

# Simulation Using Handhelds\*

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*Simulation plays an increasingly important role in electronic learning. With computers readily accessible by the students in the modern campus, many courses have an assimilated simulation content. Simulation is especially prominent in engineering courses (such as control engineering), whereby complex mathematical equations alone often elude a good understanding. With the help of a simulation study, students are able to make changes to the parameters of a model and observe the impact of the change on the system performance. This helps to improve their understanding of the system model. Advancement in wireless technology has transmuted electronic learning into mobile education. Mobile education in essence allows the learner the flexibility of time and space to access education resources. In order for mobile education to be pervasive, especially to people on the move, the system has to be adaptable to include affordable handheld mobile devices (e.g. cellular phones). Unfortunately, handheld devices typically have small display units and limited memory space. Running simulation on these handheld devices will be unthinkable if not impossible. In this paper, we propose an innovative method to run simulation on handheld mobile devices. We present the development of a system which will allow the learner to access a remote personal computer (PC) that houses an Excel simulator, and converts the results to a standard picture file format which can then be viewed via cellular data technology (e.g. GPRS). The methods and difficulties involved in the construction of the system will be duly discussed.*

## INTRODUCTION

SINCE THE EARLY 1980s, the computer has infiltrated into many aspects of our daily lives. It has brought about great changes in which we do business and go about our daily lives, and it has greatly enhanced the speed at which knowledge propagates. In the late 1990s, when the World Wide Web (WWW) blossoms from the initial few web pages to several millions, a new form of learning evolves, electronic learning (e-learning), which makes use of electronic devices such as computers to aid in learning, and includes distance learning, digital libraries and virtual universities. However, the high dependency on the computer restricts electronic learning to the nearest available and wired terminal. With the advancement in wireless communication, the boundary of computing is now expanded; there are now numerous handheld mobile devices (e.g., Personal Digital Assistants (PDAs)) and cellular phones) that allow computing to be done on the move. This advancement, in turn, has helped to further extend the reach of electronic learning to mobile education.

In [1], mobile education is defined as 'learning that can take place anytime, anywhere with the help of a mobile computer device'. In this paper, to fulfill the 'anywhere' requirement, we will enable the access and dissemination of education resources via handheld mobile devices that use the Wireless Wide Area Network (e.g., General Packet Radio Service (GPRS)).

Currently, there are relatively few research works reported on mobile education. Based on the published works, we can generally categorize mobile education into three categories:

1. *Information sourcing.* The education resources can be accessed via a known server or via web surfing on the WWW. An example of accessing a central server for information is the KNOW-MOBILE [2]. In the KNOWMOBILE project by University of Oslo, the medical student can access web-based medical information via PDAs. There is also a service provided by National University of Singapore, known as Mobile IVLE (Integrated Virtual Learning Environment) [3], which allows the student to download lecture materials using a smartphone.
2. *Virtual Laboratory.* This can be thought of as an extension to the E-Learning version of a laboratory session. Wireless Internet Learning Devices (WILD) [4], uses handheld devices for Computer Support Cooperative Learning (CSCL).
3. *Virtual community.* This consists of a group of users linked wirelessly via the handheld mobile devices. MOOsburg++ [5] is an example of an online virtual community which allows different groups of users to interact in collaborative learning while on the field.

Of the three categories stated above, we note that Virtual Laboratory is particularly useful for engineering courses. Engineering courses which are experimentally intensive require the students to undergo long hours of laboratory sessions. Virtual Laboratory helps to ease the number of hours the

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student spends in laboratory. However, the extent of pervasiveness is restricted by the type of handheld mobile devices that the user uses. In many cases, the student may only use the service using a Smartphone or a PDA.

