

OPEN SOURCE SOLUTION FOR NUMERICAL COMPUTING EDUCATION

(Penyelesaian Sumber Terbuka untuk Pendidikan Pengkomputeran Berangka)

Mohammad Khatim Hasan¹ and Jumat Sulaiman²

¹School of Information Technology, Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor

²School of Science and Technology, Universiti Malaysia Sabah, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Selangor, Malaysia

Abstract

The growth in open source software in this era gave positive impact on academia culture throughout the world. The expansion of the initiative has affected the education world, the development of open course content and open access research. This shift toward "openness" in academic practice is truly a positive trend and may impacted innovation in the world of academia. The main reasons why should academic institutions turning to open source software solution is the cost of software license. Lecturer and student will not be burden with yearly license cost to do research, teaching and learning. In this paper, we will discuss the use of open source software, which called Scilab in numerical computing education. The software is available free of charge via the internet and was developed for the purpose of matrix manipulation which is well suited for numerical computing course and it is comparable with the well-known, highly cost MATLAB software. The purpose of this paper is to show that the open source software can be used as the alternative for numerical computing education. Scilab has been developing for Linux, Windows and MacOSX operating systems. The package can serve the needs of numerical computing student if commercial software is not available.

Abstrak

Pertumbuhan dalam perisian sumber terbuka di zaman ini memberi kesan positif ke atas budaya akademik di seluruh dunia. Pengembangan inisiatif tersebut telah memberi kesan kepada dunia pendidikan, pembangunan kandungan kursus terbuka dan penyelidikan dalam akses terbuka. Peralihan ke arah "keterbukaan" dalam amalan akademik ini merupakan tren positif dan boleh memberi kesan kepada inovasi dalam dunia akademik. Sebab utama mengapa institusi akademik perlu bertukar kepada perisian sumber terbuka adalah kerana kos lesen perisian. Pensyarah dan pelajar tidak perlu dibebani dengan kos lesen tahunan untuk melakukan penyelidikan, pengajaran dan pembelajaran. Dalam kertas ini, kita akan membincangkan penggunaan perisian sumber terbuka, yang dipanggil *Scilab* dalam pendidikan pengkomputeran berangka. Perisian ini dibangunkan bagi tujuan pemanipulasian matriks, jesteru sesuai untuk kursus pengkomputeran berangka dan ianya setanding dengan perisian yang terkenal dan mahal, iaitu MATLAB. Tujuan kertas ini adalah untuk menunjukkan bahawa perisian sumber terbuka boleh digunakan sebagai alternatif dalam pendidikan pengkomputeran berangka. Perisian *Scilab* telah dibangunkan untuk system pengoperasian *Linux*, *Windows* dan *MacOSX*. Sistem ini dapat memenuhi keperluan pelajar komputeran berangka jika perisian komersil tiada.

Introduction

Numerical computing is an essential knowledge for simulating phenomenon in science and engineering. It covers the technical knowledge of methods used in the field. Thus, it is a compulsory course need to be taught to the student. Numerical computing course lies in various faculties, such as Information Technology, Mathematics, Engineering and Science and technology. The subject covers roots of equation, system of linear equation, Interpolation,

Integration and differentiation, Optimization, Ordinary differential Equation and Partial Differential Equation.

Numerical computing is a different mathematical course, from the course student took before. The subject needs learners to understand mathematics and skills in computing. Previous student feels the subject hard to understand and scared by its requirement. Thus, we feel teaching method of the subject needs improvement.

Matlab is the most widely used numerical computational package (Antoch, 2008). However, the software is very costly to be maintained by student. Alternatives to Matlab, are FreeMat, Octave, Sage and Scilab. These alternatives are freely available on the internet and known as open source software.

The concept of openness in higher education has been adopted by many countries in the world, such as United Kingdom. However the concept raised some interesting challenges. The concept includes open source software, open standards and open access to research publication and data. The Joint Information Systems Committee (JISC) of the United Kingdom education funding councils has been engaged in a long-running process of engaging with the concept of openness in educational technology and digital content since the transformation is not an easy tasks (Kelly et al, 2007).

Malaysian government has launched the Open Source Software (OSS) Master Plan on 16 July 2004 to encourage and expand the usage of OSS in public sector. The objectives of the initiative are to reduce the total cost of ownership, freely use software, increase interoperability between software, increase the growth of ICT industry, enhance the growth of OSS industry, increase the growth of OSS user and developer community, increase the growth of knowledge-based society and reducing the digital gaps (<http://www.mampu.gov.my/guest/opensource>).

Recently, internet has been the major resource of knowledge to the academic as well as public. They use the internet for so many reasons such as improve knowledge, skills, distributing information, economics, socialize, and many others. The tools provide rapid and often free access of information. It has a vast and very rich repository of open source solution to solve variety of problems.

In this paper, we will focus on the Scilab software. This software is available freely on the internet, thus gives the users with limited resources to perform significant computational studies. However, we will also discuss briefly on FreeMat, Octave and Sage software.

The discussion in this paper for the remaining section will be based on figure 1.

