A GRAPHICAL USER INTERFACE TO APPROXIMATE THE AREA OF AN ISLAND BY SIMPSON'S ⅓ RULE

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ABSTRACT

Area miscalculation is a serious issue and one of the most vital issues for daily conveniences like parking lots, lobbies, airport architecture, and many others. With a precise area, individuals may strive to supply adequate space for the building, provide the size based on the area of the linked structure, and even perfectly calculate the price. However, the aforementioned requirements cannot be attained if the area is calculated incorrectly. Therefore, this project was done to make it possible for anybody to compute areas without needing to be a mathematician or programmer. Furthermore, to complete projects, assignments, and tutorials students may also use the software. Our work's primary contribution is to offer them a reliable programme that will approximate the area by using Simpson's ⅓ rule approach based on the data given by users. The MATLAB App Designer simulator was used to create and code the app. After the interface development was complete, functional testing was carried out to ensure that the programme is operating properly. Then, using percentage error, we compared and examined the result between the exact and approximation areas, with the exact area being determined by manual computation and the approximation area being determined via a graphical user interface. To evaluate the software's output's accuracy, three cases had been used. The findings for the three scenarios with number-of-sub intervals equal to 32, 64, and 128 segments indicated that the percentage error increases as the number of subintervals decreases. Therefore, this project is successful since all the objectives have been achieved.

Keywords: *Area approximation, Graphical User Interface (GUI), MATLAB App Designer simulator, Simpson's ⅓ Rule.*

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1. Introduction

Human-computer interaction is sometimes assumed to be completely dependent on the design and use of computer technology. However, underneath such technologies there is a type of user interface known as Graphical User Interface (GUI), which allows people to interact with electronic devices via graphical icons and audio indicators. Designing the look and behavior of a GUI is vital in software application programming because GUI displays elements that transmit messages and represent actions that the user may do. A mouse, for example, may be used to move a cursor and click on a programme icon to launch it. In the meantime, there is a lot that can be designed with a command line interface where one needs to know how and where to browse to the program's directory, list the files, and then run the file.

By the word area, one often gets confused between the area and perimeter of a shape. Winarti et. al. (2012) defined area as the entire covered surface of a shape, not the length, which is a term involved in perimeter calculations. The term 'area' refers to an empty surface occupied by a two-dimensional figure. To put it another way, it is the quantity that counts how many unit squares cover the surface of a closed figure. However, the area of a shape can be approximated and found by comparing the shape to squares of a defined size, such as a grid graph, and determining whether the shape occupies a complete unit square or not. In addition, the majority of the figures have edges and corners where the length and width of these edges are taken into account when calculating the area of a shape.

Simpson's ⅓ rule of integration of a function is when a domain of integration is split into an even number of subintervals, n of the same width, h. Integration may be thought of as the process of calculating the area under a graphed function. Simpson's ⅓ rule provides the most accurate estimate since parabolas are used to approximate each part of the curve (Ray, 2020). It is also worth noting that the larger the n in Simpson's ⅓ rule, the more accurate the area of a figure discovered for this research.

A MATLAB-based Graphical User Interface (GUI) to be used in this research to evaluate the area of a place with the help of Simpson's ⅓ rule. To determine the error, the estimated area is compared to the actual area computation on the graph. By designing the interface to approximate area, the desired output may be readily computed by just entering the value of h and n.

1.1 Graphical User Interface

Steven (2018) stated that graphical user interface (GUI) is a computer application that allows people to interact with computers using symbols, visual metaphors, and pointing devices. Since it was proven that GUI has made use of computers become easier to master, more pleasurable and natural (Steven, 2018), a lot of applications were conducted using GUI, based on the previous studies.

Moreover, Song and Peiyue (2020) built a MATLAB-based GUI with the goal of making it easier to make hydrogeochemical diagrams. The project was a success since the findings demonstrated that the MATLAB-based GUI saves users a lot of time when producing hydrogeochemical diagrams. Similarly, another project by Tahri et. al. (2022) created a MATLAB-based GUI application but with a different aim, which is to help decision-makers prioritize choices and criteria goals. The researchers employed two separate example applications to improve the decision-support system process in a variety of domains. The project was also a success based on the results shown.

In addition, a project on reprinting systems with a GUI was also completed. The goal of this project is to use constraint satisfaction to aid the human process of interpreting Japanese historical texts. In contrast to the projects mentioned in the previous paragraph, the constructed GUI is intuitively useful. However, there are several areas in the GUI that need to be enhanced, according to a survey conducted by the researchers (Atsushi et al., 2018). This is due to the fact that the system is still being worked on. Instead, the GUI is still viable and useful since future GUI advancements will undoubtedly be made, resulting in better solutions being provided (Atsushi et al., 2018). Hence, to summarize, the usage of a graphical user interface (GUI) is global due to its adaptability and suited for a wide range of applications in diverse industries.

1.2 Area

Area measuring is an important aspect of mathematics. For instance, the usage of area has several practical applications in construction, farming, architecture science, and even the tiniest of details such as how much carpet one needs to cover the rooms in one's home (Russell, 2019). He found that sometimes determining the area is simple. On the contrary, this may not always be the case as the area of a circle or even a triangle might be more complex to calculate since it involves the use of several formulae.

In addition, not only students but even teachers have trouble comprehending the concepts of circle area measurements (Rejeki et al., 2018). The major issue is a misunderstanding of the notions of area and parameter. The argument is supported by other research that stresses that the understanding of pupils about measuring area and perimeter has shown that both children and adults have inaccurate perceptions of area (Tossavainen, et al., 2016). Meanwhile, Machaba (2016) revealed that Grade 10 students both locally and globally have a weak knowledge of area and parameter concepts and it has been a constant source of perplexity for students. In conclusion, responsible parties should take certain steps to address this problem. This is because, as stated in the preceding paragraph, the utilization of area is critical in every element of life.

