120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #7633

Work-in-progress: iOS® Devices as DAQ and hardware for experiments in class to enhance the real touch, feel and see experiences

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Mr. Alexander Nagl is a sophomore at Pennsylvania State University-Berks Campus studying towards a degree in Computer Science. He has a very deep interest in developing apps for the iOS devices and is also looking at developing video games for these platforms. In the past year he has been working on several engineering educational apps that will enhance and bring experiments to the class to enrich student learning.

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Work-in-Progress: iOS® Devices as DAQ and Hardware for Experiments in Class to Enhance the Real Touch, Feel and See Experiences

In today's world, sensors are everywhere and they are used extensively in every walk of life. Sensors are used for opening and closing doors, to ensure you have your seat belt on, house alarm systems, traffic monitoring and control, almost every industrial process and many more applications. Using sensors and sensor data in engineering classrooms is becoming increasingly beneficial for engineering education. It motivates students to pursue science and engineering disciplines as well as associated career paths[1]. Lessons in the classroom quickly become more interesting[2] and engaging[3].

Advances in mobile devices, education, business and research have resulted in the use of powerful microprocessors with an array of capabilities and sensors built in[4]. Mobile devices are capable of word processing, Internet access, and some are even capable of preliminary human motion analysis[4]. It seems like our students are "born with a mobile device" and these devices come equipped with several sensors, such as

i) camera (often multiple),
ii) Microphone (often multiple),
iii) 3-axis Accelerometer (of interest to this WIP (**W**ork **I**n **P**rogress))
iv) 3-axis Gyroscope (of future interest to this WIP) and
v) Proximity, Ambient Light, Touch, Magnetometer (compass), etc.

With these mobile devices students can design experiments that will help validate theory and provide instantaneous experimental data. This will hopefully initiate their interest in science and engineering, as well as build their enthusiasm.

Real touch, feel and see experiences are very important aspects for most engineers to gain a deeper understanding. For this primary reason, in the past several decades educational institutions have always included laboratory experiments as part of the undergraduate curriculum. These experiments built the "gut instinct" for many engineers as part of their educational experience. This has proved useful in their professional career.

Laboratories in general are expensive, occupy unused real estate, and become the primary target for cost reduction in most colleges and universities. With the advent of computers and their increased capability of generating realistic simulations as substitutes for laboratories, administrators of colleges and universities found a justification for eliminating laboratories. When the second author compared several ABET approved programs in the country, he found that they have fewer laboratories in their recommended academic plans than they did a few years ago. The reduction or elimination of real touch, feel and see experiences of laboratories have contributed to the loss of “gut instinct” for many engineers.

Using the common smart phone with cost effective hardware, experiments have been designed to bring back some of the touch, feel and see experiences to the classroom. Almost every smart phone on the market has two sensors that can be used for creating in-class experiments: a gyroscope and an accelerometer. More and more smart phones have a 3-axis accelerometer and 3-axis gyroscope. This work in progress (WIP) has utilized the accelerometer for the development of in class experiments. First, a mobile app was developed to access and graph the accelerometer. Figure 1., shows the acceleration recorded using an iOS device the iPod. The app had features to start, stop, record and graph the raw data. A feature to e-mail the data was originally included to transfer data to a PC for further analysis. Data transfer can be done using iTunes®. The app also gathers and displays the raw data of the sensors as shown in Figure 2. The data could be displayed instantaneously, averaged at 10

