Incorporating MatLab in the Mechanical Engineering Courses at Alabama A&M University

Amir A. Mobasher, A.R. Jalloh, R. Rojas-Oviedo, Z.T. Deng, C. Qian
Mechanical Engineering Department
Alabama A&M University
Huntsville, AL 35762
Amobasher@aamu.edu

Abstract

Nowadays, entry-level engineers may find themselves in an environment that programming, simulation and modeling may become an integral part of their career. In instances that they are involved with enhancement and development of pre-existing programs, the size and complexity of a particular program may become overwhelming. Universities are faced with preparing the students to cope with the challenges that they are faced in their work environment in the context of simulation and modeling. Different tools may be adopted in various departments for training the students in programming such as C, C^{++}, Basic ,Visual Basic, Fortran, or Matlab to name a few and the departments are faced with the question of what environment to adopt to train the students.

One of the requirements of the Mechanical Engineering program at Alabama A&M University is that all students participate in a project in every course. These projects require utilization of computer programming. Two programming environments adopted by the ME Department are Fortran and Matlab. In some courses such as Strength of Materials, Automatic Control Systems, Analysis and Instrumentation of Physical Systems, Kinematics and Dynamics of Machines, and Finite Element Methods, students are given the option of utilizing either a Matlab or Fortran to develop their projects. In some cases students find that the development time in the Matlab environment may be shorter, easy access to the built-in functions may eliminate the "overhead" associated with developing and or calling relevant subroutines, and the graphical features in that environment may be utilized directly in their report preparation. This paper discusses how Matlab is used in the ME program to enhance the programming skills of the students.

I. Introduction

The entry-level engineers may find themselves in an environment that programming, simulation and modeling may become an integral part of their career. This is particularly true for companies involved in the development of commercial software in the general areas of Computational Fluid Dynamics (CFD) as well as Solid Mechanics in the area of Mechanical Engineering curricula. In instances that engineers are involved with enhancement and development of pre-existing programs, the size and complexity of a particular program may become overwhelming. Universities are preparing the students to cope with the challenges that they are encountering in their work environment in the context of simulation and modeling. Different tools may be adopted in various departments for training the students in programming such as C, C^{++}, Basic, Visual Basic, Fortran, or Matlab, etc. Some departments are facing the question of what environment to adopt to train the students. Many departments have incorporated Matlab in some of their courses. References [1-3] are a few among many references sited. Two programming environments adopted by the ME Department are Fortran and Matlab. In this paper we address how students in the ME program benefit from utilization of the Matlab in enhancing their programming skills. Several projects that utilized Matlab for selected classes in the program are provided as examples.

II. Building a Design Portfolio

A system approach, denoted as SEAARK (Knowledge, Repetition, Application, Analysis, Evaluation and Synthesis in reverse order), was adopted by the faculty of the mechanical engineering department at Alabama A&M University for instruction and teaching method that starts from the basic to the complex levels or learning. The implementation of SEAARK approach was discussed in an earlier paper by Ruben Rojas-Oviedo et. al. [4,5,6]. The SEAARK approach for lectures is also utilized for the class projects. As part of the vertical and horizontal integration of design and project development, a project is required in each course. The ME program strongly encourages teamwork on a class project for courses in the major. This allows students to develop a design portfolio starting from the freshman year [5]. Therefore, project training continues through their capstone design course in the senior level. The projects assigned to the students are often combined with the on-going externally funded research. These funded aspect of program keeps the students in touch with leading-edge technology and current research programs are acquired by the faculty members. This aspect of the program keeps the students in touch with the leading edge technology and state-of-the-art innovative activities in the real world. Nevertheless, project development in each course require utilization of the computer programming.