The spreadsheet has been widely used as a simulation tools in engineering courses. The numerous advantages for learning via simulation have been testified in many papers [6, 7]. The dynamic correspondence among the spreadsheet cells make a spreadsheet application like Microsoft Excel, especially suitable to model linear and nonlinear control systems. In view that Excel is an excellent simulation tool for control engineering and it is widely and easily available, in this paper we introduce a system that allows the user to run Excel simulation on handheld mobile devices. In the construction of this system, we have devised a method which is able to convert different file formats (e.g. PDF, DOC, PPT and XLS file formats) to standard picture file format (e.g. JPEG). The rationale for this is that while only a small percentage of handheld mobile devices can store and run Microsoft Office files (e.g. the Excel file), most handheld mobile devices are able to display a JPEG file. By converting the Excel to image format, we allow handheld mobile devices that do not have the Excel application to display the result of the simulation. Image processing techniques are used to resize and refine the image file to make it viewable over a small display area.

## FILE CONVERSION

File conversion is the key step to address the issue of allowing access and display of remote documents. This is done by converting them to a form which is acceptable by handheld devices. The aim of the file conversion method devised is to convert the results of an Excel simulation to the image format. The file conversion method is a generic method that can be used on other Microsoft office applications. This section will address the issues involved.

### *Current trends*

The number of PDAs sold is estimated to be around 14 million in the year 2003 [9]. On the other hand, the number of cellular phones sold about 500 million units in 2003 [10]. From these statistics, we can conclude that there are far more people using cellular phones than PDAs. In order for mobile Excel simulation applications to have mass appeal, the application developed must be able to run in 'ordinary' handheld mobile devices owned by most people. We term 'ordinary' handheld mobile devices to refer to cellular phones with small color display screen and a limited memory space. These cellular phones usually do not have enough memory space to store a typical PDF, DOC, PPT or XLS file.

Presently, the cell phone makers attempt to increase the memory capacity of the cell phone by having a memory expansion slot for either a multimedia card or a secure digital card. This addition proves to be an expensive solution as one multimedia card costs about 100 euros. The additional expansion slot will also enlarge the physical size of the phone.

Another alternative adopted by the industry is to have conversion software that reduces the file size by removing some of the features from the original files. This will allow them to be displayed on cellular phones with limited CPU power and memory resources. However, the loss in data may be crucial especially when the data pertains to educational resources which typically contain substantial amounts of both graphics and text.

In the following subsections, we will present our proposed methods to convert PDF, DOC, PPT and XLS files to an image file format. Presenting educational information in an image file format offers two advantages:

1. All handheld mobile devices with a screen display are able to display image file. Thus, the image file format can be considered to be a universal format that does not require special processing (e.g., Extensible Markup Language Transformation (XSTL) to cater for different handheld mobile devices).
2. The file size will be reduced tremendously. A 100Kb 10-page Word document can be converted to 10 image files with an aggregate file size of less than 15Kb. This will allow cellular phones with a limited storage to download and store the image files.

### *Word, PowerPoint, Excel source files*

There is a common characteristic among these three (DOC, PPT, XLS) seemingly different file types. They are all compound documents which means that the copying and editing of a document embedded in another document is allowable. In short, a compound document is characterized by object linking and embedding (OLE) [11]. These features prove to be useful in the method proposed in this paper to convert DOC, PPT and XLS to an image file. The details behind the method will be discussed shortly.

One key objective here is to automate the conversion process. Automation, in this context, refers to the ability to control an application from within another application. The handheld mobile device will access the server to activate the application to carry out the conversion without human intervention. Figure 1 illustrates the automated conversion of a PPT file via the control of a cellular phone.