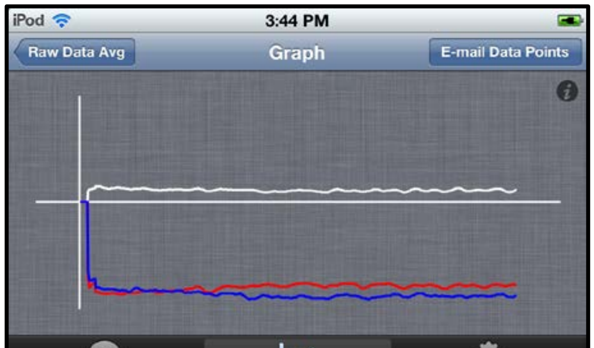

Figure 1. Trace of acceleration from the accelerometer obtained from an iPod

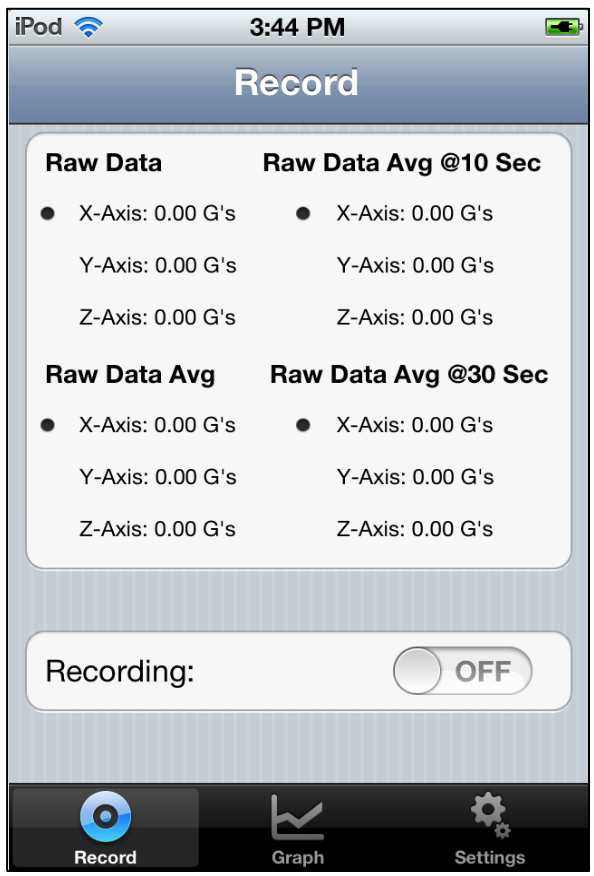

Figure 2. Raw data interface on an IPod.

seconds, averaged at 30 seconds and the total average from the time recording was started. Past recordings were stored using the date and time format (current implementation) as shown in Figure 3. Bluetooth communications were developed to transfer data from iPod to iPad or any other iOS device for further processing. Figure 4 shows the exported data graphed using Excel.

Figure 3. Raw data gathered stored by date and time

Once the basic app for gathering and exporting data was developed, experiments to study dynamic systems were explored. To do this a simple spring-mass-damper system was developed as shown in Figure 5. The setup makes use of a toy car for a mobile platform. This mobile platform which houses the iPod serves as the mass in a mass-spring-damper (MSD) system. The everyday rubber bands emulate the spring in the MSD system. Additional hardware like a hook, end plates make up the MSD system. These are easily available to most students and faculty on any campus at a very low cost or even for free. Using a ruler and a few known weights, the spring stiffness can be easily obtained as taught to students in the Physics lab for any engineering student. This experiment was performed a few times and an average value was obtained. Using a weighing scale, the rubber bands, an iPod, and all the other miscellaneous hardware objects that constituted the lumped mass was measured. Two blocks are used to hold the moving mass as shown in Figure 5 (orange color at the bottom part of the picture) to the table. A small adapter fabricated in insulation foam was made to go on the car to hold the iPod in place. The car can be displaced a known distance (initial condition) and

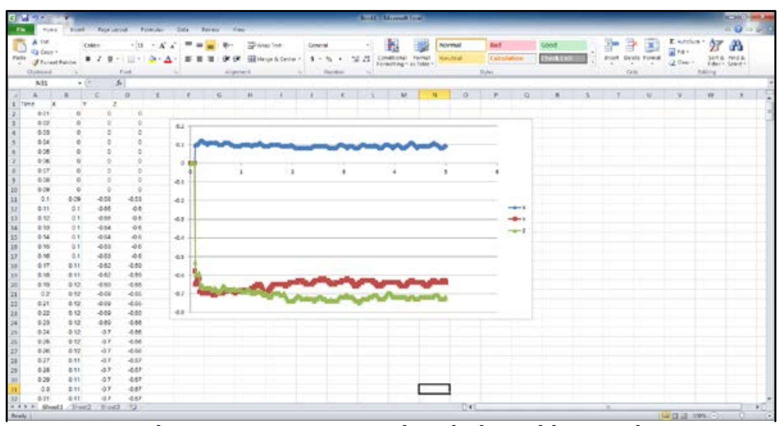

Figure 4. Data exported and plotted in Excel

one can obtain the unforced response to a simplified MSD system due to initial conditions. The recorded data was then exported to Matlab® (Figure 6.).

Most smart phones SDK (System Development Kit) provide access to current and future sensors for the development of apps. Using the SDK, this WIP has developed smart phone apps to read the current sensors, process them and generate graphs. The data from these sensors can also be wirelessly transmitted to other platforms (like other smart phones, IPads®, laptops etc.) for further use. This WIP has used Excel® and Matlab® to process the data and integrate it with a simulation to provide the student. All this makes the smart phone a very powerful tool in the classroom.

