

Designs and Implementation of Learning Application of Fourier Series on Mobile Phones

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Abstract

Nowadays there are a huge number of mobile phone users, ranging from children to adults who use mobile phones for the purpose of communication media or entertainment during leisure time. Varied features offered such as games, internet access, and social networks have become points of attraction to use mobile phones. However, features offered are mainly for entertainment and communication. There are only a few features that provide education support for users, especially for students. This study was aimed at developing a learning application that could be run on mobile phones (in-learning) to assist users to learn something. Difficulties to learn Fourier series for electronic students was the main reason of this study to choose the topic of Fourier series. It was expected that this learning application could help students to more easily understand Fourier series using their mobile phones instead of books. Fourier series is a sinusoidal series (sinus and cosine) used to represent functions of periodical signs in general. This application can be used to determine Fourier series, started from calculating Fourier coefficients namely a_0 , a_n and b_n , using Romberg Integration approach and based on trapezoidal rule so that it can be achieved integral values with high accuracy. Test results of the application on mobile phones show that users can easily run the application program, choosing the menu providing explanation about Fourier series, doing practices to determine Fourier series coefficients, presenting graphs of Fourier series functions $f(x)=a$ and $f(x)=ax$. This application was proven to assist students to learn and understand Fourier series more easily.

Keywords

Fourier series, Romberg Integration, functions sinus-cosine, m-learning.

1. Introduction

Nowadays mobile phones are needed by people of all classes as media of communication and other functions. There are a lot of facilities offered such as facilities to access social network and download games. Playing mobile phones make users unable to manage time, including unable to accomplish their duties such as students who do not study appropriately. A lot of university students use mobile phones as media of communication; they are not aware that mobile phones can be used as media of learning. As portable media, mobile phones can be functioned as effective and practical learning media. A study by Sarosa et al. (2011) revealed the advantages of mobile phones as learning transistor. Application used in this study was providing tutorial regarding transistor installed at mobile phone. Several transistors were introduced, namely BJT, JFET, and MOSFET, including the working transistor, examples of calculation, and practices of transistor use installed as an analog series [1].

This study was aimed at developing a learning application that can be run on mobile phones. Fourier series was the chosen learning materials due to difficulties to understand this topic. One of the reasons for the difficulties was the limited media of learning. Therefore, it was a necessity to design a learning media that was more interesting to the students.

Fourier series is sinusoidal series (sinus and cosine) that can be used to represent functions of periodical signs in general. This type of function is very interesting due to its high use in various physics problems such as mechanical vibration, AC voltage, sound wave, electromagnetic, and so forth.

2. The Roles of Technology in Learning

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Technology and media play important roles in learning. In student-centred learning, technology and media really support the presentation of learning. In turn, in student-centred learning, students are the main users of technology and media. This may lead to the fact that students can learn independently without strict guideline from the teachers. In this sense, internet facilities can be used to access learning resources, especially those taken outside the classroom [2].

The vast development of telecommunication technology, especially which of moving telecommunication and features provided for mobile phones, necessitates studies and research to optimize the use of the technology and features. One way of optimizing is using mobile phones as instruments of learning, known as m-learning [3]. M-learning impacts on study results because m-learning can save time during the process of teaching and learning, save travel expenses, and save other education expenses (for example, infrastructure, equipment, books). M-learning can also reach wider geographical scope including remote areas, and this stimulates students to autonomously acquire knowledge.

In 2007, Uden [4], explicates that the broad use of mobile phones creates a lot of benefits during the learning process on the part of the students. The use of mobile phones can increase students' motivation and responsibility because they can learn not only in the classroom but also outside the classroom and they can decide their own time of studying. However, learning through mobile phones may encounter problems such as the small size of the screen, the low processing capability, and the low bandwidth. Therefore, for mobile phones can be used appropriately as learning media, m-learning should be equipped with interesting design and suitable learning theories.