The research by Rejeki and Putri (2018) emphasizes that school-based learning experiences place a greater emphasis on remembering formulas than on comprehending the topic. Therefore, the researchers implemented two models to support students' understanding of measuring area of circles. The models yielded favorable findings, as students' comprehension of the area of a circle has progressed as a result of the models presented. Similarly, Machaba (2016) stated the inability to generate new information based on current knowledge resulted in the lack of an integrated network of links between ideas. Learners who struggle to translate concepts from one representation to another have a hard time solving problems and comprehending computation. (Machaba, 2016). In a nutshell, teachers should focus on improving the students' grasp of area ideas, rather than simply training them to memorize formulas. As a result, defining regions should be simple.

Moreover, Kuang et. al. (2016) discussed proposing the Area-Under-The-Curve (AUC) method as an alternative to model-based delay discounting function indices. The area of several polygons generated by plotting each indifference point as a function of delay is known as the Area-Under-The-Curve model of delay discounting Borges et. al., 2016. Straight lines are drawn from each indifference point to the subsequent (by delay) indifference point and to the abscissa to compute AUC. Each of the resulting sequence of polygons has an area computed as a standard trapezoid, $(x_2 - x_1)\left[\frac{y_1+y_2}{2}\right]$ with x_1 and x_2 being the delays connected with subsequent indifference points, and y1 and y2 being the indifference point values associated with those delays. The AUC has a lot of potential as an atheoretical indicator of delay discounting. However, the conventional method of computing the AUC is inefficient. As a result, a base-10 logarithmic transformation (AUC_{logd}) and an ordinal scaling transformation (AUC_{ord}) of delays were added to the conventional AUC approach. The first technique, AUC_{logd}, represents this scaling while also partially accounting for each indifference point's uneven contributions in the original model. The second technique, AUC_{ord}, is theoretically neutral in terms of the original delay scaling and uses an ordinal transformation to compensate for the pseudo exponential scaling of delays.

Furthermore, calculating the area of a leaf is an essential indicator of a plant's photosynthetic potential (He et. al., 2020). By multiplying the product of leaf length (L) and width (W) by a constant, such as the Montgomery parameter (MP), leaf area (A) may be easily computed. The Montgomery equation (ME) was used to calculate the leaf area of Magnoliaceae species in this study, with data on leaf length, breadth, and area collected from scanned images. He et al., (2020) used of four models to fit the data, which is the Montgomery equation (ME) by taking into account that the leaf area is proportional to the product of leaf length and width, a power-law function between leaf area and the product of leaf length and width, a power function with an exponent of 2 between leaf area and leaf length, and a power function between leaf area and leaf length. The leaf was scanned and converted to images in bitmap format, and the leaf profiles were then extracted by MATLAB. The R software was used to determine the leaf area, length, and breadth. He et al., (2020) found that leaf area, leaf length, width, and the ratio of leaf width to length vary significantly across Magnoliaceae species. Ma. denudata and Ma. liliiflora exhibited the highest leaf area, length, width, and W/L ratio, respectively. Results also show that the larger the mean leaf area, the greater the mean leaf length or mean leaf width.

1.3 Application of Simpson's ⅓ Rule Method

In the past study, the Simpson's ⅓ rule can be defined in numerical integration as a numerical scheme for discovering the integral dx within some finite limit a and b (Moheuddin et. al., 2019). A polynomial of degree two, p(x) can be approximated using Simpsons's ⅓ rule for example a parabola between limits a and b. Furthermore, Simpson's ⅓ rule is a trapezoidal rule tract in which the integrand is approximated by a second-order polynomial. They explained that the term 'Numerical Integration' was first used in 1915 by David Gibb in his books A Course in Interpolation and Numeric Integration for the Mathematical Laboratory. Numerical integration has a wide range of applications, including applied mathematics, statistics, economics, and engineering, among others. Besides, numerical integration uses a variety of approaches, including as quadrature methods, Gaussian integration, Monte-Carlo integration, Adaptive Quadrature, and the Euler-Maclaurin formula, to calculate functions that are difficult to integrate.

In the context of Numerical Integration, research of establishing a better numerical integration formula for uneven data space is carried out. According to Dhali et. al., (2019), numerical integration is the approximate computation of an integral using numerical techniques and may be used to solve initial value and boundary value problems involving ordinary or partial differential equations. They obtained the numerical integration for the Trapezoidal rule, Simpson's ⅓ rule, and Simpson's ⅜ rule by setting the subinterval, n of n = 1, n = 2, and n = 3 correspondingly, after establishing the general quadratic formula for uneven space. They then compared the findings to the precise solution to identify the related errors by applying various numerical examples to the general solutions of numerical integration. With the same number of subinterval, n of 60, Dhali et. al., (2019) discovered that Simpson's ⅓ rule delivers the least error from all the three numerical examples and identified that Simpson's ⅓ rule gives better results than any other numerical approach for uneven data space.

Cooper et al. (2005) presented a local study to establish the focus region characteristics for a converging spherical wave. He approximates the Rayleigh–Sommerfeld diffraction integral by computing the sum of each aperture point that is described by the integers m and n for a M x M aperture grid. The integral was numerically analyzed in this previous study using a two-dimensional Simpson's 1/3 rule in MATLAB. The desired output may be found at aperture grid points M = 9 and M = 11. The focal region of a converging spherical wave has been effectively approximated using double integrals in Cartesian or polar form, with $f(x, y)$ evaluated at M x M evenly spaced points in the XY plane and $S_{mn} = S_m S_n$ as the two-dimensional Simpson's coefficient matrix.

Furthermore, Saket & Zoba (2009) aimed to use Simpson's ⅓ rule to evaluate the probability of failure, Loss of Load Probability (LOLP) considering load duration curve as stepped load duration curve. The generation capacity data for evaluation of LOLP has been obtained where the load duration curve is assumed to be a straight line assuming $P_{dmax} = 1000$ MW and $P_{dmin} = 500$ MW with stepped load duration curve of 20 steps. By applying Simpson's ⅓ rule, when the standard deviation of generating capacity rises, the system's failure probability rises at the same generating capacity resulting in lowering overall system dependability.

