Recent NDE Lab Theses and Dissertations

Prof. Mark Hinders http://as.wm.edu/Nondestructive.html

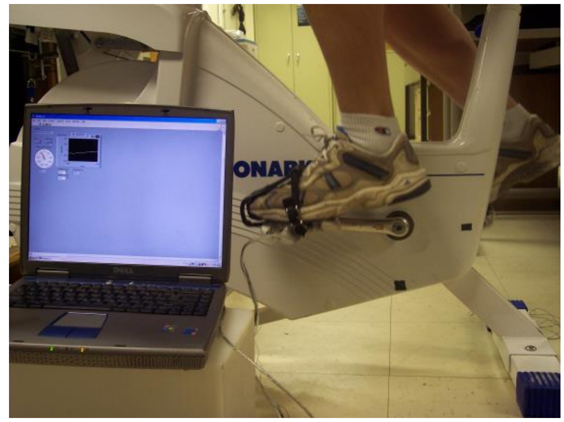
Alison Pouch, BS 2007: ***Ultrasonic Classification of Emboli,*** (PhD from U. Penn)
Alison developed a sophisticated mathematical model of the interaction of medical ultrasound with bubbles and other emboli in the bloodstream, which resulted in algorithms to allow a new medical device to more accurately size emboli during cardiac surgery. Some fraction of people undergoing heart bypass surgery aren't quite right mentally afterwards, due to emboli blocking blood flow to parts of the brain, but the new EDACS device developed by a local company can now detect and size emboli during the surgical procedure.

- **Danielle Dumond, BS 2007:** ***Mobile Robot Sensor Fusion*** (PhD in Robotics, Dartmouth)

Danny's work involved exploring the usefulness of thermal infrared (IR) imaging for robotic navigation. Our second Ectobot, ***rMary*****,** has an IR camera which reflects off a 45-degree mirror to image the heat patterns of objects in front. Using our knowledge of the recent temperature, weather, etc. along with an understanding of the physics of how various everyday objects (trees, fences, brick walls, hedges, etc.) store and radiate heat, we define abstract features that can be extracted automatically via computer image processing from the IR imagery. Assessment of what an object might be is then done in some abstract mathematical feature space. Oh, and by the way, it works in perfect darkness.

- **Kevin Rudd, PhD 2007:** ***Three Dimensional Finite Integration Time Domain Simulations of Ultrasonic Propagation and Scattering*** (Now at Naval Research Lab)
In his dissertation, Kevin presented two parallelized 3D simulation techniques for three-dimensional acoustic and elastic wave propagation based on the finite integration technique. He demonstrated their usefulness in solving real-world problems with examples in the three very different areas of nondestructive evaluation, medical imaging, and security screening. More precisely, these include concealed weapons detection, periodontal ultrasonography, and guided wave inspection of complex piping systems. He employed these simulation methods to study complex wave phenomena and to develop and test a variety of signal processing and hardware configurations. Simulation results were compared to experimental measurements to confirm the accuracy of the parallel simulation methods.

- **Mark Cohey, BS 2008:** ***A Gage for Measuring Pedal Forces on a Stationary Bicycle,*** (MD from EVMS)
  Mark investigated, created, and tested a device used to measure the pedal forces on a stationary bicycle. Such devices have uses in the medical, biomechanical, and sports sciences. This study encompassed researching previous devices to determine the most effective technique, building a device capable of retrieving useful data, and testing the device in a live experiment with human test subjects. Initial research found that most previous designs created pedals that could measure forces with high precision, but usually involved costly components or bulky computers. The primary focus on the experimental design was to create an effective device that not only took force measurements, but that was small enough that it could be incorporated into a non-stationary bicycle and low cost enough that it could be reproduced easily and available for larger studies.



- **LtC William L. Fehlman II, PhD 2008:** ***Classification of Non-Heat Generating Outdoor Objects in Thermal Scenes for Autonomous Robots*** (Now Senior Principal Data Scientist at Clarity Insights)

  Bill's dissertation, published by Springer in 2009, describes a physics-based adaptive Bayesian pattern classification model that uses a passive thermal infrared imaging system to automatically characterize non-heat generating objects in unstructured outdoor environments for mobile robots. In the context of this research, non-heat generating objects are defined as objects that are not a source for their own emission of thermal energy, and so exclude people, animals, vehicles, etc. The resulting classification model complements an autonomous bot's situational awareness by providing the ability to classify smaller structures commonly found in the immediate operational environment. Since GPS depends on the availability of satellites and onboard terrain maps which are often unable to include enough detail for smaller structures found in an operational environment, bots will require the ability to make decisions such as "go through the hedges" or "go around the brick wall."