There are several ways to achieve the automated conversion of a Microsoft office source file into an image file. One way is to read the data from the source file, parse the data and rewrite the data into image file format. Reading the data is a trivial task;



Fig. 1. PowerPoint viewing. When the user accesses the server that hosts the PowerPoint file, the application on the server automatically converts the file to an image file.

there exist open source libraries (e.g. Sourceforge) which can perform the task easily. The parsing of data, on the other hand, is a very tedious process, which involves recognizing and converting various strings and number formatting. Loss and distortion in the conversion process will also occur due to the misinterpretation of formatted information. Alternatively, a virtual printer driver can be developed to print the source file to an image file. However, this method may be considered to be intrusive as it requires the server to install the virtual printer driver. The conversion may also take a substantial amount of time, which may trigger a timeout problem (WAP [12] gateway timeout problem will be illustrated in a later section).

#### *COM and Clipboard*

Compound documents have the OLE feature that allows raw data to be copied to the clipboard and enables parts of two documents to be joined together. Through the clipboard, we have the means to convert a Microsoft Office file to an image file easily. When part of the compound document is copied to the clipboard, the object is stored in one or more of the clipboard formats. One of the clipboard formats that the object is stored in is the Enhanced Windows Metafile graphic (EMF) format. EMF as the name suggests refers to metafile graphics which contain both raster and vector data.

The object is stored as a vector with bitmap attributes. Using Windows graphics and multimedia API, the EMF file can be converted to a bitmap file.

To automate this clipboard copying process, we can make use of the Component Object Model (COM) server. COM defines a standard communication interface between the server and client module. As an illustration, the following subsection will show the use of COM to control the Excel application from within another application.

#### *Excel to Bitmap*

There are basically two methods to control Excel from within another application; early bind-

ing and late binding [13]. Binding, in this example, refers to the process of linking the function calls in the developed application and the code in the Excel application. Binding replaces the function names in the developed application with the memory addresses in the table of pointers known as v-table. Programming the pointers in the v-table is complicated and error prone. A programming environment, such as Delphi and Visual Basic, provide matching of the function calls behind the scene, thus greatly reducing the complexity and the time for development.

In early binding, the application is called the IUnknown interface of the Excel's COM object. The access to the IUnknown interface is obtained by making reference to the type library 'Microsoft Excel 8.0 Object Library'. This method is called early binding, as the object is known at the design time.

In late binding, the application binds to Excel COM object via the IDispatch interface. The properties and methods in the COM object are determined and called using the GetIDsOfNames and Invoke functions in the IDispatch at runtime, hence the name 'late binding'.

The main advantage of early binding over late binding is the speed of execution. Early binding is at least twice as fast as late binding. This is due to the direct linking of the application and function address in the COM, thus there is no overhead in runtime lookup as in the case of late binding. Late binding, on the other hand, is version independent, as the exact COM object need not be known at design time. For example, to use Excel 2002, Excel95-type library must be used in early binding, but the version does not matter for late binding. The type of binding to use will thus depend on the nature of the application.

After the application has completed the binding to the Excel COM, the application will be able to use the functions present in the Excel application. The application can then specify the parts of the Excel spreadsheet that is to be copied to the clipboard. The part that is copied to clipboard is in several different types of clipboard formats, e.g., CF\_METAFILEPICT and CF\_TEXT. Using the graphics device interface (GDI) API, the EMF representation of the copied part can be converted to a bitmap file.

By iteratively checking the number of active workbooks and worksheets in the Excel file, all the worksheets and charts in the file can be converted to a bitmap file. Figure 2 shows the concept of using the clipboard to convert the Excel file to a Bitmap file diagrammatically.

In the case of PowerPoint, the conversion process is more direct. As there is an in-built function in the PowerPoint COM to save the PPT file as an image file, the clipboard copy step can be skipped. This in-built function however is not available in the Word and Excel applications.

