Smartphone labs with MATLAB for accelerated physics

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Abstract. Used in conjunction with a computational environment such as MATLAB, mobile phones facilitate low-cost, in-depth mobile laboratory learning experiences for physics students. Sophisticated mobile phone sensors provide high quality extensive data sets for display, analysis, modeling, and simulation. Learning objectives that span the physics curriculum, as well as technology and computational literacy, can be simultaneously addressed. Such labs are appropriate for active, blended, or fully online learning.

1 Introduction

The ubiquity of smartphones, the increasing sophistication of smartphone sensor, audio, and camera systems, and the availability of applications providing access to sensor data have enabled a variety of engaging low-cost learning experiences for physics education. New applications such as Phyphox (http://phyphox.org) and MyTech (https://projects.delta.ncsu.edu/mytech/) support smartphone-based labs with app-processed simple experiments for beginning students [1]. For more sophisticated students, smartphone labs can provide opportunities to study physical phenomena in more depth using a hands-on external computational environment.

An effort to develop and test smartphone labs linked to a first exposure to the MATLAB programming environment is underway in an accelerated introductory physics sequence for 1st year university students majoring in physics, applied math/engineering/physics, or astronomy-physics. Accelerometer, gyroscope, magnetometer, GPS, and barometer data are collected with free or low-cost apps (Sensor Kinetics, Sensor Play, Sensor Logger, MATLAB Mobile) available for both Android and IOS operating systems. Audio and optical data are collected by standard smartphone system applications. Data are transferred to student computers by email or synchronous wireless channels. MATLAB provides professional-grade functionality, comprehensive documentation and examples, and an integrated development environment for analysis and modelling. The MATLAB student edition is free to local students. Open source alternatives include OCTAVE and Python.

The physics content addressed thus far includes topics in mechanics such as rotational motion and simple and coupled oscillations, the Doppler effect, and reflections of acoustic waves. Labs about to be tested concern magnetic field mapping, optical phenomena, optical instruments, and spectroscopy. The computational content includes nonlinear curve fitting, statistical analysis, applications of complex variables, Fourier transforms, acoustic signal processing, image analysis, and symbolic and numerical solutions to coupled ordinary linear differential equations. The technical content includes design and performance of IMU MEMs sensors and of mobile acoustic and optical systems. The typical data set size exceeds what can be managed in a spreadsheet.

2 Example mobile phone lab with computation

A simple beam physical pendulum with an attached smartphone data logger illustrates the affordances of this approach to educational physics labs. A traditional experiment with a light gate to measure period alone provides limited information. Recording 3-axis accelerometer and 3-axis gyroscope data at 100 Hz for a few minutes produces of order 100 thousand measurements.

Figure 1 shows the power spectra for the three components of the linear acceleration obtained in a smartphone physical pendulum experiment. The spectra evidence geometrical cross coupling of radial and azimuthal acceleration resulting from the exact IMU location and orientation, and excitation of the fundamental bending mode of the pendulum. For appropriately damping, a single continuous data set provides observations of the nonlinear and linear regimes. The student may perform the spectral analysis shown with a single function call, and perform detailed fits to analytic and simulated models of the motion with only a few lines of code.

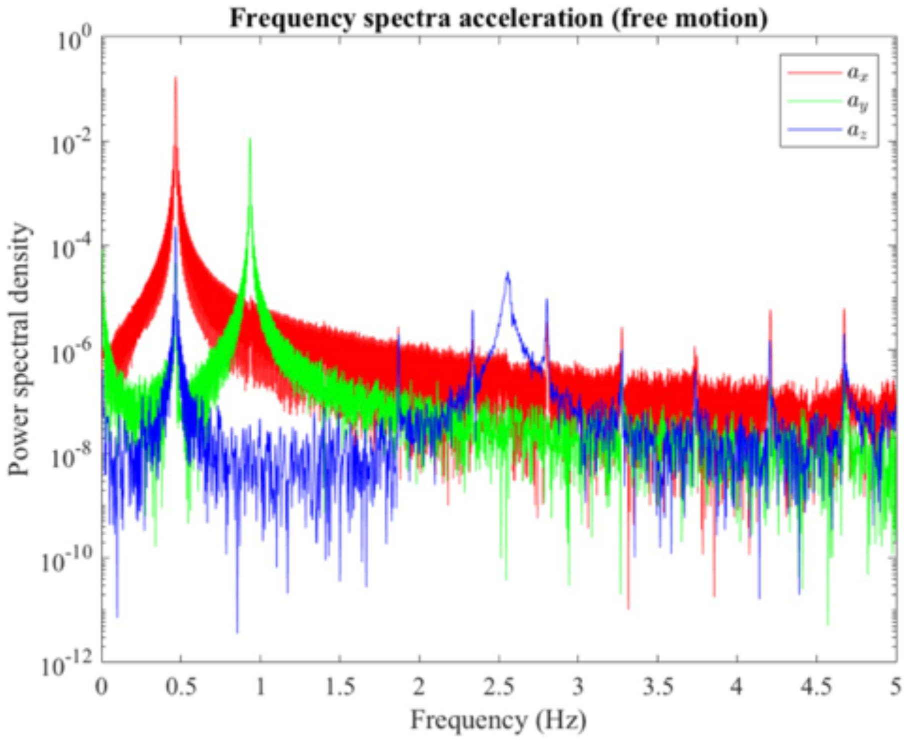

Fig. 1 Lomb-Scargle transform of 3-axis accelerometer data from a mobile phone attached to a knife-edge physical pendulum. The z-axis is normal to the plane of the motion and the y-axis along the radial direction. [Image by Duncan Carlsmith]

3 Conclusion

Combining mobile phone sensor technology with computation in the physics educational setting presents many new exciting opportunities for low-cost learning experiences.

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References

[1] Colleen Countryman and M.A. Paesler., Enhancing Students' Understanding of Scientific Equipment: Smartphones in the Laboratory, *eprint arXiv:1607.03736,* (2016). Available from: http://adsabs.harvard.edu/abs/2016arXiv160703736C.