Acoustic Imaging

by

Matt Kaiser and John Lewis

Department of Electrical and Computer Engineering

Advised by

Dr. James H. Irwin and Mr. José Sánchez
Often fossils are found buried within rocks of similar composition to the fossil. Ultrasonic imaging is becoming a popular form of nondestructive testing, which can be used to find buried fossils with minimal damage to the fossil. The aforementioned statement is the group’s ultimate objective. Obtaining this objective will help geologists to best determine how to extract fossils from rocks. The research covers techniques for imaging a fossil through nondestructive testing in three dimensions without risking damage to the fossil by removing extraneous material. The team was responsible for all research and development of the entire system.

Initial research began with the testing of a 50 [kHz] air type longitudinal wave acoustical transducer. The transducer was pulsed with a Krohn-Hite function generator and received via a Tektronix digital oscilloscope. The oscilloscope is then interfaced to the Internet. Data is then downloaded from an Internet address, which the oscilloscope selects. A graphical user interface allows the user to control the oscilloscope through the Internet. The data is then saved in comma separated variable format and can be opened in most any spreadsheet software. Once the data is saved into a folder, it can be then opened and processed in MATLAB.

Through initial research, the team was able to use signal processing to image simple objects in three-dimensions. This was accomplished by using the time delay from the transmit pulse to the receive pulse, and a simple algorithms. Due to the low frequency of the transducer, only holes of three inches or larger could be found in objects. Much of this poor resolution can be remedied by switching to a higher frequency transducer.

Preliminary results give the location and shape of an object buried under a homogenous layer. These results are a bit misleading. Though the team was able to find an object buried under a small layer, it will not be possible for a thicker layer. This is because sound waves
reflect off of objects when transmitted through air. The solution to the problem was to purchase a 2 [MHz] immersion type transducer. Not only will this increase resolution, but also objects buried within a homogenous layer should be able to be recovered through signal processing if a fluid such as water is used as the transmission medium. Sound waves will actually penetrate an object if sent through water rather than reflecting off in a medium such as air. The impedance match is much closer in a fluid than in air. In air these higher frequencies will be severely attenuated and nearly unusable.

A large problem with acoustical imaging is the near field. Acoustical transducers are blind to objects that are too close to them. One solution is to use focused transducers. Acoustical waves are much like optics in the sense that they can be focused to a point. Currently, focused transducers can eliminate some of the near field effect but not all of it. Another solution to the problem is to use multiple transducers. By transmitting with a main transducer, the other transducers are able to pick up the reflection of the transmitted pulse. The transducers need to have a mathematical relationship to determine the actual distance traveled to reach the receiving transducer. Ultimately, the team chose to use one focused narrow beam transducer.

The software will consist of multiple MATLAB files and functions to do all of the digital signal processing. The team has a file that imports all of the data into arrays for easier processing. A different file is then called to do all of the threshold detection and implement the depth algorithm. The depth and data number stamp are then saved into an array which is later used to display a three dimensional plot of the data. Noise in the analog signal forces the software to use simple noise detection as to not trigger a false reading. Future processing will include a cross correlation function to compare the returned signal to the received signal for
signal clean up. Also included will be algorithms for multiple sensors, hole detection, and any nonlinear characteristics of the transducer used.

Current progress is good and will hopefully continue. The first object imaged was a solid box in air. The MATLAB processing worked well. The second object imaged was a tissue box with a hole and a low level of tissues. The MATLAB processing provided a nice picture of the tissue box, which included the hole with the tissues, but there are still some problems. Edge detection needs to be adjusted to sharpen the accuracy of the system around the hole and around the outer edges of the tissue box.

The team implemented the 2 [MHz] transducer with excellent success. Using the MATLAB algorithms developed for the air transducer, the underwater 2 [MHz] transducer was quickly integrated. The first success was successfully imaging a washer on top of a metal block. The group was able to detect that there were two objects on top of each other. The system was capable of displaying the point of contact of the washer and metal block. The second success was being able to find metal objects buried in plaster. These objects could not be seen by the naked eye, but could be imaged using our system. This gets the team one step closer to its final goal of imaging objects buried within rock. The next step will be to image objects beneath sand. It is anticipated that this will have similar results to the plaster.

There are, however, other uses for object detection using acoustical imaging. With some modification this technique also promises to be useful for such things as security screening, flaw detection, mineral detection for mining, and landmine detection.