The requirement of the "project in each class" poses additional constraints on the students' time, particularly in the junior level classes. These students typically take four Mechanical Engineering courses each semester along with two or three laboratory courses. Therefore, effective utilization of time plays an important role in the students' performance.
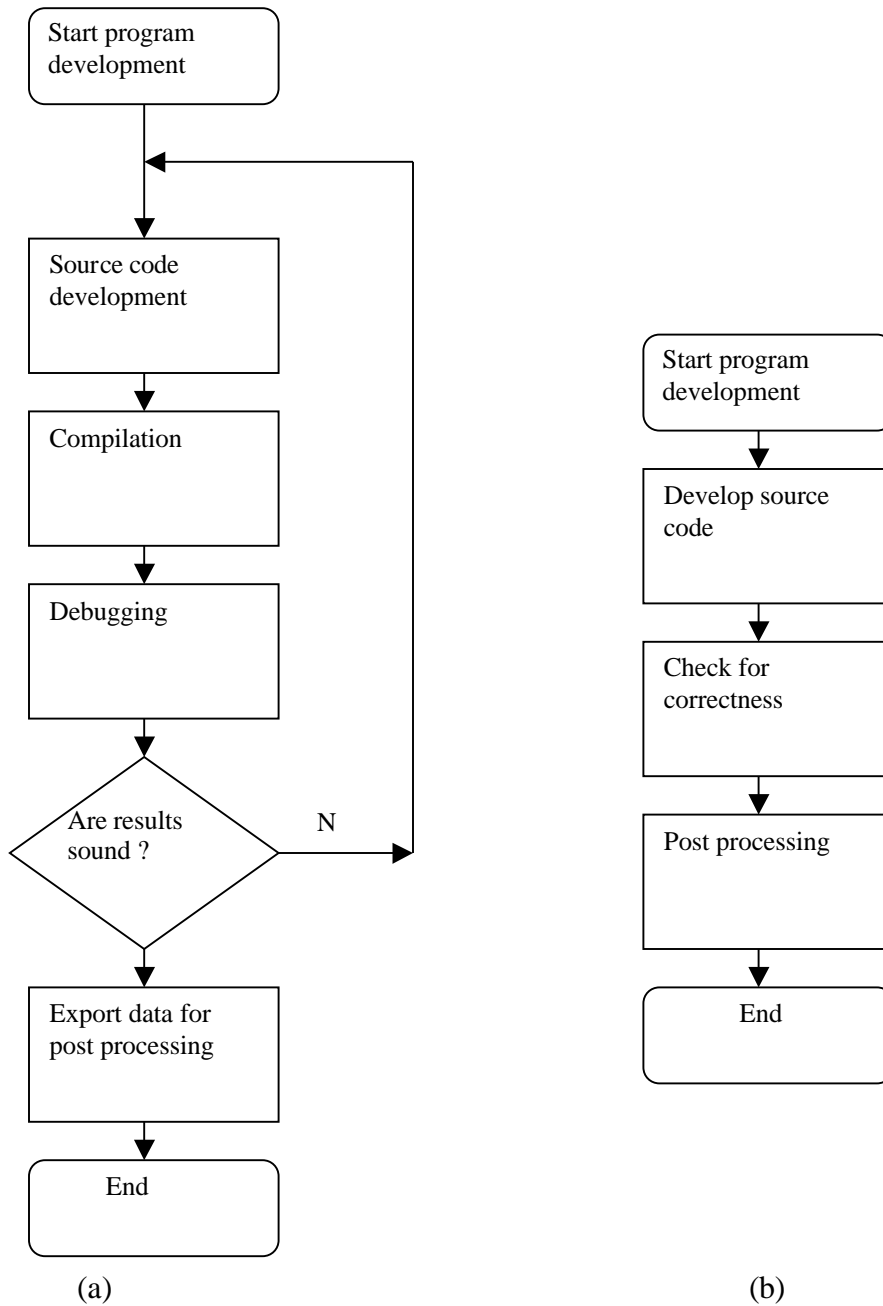
Figure1. Comparison of program development process for the classical programming environments (a) and the Matlab environment (b).

Matlab is a powerful simulation environment with graphical representation. In most cases development time in the Matlab environment may be shorter. Easy access to the built-in functions may eliminate the "overhead" associated with developing and or calling relevant subroutines. Graphical features in that environment may be utilized directly in the preparation of project report. Unlike a general-purpose language, Matlab

development goes much faster and the corresponding source codes are dramatically shorter.