Suganya and Arulmozhi (2021) look into the passivity of Simpson's ⅓ rule fuzzy neural network system (SFNNS) of wheeled mobile robot (WMR) navigation in order to regulate the position and orientation of mobile robots in the environment. With the ideal assumption of pure rolling (zero slippage), the issue of WMRs limitless workspace and surface slippage of coordination of master robot position and slave robot velocity is proven. The passivity of neural network systems (NNS) and Simpsons' ⅓ rule fuzzy neural network systems (SFNNS) were compared in order to achieve smooth and stable movement of a wheeled designed controller, where the master robot was supposed to generate the path for the mobile robot and the slave robot was supposed to follow the navigation based on sensor device responses. When compared to a neural network system, error convergence of a wheeled mobile robot system using Simpsons' ⅓ rule fuzzy neural network system (SFNNS) is more efficient in terms of left or right reported angle and detected angle, as well as coordination of master and slave robots (NNS).

Like any other research, this study was motivated by problems in the actual world. According to earlier findings, there were several cases in which incorrect miscalculation and negligence in area measurements may result in unfavorable outcomes. Binetti & McMurtry (2020), for example, demonstrated in their research that a purchase and sell agreement was rejected to be canceled due to the negligence in the square footage measurements by the home buyer. This is due to the fact that, despite having several opportunities to do so, the house buyer never measured the property himself, according to the courts in Ontario. Thus, before moving on with your goal, Schubach (2019) recommended that one shall take their own measurements, whether alone or with the help of an architect or appraiser. This will prevent circumstances like the ones outlined above from occurring again in the future.

As specified by Schubach (2019), people will measure space in different ways. However, there are no dependable guidelines on how to measure the area of a particular place automatically. To address this problem, a graphical user interface (GUI) that is user-friendly, easy to use, and available to everyone was created. It was built to automatically approximately calculate the area of a certain location by utilizing Simpson's ⅓ rule. Since the area computation was already standardized in the designated GUI, one can take their own measurements, as suggested by Shubach (2019). This study will benefit everyone who requires area measurements in their daily lives, such as developers and entrepreneurs.

The purpose of this study is to create a GUI to approximate the area of an image of an island in Malaysia, named Pulau Besar. This study suggests several research objectives to be attained as researchers need to design a GUI that approximates a location's area. Next, to compute the area approximation of a location by using Simpson's ⅓ rule and to obtain the error between the manually calculated exact area on a graph paper and approximation area. In this project, researchers will create a GUI to approximate the area of an island. Firstly, we will design the layout for the interface and program the interface with the implementation of coding regarding the calculation using Simpson's ⅓ rule method. The area calculation obtained from the interface designed is the approximate area of the island. Moreover, we will calculate the exact area of the island that has been depicted on a graph paper. After that, percentage error will be obtained based on the calculation of the exact and approximated area.

2. Methodology

This section explains the steps and methods to be carried out to create a Graphical User Interface (GUI) that can approximate areas using Simpson's ⅓ rule method. The findings will be compared to different accuracy tests for analysis and discussion. An overview of the procedures performed to establish the project approach is shown in Figure 1.

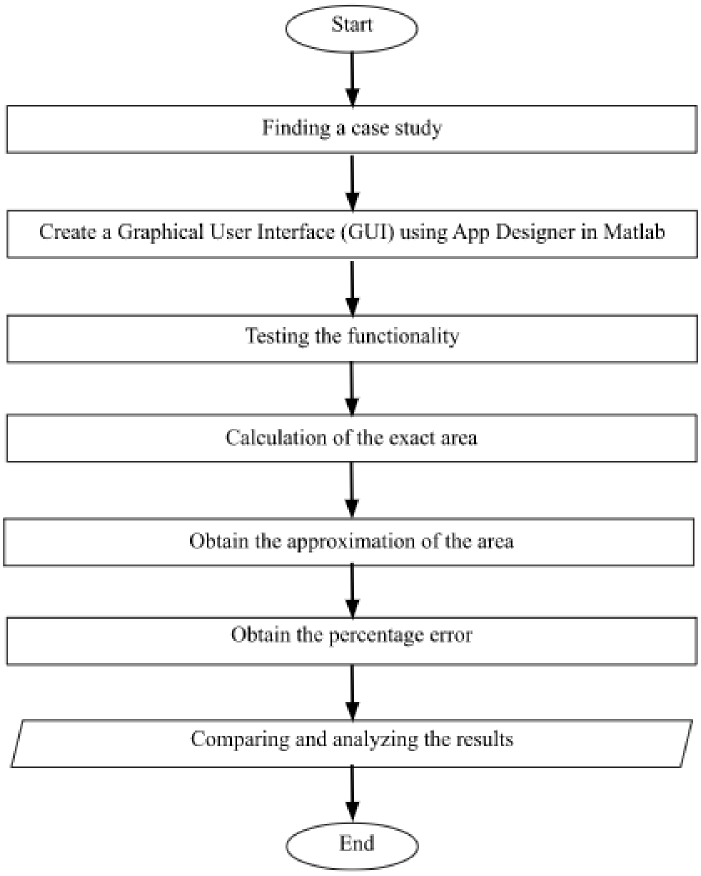

Figure 1. The flowchart of the project

Step 1: Finding a case study

Data for this project is taken from an image of an island in Malaysia, named Pulau Besar, Johor that is printed on graph paper.

Step 2: Create a Graphical User Interface (GUI) using App Designer in Matlab

App Designer is a platform tool in MATLAB that enables the creation of an app's interface and the programming of its functionality. According to Hossain (2022), the process of developing an app using the App Designer may be summed up by a number of concepts, including calculator, risk warning app, and app for second-order system step response. By using MATLAB Compiler to develop standalone desktop or web apps, the created apps can be shared with others even if they do not have MATLAB. The MATLAB R2021a version's App Designer platform is utilized in this project.