Litchfield, et al [5] states that m-learning can improve active learning, and this statement is supported by his research, in which 72% of the respondents were interested to use m-learning and 95% of the respondents considered the importance of integrating technology into teaching and learning environment. Furthermore, Landers' research (2002) proves the effectiveness of using mobile phones in learning, and he concluded that:

- a. 77% of the respondents claimed that m-learning can improve the quality of learning

- b. 77% of the respondents stated that m-learning helped them to reach the learning goals
- c. 66% of the respondents agreed that m-learning was effective when supported with graphs and illustration.
- d. 66% of the respondents claimed that effectiveness of evaluation through m-learning.

3. Fourier series

Fourier series is a sinusoidal series (sinus and cosine) used to represent general periodical functions. For example, $f(x)$ is defined at the line of $(-L, L)$ and outside the hose as $f(x+2L)=f(x)$, in which $f(x)$ is interpreted as having period $2L$. The associated Fourier series $f(x)$ is determined as [6]:

$$\frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos \frac{n2\pi x}{p} + b_n \sin \frac{n2\pi x}{p}) \quad (1)$$

Where the Fourier coefficients a_n and b_n are

$$\begin{cases} a_n = \frac{2}{T} \int_{-L}^L f(x) \cos \frac{n2\pi x}{T} dx \\ b_n = \frac{2}{T} \int_{-L}^L f(x) \sin \frac{n2\pi x}{T} dx \end{cases} \quad (2)$$

$n=0, 1, 2, \dots$

When $f(x)$ has period of $2L$, the coefficients are a_n and b_n , then it is found the equivalence of:

$$\begin{cases} a_n = \frac{2}{T} \int_c^{c+2L} f(x) \cos \frac{n2\pi x}{T} dx \\ b_n = \frac{2}{T} \int_c^{c+2L} f(x) \sin \frac{n2\pi x}{T} dx \end{cases} \quad (3)$$

In which c is a real number.

To determine a_0 at (1), formula (2) or (3) was used with $n=0$.

For example (2),

$$a_0 = \frac{1}{L} \int_{-L}^L f(x) dx \quad (4)$$

Constant term at (1) is

$$\frac{a_0}{2} = \frac{1}{2L} \int_{-L}^L f(x) dx \quad (5)$$

Which is the average $f(x)$ at a certain period.

Fourier series or half range cosine is a series presenting only sinus or cosine terms, then, this function is defined at line $(0, L)$ [half range $(-L, L)$] and this function is further categorized as odd or even in order that it can be defined at other half range as $(-1, 0)$. In this case, it is known [7]:

- Half range cosine series (even function)

$$a_0 = \frac{4}{T} \int_0^T f(t) n \frac{2\pi}{T} t dt \quad (6)$$

$$a_n = \frac{4}{T} \int_0^T f(t) \cos n \frac{2\pi}{T} t dt \quad (7)$$

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos n \frac{2\pi}{T} t) \quad (8)$$

- Hal way sinus series (odd function)

$$b_n = \frac{4}{T} \int_0^T f(t) \sin n \frac{2\pi}{T} t dt \quad (10)$$

$$f(t) = \sum_{n=1}^{\infty} (b_n \sin n \frac{2\pi}{T} t) \quad (11)$$

4. The Romberg Integral

Let $T(n)$ be the Trapezoidal Rule with n subdivisions of the interval $[a,b]$. Let m be a given positive integral for $k = 1, 2, \dots, m$, let [8]

$$A_{k,1} = T(2^{k-1}) \quad (12)$$

Then inductively define

$$A_{k,j} = \frac{4^{j-1} A_{k,j-1} - A_{k,j-1}}{4^{j-1} - 1} \quad (13)$$

for $j = 2, 3, \dots, m$ and $k = 1, 2, \dots, m - j + 1$.

5. Designing Application to Learn Fourier series

Learning application of Fourier series is an assistance to learn Fourier series that present theories related to Fourier series, providing explanation on the working principles of Fourier series visually as well as providing examples of problem solution and interactive practices regarding Fourier series. Learning materials about Fourier series selected for this learning application are basic Fourier series commonly discussed in technical mathematics books [9]. Figure 1 illustrates the framework of the application, including introduction, theories, exercises, test, and guideline.