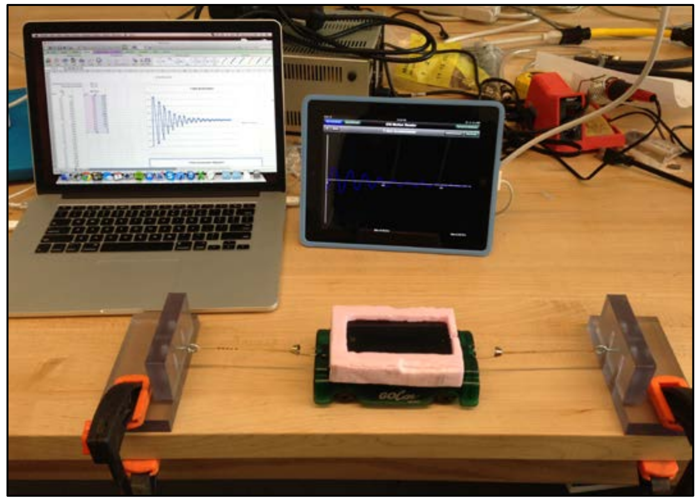

Figure 5. Experimental Setup for a spring-mass-damper mechanical system

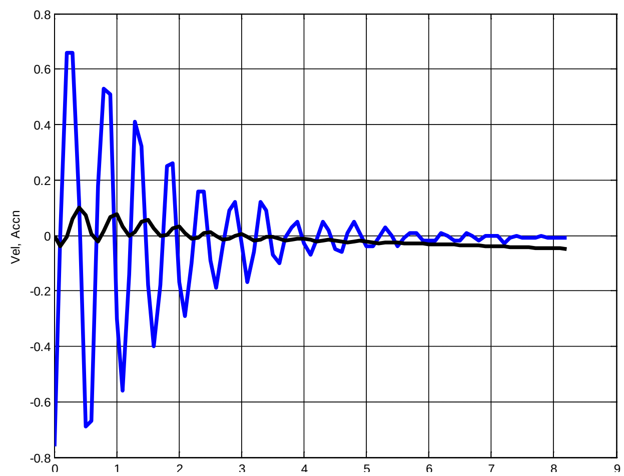

Figure 6. Matlab processed data showing Accn and velocity (obtained from Accn)

Below is a list of some of the examples that are in the pipeline for the immediate future (targeted to be finished before Summer 2013)

1. Position, Velocity and Acceleration: A simple structure to convert the Iphone/Ipod into a simple cart as shown in Figure 5 has already been done. By applying a force and moving the cart acceleration data can be obtained. This data can be numerically integrated (with caution) using software like Matlab® to obtain velocity and displacement. If the cart's acceleration can be controlled, we can generate acceleration profiles that can be fit to curves which approximate analytical functions (say sinusoid, exponential etc.). Using this analytical function the instructor can show the application of integration to obtain velocity and position. Also several other issues can be

brought in for discussions – numerical inaccuracies, DAQ and sensor related issues etc. Work is in progress to explore using the camera and a graduated ruler to measure displacement data. Additional use of the headphone jack to integrate a displacement sensor is under investigation. The displacement information will help with numerical errors that creep in due to integration of acceleration to obtain displacement.

2. Using a ruler and pin joint the instructor can demonstrate the concepts of tangential velocity, radial and tangential acceleration. For this again the accelerometer data gathered will be used. Velocity measurement using the audio input is currently in progress. The idea is based on how merchants use the microphone input to scan credit cards etc. Analog input sensors will be used and integrated into the existing app to obtain velocity and position information.

3. Using the same ruler and pin joint simple pendulum motion can be demonstrated in class.

4. Using the cart in the first example and shown in Figure 5, along with springs (rubber bands) of known stiffness, with dampers (remember the ones used for cassette player doors) one can create a simple spring-mass-damper system. This can be used in class within matter of minutes to generate data that is individualized, but the fundamental concepts are the same for the whole class. This will also enable the instructor to teach at a higher level of symbolic solutions, but enable immediate use of experimental data to reaffirm theory. The instructor can also create data on the fly to teach the class. (If we add actuators we can start looking at feedback control problems in class)

5. Inclined plane experiments for friction can be designed in a similar manner. Put the IPhone on a base and use different materials for the inclined plane. If one can obtain the coefficient of friction this can be used in a statics class. It can be used in a dynamics class when the acceleration measurements are made.

For the future one can seek to use the iOS devices as a DAQ platform, an embedded controller, a potential tool for research. The list is endless and is bound only by one's thoughts and imagination.

The basic app developed can be used for the experiments outlined above.

The current work does not have any student assessment as it is still in the development or WIP phase. Once the development is complete, student assessment has to be done to evaluate the impact these experiments have on student learning. Comparative studies will be done to compare and contrast two sets of students – one taught the material with the experiments and another without the experiments. A detailed assessment questionnaire will be used to gather information about the effectiveness.

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