Research Article

i-Swift: Newton Forward Divided Difference Interpolation-Distance and Time Arrival Calculator for Teaching and Learning Processes

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Abstract: *i-Swift was designed to assist the public navigate and manage logistics industries. People often struggle with estimating travel distances based on the time taken, especially during exercise routines, outdoor activities, or daily commutes. The lack of a fast and accurate method to calculate distance from elapsed time hampers individuals' ability to monitor progress, plan activities, and make informed decisions about their physical movement. Nevertheless, calculating the optimum distance may be tedious and error-prone due to doing it manually. As a solution, with this graphical user interface (GUI), referred to as i-Swift, it can help to improve travel and commuting experience by estimating the distance using The Newton Forward Divided Difference Interpolation Formula. i-Swift also assists to determine the mathematical equations for providing instant, accurate distance estimates. This app takes the complexity out of distance calculations, utilizing the Newton Forward Divided Difference Interpolation Formula to swiftly determine distances based on time. i-Swift presents an innovative solution catering to both the public and the logistics sectors. By simplifying travel for the public, it eliminates hurdles, ensuring stress-free journeys. i-Swift enables logistics firms to improve their operations, promoting punctuality in deliveries and cutting operational expenses. Furthermore, educators and researchers in logistics, mathematics, and technology can benefit from i-Swift, offering applications for academic exploration.*

Keywords: i-Swift, Newton.

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1. INTRODUCTION

In the fast-paced landscape of today's society, accurately gauging travel distances based on time has emerged as a significant challenge. Whether individuals are planning their daily fitness routines, coordinating outdoor events, or strategizing optimal commuting routes, having a swift and precise method for distance calculations is paramount. Traditional manual methods, prone to errors and time-consuming processes, hinder efficient planning and decision-making (Prentow et al , 2014).

This challenge extends into the realm of business, particularly in transportation and logistics, where selecting the most efficient route isn't just about cost-effectiveness. It's also about reducing environmental impact. Recognizing these complexities, i-Swift has emerged as a transformative solution. i-Swift mainly used Newton Forward Divided Difference Interpolation Formula to calculate distance function. Interpolation is a method used to guess or estimate values of one thing based on known values of something else (Anshul Dubey & Rajan Singh, 2020). i-Swift presents a sophisticated yet user-friendly graphical interface. It simplifies the intricate process of distance estimation, empowering individuals, and industries alike with seamless and accurate tools for decision-making (Dass, Arul & Dhanapal, M. ,2018).

By employing i-Swift, we not only streamline our daily activities but also enhance the operational efficiency of businesses. Beyond the immediate benefits of time and cost savings, i-Swift contributes to environmental conservation by optimizing routes and reducing fuel consumption. In a professional context where precision and efficiency are paramount, i-Swift stands as a testament to innovation. It embodies a harmonious fusion of advanced technology and practical utility, ensuring informed decision-making and a reduced ecological footprint. As we navigate the complexities of our modern world, i-Swift emerges as a professional ally, simplifying complex tasks, optimizing resources, and fostering a sustainable future. (Chakrabarty, Dhritikesh. ,2017).

2. METHOD & MATERIAL

Method:

1. Data Preparation: Gather a set of data points t_i where t_i are time intervals (minutes) and the independent variables, and d_i are distance traveled (km) and the corresponding dependent variables.
2. Divided Differences: Calculate the divided differences using the given data points. Divided differences represent the rate of change between points.

$$d(t_i, t_{i+1}, t_{i+2}, \dots, t_{1+k-1}, t_{i+k}) = \frac{d(t_{i+1}, t_{i+2}, \dots, t_{i+k}) - d(t_i, t_{i+1}, \dots, t_{i+k-1})}{t_{i+k} - t_i}$$

3. Interpolating Polynomial: Construct the interpolating polynomial using the Newton Forward Divided Difference Formula. This polynomial estimates, d (distances traveled) values for any given t (time interval).