Step 3: Testing the functionality

Functional testing is a type of software testing that involves evaluating the system against functional specifications and needs. In this project, researchers tested the functionality of the GUI in all apps, namely app1, app2, and app3, with the goal of successfully obtaining the output without encountering any error messages as shown in Figure 2 below, while they were being executed. This procedure was carried out on purpose to ensure that each software application function operates in accordance with the need and specification. After it was confirmed that this project's most important objective had been accomplished, researchers could proceed to the next steps.

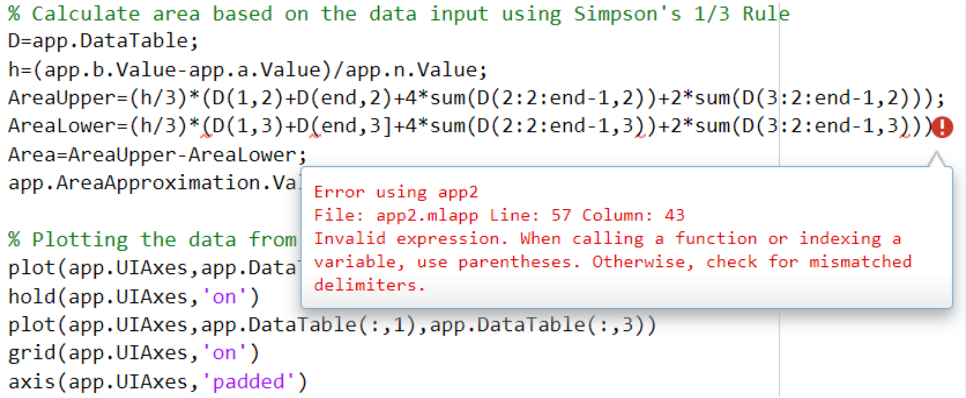

Figure 2. Example of an error message

Step 4: Calculation of the exact area

In this study, researchers used the multiple application of Simpson's ⅓ rule formula to calculate area. Theoretically, Equation 1 is the standard formula to calculate areas using Simpson's ⅓ rule, which indicates the area under the graph, f(x), the lower limit, a, upper limit, b, step size, h, and number of subintervals, n.

$$\int_a^b f(x)\,dx = \frac{h}{3}\left[f(x_0) + 2\sum_{i=2,4,6}^{n-2} f(x_i) + 4\sum_{j=1,3,5}^{n-1} f(x_j) + f(x_n)\right] \qquad (1)$$

Since the study case has 2 curves involved, researchers used functions of f(x) and g(x) where function f(x) is the upper curve and function g(x) is the lower curve. Firstly, researchers divided the area under the graph into even segments with equal spacing. Segments indicate the number of subintervals, n. On a graph paper, coordinates of the upper curve, (x, f(x)) and lower curve (x, g(x)) were plotted. Subsequently, two tables were created to add the plotted coordinates, as shown in Table 1 and Table 2.

Table 1. Coordinates of upper curve, f(x)

x	x_0	x_1	x_2	x_n
y = f(x)	N/A	N/A	N/A	N/A

Table 1 shows the coordinates of the upper curve, f(x) that were plotted on a graph paper of an island in Pulau Besar, Johor.

Table 2. Coordinates of lower curve, g(x)

x	x_0	x_1	x_2	x_n
y = g(x)	N/A	N/A	N/A	N/A

Table 2 shows the coordinates of the lower curve, g(x) that were plotted on a graph paper of an island in Pulau Besar, Johor.

N/A in Table 1 and Table 2 indicates that the data is not applicable at the moment.

Next, areas under the graph of f(x) and g(x) were computed as in Equation 2 and Equation 3, where f(x) is the upper curve, and g(x) is the lower curve.

$$\int_a^b f(x)\,dx = \frac{h}{3}\left[f(x_0) + 2\sum_{i=2,4,6}^{n-2} f(x_i) + 4\sum_{j=1,3,5}^{n-1} f(x_j) + f(x_n)\right] \qquad (2)$$

$$\int_a^b g(x)\,dx = \frac{h}{3}\left[g(x_0) + 2\sum_{i=2,4,6}^{n-2} g(x_i) + 4\sum_{j=1,3,5}^{n-1} g(x_j) + g(x_n)\right] \qquad (3)$$

Finally, the exact area of this research study could be obtained by calculating the formula using Equation 4.

$$Area = \int_a^b f(x)\,dx - \int_a^b g(x)\,dx \qquad (4)$$

Step 5: Obtain the approximation of the area

Approximation of the area was obtained using the graphical user interface that has been created. Before inserting the data into GUI, users should have the x and y coordinates or data from excel file, limit of a and b, and the number of subintervals, n. Users could then simply input the data by following the directions indicated in the interface. Following that, the output, which is an estimate of the area, will be produced.

Step 6: Obtain the percentage error

Obtaining the percentage error is important to observe how accurate the calculation from graphical user interface is to the manual calculation. Researchers would calculate the percent error of the obtained areas using the percent error formula as in Equation 5.

$$Percentage\ Error = \left|\frac{Exact\ area - Approximated\ area}{Exact\ area}\right| \times 100\% \qquad (5)$$

Exact area was obtained from the manual calculation, while the approximated area was obtained from the output in graphical user interface.

Step 7: Comparing and analyzing the results

This step completes the study's last phase. Researchers would compare the percentage error between the exact and approximation of the areas throughout this phase, assess the outcome, and draw conclusions about whether this project was successful or unsuccessful, and if all of its objectives were attained.

In addition, three cases of different numbers of subintervals, for the approximation of the area were done to observe how much they could influence the percentage error between the exact and approximated areas. The initial n would be 128, the subsequent n would be 64, and the last n would be 32 segments. This addition is crucial because it would justify why the percentage errors of a certain number of subintervals, n, could be extremely high and help users comprehend the results. Finally, by using Excel's line and clustered column charts, researchers would compare, analyze, and make conclusions on the variation in percentage errors based on the three selected numbers of subintervals, n.