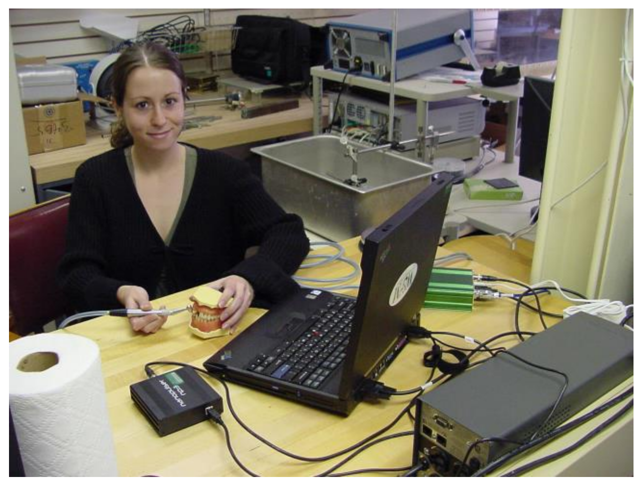
- **Jill Bingham, PhD 2008:** ***Ultrasonic Guided Wave Interpretation of Structural Health Inspections*** (Now at Boeing in Seattle)

SHM combines the use of onboard sensors with artificial intelligence algorithms to automatically identify and monitor structural health issues. A fully integrated approach to SHM systems demands an understanding of the sensor output relative to the structure, along with sophisticated prognostic systems that automatically draw conclusions about structural integrity issues. Ultrasonic guided wave methods allow us to examine the interaction of multimode signals within key structural components. Since they propagate relatively long distances within plate- and shell-like structures, guided waves allow inspection of greater areas with fewer sensors, making this technique attractive for a variety of applications. In order to understand guided wave propagation through real structures containing flaws, Jill developed a parallel processing, 3D elastic wave simulation using the elastodynamic finite integration. This full field, numeric simulation technique easily examines models too complex for analytical solutions, and is developed to handle built up 3D structures as well as layers with different material properties and complicated surface detail.

- **Christopher Houck, BS 2010*: Portable High-Frequency Ultrasound for Subsurface Characterization of Microelectronics*** (Graduated from VaTech School of Architecture)

Counterfeit, recycled, and maliciously modified integrated circuits (ICs) have increasingly become a threat to our information technology infrastructure. Delamination flaws in integrated circuits (ICs) present evidence that a chip has either been tampered with or modified. Chris helped develop methods of introducing delamination flaws and detecting their presence through construction of a portable, high-frequency, dry, ultrasonic apparatus. We tested the ICs using high frequency ultrasonic transducers powered by an industrial PC equipped with an analog to digital board. We wrote programs in Matlab to process the signals and adapted the Dynamic Wavelet Fingerprint to decipher the data. We discovered a repeatable pattern in the wavelet fingerprints for flawed and un-flawed ICs.

- **Crystal Bertoncini, PhD 2010: *Applications of Pattern Classification to Time-Domain Signals*** (Now at Naval Research Laboratory in DC)



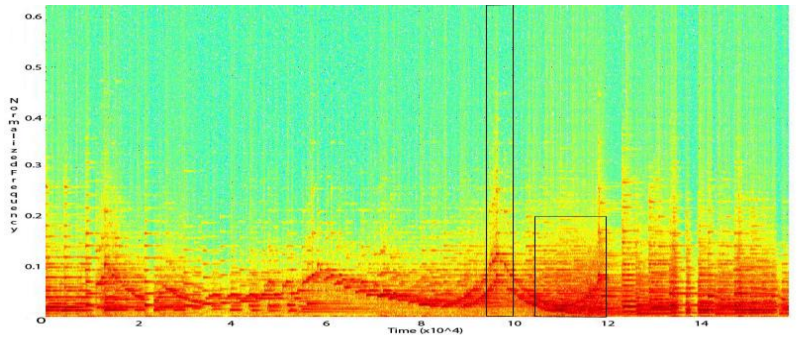
Many different kinds of physics are used in sensors that produce time-domain signals, such as ultrasonics, acoustics, seismology, and electromagnetics. The waveforms generated by these sensors are used to measure events or detect flaws in applications ranging from industrial to medical and defense-related domains. Interpreting the signals is challenging because of the complicated physics of the interaction of the fields with the materials and structures under study. Often the method of interpreting the signal varies by the application, but automatic detection of events in signals is always useful in order to attain results quickly with less human error. Crystal used pattern classification techniques to aid automatic detection of events in signals using features extracted by a particular application of the wavelet transform, the Dynamic Wavelet Fingerprint (DWFP), as well as features selected through physical interpretation of the individual applications. The wavelet feature extraction method is general for any time-domain signal, and the classification results can be improved by features drawn for the particular domain.