$$d_n(t) = d(t_0) + d(t_0, t_1)(t - t_0) + d(t_0, t_1, t_2)(t - t_0)(t - t_1) + \cdots + d(t_0, t_1, t_2, \dots, t_n)(t - t_0)(t - t_1)(t - t_2) \dots (t - t_{n-1})$$

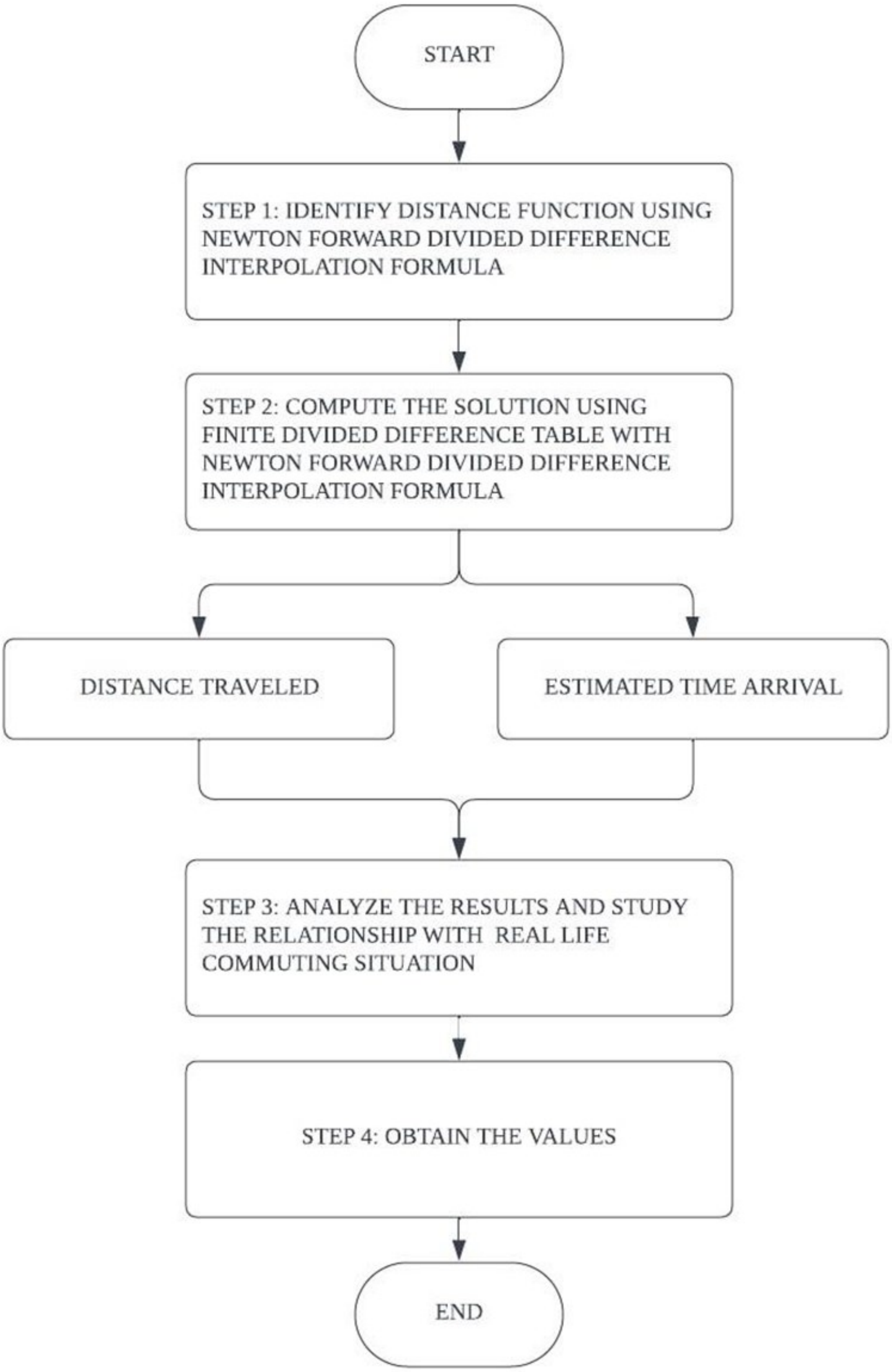
4. Evaluation: Use the polynomial to estimate d (distances traveled) values for specific t (time interval) values.