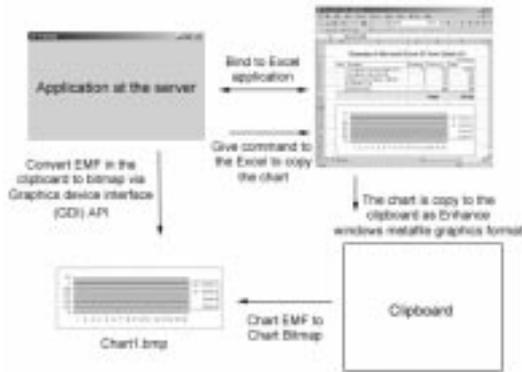


Fig. 2. Clipboard conversion. The figure illustrates the use of the clipboard to convert a chart in an Excel file to bitmap format. Note that besides the enhanced Windows metafile format, the chart is also stored in other clipboard formats.

### COMPARING WITH COMMERCIAL CONVERSIONS

The time needed for the conversion of the Microsoft Office file to an image file plays a crucial role in the dissemination of education resources as an image file. If the conversion time is too long, timeout of the connection is likely to occur. In this section, we will compare the conversion time between a commercial printer driver (Universal Document Converter [14]) with the conversion method proposed in this article.

To compare the speed of conversion, the two applications are run in turn to convert an Excel file to image file. The time taken is shown in Table 1. The Excel file consists of 1000 rows by 9 columns of text and a picture chart. The ratio between the amount of text and picture is varied; Figure 3 shows the results obtained. From the graph shown in Figure 3, we observe that the clipboard method converts about 10 times faster than the virtual printer driver. The changes in the ratio between the amount of text and graphics have little impact on the conversion time. However, it

Table 1. Excell conversion time

Percentage of color picture chart	Time taken by the application (sec)	
	Universal document	Clipboard method
0%	20.00	3.20
10%	19.50	3.17
20%	19.70	2.80
30%	19.00	2.75
40%	18.50	2.75
50%	18.30	2.50
60%	18.00	2.40
70%	17.65	2.10
80%	17.50	2.00
90%	17.20	2.00
100%	17.00	1.90

The first column show the ratio of text to picture chart in the excel file, for example first row is 100% text and 0% picture chart.

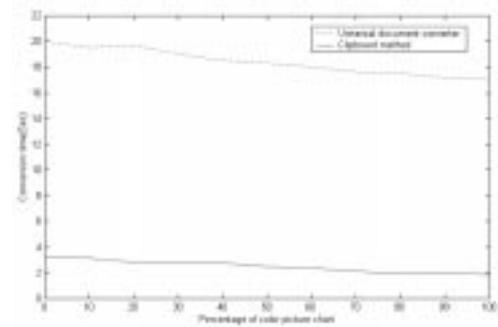


Fig. 3. Conversion time. The dotted line shows how the conversion time of the universal document converter varies as the proportion of color picture chart in the file increase. The solid line shows the same changes when the proposed clipboard method is used.

is generally noted that as the proportion of graphics increases, the conversion time decreases.

#### Image processing

In the raw form, the bitmap file obtained from the file conversion process is still not suitable to be displayed on cellular phone for the following reasons:

1. The image size, in terms of pixel height and width, is too large for the cellular phone display screen. After conversion, the image size is usually several hundreds pixels in dimension. The average cellular phone display screen is only about  $200 \times 200$  pixels. Thus, resampling is needed.
2. Due to resampling, the image will become less refined and the words may be distorted beyond recognition. Thus, further image processing is needed to refine the resampled image.
3. Although the cellular phone can support a wide range of image formats, the service provider usually only allows Joint Photographic Expert Group (JPEG) or Graphics Interchange Format (GIF) to be transmitted.

#### Resize and resampling

To this end of image processing, we have preferred resampling to resizing. When the image is enlarged using resizing, some of the pixels are duplicated. When the image is reduced using resizing, some of the pixels are just discarded. Hence, thin lines and fine features may be removed in the resized image. In the case of resampling, the pixels are recalculate using mathematical interpolation techniques. The resultant image produced by resampling is of better quality than that produced by the resizing method.

Nearest Neighbour, Bilinear and Bicubic are three interpolations commonly used in a resampling method [15]:

1. Nearest Neighbour method determines the pixel at the resultant image from the neighbor pixel at specified coordinates of the input image.