3. Results and Discussion

The results from the interface designed will be discussed in this section. In order to test the interface design, data from the image of an island that has been depicted on a graph paper is used. Then, a comparison of the approximation area and the exact area was done by calculating the percentage error.

3.1 Layouts of the Graphical User Interface

Following the implementation of the design and code using the App Designer simulator, this part will illustrate the layouts of the graphical user interface. The software's user guide has been discussed during the implementation stage. Figure 3 below shows the first layout, second layout and the third layout of the GUI accordingly.

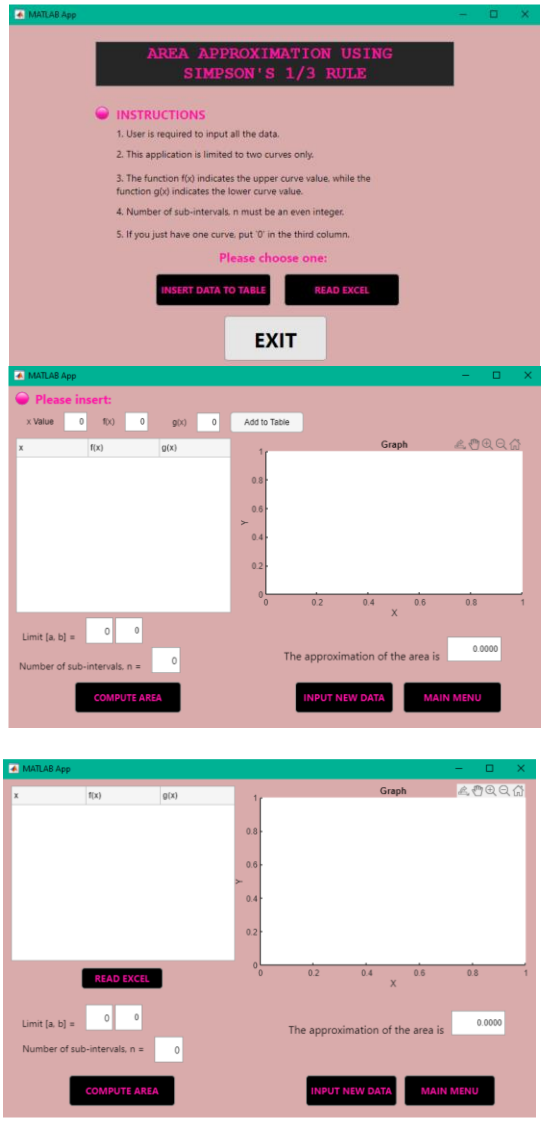

Figure 3. Three layouts of the interface.

3.2 Accuracy Testing

In this part, the graphical user interface's accuracy was evaluated. The precise area was tested with 128 subintervals, while the approximation areas were tested with three different cases, namely n = 32, n = 64 and n = 128. The intent is to compare the approximations obtained using the interface with the calculation obtained manually using a calculator, as well as the percent error.

For exact area calculation, the tables in this section show the data of x values, upper curve values, and lower curve values of an island that has been depicted on a graph paper. Meanwhile for approximation of the area, the data from the corresponding tables from exact area, limit a and b, and the number of subinterval, n, were inserted to the interface by clicking on the Read Excel button. Then, the figures in this section would display the result obtained from the interface.

3.2.1 Exact Area Calculation

In this project, researchers intend to assume the case of subinterval, n equal to 128 as the exact calculation of Pulau Besar's area. By taking the greater subinterval, n, researchers believe that the area calculation is somehow accurate and acceptable. Therefore, the approximation area of all three cases are being compared with this exact area calculation. Table 3 shows the data for n = 128 and the exact area calculation.

Table 3. Data for n = 128

x	fx	gx	x	fx	gx
0	10.5	10.5	65	64.5	13.7
1	14	7	66	65.5	14
2	14	5.5	67	65	14
3	14	5	68	64.7	14
4	14	4	69	64.15	14
5	21.5	2	70	64	14
6	21.5	0	71	63.5	14
7	21.5	0	72	62.9	14
8	21.5	0	73	62.9	13.15

9	21.5	0
10	21	1
11	21	1
12	20	1.5
13	19.5	2
14	19.5	3
15	19.75	6
16	20	6.7
17	20.75	7
18	21.9	7.2
19	22.5	7.9
20	24	8
21	25	8.45
22	26	7.8
23	27	8
24	28	8
25	29	8
26	29	7.8
2	31	7.8

74	62.9	13
75	63	13
76	63.25	12.1
77	63.25	12
78	64	12
79	64	12
80	65	12
81	67	12
82	68	12
83	69	12
84	69.8	12
85	69.95	12
86	70	12
87	70.5	12
88	71	12
89	72	12
90	73	12.1
91	73.2	12.98
9	74	13

7		
28	32	7.5
29	37	7.5
30	39	7.2
31	40.7	7.2
32	41.8	7.1
33	43	7
34	43.7	7
35	44.5	7
36	45	7
37	45.8	7
38	46	7
39	46.5	7
40	47	7
41	47.3	7.05
42	47.5	7.5

2		
93	74.5	13.98
94	75	14
95	76.4	14.95
96	77.5	15.6
97	78	16.85
98	79.2	18
99	79.7	19
100	79.8	19.5
101	80.2	21
102	81	22
103	82	23
104	83	24
105	84	25
106	85	25.5
107	86.15	26.5

43	48	7.65
44	48.5	7.7
45	48.5	7.95
46	48.5	8
47	48.5	8
48	48.5	8
49	48.5	8
50	48.5	8
51	48.5	8.8
52	48.5	8.9
53	48.9	9
54	49.5	9.5
55	50	9.8
56	50.5	10

108	87.8	27
109	88.1	28.1
110	89	30
111	90	31
112	91.2	32
113	91.3	34
114	91.5	45
115	90.95	46.05
116	90.5	48
117	89.1	49
118	88	52
119	86	55
120	86	56
12	86	59