Materials:

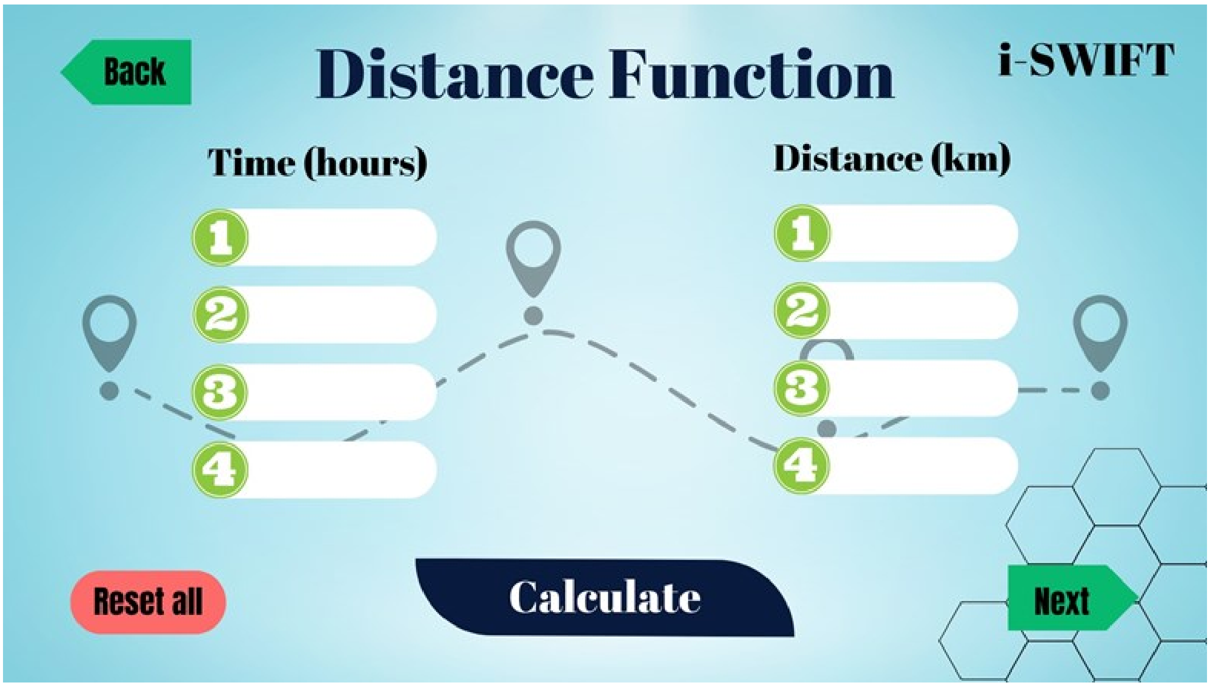
1. Data Points: Set of (t_i,d_i) data points for interpolation which are time interval (minutes) and distance traveled (km)