- **Cara Campbell Leckey, PhD 2011: *Investigation of Ultrasonic Wave Scattering Effects using Computational Methods*** (Now at NASA Langley Research Center, NDE Sciences Branch & LaRC HPC Incubator)

Advances in computational power and expanded access to computing clusters has made mathematical modeling of complex 3D wave effects possible. In Cara's work she used multi-core and cluster computing to implement analytical and numerical models of ultrasonic wave scattering. We then investigated scattering of both acoustic and elastic waves. Acoustic waves are traditionally modeled as longitudinal waves, however, viscous fluids can support both longitudinal and shear wave motion, although the latter are strongly damped. Elastic media also supports both longitudinal and shear waves and both wave modes propagate independently, although scattering converts energy between them. Applications are to emboli removal from cardiopulmonary bypass circuits and the micromanipulation of algal cells to aid in biomass processing for algae biofuels, as well as Lamb wave scattering for aircraft structural health monitoring.

- **Ryan Laney, BS 2011: *Automatic Detection of Flaws in Recorded Music*, BS** (Now ryanlaneymusic.com)

Recording music in any form often produces artifacts that are not pleasing to the ear. Reducing these artifacts is the focus of millions of dollars in research for music companies every year. However, despite this research, there is still a considerable volume of work that requires special attention, and historic non-commercial recordings are often never cleaned up enough to be sold, or even provided, to the general public because of the great amounts labor each recording demands. The goal of our research is to develop an automated process to clean up the damage to this piece of human history. Ryan continued the work of Jori S. Byrne-Diakun, BS 2008.



- **Corey Miller, BS 2008 & PhD 2013: *Intelligent Structural Health Monitoring*,** (Now Ursa Space Systems)

Corey's projects developed a robust signal analysis technique suitable for a wide variety of time-domain signal applications. Pattern classification is a subset of artificial intelligence that assigns labels to raw data based on multivariate statistical measures of that data set. Since these algorithms consider multi-dimensional feature spaces, many characteristics of a signal can be considered simultaneously in the decision process. The classification abilities are therefore directly related to the choice of feature representation for a data set. The *a priori* choice of optimal features is often unknown, and in practice, features are chosen based on intuition of the problem at hand. Feature selection techniques are designed to reduce the size of the feature space by identifying which subsets produce the best classification performance. Corey applied pattern classification techniques to a variety of applications involving a physical change in the data collection that translates to change in the signal characteristics, and explored feature selection techniques that incorporate the context of the problem into the feature space reduction.

- **Eric A. Dieckman, PhD 2014 *Use of pattern classification algorithms to interpret passive and active data streams from a walking-speed robotic sensor platform*,** (Univ. New Haven)

An unresolved issue for autonomous walking-speed robots in unstructured outdoor environments is maintaining situational awareness. One strategy is combining information from different sensors so the robot can function in a variety of conditions and environments. The very low-cost Microsoft Kinect accessory incorporates active infrared and RGB video sensors to provide real-time depth information, as well as a 4-channel microphone array. We are using the Kinect sensors in combination with traditional infrared imaging, non-linear acoustic echolocation, and a low-cost "coffee-can" radar on our mobile robotic sensor platform. By using an acoustic parametric array to generate the audible echolocation signal, a tightly-controlled beam of low-frequency sound can interrogate targets at long distances to complement the radar backscattering, while infrared imaging works well in the near field. Sophisticated signal processing techniques are required to combine and interpret the collected data. We make use of an understanding of the physics of the target and clutter responses to guide the development of pattern classification algorithms.

- **Matthew Groves, BS 2016,** ***Applications of a Length-Limited Parametric Array: Benignly Excluding Birds*** (Master of Divinity from Vanderbilt U.)

Birds present major problems in both the developed and the developing world, and the approaches to exclude them are broadly ineffective or inefficient. Noticing that birds are highly social creatures, we aim to fill the frequency range that birds use to communicate with static, so they cannot communicate with each other and subsequently leave. The static is within the audible spectrum, so we are applying two acoustic techniques – the parametric array and length-limiting – to create highly directional sound and minimize noise pollution. Specifically, we collected data of a length-limited effect at various parameters, which we used to benchmark simulations and maximize the effect.

