Research Article

AccelSquare: Acceleration of a Movement at Non-linear Areas Estimator for Teaching and Learning Processes

Aina Zulaikha Alauddin [1], Nurrin Shafiya Shaharin [2], Nurzalina Harun [3], Zubaidah Sadikin [4], Sidik Rathi [5], Nur Zafirah Mohd Sidek [6], Siti Rahimah Batcha [7], and Mohd Agos Salim Nasir [8]

1 Universiti Teknologi MARA Shah Alam; 2023379931@student.uitm.edu.my; 0009-0009-0485-447X
2 Universiti Teknologi MARA Shah Alam; 2023375625@student.uitm.edu.my; 0009-0001-1225-9963
3 Universiti Teknologi MARA Shah Alam; nurzalina@tmsk.uitm.edu.my; 0000-0003-0477-580X
4 Universiti Teknologi MARA Shah Alam; zubaidah1590@uitm.edu.my 0000-0003-3967-5243
5 Universiti Teknologi MARA Shah Alam; sidik8423@uitm.edu.my; 0000-0002-6408-3920
6 Universiti Teknologi MARA Shah Alam; nurzafirah@uitm.edu.my; 0009-0004-8657-8053
7 Universiti Teknologi MARA Shah Alam; rahimahbatcha@uitm.edu.my; 0009-0003-9943-9901
8 Universiti Teknologi MARA Shah Alam; mohdagos066@uitm.edu.my; 0000-0002-8761-4595

* Correspondence: rahimahbatcha@uitm.edu.my; +601140008689

Abstract: *The current research is designed to assist the calculation of acceleration of a movement at non-linear area by using Discrete Least Square Method. Hence, the purpose of producing this prototype is due to the problem faced, which is the difficulty in calculating the acceleration of a movement due to the areas in UiTM Shah Alam that is in the form of rectangular domain and hilly terrain. AccelSquare works to calculate the acceleration of a movement at any non-linear areas using the data collected. It also works to utilize parametric equations in complex calculation. This prototype has its own value in terms of new idea development. It can be used by everyone to find an acceleration of any movement at any difficult areas, such as at any rectangular domain areas or hilly terrain. Next, based on the interfaces, AccelSquare can be used in learning and teaching processes which related to any calculation of acceleration in the subject syllabus. People who involve in the learning and teaching processes can be exposed to this prototype to facilitate the processes. However, since the process of calculating the acceleration manually can be very crucial and takes a long time, this system will be served as an alternative to the user as it will make the calculation process easier and more efficient. Other than that, AccelSquare helps the student from mathematics and physics background to understand better about acceleration in real life. This prototype can be upgraded for being used in any online platform.*

Keywords: Discrete Least Square Method; AccelSquare; acceleration.

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1. INTRODUCTION

In this research, we intend to carry out the mathematical and numerical approaches for computing the acceleration of a movement. Acceleration is the rate at which velocity changes with time in terms of both speed and direction. A point or an object moving in a straight line or in a circle is accelerated if it speeds up or slows down. For all other kinds of motion, both effects contribute to acceleration. (Erik Gregersen, 2023)

The goal of this research is to build a working prototype that can estimate the acceleration of a movement in non-linear areas, such as the mountainous terrain of UiTM Shah Alam. The rectangular domain, hilly terrain, and other difficult landscapes can make it difficult to calculate the acceleration in a non-linear area. The existence of this prototype makes it possible to calculate the acceleration of any movement in all the challenging areas without difficulty. However, we must conduct a research study first, such as trial and error, to determine the ideal prototype, which requires calculating the acceleration of a movement in order to produce an effective and ideal prototype. The main objective of this research is to calculate and find the acceleration of the prototype.

2. METHOD & MATERIAL

Firstly, the making of AccelSquare requires many materials and methods. The first materials that will be needed are a map application and paper. The map application, such as 'Strava' or 'Waze', is for tracking live performance data such as distance, speed, velocity, and also the route map of anywhere that the user goes. A paper is for the user to jot down the data that has been analysed from the map application. After the complete data has been identified and collected, the user can calculate the data using the least squares method. The least squares method is a form of mathematical regression analysis used to determine the line of best fit for a set of data, providing a visual demonstration of the relationship between the data points. Each point of data represents the relationship between a known independent variable and an unknown dependent variable. (Kenton, 2023) In addition, graph paper has also been used to compute a graph of time versus velocity from the data that has been collected before.