2. Calculating Tools: i-SWIFT.

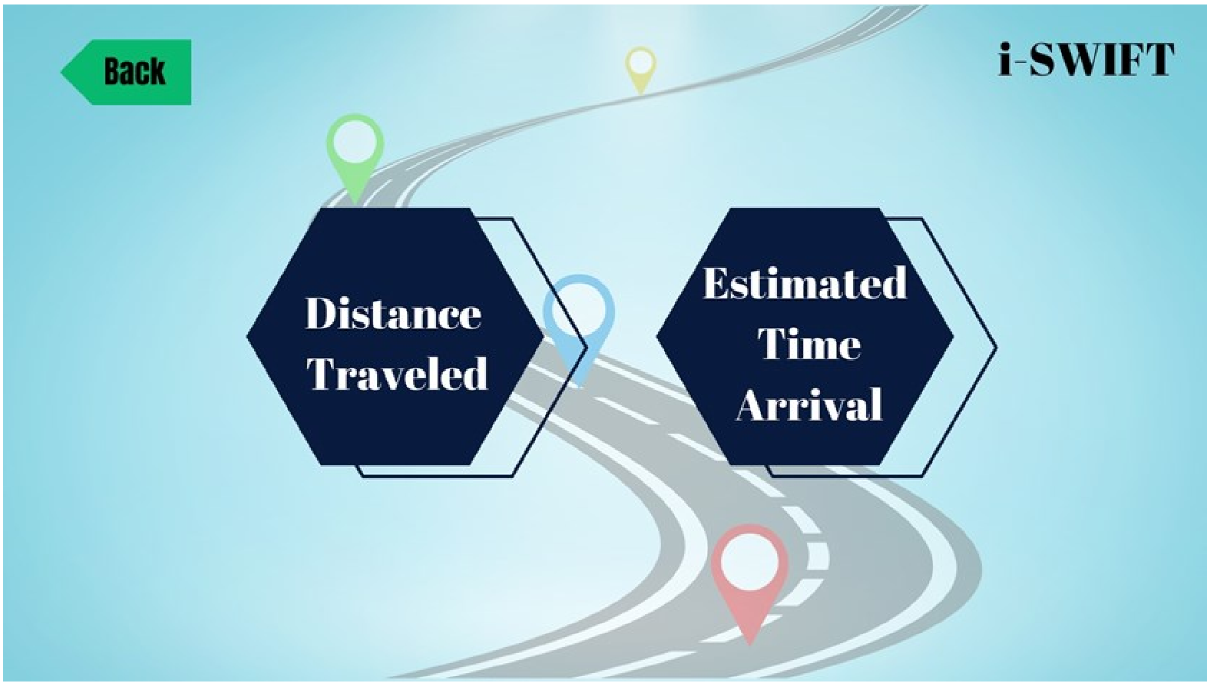
The diagrams below show the flowchart and the interfaces of i-SWIFT software prototype.



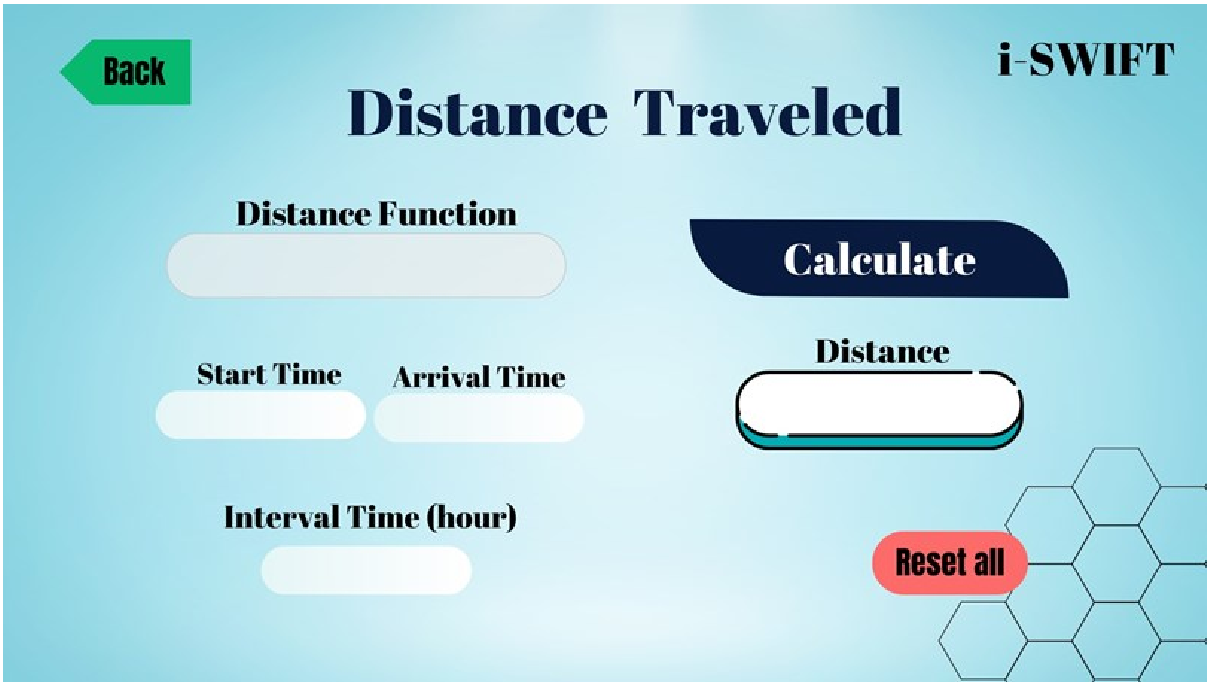
First interface: Press "Start" to start.