2. Bilinear method uses the colors from four nearest neighbor pixels of a specified point.
3. Bicubic method uses eight surrounding pixel colors, taking the average of the pixels at the resultant image.

Of the three methods, the Nearest Neighbour interpolation method is the fastest; however, it produces low quality image. The Bicubic produces the best resultant image at a longer processing time. In the application that will be introduced in the next section, Bicubic interpolation is used as the delay incurred is acceptable.

*Resampling and Gaussian blur*

Although resampling using Bicubic interpolation has produced relatively good quality image, undesirable artifacts, e.g., distortion of straight line, still exist. As most alphabets contain fine straight lines, this poses a serious problem to the viewability of the resultant image. The distortion can be critical when the scaling factor is high as shown in Fig. 4.

Gaussian blur is adopted to smooth out these artifacts. In the Gaussian blurring process, each pixel in the RGB image is mixed with its adjacent neighboring pixel with a Gaussian probability. Thus, the nearer pixel will have a greater effect

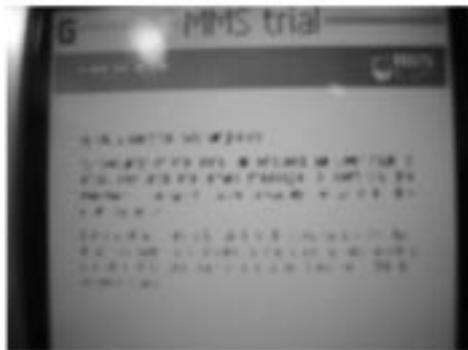


Fig. 4. The figure shows a resample image of 130 × 90 pixels. The resampling scale is approximately 5 times. The cellular phone used is Nokia 6610. Note that the text wording is been distorted and is unreadable.

Table 2. Rate scale of the Television Allocations Study Organization

Value	Rating	Description
1	Excellence	An image of extremely high quality, as good as you could desire.
2	Fine	An image of high quality, providing enjoyable viewing. Interference is not objectionable.
3	Passable	An image of acceptable quality. Interference is not objectionable.
4	Marginal	An image of poor quality; you wish you could improve it. Interference is somewhat objectionable.
5	Inferior	A very poor image, but you could watch it.
6	Unusable	An image so bad that you could not watch.

on the desired pixel. The amount of affected pixels on either side is determined by the convolution radius specified. By blurring the image before performing the resampling, the fine details are ‘enlarged’ and they remain visible even after resampling. The size of the convolution radius used is dependent on the resampling scale factor. The subjective fidelity criteria is used to find the best fit convolution radius size.

Using Table 2, a group of 40 people is asked to rate the image displayed on a cellular phone (Figs 5–8).

*Subjective fidelity criteria*

There are two general classes of criteria to assess the quality of an image [16]: (1) Objective fidelity criterion and (2) subjective fidelity criterion. Objective fidelity criterion involves the use of complex mathematical model and is beyond the scope of this paper. Below we describe how the

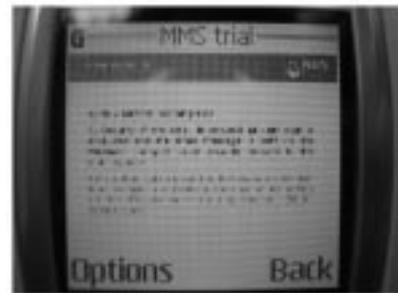


Fig. 5. The convolution radius used is 1. Notice that the straight line is thicker as compare to Fig. 4.

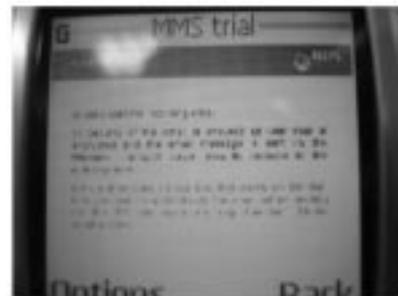


Fig. 6. The convolution radius used is 2. Notice that some of the wording is now recognizable.