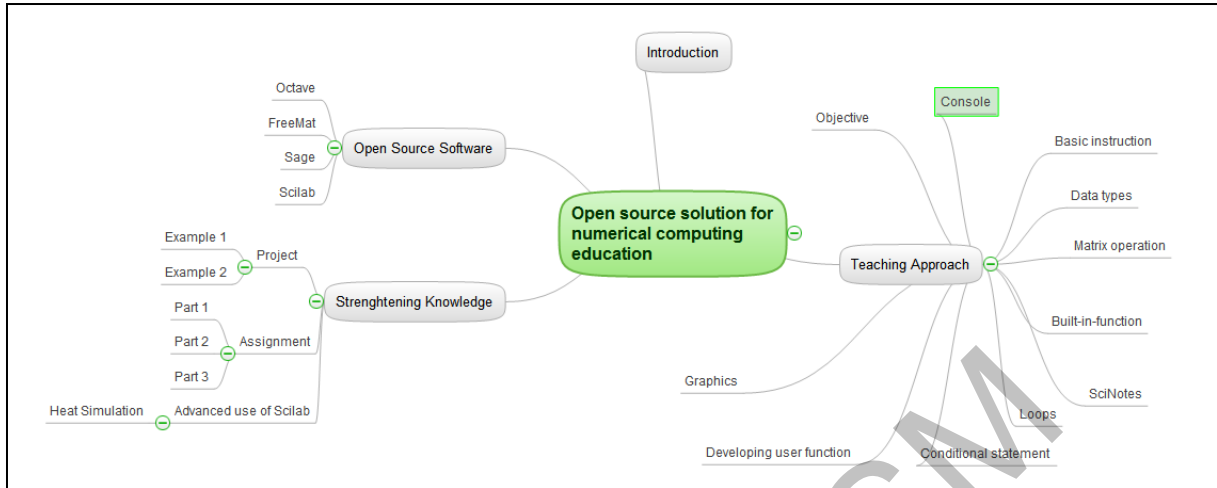


Figure 1. Discussion structure

Octave

Octave is a high level programming language. This software was developed by John W. Eaton. The name of the software was given after a professor at Oregon State University, Octave Levenspiel. The software was first developed for simulating chemical reaction engineering. The software was developed using C++. The software also uses libraries such as LAPACK and BLAS. The first release of the software was on January 4, 1993. The software can be downloaded at <http://sourceforge.net/projects/octave>. The software has been included in MARIE project; a programming environment for robot application (<http://marie.sourceforge.net>).

FreeMat

Another alternative to MATLAB is FreeMat. The software was developed by Samit Basu to handle eigenvalue and singular value decomposition, plotting, parallel processing, graphics, function pointers and many others. The software can be downloaded at <http://sourceforge.net/projects/freemat>.

Sage

Another alternative to MATLAB is Sage (Erocal & Stein, 2010). The software was developed by William Stein, a professor at Washington University in 2005. The software won the first place at Trophées du Libre 2007 for free scientific software category, Special Interest Group on Symbolic and Algebraic Manipulation (SIGSAM).

Researchers have used Sage among others for research in Ocean Modeling (Sommer et al, 2011), Computing Hermite normal form (Pernet & Stein, in Press) and Multiplication of dense matrices over the field of two elements (Albrecht et al, 2010).

Scilab

Scilab is a numerical computing software developed at INRIA (Institut National de Recherche en Informatique et en Automatique), France. The capability of the software is similar to MATLAB. The software have a script editor call SciNotes that can be used to develop function as addition to its console called the Scilab console. The software can be group as high level programming language and as an interpreter. Scilab language can be interfaced easily with C or Fortran programs using dynamic links, through the links primitive, or using interfacing or gateway programs. Beside that, several toolboxes are available for Scilab users; Scicos which can be used for modeling and simulation of dynamical systems; ANN, toolbox for artificial neural network, signal processing toolbox and FRACLAB, for fractal, multifractal and wavelet analysis. In addition, the software also support the execution of parallel jobs via pvm library.

Scilab have been used by researcher in many application, among others are in forecasting economic behavior (Buss, 2009), in statistical analysis (Antoch, 2008; You et. al, 2009) and in solving linear system of equation (You & Xie, 2010). However, Koshikawa et. al (2010) use Scilab to improve drawing figure in Latex.

In this paper, we will discuss our experience of using Scilab in teaching Numerical Computing at the Faculty of Information Science and Technology. We explore different approach compared to Anido and Scola (2012). In the paper, they use Scilab in the teaching as the alternative approach to the traditional method, in contrast, we use Scilab as an additional knowledge (programming knowledge) and as the guidance of solving problem in Numerical Computing education. We use this approach since one of the finding in the paper was using the software as an alternative may impact on student losing the skill of solving problem manually. We allocate additional 2 hour for Scilab laboratory for the purpose of strengthening student skills in Scilab.

Our approach of teaching Scilab was decompose in two stages; **stage 1**: using Scilab Built-in function as student guidance in solving numerical problem and **stage 2**: developing Scilab script using SciNotes.