Figure 1 shows the flowchart of our research on experimenting and building our prototype, which is AccelSquare. Next, figure 2 shows a screenshot of the map application that we used to trace our route to where we were going. Figure 3 shows the first interface of our prototype, AccelSquare. From there, we need to press the start button to start the prototype. Figure 4 shows the second interface of AccelSquare. It needs the user to key in the required inputs, such as time, distance, and velocity, that they have collected, and then press the Calculate Acceleration button to calculate the acceleration. Lastly, figure 5 shows the last interface of our prototype, AccelSquare, that will display the calculated acceleration, and the user can press the Back button to return to the previous interface or the Exit button to exit AccelSquare.

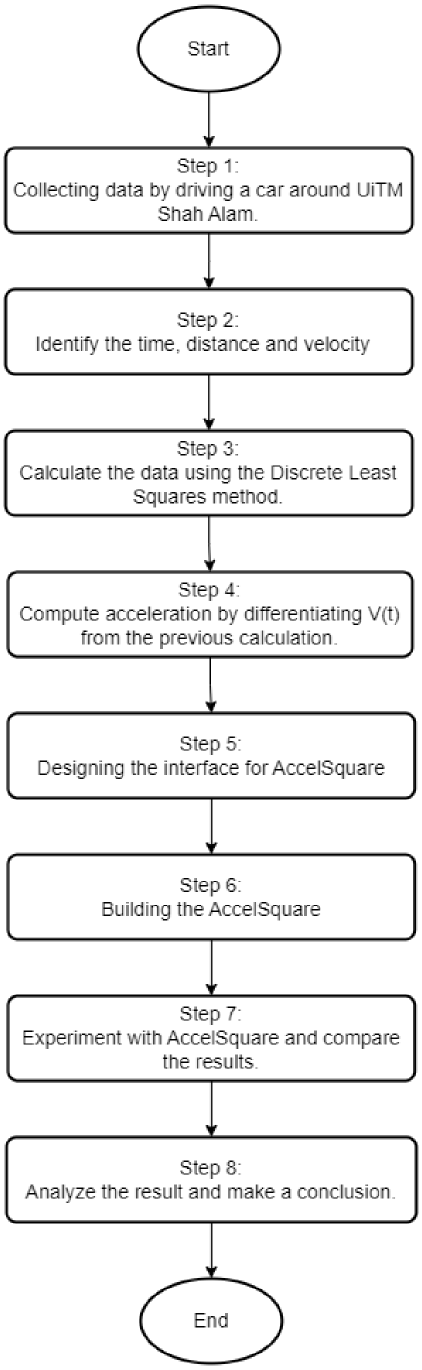

Figure 1: Flowchart Of AccelSquare

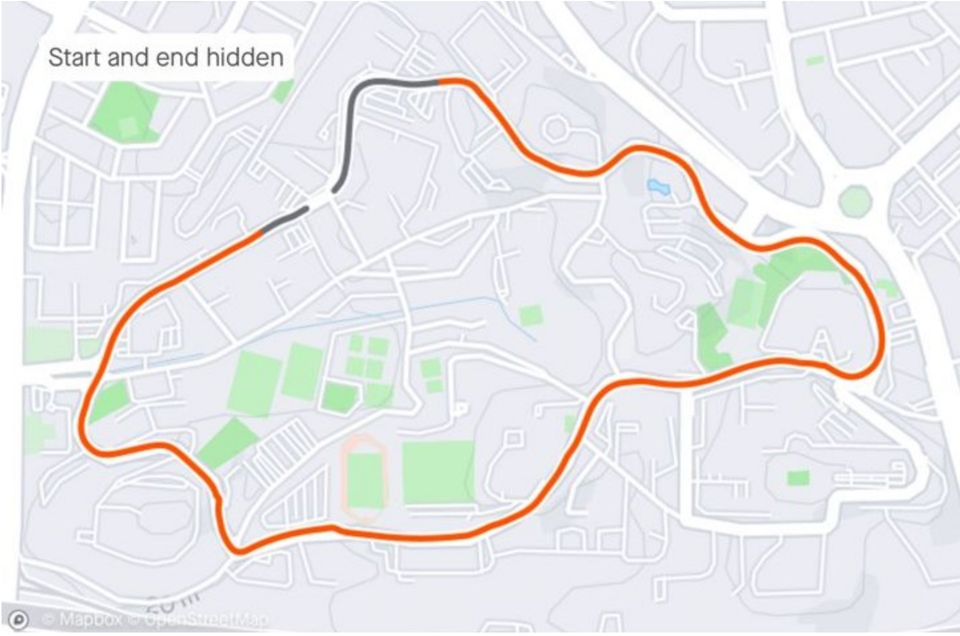

Figure 2: Route Map of UiTM Shah Alam

Figure 3: First Interface of AccelSquare

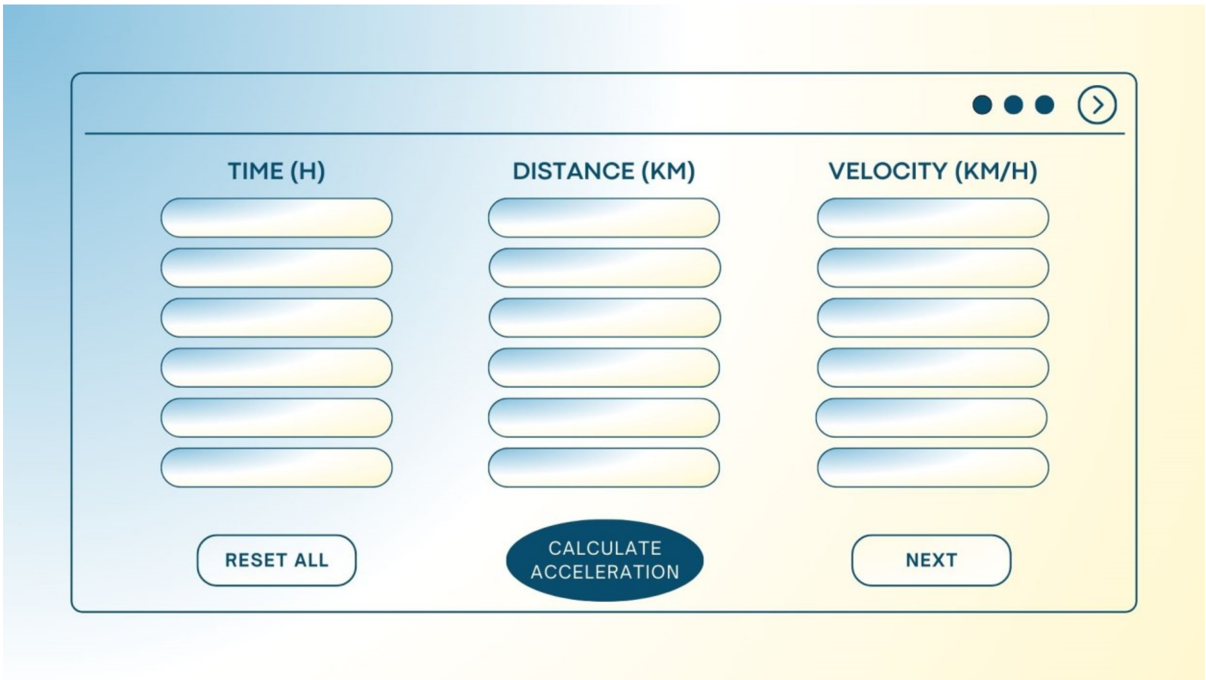

Figure 4: Second Interface of AccelSquare

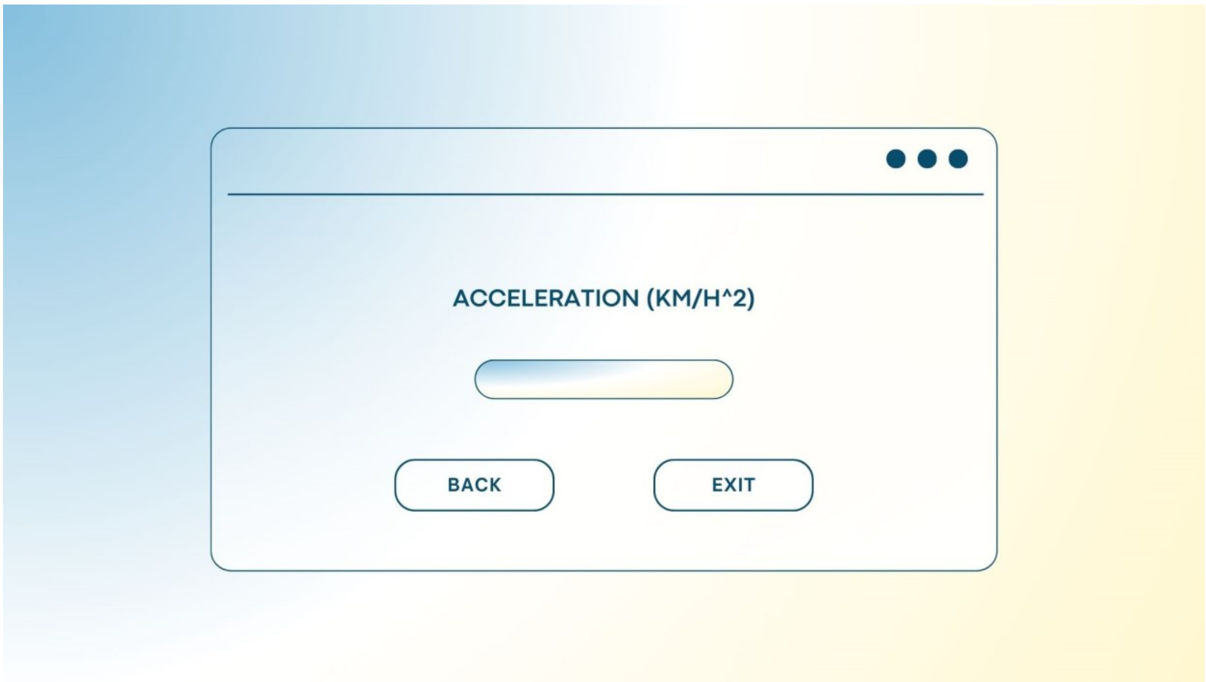

Figure 5: Last Interface of AccelSquare

3. FINDINGS

3.1 Table of Data Collected

Table 1 below shows the data that has been collected manually throughout the research.

Table 1: Data collected

Time (h)	0.0000	0.0167	0.0333	0.0500	0.0667	0.0833	0.1000	0.1167	0.1333	0.1500	0.1667	0.1833	0.2000
Distance (km)	0.00	0.30	0.25	0.36	0.26	0.47	0.23	0.34	0.33	0.50	0.50	0.19	0.13
Velocity (km/h)	0.00	14.00	17.00	23.00	31.00	13.00	33.00	9.00	25.00	25.00	35.00	18.00	34.00

3.2 Graph

Figure 6 shows graph of time versus velocity that we have computed from the data collected.