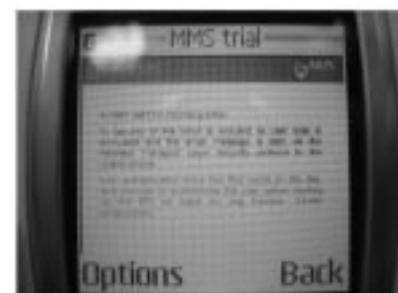


Fig. 7. The convolution radius used is 3. The display image is voted to be most recognizable.

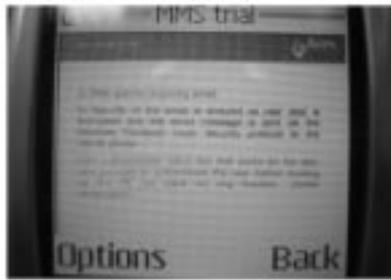


Fig. 8. The convolution radius used is 4. The display image is starting to get blurred

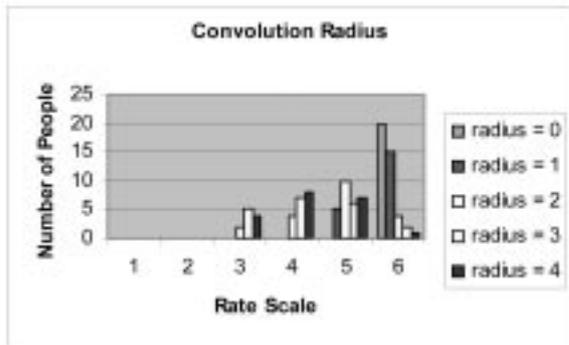


Fig. 9. The bar chart shows the result obtained from a 40-person survey rating the quality of image according to subjective fidelity criteria.

subjective fidelity criterion was performed and the result is shown.

For the survey,  $720 \times 540$  pixels of a converted PowerPoint image is blurred using Gaussian blur before it is resampled to an image size of  $130 \times 90$  pixels. The resultant image is displayed on a cellular phone with a small display screen. A bar chart, as shown in Fig. 9, was plotted based on the survey results. From the subjective fidelity criteria test, we conclude that a convolution radius of 3 produces the best viewable image in this example. As the convolution radius increases beyond 4, the displayed image begins to blur. The convolution radius is dependent on the original image size and the resampling scale factor. In general, a smaller image size and scale factor requires a smaller convolution radius.

*Zoom function*

Despite the image processing effort, the readability of the resultant image can still be further improved. To this end, a zoom function is introduced. The zoom function allows the user to enlarge the area of interest by selecting one of the regions 1, 2, 3 or 4 from Fig. 10(a) or 10(b). The selected region will then be cropped from the original image. As the cropped image has a lesser number of pixels, the resampled scale factor will be small and the image will appear magnified as shown in Fig. 11. Figure 10 shows two possible ways to split the original image. It is found that the method depicted in Fig. 10(a) is preferred when dealing with picture-based image, while the

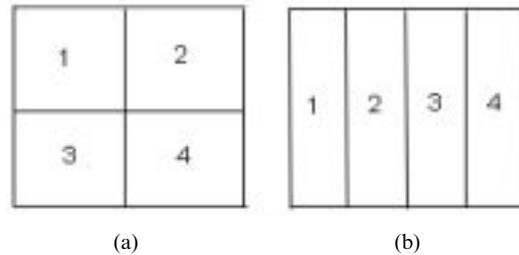


Fig. 10. (a) On the right shows the original image been split into four equal length square regions. (b) On the left shows the image split into four rectangular regions.



Fig. 11. Using the zoom function the processed image shown in Fig. 7 is enlarged.

method depicted in Fig. 10(b) is more suitable for text-based images.