57	51.3	10.5
58	52	11
59	52.9	11.25
60	53.8	11.5
61	54.6	12
62	55	12
63	55.2	12.85
64	63.5	13.3

1		
122	85	61
123	81	64
124	80.5	66
125	80	68
126	79	69
127	78	70.95
128	75	75

From Table 3, the exact area calculation of the island are shown below,
$n = 128,\ a = 0,\ b = 128,\ h = (a - b)/n = 1$

By adapting equations (2), (3) and (4), respectively,

$$Area\ upper = \frac{1}{3}[10.5 + 2(14 + 14 + 21.5 + 21.5 + 21 + 20 + 19.5 +$$

$$20 + 21.9 + 24 + 26 + 28 + 29 + 32 + 39 +$$

$$41.8 + 43.7 + 45 + 46 + 47 + 47.5 + 48.5 +$$

$$48.5 + 48.5 + 48.5 + 48.5 + 49.5 + 50.5 +$$

$$52 + 53.8 + 55 + 63.5 + 65.5 + 64.7 + 64$$

$$+62.9 + 62.9 + 63.25 + 64 + 65 + 68 + 69.8$$

$$+70 + 71 + 73 + 74 + 75 + 77.5 + 79.2 +$$

$$79.8 + 81 + 83 + 85 + 87.8 + 89 + 91.2 +$$

$$91.5 + 90.5 + 88 + 86 + 85 + 80.5 + 79) +$$

$$4(14 + 14 + 21.5 + 21.5 + 21.5 + 21 + 19.5$$

$$19.75 + 20.75 + 22.5 + 25 + 27 + 29 + 31$$

$$+37 + 40.7 + 43 + 44.5 + 45.8 + 46.5 +$$

$$47.3 + 48 + 48.5 + 48.5 + 48.5 + 48.5 +$$

$$48.9 + 50 + 51.3 + 52.9 + 54.6 + 55.2 +$$

$$64.5 + 65 + 64.15 + 63.5 + 62.9 + 63 +$$

$$63.25 + 64 + 67 + 69 + 69.95 + 70.5 + 72$$

$$+73.2 + 74.5 + 76.4 + 78 + 79.7 + 80.2$$

$$+82 + 84 + 86.15 + 88.1 + 90 + 91.3 +$$

$$90.95 + 89.1 + 86 + 86 + 81 + 80 + 78) + 75]$$

$$= \frac{1}{3}[10.5 + 2(3556.25) + 4(3601.05) + 75]$$

$$= 7200.7333\, unit^2$$

$$Area\ lower = \frac{1}{3}[10.5 + 2(5.5 + 4 + 0 + 0 + 1 + 1.5 + 3 +$$

$$6.7 + 7.2 + 8 + 7.8 + 8 + 7.8 + 7.5 + 7.2 +$$

$$7.1 + 7 + 7 + 7 + 7 + 7.5 + 7.7 + 8 + 8 +$$

$$8 + 8.9 + 9.5 + 10 + 11 + 11.5 + 12 + 13.3$$

$$+14 + 14 + 14 + 14 + 13 + 12.1 + 12 + 12$$

$$+12 + 12 + 12 + 12 + 12.1 + 13 + 14 + 15.6$$

$$+18 + 19.5 + 22 + 24 + 25.5 + 27 + 30 +$$

$$32 + 45 + 48 + 52 + 56 + 61 + 66 + 69) +$$

$$4(7 + 5 + 2 + 0 + 0 + 1 + 2 + 6 + 7 + 7.9$$

$$+8.45 + 8 + 8 + 7.8 + 7.5 + 7.2 + 7 + 7$$

$$+7 + 7 + 7.05 + 7.65 + 7.95 + 8 + 8 + 8.8$$

$$+9 + 9.8 + 10.5 + 11.25 + 12 + 12.85 +$$

$$13.7 + 14 + 14 + 14 + 13.15 + 13 + 12 +$$

$$12 + 12 + 12 + 12 + 12 + 12 + 12.98 +$$

$$13.98 + 14.95 + 16.85 + 19 + 21 + 23 + 25$$

$$+26.5 + 28.1 + 31 + 34 + 46.05 + 49 +$$

$$55 + 59 + 64 + 68 + 70.95) + 75]$$

$$= \frac{1}{3}[10.5 + 2(1028.5) + 4(1069.91) + 75]$$
$$= 2140.7133\, unit^2$$

$$Actual\ Area = Area\ upper - Area\ lower$$
$$= 7200.7333 - 2140.7133$$
$$= 5060.0200\, unit^2$$

Thus, the actual area of Pulau Besar is 5060.0200 unit^2.

3.2.2 Area Approximation and Percentage Error

The graphical user interface that has been developed was used in this section to approximate the region. As previously noted, three examples of n = 32, n = 64 and n = 128 for the number of subintervals were performed. The % error for each example would then be used to compare the approximation values to the reference value, which is the precise area value.

Case 1 (n = 32)

Table 4. Data for n = 32

x	fx	gx
0	10.5	10.5
4	14	3.5
8	21.5	0
12	19.9	1.5
16	20	6.5
20	23.7	8
24	28.3	8.3
28	32	8
32	42	7.2
36	45.5	6.5
40	47	7

44	48	7.8
48	48.5	8
52	48.5	9
56	50.6	10
60	53.5	11.5
64	63.5	13
68	64.85	13.9
72	62.9	13
76	63	12
80	66.4	12
84	69.9	12
88	71.5	12
92	74	13
96	77	15.5
100	80	19.5
104	83	24
108	87.8	27.5
112	91.3	33
116	91	48
120	86	57.2
124	80.5	66
128	75	75

For case 1, the approximate area for $n = 32$ was calculated by entering the data from Table 4 into the graphical user interface, as presented in Figure 4.