Second interface: User key-in the required inputs and press calculate to obtain the distance function.



Third interface: Choose to obtain the distance traveled or estimation of time arrival



Fourth interface (Distance traveled interface): Insert the distance function from the second interface together with other required inputs. Press "Calculate" to obtain the distance traveled.

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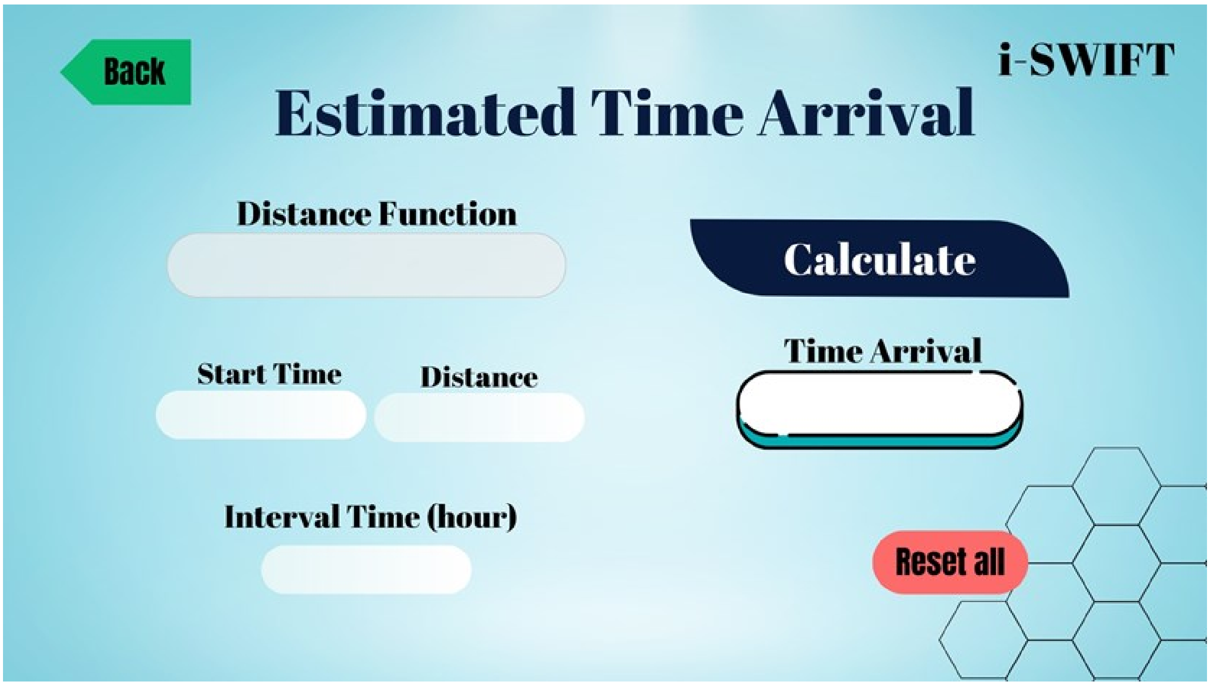

Fifth interface (Estimated Time Arrival interface): Insert the distance function from the second interface together with other required inputs. Press "Calculate" to obtain the time of arrival.

