CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

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Project Number

S1422

Project Title

Two Dimensional Localization of Impacts Using Acoustic Time Delay Measurement

Abstract

Objectives/Goals

This project's main goal is to show that using time delays on the microsecond scale is a viable way of determining the source of a vibration caused by an impact on a two dimensional surface.

Methods/Materials

An Arduino Microprocessor connected to three analog-digital converters, which are connected to three accelerometers, is used to detect vibrations that propagate through a plastic board in the event of an impact. The Arduino transmits the set of acceleration data it collected from each sensor to the computer, which can then apply three data analysis algorithms. Because the general method of finding the intersection of three hyperbolas to determine the impact location depends on accurately determining the arrival time of the vibration, the three algorithms can be tuned interactively. The first method uses simple a threshold comparison, the second uses a least squares line fit through increasing maxima of rectified acceleration data, and the third uses wavelet decomposition to determine the starting time of the vibration.

Results

Three signal analysis methods were tested. Of the three, wavelet decomposition of the signal yielded the best results. Second best by a large margin was the basic threshold comparison that worked best closer to the center of the board. Lastly, the least squares line fit algorithm usually failed to get even 15 cm radius accuracy when the impact did not occur in the center. It was also found that applying a spline fit (which is required anyway for wavelet analysis) improved accuracy for the other two algorithms.

Conclusions/Discussion

The results show that it is completely possible to localize impacts on a hard surface, and the accuracy depends on analysis methods used, signal noise, and inherent limits of the hardware. The maximum theoretical accuracy, as restricted by sampling speed, is about a one centimeter radius, and the system developed can achieve a root mean square error of close to two centimeters.

Summary Statement

This project uses multilateration based on the time differences of arrival times of a vibration at three accelerometers to localize the impact that caused the vibration.

Help Received

Dr. Uwe Send (father) helped understand the concepts of wavelets and decypher the wavelet library for Python.