Learning application of Fourier series consists of the following algorithm:

1. When this application is run, there are five main menus presented, namely introduction, theories, exercises, test, and guideline.
2. When 'introduction' menu is chosen, it presents explanation about the application of how to use Fourier series.
3. When 'explanation' menu is hit, there are several sub-menus consisting of learning materials of Fourier series, half range Fourier series, and examples of problems.
4. When one of the sub-menus is chosen, it is presented explanation of that sub-menu.
5. When 'exercises' menu is chosen, there are three sub-menus namely Fourier series, Fourier cosine series, and Fourier sine series. Users can input functions, lower

limit, and upper limit. Then, it will be presented the coefficient and graph of Fourier series.

6. At the 'exercise' menu, there are sub-menus of 'calculating' (order to calculate the values inputted), 'adding component' (adding the function when there are two functions will be inputted and emptying the values inputted)
7. When menu 'test' is chosen, there will be choices of difficulty levels of the problems and the number of items. After all problems are solved, scores and correct answers are presented.
8. When menu 'help' is selected, there will be explanation of the whole materials about the application and functions of each component.

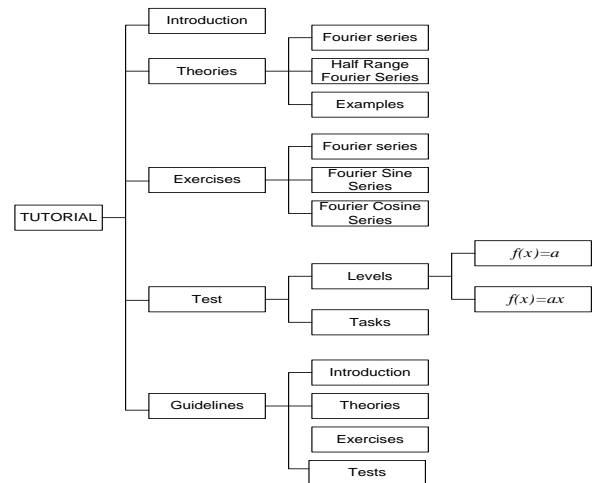


Figure 1: Framework of Application Materials

In general, this application works following the above algorithm while to determine related values using Fourier series should also calculate the integral values of a certain function. To get integral values of a certain function needs numerical computation process. In order that the computation gets the closest values, this research used Romberg Integration method as based on the trapezoidal rule that is believed to give a high accuracy.

6. Implementation

The system design was implemented using NetBeans 6.8 which had been integrated with Java Development Kit (JDK) 1.6.0 and Sun Java TM Wireless Toolkit 2.5 for CLDC. Below is the display

of the application run using Java TM Wireless Toolkit (WTK). This display also shows test results on the emulator devices WTK used to produce display of Default-Color-Phone for m-learning application of Alfa-numeric version and to produce display of Qwerty-Device for m-learning application of Qwerty version.

Figure 2 presents the displays of application during simulation. Figure 2a presents the display of main menu in which *Image Item* is used to display images and *String Item* is used to display texts. Figure 2b is the simulation of the sub menu display consisting of introduction, explanation, practices, tests, guide lines, and the author's bio-data. Figure 2c presents display of introduction menu, introducing the learning application of Fourier series and the explanation about Fourier series which is presented using *String Item*.