**APPLICATION**

Utilizing the file conversion and image processing methods developed as described in the previous sections, an application demonstrating the running of Excel simulator on mobile handheld devices has been developed. The application will be described in this section.

*Excel PID control simulator*

The Excel simulator models a digital PID controller and simulates its performance in a simple control loop. The process model used in this experiment is a standard ‘first-order lag plus delay’ model used in many process control applications:

$$Y(s) = A \frac{e^{-sL}}{1 + sT} U(s) \tag{1}$$

where  $u(t)$  is the input to the process, and  $y(t)$  is the corresponding process output.  $T$  is the time constant,  $A$  is the gain and  $L$  is the time delay of the process. The transfer function of the PID controller is as follow:

$$U(s) = G(1 + \frac{1}{sT_i} + sT_d)X(s) \tag{2}$$

Figure 12 illustrates a simple PID control system. The Excel simulator developed allows the user to set the system parameters  $A$ ,  $L$  and  $T$ . By

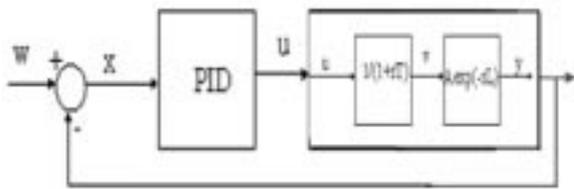


Fig. 12. The diagram shows the working of a PID controller.

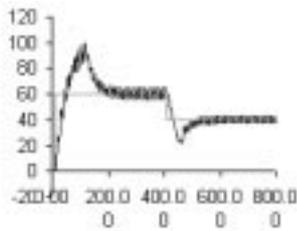


Fig. 13. The diagram shows the performance of the PID controller.

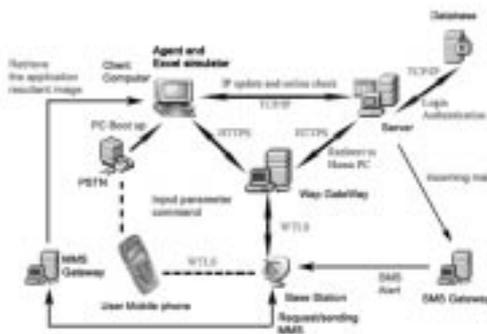


Fig. 14. Network architecture. The diagram briefly shows the communication between the various components in the architecture.

varying the controller parameters (G,  $T_i$ , and  $T_d$ ), a different performance in term of response speed and magnitude of overshoot can be observed as shown in Fig. 13.

*Mobile Excel PID simulator*

The application that resides in the computer (it can be a server or user personal computer) that establishes connection with the hand-help mobile device, is termed Agent. It is through the Agent that the handheld mobile device controls the COM library mentioned above.

As can be seen from Fig. 14, the handheld mobile device and Agent exhibit a thin client relationship. Adopting this model has several advantages. Firstly, the handheld mobile device does not need to install any program. This simplifies the system development as we need not consider the low hard disk size of the handheld mobile device. Secondly, the interoperability is enhanced as different handheld mobile devices with the same type of WAP browser will be able to view the output of Agent correctly.

Here the Agent acts as a server. To allow the user to control Excel application remotely. The Agent is able to change the value in the Excel cells, the preset



Fig. 15. Mobile Excel Simulator. The figure shows the Excel simulator result display on a cellular phone.

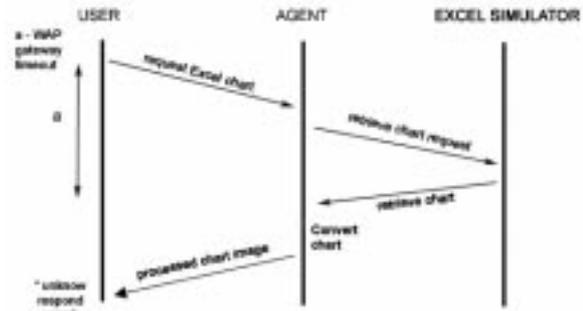


Fig. 16. Effect of timeout. An average of 300 s is set for the timeout period.

formula in the excel will recalculate the value in the correspondence cell. The Agent will capture and convert the resultant chart as image and sent it to the user mobile handheld. Figure 15, shows the display of the Excel chart on a cellular phone.