- ***Jordan Leek*, BS 2017,** ***Acoustical Response of Traditional Speakers to Single-Frequency Sine Waves***

Birds communicate within a characteristic frequency band dependent upon their species. When noise at the same frequency band is present, birds tend to leave due to the noise's impact upon on their communication. By isolating the frequencies that a species of bird communicates in, and playing noise at this frequency band over a specific area, birds are effectively displaced, both in the short- and long-term. The downside to projecting this noise over a large area is that it is within the human range of hearing and therefore it adds to noise pollution. For this method to be viable in highly populated areas, a means of spatial noise control must be developed. In an effort to minimize the noise pollution of this signal in undesired areas, and better focus the pink noise signal, a multi-frequency acoustic mirror will be designed, constructed, and tested with various speaker designs at the focal point. To better understand the amount of noise pollution that currently occurs and to optimize the design of the acoustic mirror, we first characterize the acoustic spread of each of the four speakers using ten 500 Hz to 10kHz sine wave signals.

- **Victor E. Trujillo II, PhD 2019,** ***Global Shipping Container Monitoring Using Machine Learning with Multi-Sensor Hubs and Catadioptric Imaging,*** (Battalion Commander, 1-410 Brigade Engineer Battalion)

We describe a framework for global shipping container monitoring using machine learning with multi-sensor hubs and infrared catadioptric imaging. A wireless mesh radio satellite tag architecture provides connectivity anywhere in the world which is a significant improvement to legacy methods. We discuss the design and testing of a low-cost long-wave infrared catadioptric imaging device and multi-sensor hub combination as an intelligent edge computing system that, when equipped with physics-based machine learning algorithms, can interpret the scene inside a shipping container to make efficient use of expensive communications bandwidth. The histogram of oriented gradients and T-channel (HOG+) feature as introduced for human detection on low-resolution infrared catadioptric images is shown to be effective for various mirror shapes designed to give wide volume coverage with controlled distortion. Initial results for through-metal communication with ultrasonic guided waves show promise using the Dynamic Wavelet Fingerprint Technique (DWFT) to identify Lamb waves in a complicated ultrasonic signal.

Applied Science is an interdisciplinary graduate department which offers M.S. and Ph.D. degrees in the physical and biological sciences. Courses are offered cooperatively by the core faculty of Applied Science along with affiliated faculty from the Departments of Biology, Chemistry, Computer Science, Mathematics, Physics, and the Virginia Institute of Marine Sciences (VIMS), as well as from the NASA Langley Research Center (LaRC) and the Thomas Jefferson National Accelerator Facility (Jefferson Lab). In Applied Science we use the tools, the techniques, and the understanding involved in a wide range of sciences in order to solve complex scientific and technical problems. The Department has state-of-the-art facilities in: (1) theoretical and computational analysis of physical and biological systems, (2) cellular and systems neurophysiology, (3) materials synthesis and characterization of small molecules, polymers, inorganics, and composites, (4) modification and evaluation of interfaces, (5) processing of materials and surfaces, and (6) imaging technology and theory from nano to planetary scales. While Applied Science does not offer an undergraduate major, several courses in the department are particularly suitable for undergraduate students of physics, mathematics, chemistry, computer science, and biology. An undergraduate minor is offered with a track in Materials Science & Engineering.

In Prof. Hinders' research group the term nondestructive evaluation means many seemingly different things:

- **Medical Diagnostics:** Ultrasound images, mammograms, etc. are two-dimensional "cuts" of three-dimensional anatomy. Doctors are expert at interpreting them, but the diagnosis is still quite subjective.

- **Structural Flaw Detection:** Technicians are not as highly trained at diagnosis, plus there is no standard "anatomy" and the structure can't tell where it hurts. There's also the morning after bowling night!

- **On-line Inspection:** Engineers don't want to interpret images. They want the instrumentation to give a green light if the process is OK, and a red light if it's out of spec.

- **Intelligent Robotics:** The key to useful robots is a combination of imaging sensors and the on-board intelligence to interpret them. Want to tell the robot to turn left at the big tree, not feed it GPS coordinates.

The focus of our work is to implement new and better measurements with both novel instrumentation and artificial intelligence that automates the interpretation of the various (and multiple) imaging data streams. Each student's research typically has application to several seemingly quite different areas, in order to gain meaningful experience in multiple industries. Our graduates have gone on to work in a wide variety of jobs, and many of our current research projects are being done in close collaboration with our former students. Youtube videos of Prof. Hinders are here. These videos and the other links are intended for prospective graduate students who want to get a sense for who we are, what we do, and where we do our work.