WHITE PAPER ON

SIMULATION OF PROPELLANT LOADING SYSTEM
SENIOR DESIGN IMPLEMENTATION IN COMPUTER ALGORITHM

By
Dr. Alak Bandyopadhyay
Associate Professor, Computer Science
Alabama A & M University, Normal, Al

OVERVIEW OF THE PROJECT:
1. Description of the Senior Design Project Work:
Propellant loading from the Storage Tank to the External Tank is one of the very important and time consuming pre-launch ground operations for the launch vehicle. The propellant loading system is a complex integrated system involving many physical components such as the storage tank filled with cryogenic fluid at a very low temperature, the long pipe line connecting the storage tank with the external tank, the external tank along with the flare stack, and vent systems for releasing the excess fuel. Some of the very important parameters useful for design purpose are the prediction of pre-chill time, loading time, amount of fuel lost, the maximum pressure rise etc. The physics involved for mathematical modeling is quite complex due to the fact the process is unsteady, there is phase change as some of the fuel changes from liquid to gas state, then conjugate heat transfer in the pipe walls as well as between solid-to-fluid region. The simulation is very tedious and time consuming too. So overall, this is a complex system and the objective of the work is student's involvement and work in the parametric study and optimization of numerical modeling towards the design of such system. The students have to first familiar and understand the physical process, the related mathematics and the numerical algorithm. The work involves exploring (i) improved algorithm to make the transient simulation computationally effective (reduced CPU time) and (ii) Parametric study to evaluate design parameters by changing the operational conditions.

2. Implementation of the Senior Design Work:
The students involved in the senior design project work are Computer Science Seniors with experience in data structure, programming in C++. As the project work demanded knowledge in Thermodynamics, Fluid Flow, and related physics the course was designed into lectures and labs. First few weeks the students learned basic physical phenomena related to the topic area, and being familiar with aerospace propulsion systems. Student also learned about the basic principles of System Engineering as the system engineering approach of solving an industry level problem was attempted in this work. The course was designed to teach the following learning outcomes:
  i) Familiarity and working knowledge of Aerospace Propulsion Systems, in particular to the Ground Operation Systems.
  ii) Basic and working knowledge in related Physical Processes.
  iii) Learning the basic concepts of Systems Engineering.

iv)   Learning to break down the project based on System Engineering concepts and dividing the work in groups.
v)   Learning the Numerical Algorithms to solve the mathematical equations formed based on the physical phenomena suitable for the components included in the propellant loading system.
vi)   Learned FORTRAN Programming Language.
vii)   Learned to use the NASA's in-house System Level Fluid Flow Simulation Program GFSSP.
viii)   Incorporated the knowledge of all of the above for the optimization of the simulation software and design study of the integrated system.

The final goal of the students was to improve the existing capability to optimize the numerical simulation and evaluation of the engineering parameters.

In order to implement the work, the course was split into four parts:
1. Physical and Mathematical Model details.
2. Numerical Algorithm and FORTRAN Programming
3. Learning how to use the software tools by solving the sub-problems.
4. Integrated simulation and rigorous numerical computation, validation, testing and parametric study.

Many of these areas are overlapping, so was taught and followed and taught as needed. The students had to go through taking the lectures, working on the labs, doing homework assignments and taking tests. A complete evaluation is being done in the following manner.

Assignments:	15%
Labs and lab tests:	15%
Tests + Exams:	30%
Presentation:	10%
Project Report:	25%
Class Participation:	5%

ASSESMENT PLAN RESULTS:
The following table shows students performance in the student assessment areas. The raw data scores are normalized to 5 levels:
Poor: 1, Needs Improvement: 2, Fair: 3, Good: 4 and Excellent: 5

Student	Assignments	Lab Exercises	LAB Tests	Test + Exam Av.	Presentation	Final Report
Student 1	3	4	3	3	4	3
Student 2	5	5	4	5	4	5
Student 3	4	5	5	4	5	5

| Student 4 | 4 | 4 | 2 | 3 | 4 | 3 |
| Student 5 | 4 | 3 | 4 | 5 | 4 | 5 |

Overall, 60% students performed very well and 40% did fairly well. The student's performance was quite poor initially, but gradually they improved and a continuous assessment was done in order to achieve that. Students also learned how to work in teams and how to coordinate among themselves to achieve the goal.

FINAL SENIOR DESIGN PROJECT RESULTS:
A total of five students participated in this senior design project work. Students got hands-on training from me as well as from the NASA Engineer Dr. Alok Majumdar who is the principal developer of the software. Students were very enthusiast about the work and they expressed they want to do similar type of work from NASA. As the students are Computer Science students and many of them did not have much exposure to NASA works, this project work helped them immensely in learning lot of new things that are not taught in basic computer science classes and knowing about the space program, the different areas in Aerospace where they can contribute.

Students completed the work and submitted the final report. The study has shown an improvement of more than 50% in the computational time optimization. The results for the sub problems were validated against some of the results NASA MSFC Engineers found. The parametric study featured some keys results that could be useful towards the final design of the system. Students did biweekly presentation of the work to the rest of the class and the final presentation before turning in the report. Despite not knowing much of the things before taking the course, the students worked hard to explain what they have learned. The students had to write short reports on System Engineering concepts and how they used these concepts into their project work.

The students were evaluated based on their performance in all aspects of learning and 60% of the students performed excellently and 40% moderately well. After doing the senior design course, 80% of the students in the class see the usefulness of computer science in space applications and expressed their view in exploring career in NASA. Students learned the concept of System Engineering, learned how to break a challenging problems into subgroups and sub-subgroups in order to achieve the final goals.

LESSONS LEARNED:
First of all it was a very challenging work to implement and incorporate such a design project into a computer science course curriculum. The project was introduced in a senior level design and analysis of algorithm class. Traditionally, this course teaches basic algorithm principles towards building efficient data base, optimization, building efficient computer architecture etc. As the current project demanded, aerospace propulsion aspects and related mathematical models were completely new subject matters for the students. Even though in the current project, the emphasis was on the algorithm aspects and

modeling and simulation fitting in the general computer science area, but the system we tried to design needed knowledge in Physics, Aerospace Engineering and associated numerical methods. This senior design work gave the students a great opportunity to learn new things, but they had to work very hard. One of the key aspects that were learned during the course is how System Engineering concepts be a powerful tool to implement a harder task efficiently and timely.