Teaching approach

The objectives of this teaching approach are

1. To present an approach of teaching numerical computing using Scilab
2. To give student opportunity to sharpen their skill in programming and problem solving in numerical computing
3. To increase student understanding of numerical computing subject
4. To increase student confidence of doing numerical computing exercise

By implementing this approach, we belief that the quality of teaching and learning in numerical computing will be improved, student understanding will be deepened and ability to apply mathematic will be enhanced, skill to use computer technology will be sharpened, student ability of solving real problem will be increase. However, implementing this approach has to be carefully carried out since it has negative impact. The negative impact that we are afraid of happening was the approach may weaken the student ability to technically solve the problem.

In our teaching methodology, we first guide the student to download and install the software. Then we introduce Scilab common mathematical operators, such as addition (+), subtraction (-), multiplication (*), division (/), power (^) and conjugate transpose ('); common function, such as *sin*, *cos*, *tan*, *arc sin (asin)*, *arc cos (acos)*, *arc tangent (atan)*, *absolute (abs)*, *minimum*

(*min*), *maximum (max)*, *square root (sqrt)* and *sum*; special constant such as π (%pi) and $\sqrt{-1}i$ (%i).

As mention before, Scilab is a high level programming language and may be used as a calculator via interpreter. We introduce the use of Scilab Console. In the introduction phase of Scilab, we use only stage 1 approach. Using Scilab Console, Scilab can be used as scientific calculator. This capability is very suitable at the initial level of learning numerical computing. At this level, students are exposed to command-line operation. Several basic operations command for manipulating real and complex numbers was discussed. This activity was to help student to familiar with Scilab environment. Example and exercise were given for every types of data and operations. The first step in stage 1, we familiarized the student with the console by simple instruction such as

<pre>-->a=6.74,b=3.45,c=1.23 a = 6.74 b = 3.45 c = 1.23 -->a+b/c ans = 9.544878</pre>	<pre>-->b/c ans = 2.804878 -->a+ans ans = 9.544878</pre>	<pre>-->sqrt(a) ans = 2.596151 -->a^3 ans = 306.18202</pre>
<pre>-->100*12-(8/4) ans = 1198. -->(87098/45)*(35-5)+5 ans = 58070.333 -->6*a^2-3*b ans = 262.2156</pre>	<pre>-->//complex number -->m=3+4*i,k=2-6*i m = 3. + 4.i k = 2. - 6.i</pre>	<pre>-->m+k ans = 5. - 2.i -->m*k ans = 30. - 10.i</pre>

Figure 2. Simple instruction using Scilab Console

This examples show that Scilab can be used as calculator. In addition, we also discuss about Scilab data structures and how to check variable data type by using *typeof* command. In the second step, we introduce matrix operation command. We start with entering matrix data, followed by operations on the matrix, such as

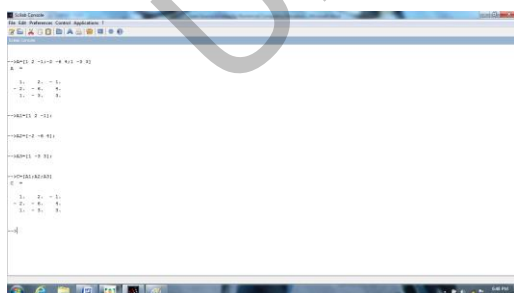
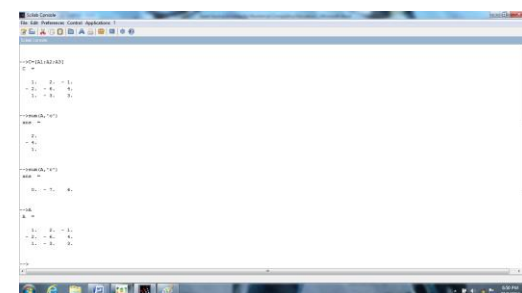
 <p>(a)</p>	 <p>(b)</p>
------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------

Figure 3. Matrix using Scilab Console

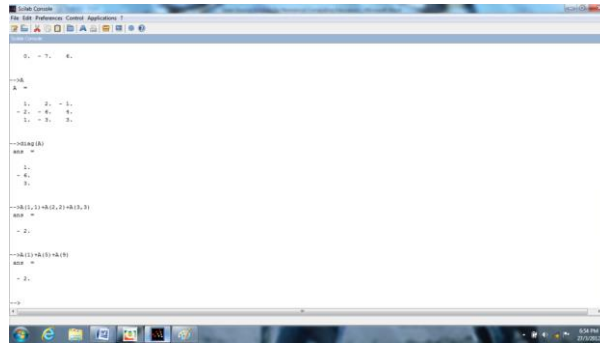


Figure 4. Matrix operation using Scilab Console

We also give some exercise to strengthen their basic knowledge on elementary operation. Once they familiar with basic mathematic elementary operation, we start solving linear system of equation, parallel to the traditional approach of linear system of equation lecture. In this topic, we implement both stage 1 and 2. In stage 1, we use built-in function prepared for solving linear system of equation. However, before introducing the command, we ask the student to solve the problem using traditional approach. The purpose of this exposure was to enable student to check the correctness of their result of traditional approach. Here, we give two examples for this topic. Example of the traditional approach and Scilab approach for example 1 is given as follows.