Typical programming environment requires a process of writing the program, compilation of the source code, viewing the results, and debugging. This process is repeated in a loop until satisfactory results are obtained. After the results are generated they may be exported to another environment for post processing. This process may itself require modification of the format of the data for compatibility with the graphical environment. It is easy to see that there exists a large overhead with this process as shown in figure 1-a. Figure 1-b depicts the program development process in the Matlab environment. Some of the overheads associated with the program development displayed in figure 1-a are eliminated by using the built-in functions, that are very easy to access, and powerful graphic environment, that is integrated into this environment. It is important to note that the interactive debugging feature may be monitored constantly to ensure the validity of the program without compiling and executing it. In addition, the graphs generated in the process of the development of the program may easily be inserted either in the document or in the report (figure1-b). Figure 1 depicts differences between these two processes. It is easy to see that the program development time using Matlab reduces significantly.

III. Examples of the Projects

In this section a few examples of the projects developed in some of the courses using Matlab are summarized. In some courses such as Strength of Materials, Automatic Control Systems, Analysis and Instrumentation of Physical Systems, Kinematics and Dynamics of Machines, and Finite Element Methods, students are given the option of utilizing either Matlab or Fortran to develop their projects. Table 1 Summarizes the projects given for each class. A brief description of each project is presented in the following paragraphs.

Table 1- A summary of projects assigned for the courses.

	Course No.	Course Title	Assignment
1	ME 231	Strength of Materials	Analysis and Design of a bicycle frame
2	ME 320	Kinematics and Dynamics of Machines	Simulation of Metal Forming apparatus
3	ME 451	Automatic Control Systems	Simulation and design of robot arm
4	ME 543	Applied Finite Element Analysis	Development of Matlab script file for truss analysis

Strength of Materials: In this sophomore level course, students utilize the program(s) developed by their peers in the finite element class to engage in design practices. At this point students employ the programs to both become familiar with development of Matlab script files as well as utilize the programs to assist them in their design. The problem

assigned for the Fall 2001 consisted of design of a bicycle frame for a given specifications such as weight of the frame, maximum concentrated loads on the handle bar and the seat. The students were required to deliver the following items:

1. A Gantt chart detailing the time table of activities: This should be turned in within 5 days after it is assigned to the students. Subsequently the students are expected to submit a progress report based on the proposed time line.

2. A report in compliance with the standard laboratory report writing practices: the students are expected to use the finite element program, FRAME, in the design work. The design should include but not limited to (a) dimensions of the bicycle frame, material used for the construction, stresses, forces and deflections in each member, (b) cost analysis for the finished frame, and (c) detailed drawing of the frame proposed for design as is provided to the manufacturer.

3. An oral presentation of the work: The presentation will be made at the end of the semester. Each group will have 15 minutes to present the work. The work will be assessed by their peers.

Kinematics and Dynamics of Machinary: In this Junior level course, the students are expected to develop a simulation program for a particular linkage system and utilize the program in the design process. For the Fall 2000, the project assigned to the students involved the utilization of Matlab in the development and the simulation of a metal forming apparatus. The machine was directed for the production of 10,000 pieces of a certain machine part per day. The project involves sizing of linkages, selection of motor for the driver link and selection of appropriate gear train. Figure 2 depicts a snap shot of the simulation program developed for this project.
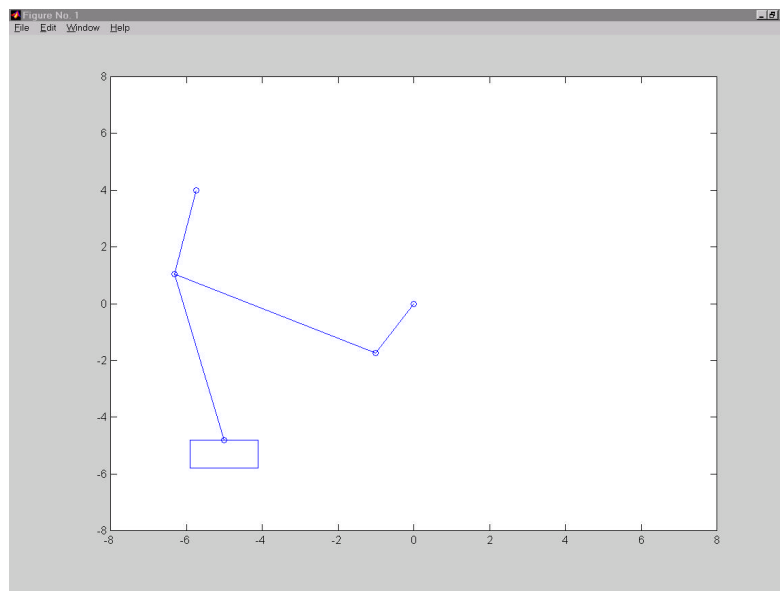

Figure 2. Schematic of the metal forming apparatus.