3. FINDINGS

3.1 The figures and the data for the prototype

Figure 1 displays the map of the UiTM Shah Alam bus route as depicted in the Strava application.

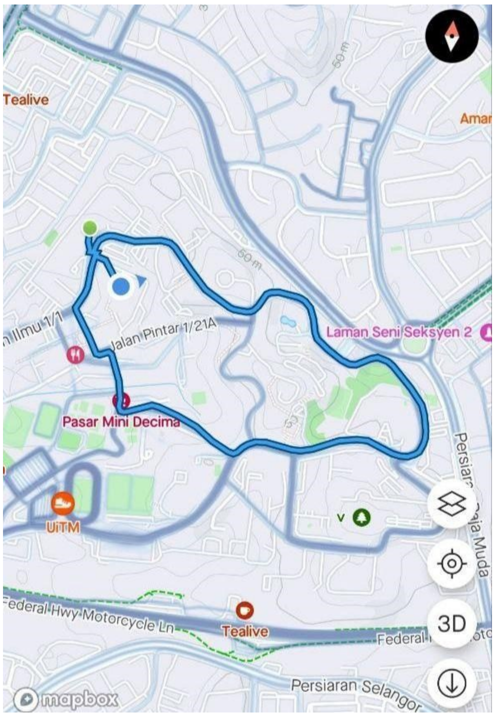

Figure 1 : UiTM Shah Alam Bus Route

Table 1 shows the successfully gathered data. Time is represented as 't' in minutes, while distance traveled is represented as 'd' in kilometers.

t(min)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
d(km)	0	0.15	0.30	0.44	0.60	0.87	1.10	1.38	1.63	1.91	2.20	2.40	2.60

Table 1

From the data collected, we construct a distance-time graph to represent the data. Figures 2 shows the graph of distance-time.

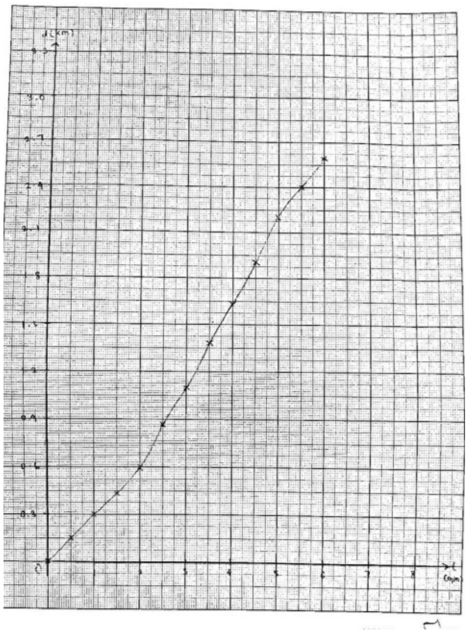

Figure 2: The graph of distance versus time based on the data collected.

3.2 Calculations for deriving the distance function

Using the 13 data points from Table 1, we aim to determine the distance function by employing the Newton Forward Divided Difference Interpolation method.

Table 1

t(min)	**0**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**	**5.5**	**6.0**
d(km)	**0**	**0.15**	**0.30**	**0.44**	**0.60**	**0.87**	**1.10**	**1.38**	**1.63**	**1.91**	**2.20**	**2.40**	**2.60**

Step 1: Construct the finite divided difference table.