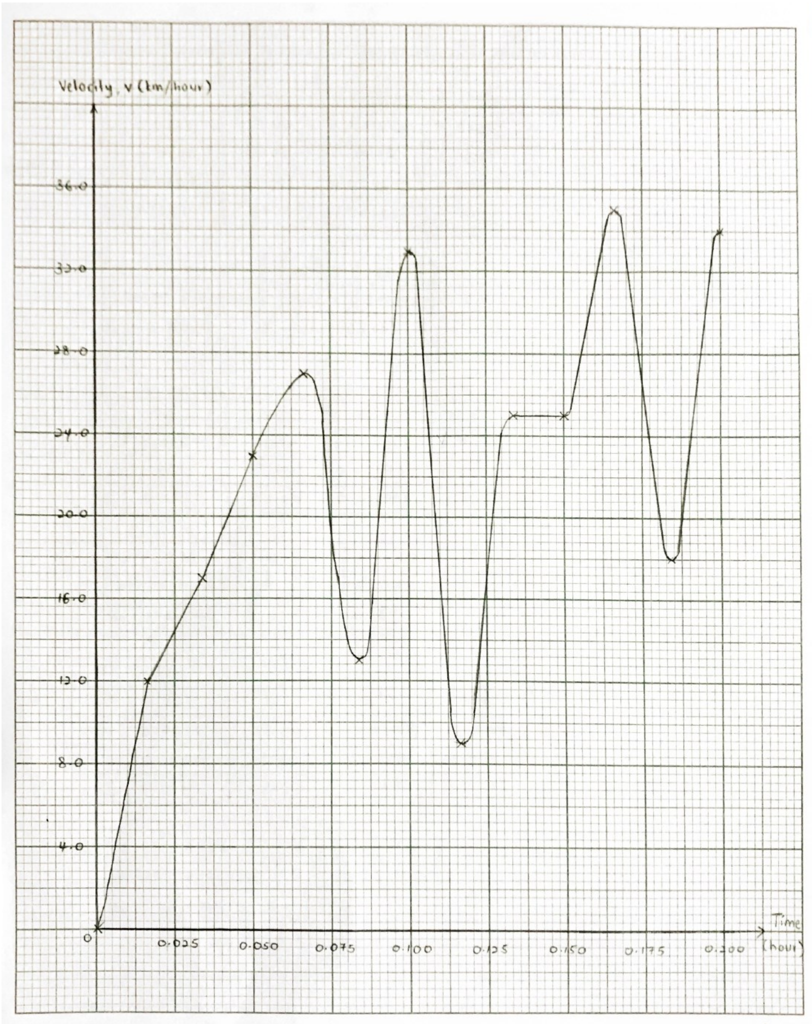

Figure 6: Graph of Time versus Velocity

3.3 Calculation

i	t	v	t^2	t^3	t^4	$t_i v_i$	$t_i^2 v_i$
1	0	0	0	0	0	0	0
2	0.0167	12.00	0.00027889	0.00000466	0.00000008	0.2004	0.00334668
3	0.0333	17.00	0.00110889	0.00003693	0.00000123	0.5661	0.01885113
4	0.0500	23.00	0.00250000	0.00012500	0.00000625	1.1500	0.05750000
5	0.0667	31.00	0.00444889	0.00029674	0.00001979	2.0677	0.13791559
Σ	**0.1667**	**83.00**	**0.00833667**	**0.00046333**	**0.00002735**	**3.9842**	**0.2176134**

$$\begin{bmatrix} 5 & 0.1667 & 0.00833667 \\ 0.1667 & 0.00833667 & 0.00046333 \\ 0.00833667 & 0.00046333 & 0.00002735 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} 83.00 \\ 3.9842 \\ 0.2176134 \end{bmatrix}$$

$$a_0 = 0.9897,\ a_1 = 558.8742,\ a_3 = -1812.8236$$

$$\mathrm{v}_1(\mathrm{t}) = 0.9897 + 558.8742\mathrm{t} - 1812.8236\mathrm{t}^2$$

$$\frac{d\mathrm{v}_1(\mathrm{t})}{d\mathrm{t}} = 558.8742 - 1812.8236t$$

i	t	v	t^2	$t_i v_i$
1	0.0667	31.00	0.00444889	2.0677
2	0.0833	13.00	0.00693889	1.0829
Σ	**0.1500**	**44.00**	**0.01138778**	**3.1506**

$$\begin{bmatrix} 2 & 0.1500 \\ 0.1500 & 0.01138778 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 44 \\ 3.1506 \end{bmatrix}$$

$$a_0 = 103.3253,\ a_1 = -1084.3373$$

$$\mathrm{v}_2(\mathrm{t}) = 103.3253 - 1084.3373\mathrm{t}$$

$$\frac{d\mathrm{v}_2(\mathrm{t})}{d\mathrm{t}} = -1084.3373$$

i	t	v	t^2	$t_i v_i$
1	0.0833	13.00	0.00693889	1.0829
2	0.1000	33.00	0.01000000	3.3000
∑	**0.1833**	**46.00**	**0.01693899**	**4.3829**

$$\begin{bmatrix} 2 & 0.1833 \\ 0.1833 & 0.01693899 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 46 \\ 4.3829 \end{bmatrix}$$

$$a_0 = -86.6818,\ a_1 = 1196.7466$$

$$v_2(t) = -86.6818 + 1196.7466t$$

$$\frac{dv_2(t)}{dt} = 1196.7466$$

i	t	v	t^2	$t_i v_i$
1	0.1000	33.00	0.01000000	3.300
2	0.1167	9.00	0.01361889	1.0503
∑	**0.2167**	**42.00**	**0.02361889**	**4.3503**

$$\begin{bmatrix} 2 & 0.2167 \\ 0.2167 & 0.02361889 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 42 \\ 4.3503 \end{bmatrix}$$

$$a_0 = 176.7126,\ a_1 = -1437.1257$$

$$v_2(t) = 176.7126 - 1437.1257t$$

$$\frac{dv_2(t)}{dt} = -1437.1257$$

i	t	v	t^2	$t_i v_i$
1	0.1167	9.00	0.01361889	1.0503
2	0.1333	25.00	0.01776889	3.3325
Σ	**0.2500**	**34.00**	**0.03138778**	**4.3828**