Automatic Control Systems: In this Senior level course the students are expected to develop a simulation program using Matlab or Simulink. The project assigned in Fall 2001 consisted of design of a compact robot arm system for space applications. The factors involved in this project were:

1. Total weight of the linkage system was specified.
2. Capable of accessing a circle of a specified radius.
3. Maximum weight of the samples for recovery is specified.
4. The design is specified to reach to within 2% of it's target position in a given time.
5. Fit in the launch vehicle cargo area of a specified size.

The students were asked to deliver the following items upon completion of their project:
1. A Gant chart (time table) detailing the activities in the development process: This is turned in five days after it is assigned to the students. Subsequently the students are expected to submit a progress report based on the proposed time line.
2. A final report in compliance with standard technical report writing practices: In this report the students include the development of a mathematical model for the system along with a simulation program for the motion and control of the linkage system. The design should include, but not be limited to, the dimensions of the arm designed, material used for the construction of the linkages, specifications of the servomotors used, and appropriate Proportional-Integral-Derivative (PID) parameters for the control of the arm.
3. An oral presentation of the design: The presentation will be made at the end of the semester. Each group will have 15 minutes to present the work. This work is assessed by their peers.

Applied Finite element methods: In this graduate level course, students develop a variety of simulation programs in Matlab for analysis of trusses, development of beam equations, two dimensional stress analysis and solutions of two dimensional heat equation. Some of the programs developed here is used in sophomore level courses both for validation and design purposes. A series of benchmark problems is used to validate and test the programs. Figure 3 depicts the solution obtained for a simple truss subjected to a concentric loads at specified locations. The dot line shows the exaggerated deflections of the nodes
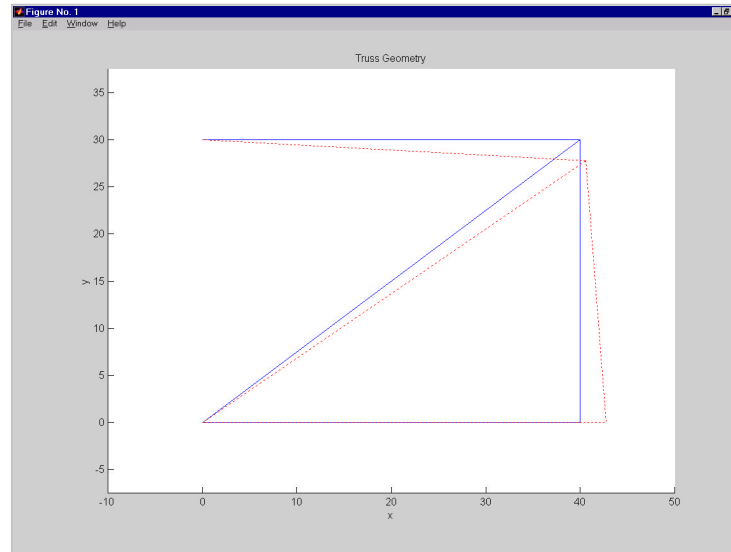
Figure 3. Truss analysis program

IV. Conclusions

In this paper we explored how Matlab was incorporated in the new Mechanical engineering program at Alabama A&M University to fit it's educational objectives and outcomes. Due to it's flexibility, Matlab program development goes much faster and the corresponding source codes are dramatically shorter. The visualization environment in Matlab generated enthusiasm towards the projects and the students seemed to have a better appreciation for the design process. Easy access to the built-in functions such as root finding, cross products, dot products solution of system of linear equations, and easy accessibility to differential equations solvers (Runga-Kutta) eliminated the "overhead" associated with development time. Graphical features in that environment not only helped the students to grasp a better understanding of the application, but also was used directly in preparation of their project report.