The mechanisms to take care of the dynamic IP (Internet Protocol) address and Network Address Translation (NAT) will not be elaborated here. The detailed implementation can be found at [8].

A potential problem to address in this application is one relating to the WAP gateway timeout. One of the critical problems faced by the Agent is the premature timeout termination by the WAP gateway. A WAP Gateway is a server that sits on the Internet and translates data into a format that is compatible for mobile phones [17].

When the Agent executes a time-consuming task, the time needed to perform this process can exceed the timeout assigned by the WAP gateway, thus causing an 'unknown response' error. As the WAP gateway is manned by the telecommunication company, therefore, the timeout period cannot be changed easily.

To resolve the problem illustrated in Fig. 16, a 'time buffer' code is additionally introduced. The following shows a pseudo code buffer class:

```

< Begin Wireless Markup Language coding >
< Timer start >
< On event timeup >
< Goto actual retrieve class >
< End Wireless Markup Language coding >
Retrieve chart
⇐ Timeout occurred
Retrieved chart
    
```



Fig. 17. Buffer. It is a small WML code downloaded into the handheld mobile device during transactions. It re-establishes the connection between the handheld mobile devices and the agent when the timeout takes place.

When the access Excel class file is run, it will first generate the Wireless Markup Language (WML) code. During the first-time execution of the Excel simulation procedure the timeout of the WAP gateway is reached, and the connection between the WAP gateway and the Agent will be lost, but the transaction between the Agent and the Excel can still carry on. The WML code generated will be downloaded to the user handheld mobile device and be executed. The WML code will direct the handheld mobile device back to the Agent after 30 s. By then, the execution of Excel simulation procedure would have completed and the user will be able to display the processed web page. Figure 17 shows the effect of the buffer.

### FURTHER DISCUSSION

Most of the current mobile 'Virtual Laboratory' development revolves around the use of PDAs. PDAs were viewed as a comparatively cheap alternative to computers. However, with the recent drastic drop in the price of computers, this view may not hold true anymore. Another popular reason for using PDAs is the wireless capabilities

which they are equipped. However, low-cost laptops with wireless connectivity are becoming widely available. The student:PDA ratio is estimated to be 10:1; student:cellular phone ratio on the other hand is expected to be 10:9. Therefore, cellular phones will make an excellent choice as the device to deliver 'Virtual Laboratory'. Based on this motivation, the developed system targeted the use of the cellular phone as the main delivery device and methods have developed to overcome its limitations. The system is based on a distributed structure. It allows the student to conduct experiments anytime and anywhere.

### CONCLUSIONS

In this paper, a 'universal format' (image file format) that can be displayed in all handheld mobile devices with color screens has been identified. A simple and fast 'clipboard method' to convert Excel into image file format has been devised. The time taken by the file conversion process plays a crucial role. If the time taken for the conversion is too long, WAP gateway timeout error is likely to occur.

Most of the users of mobile Virtual Laboratory application are students. As they usually have a tight budget, the handheld mobile devices they possess are typically cellular phones with small color display screens. Resampling the converted image to the display screen size will render the image to be unviewable. Thus, special image processing techniques which are needed to improve the image quality have been proposed and discussed. A short description on how an Excel simulator is run using mobile handheld devices is presented.

In the near future, affordable handheld mobile devices with color-rich display screens and huge storage capacity will be available in the market. However, in the mean time, the methods introduced in this paper will remain useful and relevant to mobile Virtual Laboratory.

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