Example

$$\begin{cases} 5x_1 - 2x_2 + x_3 = 4 \\ x_1 + 4x_2 - 2x_3 = 3 \\ x_1 + 2x_2 + 4x_3 = 17 \end{cases}$$

$$\begin{bmatrix} 5 & -2 & 1 \\ 1 & 4 & -2 \\ 1 & 2 & 4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 3 \\ 17 \end{bmatrix}$$

Make this to 0
Row(2)=Row(2)-Row(1)*1/5

$$\begin{bmatrix} 5 & -2 & 1 \\ 0 & 22 & -11 \\ 0 & 5 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 11 \\ 15 \end{bmatrix}$$

Row(3)=Row(3)-Row(2)*22/5

$$\begin{bmatrix} 5 & -2 & 1 \\ 0 & 22 & -11 \\ 0 & 12 & 19 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 11 \\ 5 \end{bmatrix}$$

Row(3)=Row(3)-Row(1)*1/5

$$\begin{bmatrix} 5 & -2 & 1 \\ 0 & 22 & -11 \\ 1 & 2 & 4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 11 \\ 5 \end{bmatrix}$$

Backward Substitution

$$\begin{bmatrix} 5 & -2 & 1 \\ 0 & 22 & -11 \\ 0 & 5 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 11 \\ 15 \end{bmatrix}$$

$x_3 = \frac{15}{5} = 3$

$$\begin{bmatrix} 5 & -2 & 1 \\ 0 & 22 & -11 \\ 0 & 5 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 11 \\ 5 \end{bmatrix}$$

$\frac{22}{5}x_2 - \frac{11}{5}(3) = \frac{11}{5} \rightarrow x_2 = \frac{\frac{11}{5} + \frac{33}{5}}{\frac{22}{5}} = \frac{44}{5} \times \frac{5}{22} = 2$

$$\begin{bmatrix} 5 & -2 & 1 \\ 0 & 22 & -11 \\ 0 & 5 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 11 \\ 15 \end{bmatrix}$$

$5x_1 - 2(2) + 3 = 4 \rightarrow x_1 = \frac{4+1}{5} = 1$

Figure 5. Traditional approach of solving system of linear equation

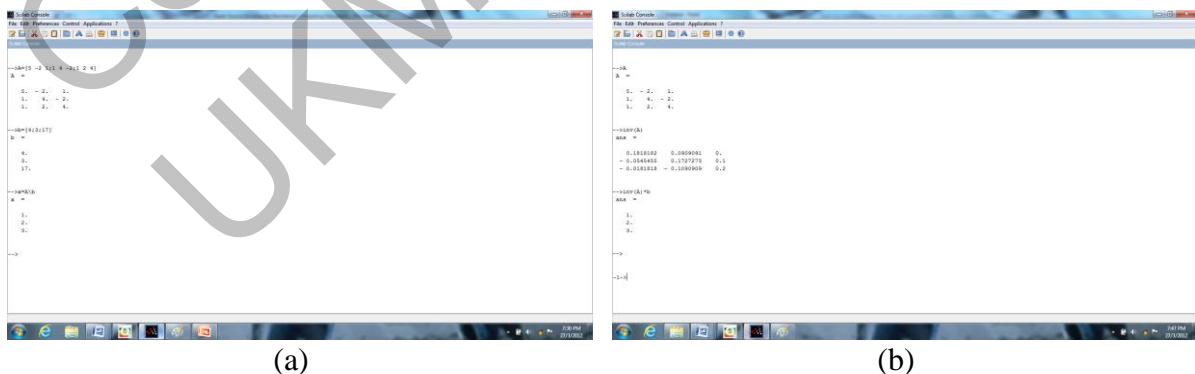


Figure 6. Built in function for solving system of linear equation

For example 2, we show that this problem can be solve by multiplying inverse of matrix A with vector b. As mention before, in this topic we also apply stage 2; the programming part of Scilab. To start the stage b, we introduce the student with SciNotes.

We start with developing and triggering simple function. Example of the function is given in Figure 7(a). The function was executed and triggered as in Figure 7(b).

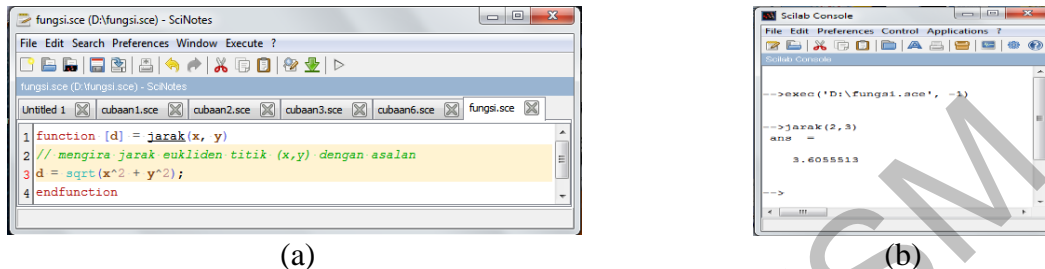


Figure 7. Matrix operation using Scilab Console

Second step, technique to plot graph were taught. Scilab provide several plotting instruction. We start with the simplest plot of graph. The simplest instruction and its graphical output are given below.