T(min)	d(km)	1st DD	2nd DD	3rd DD	4th DD	5th DD	6th DD	7th DD	8th DD	9th DD	10th DD	11th DD	12th DD
0	0												
		0.30											
0.5	0.15		0										
		0.30		0.01333									
1.0	0.30		-0.02		0.01334								
		0.28		0.04		0.01066							
1.5	0.44		0.04		0.04		-0.03022						
		0.32		0.12		-0.08		0.02844					
2.0	0.60		0.22		-0.16		0.06933		-0.01772				
		0.54		-0.2		0.128		-0.04242		0.00086			
2.5	0.87		-0.08		0.16		-0.07913		0.02083		-0.00003		
		0.46		0.12		-0.1094		0.040903		-0.00087		0	
3.0	1.10		0.10		-0.1134		0.06403		-0.01817		0.00003		0
		0.56		-0.1067		0.0827		-0.03176		0.000686		0	
3.5	1.38		-0.06		0.09335		-0.04713		0.01270		-0.00002		
		0.50		0.08		-0.05868		0.01905		-0.00029			
4.0	1.63		0.06		-0.05334		0.01956		0.00047				
		0.56		-0.02667		0		0.0003					
4.5	1.91		0.02		-0.05332		0.03003						
		0.58		-0.1333		0.09001							
5.0	2.20		-0.18		0.1267								
		0.40		0.12									
5.5	2.40		0										
		0.40											
6.0	2.60												

Step 2: Determine the initial value t_0

The initial value $t_0 = 0$

Step 3: Identify the corresponding value for k^{th} divided difference.

$$d(t_0) = 0$$

$$d(t_0, t_1) = 0.30$$

$$d(t_0, t_1, t_2) = 0$$

$$d(t_0, t_1, t_2, t_3) = 0.01333$$

$$d(t_0, t_1, t_2, t_{3,} t_4) = 0.01334$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5) = 0.01066$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5, t_6) = -0.03022$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5, t_6, t_7) = 0.02844$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5, t_6, t_7, t_8) = -0.01722$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5, t_6, t_7, t_8, t_9) = 0.00086$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5, t_6, t_7, t_8, t_9, t_{10}) = -0.00003$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5, t_6, t_7, t_8, t_9, t_{10}, t_{11}) = 0$$

$$d(t_0, t_1, t_2, t_{3,} t_4, t_5, t_6, t_7, t_8, t_9, t_{10}, t_{11}, t_{12}) = 0$$

Step 4: Apply the Newton Forward Divided Difference Interpolation Formula.

$$d_n(t) = d(t_0) + d(t_0, t_1)(t - t_0) + d(t_0, t_1, t_2)(t - t_0)(t - t_1) + \cdots + d(t_0, t_1, t_2, \dots, t_n)(t - t_0)(t - t_1)(t - t_2) \dots (t - t_{n-1})$$

$$d(t) = 0 + 0.3(t - 0) + 0(t - 0)(t - 0.5) + 0.1333(t - 0)(t - 0.5)(t - 1.0)$$
$$0.01334(t - 0)(t - 0.5)(t - 1.0)(t - 1.5) + 0.01066(t - 0)(t - 0.5)(t - 1.0)$$
$$(t - 1.5)(t - 2.0) + (-0.03022)(t - 0)(t - 0.5)(t - 1.0)(t - 1.5)(t - 2.0)$$
$$(t - 2.5) + 0.2844(t - 0)(t - 0.5)(t - 1.0)(t - 1.5)(t - 2.0)(t - 2.5)(t - 3.0)$$
$$+(-0.01772)(t - 0)(t - 0.5)(t - 1.0)(t - 1.5)(t - 2.0)(t - 2.5)(t - 3.0)$$
$$(t - 3.5) + (0.0008567)(t - 0)(t - 0.5)(t - 1.0)(t - 1.5)(t - 2.0)(t - 2.5)$$
$$(t - 3.0)(t - 3.5)(t - 4.0) + 0.00003447(t - 0)(t - 0.5)(t - 1.0)(t - 1.5)$$
$$(t - 2.0)(t - 2.5)(t - 3.0)(t - 3.5)(t - 4.0)(t - 4.5) + 0.000001191(t - 0)$$
$$(t - 0.5)(t - 1.0)(t - 1.5)(t - 2.0)(t - 2.5)(t - 3.0)(t - 3.5)(t - 4.0)$$