V.   **References**

1. Dynamic Modeling and Analysis of a Crank Slider Mechanism, Abhijit Nagchaudhuri, proceeding of 2000 ASEE Conference, session 1566, St. Luis, Missouri, June 2000.

2. Solution of Static and Dynamic Beam Bending and Static Buckling Problems Using Finite Differences and MATLAB, R. G. Jacquot and B. R. Dewey University of Wyoming, proceeding of 2001 ASEE Conference, session 2220, Albuquerque, New Mexico, June 2000.

3. Use of Excel and MATLAB to Design General Linkage Systems for Orthopedic Devices, Bob Fithen, Debra Conry, Jason Leavell proceeding of 2001 ASEE Conference, session 2220, Albuquerque, New Mexico, June 2000.

4. Implementation of a System Approach for Curriculum Design. Ruben Rojas-Oviedo, Z.T. Deng, Amir Mobasher, A. Jalloh, Mechanical Engineering department, Alabama A&M University, ASEE Paper, Session 1566, 2000 ASEE Annual Conference and exposition, St. Louis, Missouri.

5. Development of Engineering Competencies in Freshman Courses. Ruben Rojas-Oviedo, Z.T. Deng, Amir Mobasher, A. Jalloh, Mechanical Engineering department, Alabama A&M University, ASEE Paper,Session 1566, 2000 ASEE Annual Conference and exposition, St. Louis, Missouri.

6. Synthesis of Engineering Best Practices and ABET AC2K into a New Mechanical Engineering Curriculum. Ruben Rojas-Oviedo, Z.T. Deng, Amir Mobasher, A. Jalloh, Mechanical Engineering department, Alabama A&M University, ASEE Paper, Session 2266, 2000 ASEE Annual Conference and exposition, St. Louis, Missouri.

VI. Biography

AMIR MOBASHER
Amir Mobasher is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. He holds a Ph.D. degree in Mechanical Engineering from University of Alabama in Huntsville. He has research interest in the areas of Computational Fluid Dynamics, Biomechanics, and Control and Automation. His primary area of interest at AAMU is Automation, Control and Fluid Dynamics. After graduating from UAH, he worked at U.S. Army Aeromedical Research Laboratory at Fort Rucker, Alabama. During his employment there, his research focused on aircrew protection and head-supported mass and center of mass placement for the U.S. Army aviation. As a Ph.D. candidate at UAH, his research focused primarily on shock-wave turbulent boundary layer interactions

ABDUL JALLOH
Jalloh is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Jalloh earned his Ph.D.in Mechanical Engineering, with a minor in Engineering Mechanics from the University of Arizona, he obtained his M.S. Mechanical Engineering also from the University of Arizona, and he holds a B.Eng. in Mechanical Engineering from University of Sierra Leone. His research interest is in areas of mechanical vibrations, structural dynamics, structural mechanics, applied elasticity, probabilistic design, finite element analysis, manufacturing and reliability.

ZENGTHAO DENG
Z.T. Deng is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Deng has an extensive background and research experience in numerical simulation in particular high speed aerodynamics/flows with heat transfer phenomena. He earned his Ph.D., Aerospace Engineering, University of Tennessee, 1991., and his Bachelor of Science, Aerospace and Mechanical.

RUBEN ROJAS-OVIEDO
Ruben Rojas-Oviedo is Chairperson and Associate Professor of the Department ofMechanical Engineering at Alabama A&M University in Huntsville AL. Dr. Rojas-Oviedo Engineering, from Beijing University of Aeronautics and Astronautics in 1985. has international engineering experience working both in academe and industry. He has an engineering consulting company and conducts applied research. He earned a Ph. D. In Aerospace Engineering from Auburn University, he has two Masters degrees one in Mechanical Engineering from N.C. State at Raleigh and the other in Applied Mathematics from Auburn. He earned a B.S. degree in Aeronautical Engineering from the National Polytechnic Institute – Escuela Superior de Ingenieria Mecanica y Electrica - in Mexico City, Mexico.