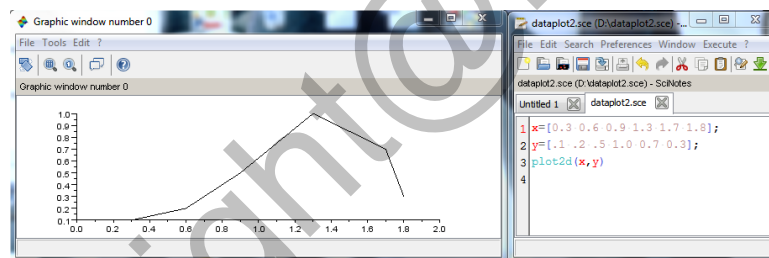


Figure 8. Simple Scilab plot instruction

Another example of plotting graph

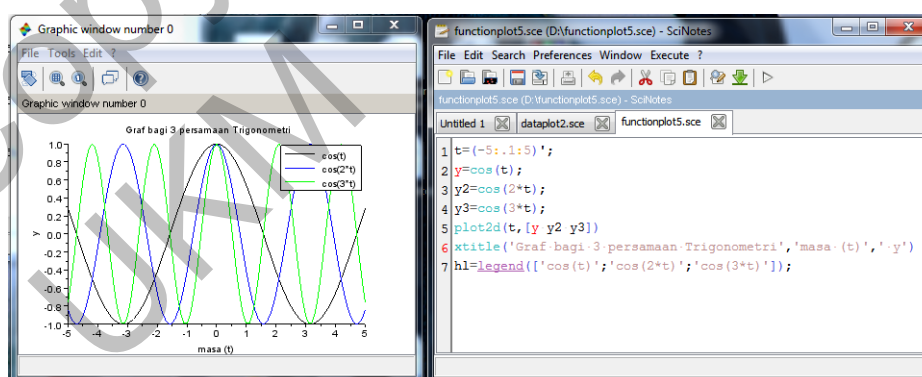


Figure 9. Another Scilab plot instruction

The third step was the loops and conditional statement. For loops, Scilab provide for and while loops.

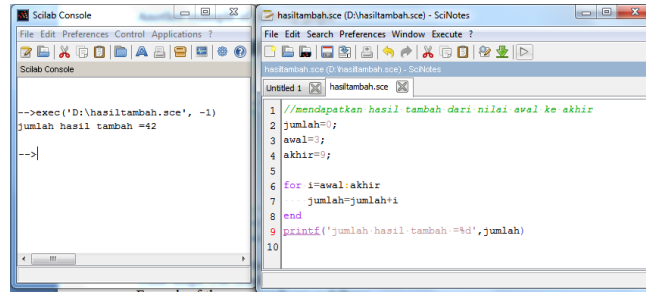


Figure 10. Simple Scilab for loops

Besides For loops, Scilab also provide While loops and do loops.

Forth step in stage 2, we teach For conditional statement, Scilab use if-then-else and select-case statement. Example of the commands is as follows.

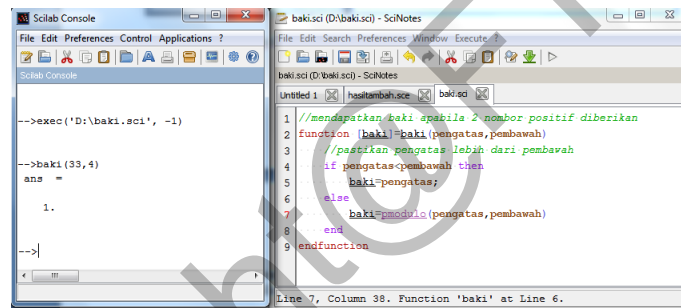


Figure 11. Simple Scilab if statement

After they understand the loops and conditional statement, student were taught with more complex function. For solving system of linear equation, we start stage 2 with simple program.

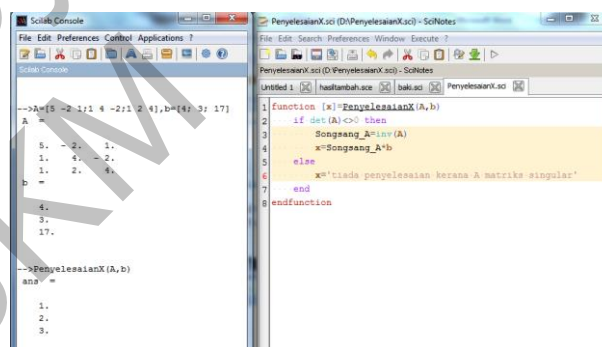


Figure 12. Simple linear equation solver function 1

If we input a singular matrix, the result will be shown as in Figure 13.


```

Scilab Console
-->A=[5 0;1 0],b=[1 1]
A =
  5.  0.
  1.  0.
b =
  1.  1.

-->PenyelesaianX(A,b)
ans =
tidak ada penyelesaian karena A matriks
singular

PenyelesaianX.sci (D:\PenyelesaianX.sci) - SciNotes
1 function [x]=PenyelesaianX(A,b)
2     if det(A)<0 then
3         SongsToang_A=inv(A)
4         x=SongsToang_A*b
5     else
6         x="tidak ada penyelesaian karena A matriks singular"
7     end
8 endfunction

