# Work in Progress - On Introducing Experiments in a Numerical Methods Course

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***Abstract:*** **Several experiments have been developed and implemented in an undergraduate course in Numerical Methods. Most mathematical procedures that are taught in the course are covered in the analysis and interpretation of the data collected in these experiments. This paper describes the implementation of these experiments and how they are used in the course. Assessment data from two semesters for this WIP will be available at the time of the presentation.**

*Index Terms* - numerical methods, experiments, data interpretation.

## INTRODUCTION

One of the prevalent themes during our graduating seniors exit interviews several years ago was that they would like more hands-on and more real-life applications in their mechanical engineering courses. In response to such requests, several lecture courses in our department have now incorporated experiments that include class demonstrations, collection of data in a laboratory and building of simple experiments.

As part of this effort, we developed a set of five simple experiments that are now used regularly in the classroom to teach the course in Numerical Methods.

We developed experiments that

1. are low cost so that other universities can develop them with minimal material cost (some experiments need use of a university machine shop),
2. are compact in size so that they can be carried to the classroom or set up in a laboratory that has limited space,
3. need low set-up time so that nominal amount of classroom or laboratory time is used. This is especially important in the Numerical Methods course at USF where other educational components such as simulations, problem-centered approach, programming, and real-life project assignments are also incorporated.

Data obtained from experiments is assigned for analysis as homework or as in-class computer laboratory assignment. Comparison between experimental and numerical results is also made.

## THE EXPERIMENTS

Five experiments are incorporated in the classroom. These experiments are described as follows.

*Experiment#1. Cooling an aluminum cylinder*

In this experiment, an aluminum cylinder that has two inserted thermocouples is immersed in an iced-water bath. The thermocouples placed in the cylinder are connected to a digital temperature recorder that measures the temperature vs. time data. Taking the data every five to ten seconds takes just a couple of minutes. The data is used for several homework exercises such as finding the rate of change of temperature via numerical differentiation, and extracting heat transfer coefficient of convection using exponential regression via theoretical models.

*Experiment#2. Loading a Truss*

A second experiment is that of an aluminum truss that is loaded in the center. Strain gages are placed on three of the truss members. Balance of forces in the truss result in a set of simultaneous linear equations. The students are asked to set up these equations using the method of joints. They can then use any of the mathematical packages such as Maple and MATLAB to find the force in the members on which strain gages are placed. Strain in a member can then be calculated from these forces and compared with the strains measured by the strain gages.

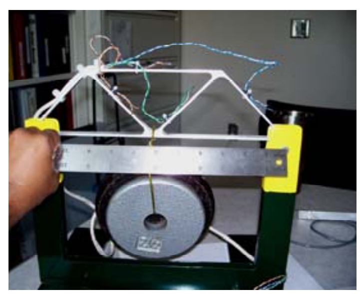

FIGURE 1
LOADING A TRUSS EXPERIMENT

*Experiment#3. Estimating the volume of a champagne glass*

A third experiment takes several odd-shaped champagne glasses that are measured for their outer radius at different locations along their height. Subtracting the thickness of the glass from the outer radius and using spline interpolation and integration, students estimate the volume of water these champagne glasses can hold.

The spline interpolation develops the spline interpolants for the inner radius as a function of height. Subsequently the volume of the champagne glass can be calculated using integral calculus. This value is then compared with the actual volume of water that the champagne glass can hold by pouring the contents of a fully filled champagne glass into a graduated cylinder.

*Experiment#4. Choosing the best mousetrap*

The fourth experiment is to choose the best mousetrap for the mousetrap-car contest. To do so, we want to pick the mousetrap that can store the most amount of torsional energy. We take several mousetraps and measure the force required to twist the spring as a function of angle of rotation.

Regression of the data to a linear model gives the torsional stiffness and the residual energy in the spring. These values are then used to calculate the torsional energy stored in each of the mousetrap springs; the one with the highest value is the one that stores the most amount of torsional energy.

*Experiment#5. Finding the length of a curve*

In this experiment, a flexible curve (Figure 2) of length 12" made of lead-core construction with graduations in both millimeters and inches is used to draw a curve on graphing paper as shown. The curve is similar in shape to the classical Runge curve of $y=1/(1+25x^2)$. This function was used by Runge [1] to show that higher order interpolation is a bad idea.

Once the student has drawn the 12" long curve, he/she is asked to choose several points along the curve. The student can now take the data pairs and use polynomial interpolation and spline interpolation to find the interpolated curve. The oscillatory behavior of the polynomial interpolant and the smooth nature of the splines are clearly noticeable. One can now find the length of the two interpolants by numerical integration.

The length of the interpolants is compared with the actual length of the original curve drawn by the flexible curve. This exercise is then related to a real-life problem of finding the shortest (and smoothest) path of a robot that needs to traverse through several discrete data points.

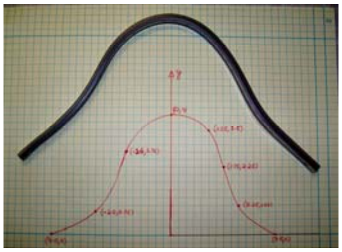

FIGURE 2
USING A FLEXIBLE CURVE TO DRAW A CURVE OF KNOWN LENGTH

## ASSESSMENT

To measure student satisfaction associated with incorporating experiments, a survey has been developed to gather information on students' perceptions of this approach and how it affected their learning of the course material. The survey includes both quantitative and qualitative questions, thus permitting exploration of the reasons behind student ratings. The instrument consists of six questions using Likert [2] scale from 1 (poor) to 5 (outstanding), and three open-ended questions. See http://numericalmethods.eng.usf.edu/experiments/surveys.html for the survey questions.

The survey will be administered in Spring 2008 and Summer 2008 semesters to two classes. The results of the survey will be available at the conference.

## ACKNOWLEDGMENT

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## REFERENCES

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