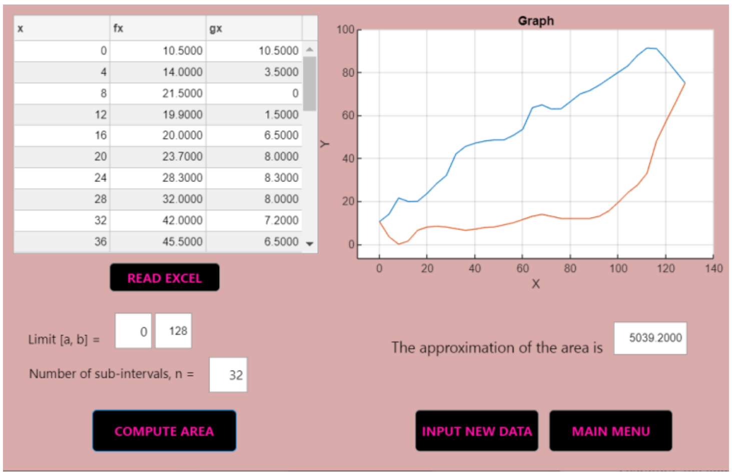

Figure 4. Result of area approximation on the interface for n = 32

Therefore, the approximation of the area of an island when the number of subinterval, n equal to 32 is 5039.2000 unit^2.

Since the precise and approximate numbers have been determined, the percentage error might be obtained as well by referring to Equation (5). The calculation are as below,

$$Percentage\ Error = \left|\frac{5060.0200 - 5039.2000}{5060.0200}\right| \times 100\%$$

$$= 0.41\%$$

Case 2 (n = 64)

Table 5. Data for n = 64

x	fx	gx
0	10.5	10.5
2	14	5.5
4	14	4
6	21.5	0
8	21.5	0
10	21	1
12	20	1.5
14	19.5	3
16	20	6.7
18	21.9	7.2

20	24	8
22	26	7.8
24	28	8
26	29	7.8
28	32	7.5
30	39	7.2
32	41.8	7.1
34	43.7	7
36	45	7
38	46	7
40	47	7
42	47.5	7.5
44	48.5	7.7
46	48.5	8
48	48.5	8
50	48.5	8
52	48.5	8.9
54	49.5	9.5
56	50.5	10
58	52	11
60	53.8	11.5
62	55	12
64	63.5	13.3
66	65.5	14
68	64.7	14
70	64	14
72	62.9	14
74	62.9	13

76	63.25	12.1
78	64	12
80	65	12
82	68	12
84	69.8	12
86	70	12
88	71	12
90	73	12.1
92	74	13
94	75.5	14
96	77.5	15.6
98	79.2	18
100	79.8	19.5
102	81	22
104	83	24
106	85	25.5
108	87.8	27
110	89	30
112	91.2	32
114	91.5	45
116	90.5	48
118	88	52
120	86	56
122	85	61
124	80.5	66
126	79	69
128	75	75

For case 2, the approximate area for n = 64 was calculated by entering the data from Table 5 into the graphical user interface, as illustrated in Figure 5.

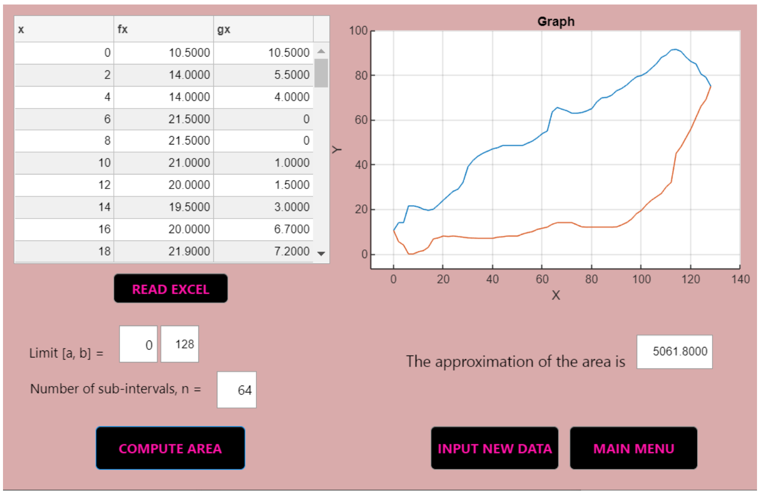

Figure 5. Result of area approximation on the interface for n = 64

Therefore, the approximation of the area of an island when the number of subinterval, n equal to 64 is 5061.8000 unit^2.

Hence, the calculation of percentage error for case n = 64 is as shown below,

$$Percentage\ Error = \left|\frac{5060.0200 - 5061.8000}{5060.0200}\right| \times 100\%$$

$$= 0.04\%$$

<u>Case 3 (n = 128)</u>

For case 3, the area approximation for n = 128 was calculated by entering the data from Table 3 into the graphical user interface, as illustrated in Figure 6.

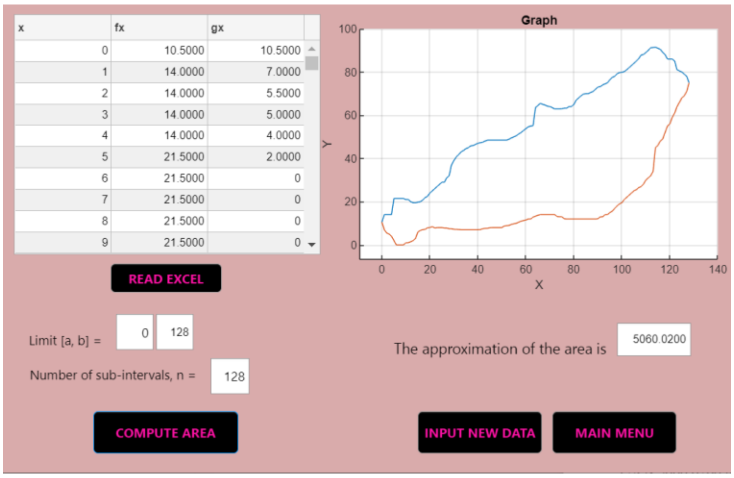

Figure 6. Result of area approximation on the interface for n = 128

The approximation of the area of an island when the number of subinterval, n equal to 128 is 5060.0200 unit^2.