```

Figure 13. Simple linear equation solver function 2

In the sixth step, we give the example of Gauss-Elimination method with partial pivoting.

```

Scilab Console
-->A=[0 2 3;2 0 3;8 16 -1],b=[7;13;-3]
A =
  0.  2.  3.
  2.  0.  3.
  8. 16. -1.
b =
  7.
 13.
 -3.

-->PenghapusanGauss(A,b)
ans =
  2.
 15.
 -1.
 3.

PenghapusanGauss.sci (D:\PenghapusanGauss.sci) - SciNotes
1 function [x]=PenghapusanGauss(A,b)
2     [mA,mB]=size(A)
3     [nB,nB]=size(b)
4
5     if mA<=nB then
6         error('Matriks A perlu lebih sedikit sama');
7         abort;
8     elseif mA<=nB then
9         error('Matriks A dan matriks b tak sepadan');
10        abort;
11    end
12
13    AB=[A b]; // membentuk matriks tambahan
14    n=nA; //size matriks
15
16    //mulakan proses penghapusan gauss
17    for k=1:n-1
18        pangsai=k;
19        NilaiMaks=abs(AB(k,k)); //seleksi pangsai pada ppenjuru
20        for l=k+1:n

```

Figure 14. Function for Gauss Elimination

Assignment and Project

To analyze the understanding of student on this topic, several questions were given to the student via assignments and projects. The assignment was divided into 3 parts; part 1: mathematical solution. This assignment was to increase the student understanding on the numerical approach of solving the problem. Part 2 questions, solve using Scilab built-in function. The purpose of this assignment was to establish student knowledge about Scilab built-in instruction regarding the related topic and also help them to find answer to their solution in part 1 using Scilab. Both part 1 and part 2 solve the same problem. Understanding both parts of question will leads to increase student capability and confidence of doing self-test or self-exercise. In part 3, students were given programming task. With these 3 parts of question, we hope student will understand both numerical and programming parts of numerical computing.

Example of questions

Part 1:

$$\begin{aligned} 3x + 2y - 9z &= -65 \\ -9x - 5y + 2z &= 16 \\ 6x + 7y + 3z &= 5 \end{aligned}$$

Solve system of linear equation above using

1. Gauss elimination
2. Gauss Seidel

Part 2:

1. Solve problem in question 1 using Scilab Built-in function
2. Compare result with the first part

Part 3:

Develop Scilab function for

1. Gauss Elimination
2. Gauss Seidel

and solve the same problem in part 1.

Project 1

The tabulated data below was observed for the short-wave radiation flux (in gram calories per cm^2 per day for September) at the outer limit of the atmosphere, estimate the flux at a latitude of 35° .

Latitude	0	20	40	60	80
Flux	891	856	719	494	219

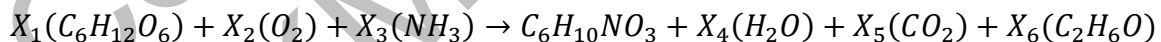
- a. Convert the observed data to system of linear equation
- b. Develop polynomial for given data

Project 2

In the project, students were given a simple but useful applied problem. The purpose of the project was to help student understand the need of the numerical approach, to help student how to solve real problem using numerical computing via mathematical and programming approach.

Ethanol production

Engineers in the food and chemical industries use fermentation in many processes. The following equation describes Baker's yeast fermentation.



$X_i, i = 1, 2, \dots, 6$ represent products masses involved in the reaction, while, $C_6H_{12}O_6, C_6H_{10}NO_3, C_2H_6O$ represent glucose, yeast and ethanol, respectively. In this task, you are required to calculate the amount of ethanol produced.

Hint,

1. Construct system of linear equation
2. Solve the system using
 - a. Gauss Elimination
 - b. Gauss Seidel
 - c. Scilab Built-in-function

Advanced used of Scilab

In the course, we also develop and demo advanced capability of Scilab in solving problem. Using Scilab, graphical simulation can be easily developed. We developed a two dimensional heat simulation for student to experience the use of numerical computing. We use the simulation to understand the behavior of heat distribution in a metal square plate. We analyzed the behavior of several initial and boundary temperature of the square plate (Figure 15).