$$(t-4.5)(t-5.0)+(-0.00000003519)(x-0)(t-0.5)(t-1.0)(t-1.5)$$
$$(t-2.0)(t-2.5)(t-3.0)(t-3.5)(t-4.0)(t-4.5)(t-5.0)(t-5.5)$$

$$d(t) = (-3.519\times 10^{-8})t^{12}+0.000002353t^{11}-0.000008283t^{10}+0.008324t^{9}$$
$$0.02912t^{8}+0.6233t^{7}-4.833t^{6}+18.01t^{5}-35.81t^{4}+38.3\ 9t^{3}-20.46t^{2}+ 4.439t$$

4. DISCUSSION

To collect data, we choose Universiti Teknologi Mara (UiTM) Shah Alam campus as reference for our project. We record the distance traveled every 30 seconds for 6 minutes. We indicated the distance covered in kilometers, while the time was measured in minutes. For convenient data collection, we utilized a mobile application named Strava to compile information regarding both distance covered and time. Throughout this process, a total of 13 data points were gathered, and based on this information, we create a distance-time graph to illustrate the data.

Subsequently, we move on to determine the distance function by creating a finite divided difference table using the data provided in Table 1. We establish the initial value t_0=0 and then proceed to ascertain the associated value for the k^{th} divided difference. Ultimately, we apply the Newton Forward Divided Difference Interpolation Formula to derive the distance function representing one complete round in UiTM Shah Alam.

Additionally, we are introducing a prototype known as i-Swift, designed to enhance the accuracy and speed of distance function calculations. This prototype consists of five interfaces. To utilize i-Swift, users must initiate the process by clicking the "Start" button in the first interface. In the second interface, users input the required data, specifically times and distances, to compute the distance function. Once the distance function is obtained, users are presented with two options in the third interface.

The first option, "Distance Traveled," directs users to the subsequent interface where they can determine the distance traveled. Users input their start time, arrival time, and interval time, then click "Calculate" to obtain the distance traveled in kilometers. The second option, "Estimated Time Arrival," leads users to the next interface, allowing them to calculate their estimated time of arrival using the distance function. Users are prompted to input their start time, desired distance, and interval time, and by clicking "Calculate," they can obtain the estimated time of arrival.

5. CONCLUSION

In conclusion, i-Swift represents a paradigm shift in the travel and logistics industry, providing rapid and precise distance computations that revolutionize how people and businesses plan their travels. Its influence goes beyond simple navigation, transforming fitness exercises into enjoyable experiences and revolutionizing logistics operations. In modern knowledge-driven economies, logistics businesses have an expanding and crucial role that remains both dynamic and impactful (Chapman, Soosay & Kandampully, 2003). Businesses such as Grab, LalaMove, and Maxim can significantly improve their productivity by utilizing i-Swift's accurate trip time calculations and optimized logistical planning. In business, i-Swift are made for those who is responsible in making decisions so that they can choose the most advantageous choice among various options in real-time situations. Similarly, within transportation matters, a variety of situations arise where decision-makers are compelled to select the most optimal option from a range of possibilities (Prachi Agrawal & Talari Ganesh, 2021).

The user-friendly interface is useful not only for ordinary commuters but also for researchers, educators, and computer enthusiasts. Furthermore, i-Swift provides a solid framework for future research endeavors, particularly concerning the investigation of the potential uses of the Newton Forward Divided Difference Interpolation approach. Developers consistently design applications to fulfill the diverse requirements of customers, no matter how distinct they might be (Thomas Striepe, 2015). By harnessing this innovative technology, there is immense potential for further advancements in travel, logistics, and related fields, making i-Swift a trailblazer in the realm of smart solutions.

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