math, which means people that have learn integration can use this method. Although there are still improvement that should be made for the process but the method as of now should suffix as an alternative method to be used in calculating parametric arc length. The improvement that we recommend to be asses in the future is on trying to maximize the trendline ability and also trying to find a way to make segmenting the graph easier.

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