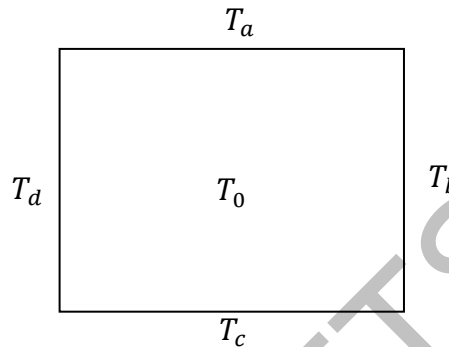


Figure 15. Problem setting for square metal plate simulation

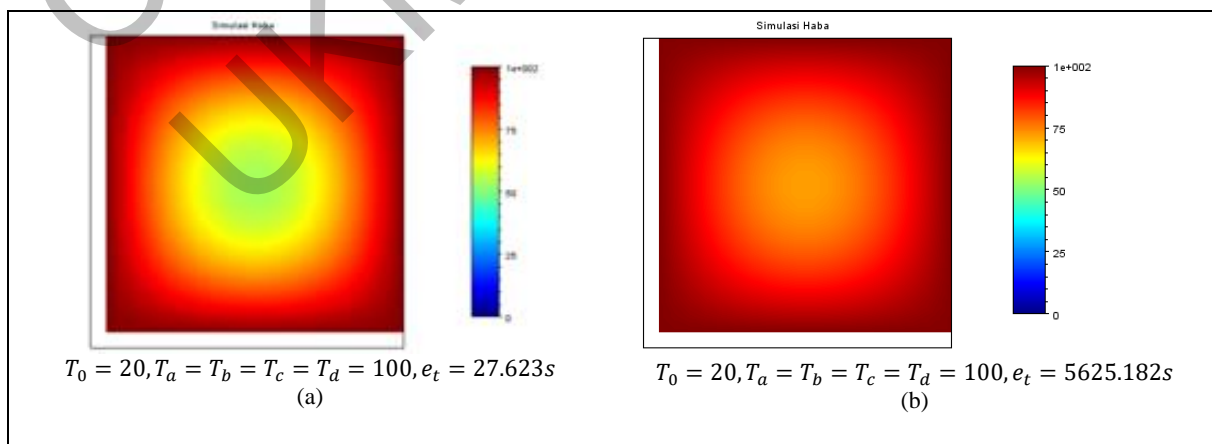
We develop Scilab function for heat simulator on a metal square plate. We name the function as *PensimulasiHaba*. The function received Δt , boundary temperature, initial temperature, tolerance value and maximum loops.

function [MasaSimulasi]=PensimulasiHaba(dt, T_amb, T_awal, eps, GelungMaks)

Four simulation was executed using above function and the result displayed in Figure 16 (a)-(d). We modified the above function to analyze difference situation. The additional situation was the heated area was not only at the boundaries but also at the middle.

function [MasaSimulasi]=PensimulasiHaba(dt, T_amb, T_awal, T_mid, eps, GelungMaks)

Two simulation was executed using above function and the result displayed in Figure 16 (e)-(f).