Thus, the percentage error was obtained by following Equation (5). As shown in the computation below,

$$Percentage\ Error = \left|\frac{5060.0200 - 5060.0200}{5060.0200}\right| \times 100\%$$
$$= 0.00\%$$

3.2.3 Discussion

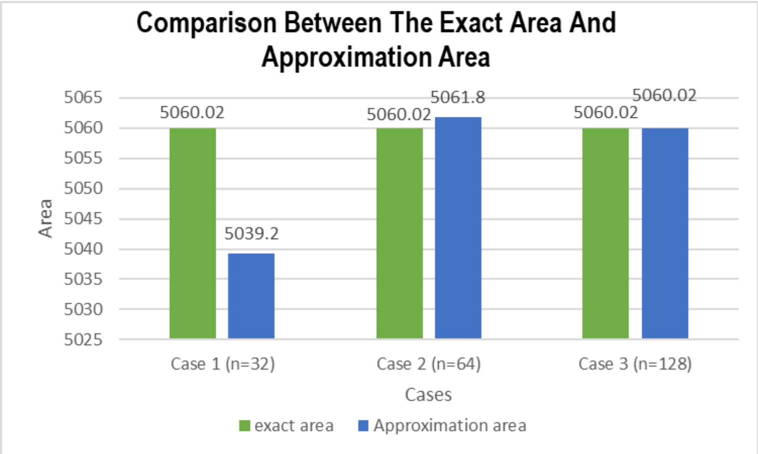

Figure 7. Comparison between the exact area and approximation area

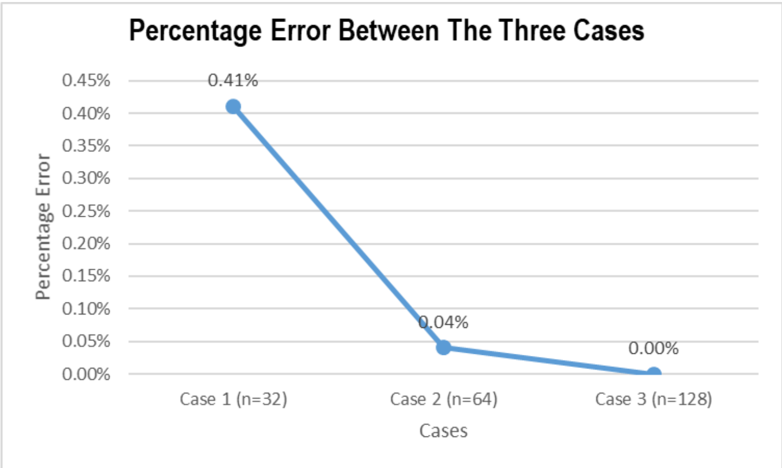

Figure 8. Percentage error between the three cases

Based on Figure 7, the comparison between the exact area and approximation area are being depicted as a clustered column chart. Meanwhile, Figure 8 displays the percentage error between the three cases of the number of subintervals. For Case 1, there are a lot of differences in height indicating the area calculation. It shows that the approximation area of Case 1 is less than accurate from the exact area since the percentage error is 0.41 percent. Meanwhile, the approximation area of Case 2 is higher than the exact area giving the percentage error of 0.04 percent. As for Case 3, the approximation area is the same with the exact area giving the percentage error of 0.00 percent.

We deduced that the correctness of the Graphical User Interface (GUI) is somewhat efficient and accurate from the testing for three cases of different subintervals, n. It was demonstrated in Figure 8 that the percentage error for the graphical user interface and the computation of the precise area on graph paper are different, with the percentage error increasing as the number of subintervals become smaller. Moreover, the inaccuracies could get worse depending on how thoroughly users enter the data. In some circumstances, the percentage error could be more than zero or even higher than 10 percent. All of this is dependent on the users themselves. Hence, this research serves as the standard for determining if the coding system is valid and reliable because a 0.00 percent percentage error is achievable.

4. Conclusion and Recommendations

From this project, researchers have gained a lot of knowledge about MATLAB capabilities and coding systems, particularly the App Designer simulator due to the extensive study done using search engines. Furthermore, the accuracy and benefits of the interface have been identified after the development process. Theoretically, the number of subinterval employed should have an impact on how precisely the region is approximated. The outcome is more accurate when there are more subintervals. Meanwhile in this project, the precision also depends on how carefully people enter the data to provide the most accurate results.

The GUI has several advantages in a variety of industries, including business, carpeting, and construction. It can also be helpful for those who lack strong programming or mathematical abilities. As indicated in the problem statement, this will stop issues like incorrectly estimating the square footage of residential homes from happening. Moreover, the interface is very helpful for estimating curve areas when function equations are difficult to extract and employing coordinates is a more effective method.

Based on the results shown, the simulator used in this project to approximate area from a two-dimensional image using Simpson's ⅓ rule was successfully developed. When any data is entered, the simulator is also able to generate an accurate approximation of the area. As a result, since the crucial pieces of information needed for usage are successful, the precise area and percent error could be collected as well. In conclusion, it can be said that this project is successful since the three objectives have all been accomplished.

For recommendations, getting a precise and accurate answer is yet impossible in this project. By having a different number of subinterval, n, the accuracy testing should be different as it is influenced in area calculation. The greater the number of subintervals the more precise the area approximation, thus, the less percentage error would be. Hereafter, further research on the implementation of a function into the interface can be used as the data from the user instead of having coordinates. Next, having advanced features that can extract the data from the GUI itself is a good innovation on the current interface. In terms of designing a GUI, the interface should be user-friendly and all instructions and descriptions should be clear and easy to understand. The implementation of the Simpson ⅓ rule method into the area approximation coding should be the same as in the exact area calculation to avoid errors in the calculation.

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