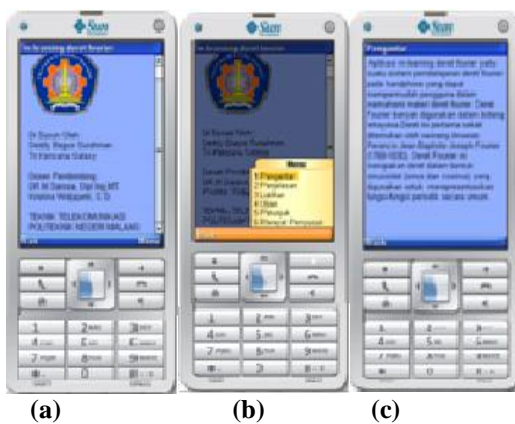


Figure 2: Display of Application during Simulation



Figure 3: Display of Exercises Menu

Figure 3 is the display of practices menu, consisting of determination of Fourier's coefficients, Fourier series, and graph of Fourier series. Using this menu, users can determine the values of the variables, suited to the functions to be calculated. The menu button at the top right side consists of sub-menus of adding the components to display Fourier coefficients and to add components when there are two functions to be calculated. This menu also contains Fourier series to show the inputted Fourier series, to check terms to show the n^{th} term of a_n and b_n , DF graph to display graph of Fourier series and Fourier terms, and emptying components to return the calculation result to zero. The components used are *Ok Command*, *Choice Group*, *Text Field*, and *String Item*.

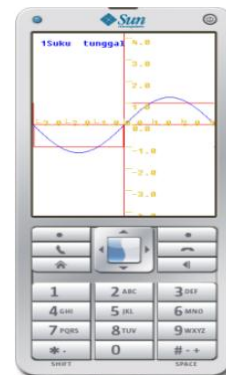


Figure 4: Display of Fourier series Graph

Figure 4 presents the display of graph structured of *Canvas*. Button "1" is used to enlarge the display of the graph, button "2" is used to move to the upper part of the graph, button "3" is used to display the 200th graph, button "4" is used to move to the left side of the graph, button "5" is used to return to the graph display with centre position of x and y axis, button "6" is used to move to the right side of the graph, button "7" is used to reduce the number of graphs, button "8" is used to move to the lower part of the graph, button "9" is used to add the number of graphs, button "*" is used to change the graph, changing from terms to series or vice versa, and button "#" is used to display the all of the graphs previously displayed as one graph.

Figures 5a and 5b are examples of the displays of Fourier graph of the 1st term and the display of Fourier series of the 5th series. Figure 6a presents display of Fourier graphs of all the 5 terms and Figure 6b presents graphs of all five series.

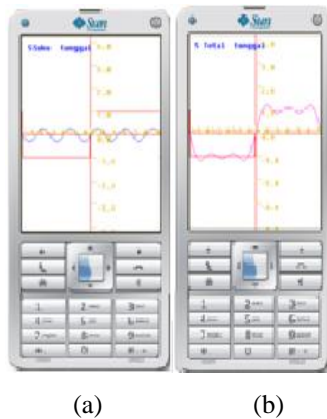


Figure 5: Display (a) Fourier Graph, the 1st term and (b) Fourier Graph, the 5th series

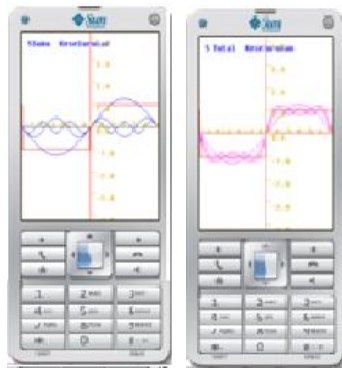


Figure 6 (a): Display of Whole Fourier Graphs and (b) Display of Whole Graph of Fourier series

7. Conclusion

Based on the design and the test done, it can be concluded that:

1. To determine the Fourier series, Fourier coefficients of a_0 , a_n and b_n need to be calculated at functions $f(x)=a$ and $f(x)=ax$ where a is the constant. This calculation uses Romberg Integration method based on the trapezoidal rule to get integral values at high accuracy.
2. Test items are displayed randomly while test results and the correct answers are presented afterwards.
3. This application has been tried-out at mobile phones with the features of MIDP 2.1 and CLDC.

8. Suggestions

Several learning application can be developed to be installed at mobile phones, including:

1. Learning certain languages (for example, English, Germany, France, and so forth).
2. Learning materials such as physics, chemistry, biology, etc.
3. Letters conversion, example, from Latin to Arabic, from Latin to Kanji, or from Latin to Javanese.

Maximizing the function of mobile phones as learning media can help learners to more easily learn the materials in terms of ease in accessing the materials in any place and at any time suited to the learners' demand.

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