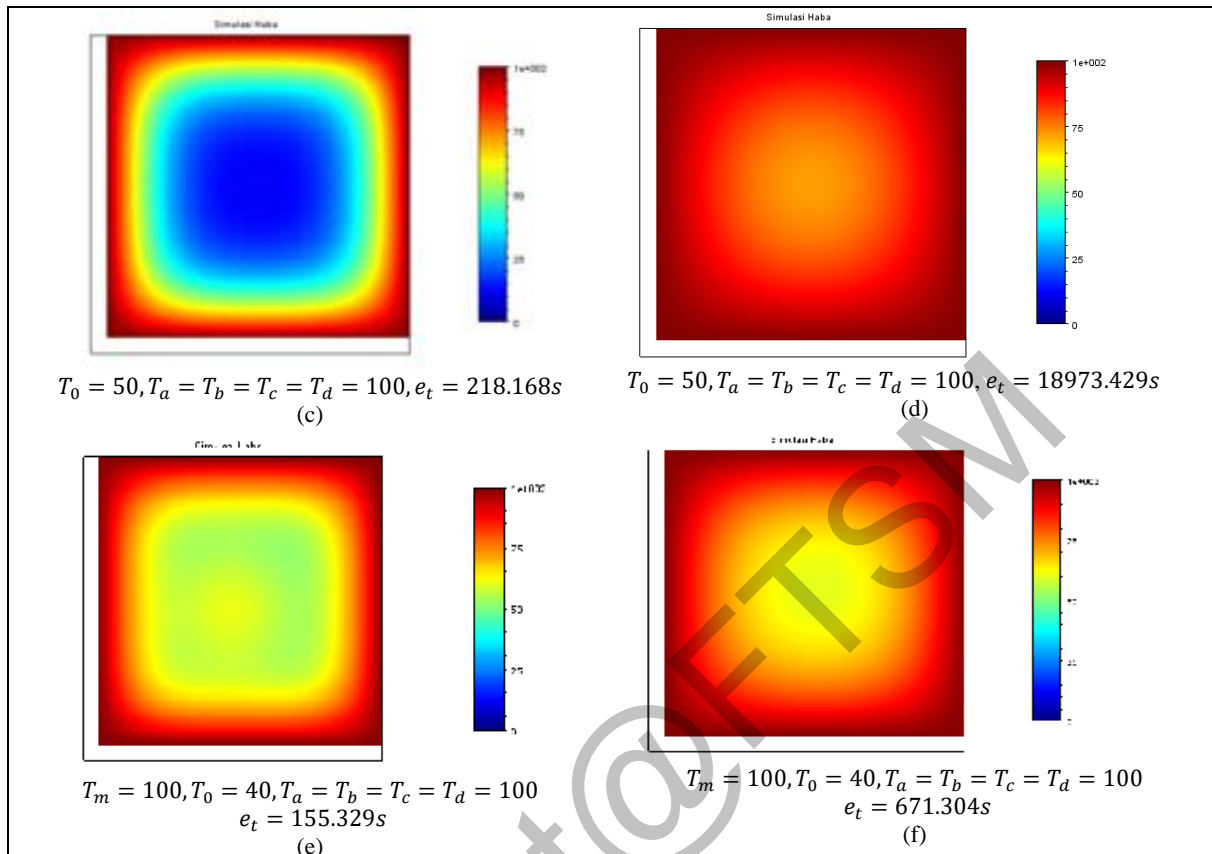


Figure 16. Heat simulation on metal square plate

Conclusion

The change of teaching approach is by integrating computer technology to Numerical Computing. The change in the teaching approach will affect students and their reflection on the subject.

At the beginning, some of the student thought this approach made Numerical Computing subject more difficult since it added new requirement; computing skills, student with less computing skills withdrawn from the course and some of the student thought they do not need to study numerical computing anymore since the built-in function in the software can solve numerical problem.

We observe some of the student have higher understanding than the other. Student with high motivation in learning mathematic and programming really appreciate the teaching approach. However, numbers of students with these motivations are less than those who did not fond of programming or mathematic. This may be the case why topic with “hard” content drag the teaching implementation.

Even though the student have experience in learning programming language, such as C++, but some of them can only be categorized as “a slow learner” to Scilab. This may be because of their C++ knowledge was not “strong”. Some of the student hard to understand the numerical techniques taught in this subject. Their basic knowledge on matrix operations is too little. Thus,

this background knowledge factor may be the reason why this teaching approach not perform as expected.

Teaching Scilab in every two hours weekly, impacted on less time to teach numerical approach. Thus, this will impact on their skills in mathematical part of numerical computing. Besides, the powerful properties of Scilab may lead the student to ignore learning mathematical part of numerical computing.

From our experience in conducting numerical conducting subject are, the subject can only be improved by improving teaching of numerical computing subject only may not be enough to achieve our goal. A proper plan for the whole mathematical education in the School of Information Technology must be “re-organized”. This is because, these mathematical subject have correlation between each other. Feeling excitement on mathematics and programming was the main key for success in this study. To achieve this objective, we need to figure out how to create this “excitement” feeling on mathematics and computing fields. Subsequently, find the strategy to maintain the “feeling”.

However, searching for an appropriate teaching approach to enhance teaching and learning in the subject must be continued for the preparation of future worker or expert in numerical computing field.

References

Sommer, J. Le, d'Ovidio, F. and Madec, G. 2011. Parameterization of Subgrid Stirring in Eddy Resolving Ocean Models. Part 1: Theory and Diagnostics. *Ocean Modelling*, 39(2011) 154-169.

Pernet, C. and Stein, W. 2010. Fast Computation of Hermite Normal Forms of Random Integer Matrices. *Journal of Number Theory*, 130(7): 1675-1683.

Erocal, B and Stein, W. 2010. The Sage Project: Unifying Free Mathematical Software to Create a Viable Alternative to Magma, Maple, Mathematica and MATLAB. In Komei Fukuda, Joris Van der Hoeven, Michael Joswig and Nobuki Takayama (eds). *ICMS 2010. Proceedings of the Third International Congress on Mathematical Software*. Springer, LNCS 6327: 12-27.

Albrecht, M., Bard, M. and Hart, W. 2010. Algorithm 898: Efficient Multiplication of Dense Matrices Over GF(2). *ACM Transaction on Mathematical Software*, 37(1), Article 9 (9:1-9:14).

Buss, G. 2009. Economic Forecasts with Bayesian Autoregressive distributed lag model: Choosing optimal prior in economic downturn. Munich Personal RePEc Archive. MPRA Paper No. 17896. (http://mpra.ub.uni-muenchen.de/17896/2/MPRA_paper_17896.pdf).

Antoch, J. 2008. Environment for Statistical Computing. *Computer Science Review*, 2: 113-122.

You, S., Xie, X. and Chen, Y. 2009. Statistical Analysis of Educational Testing Data based on Scilab, *Proceedings of Open Source Software Conference*, 81-84.

You, S. and Xie, X. 2010. A Synchronous Jacobi Iteration Parallel Algorithm for Solving Linear System Based on Scilab. Proceedings of International Conference on Anti-Counterfeiting Security and Identification in Communication (ASID) 2010, 158-161. (http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5551510)

Kelly, B., Wilson, S. and Metcalfe, R.. 2007. Openness in Higher Education: Open Source, Open Standards, Open Access. Proceedings of ELPUB2007 Conference on Electronic Publishing, Vienna, Austria, June 2007.

Koshikawa, H., Kaneko, M., Yamashita, S., Kitahara, K. and Takato, S. 2010. Handier Use of Scilab to Draw Fine Latex Figures-Usage of Ktexpic Version for Scilab. Proceedings of 2010 International Conference on Computational Science and Its Applications, 39-48.

Anido, M. and Scola, H. E. R. 2012. The Influence Of The Environment Created By The Software Scilab In The Learning Of Linear Algebra.

Copyright@FTSM
UKM