$$\begin{bmatrix} 2 & 0.2500 \\ 0.2500 & 0.03138778 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 34 \\ 4.3828 \end{bmatrix}$$

$$a_0 = -103.4819,\ a_1 = 963.8554$$

$$v_2(t) = -103.4819 + 963.8554t$$

$$\frac{dv_2(t)}{dt} = 963.8554$$

i	t	v	t^2	$t_i v_i$
1	0.1333	25.00	0.01776889	3.3325
2	0.1500	25.00	0.02250000	3.7500
Σ	**0.2833**	**50.00**	**0.04026889**	**7.0825**

$$\begin{bmatrix} 2 & 0.2833 \\ 0.2833 & 0.04026889 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 50 \\ 7.0825 \end{bmatrix}$$

$$a_0 = 25,\ a_1 = 0$$

$$v_2(t) = 25 + 0t$$

$$\frac{dv_2(t)}{dt} = 0$$

i	**t**	**v**	**t^2**	**$t_i v_i$**
1	0.1500	25.00	0.02250000	3.7500
2	0.1667	35.00	0.02778889	5.8345
Σ	**0.3167**	**60.00**	**0.05028889**	**9.5845**

$$\begin{bmatrix} 2 & 0.3167 \\ 0.3167 & 0.05028889 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 60 \\ 9.5845 \end{bmatrix}$$

$$a_0 = -64.8204, a_1 = 598.8024$$

$$v_2(t) = -64.8204 + 598.8024t$$

$$\frac{dv_2(t)}{dt} = 598.8024$$

i	**t**	**v**	**t^2**	**$t_i v_i$**
1	0.1667	35.00	0.02778889	5.8345
2	0.1833	18.00	0.03359889	3.2994
Σ	**0.3500**	**53.00**	**0.06138778**	**9.1339**

$$\begin{bmatrix} 2 & 0.3500 \\ 0.3500 & 0.06138778 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 53 \\ 9.1339 \end{bmatrix}$$

$$a_0 = 205.7169, a_1 = -1024.0964$$

$$v_2(t) = 205.7169 - 1024.0964t$$

$$\frac{dv_2(t)}{dt} = -1024.0964$$

i	**t**	**v**	**t^2**	**$t_i v_i$**
1	0.1833	18.00	0.03359889	3.2994
2	0.2000	34.00	0.04000000	6.8000
Σ	**0.3833**	**52.00**	**0.07359889**	**10.0994**

$$\begin{bmatrix} 2 & 0.3833 \\ 0.3833 & 0.07359889 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \end{bmatrix} = \begin{bmatrix} 52 \\ 10.0994 \end{bmatrix}$$

$$a_0 = -157.6168,\ a_1 = 958.0838$$

$$\mathrm{v_2(t)} = -157.6168 + 958.0838\mathrm{t}$$

$$\frac{\mathrm{dv_2(t)}}{\mathrm{dt}} = 958.0838$$

4. DISCUSSION

After obtaining the data, we start creating the graph based on the data we get. The x-axis represents time in hours, while the y-axis represents velocity in kilometres per hour. From the graph, we partition it into nine segments. Then, we applied the Discrete Least Squares method to derive the functions of velocity, V(t), for each segment. After we obtain the equations of velocity for each segment, we can differentiate each of them to get the acceleration. Clearly, in this case, we divided it into nine sections to reduce errors and create more precise calculations.

Furthermore, this prototype possesses three interfaces that are designed for the users to use. First of all, users can start the acceleration calculation by pressing the start button at the beginning. Then, they can insert the data that has been obtained into the space provided. All the data must be in the right unit. By pressing the next button, the prototype will automatically compute the acceleration based on the discrete least squares formula. The acceleration value we get from this prototype is more accurate than the manual calculation.

5. CONCLUSION

To sum up, the production of this prototype is to simplify the process of calculating the acceleration of a movement in non-linear areas, such as rectangular domain areas, hilly terrain, and other difficult landscapes, by using the Discrete Least Square Method. It works as a beneficial and productive device for everyone, especially students and educators, as it can be used in teaching and learning processes. Moreover, the prototype can be accessed easily on an online platform by anyone. This prototype will work as guidance to make a better improvement for any other mathematical calculation. Ultimately, a prototype named AccelSquare is successfully designed for calculating the acceleration of a movement in any non-linear area.

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