

RESEARCH STATEMENT

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Broadly, my research interest is in the field of digital signal processing and image processing. My work over the last 7 years has focused on the interdisciplinary application of digital signal processing and image processing techniques particularly in the medical field.

My dissertation project was on the identification of congenital heart defects in fetuses using four-dimensional (4-D) ultrasound images. A congenital heart defect is a disease present at birth affecting the structure and function of the heart and major vessels. It is the most common type of birth defect occurring in 8 per 1000 births in the United States according to the Centers for Disease Control and Prevention (CDC). Despite advances in diagnostic imaging, the prenatal detection rate of these defects is between 30-50%. This low detection rate is attributed to the lack of trained personnel in underserved areas where many cases go undetected. The project was initiated by the need for an automated detection system that can be deployed in these underserved areas as a way of improving the overall detection rate of these defects and potentially decreasing mortality associated with missed detection. My system is the first of its kind to leverage 4-D ultrasound imaging technology for this specific application.

The design of the detection system was an interdisciplinary effort where I sort out collaborations with a pediatric cardiologist, Dr. M. D. Puchlaski, and an obstetrician, Dr. P. C. Struijk to learn the intricacies of congenital heart defect diagnosis in fetuses. Dr. Puchalski is the Director of Non-Invasive Imaging at the Primary Children's Hospital in Salt Lake City Utah, and Dr. Struijk is the Chief Scientist in the Department of Obstetrics and Gynecology at the University Medical Center St. Radboud in Nijmegen, The Netherlands.

The detection system I designed consisted of three main components: 1) a location estimation component, 2) a segmentation component and 3) a classification component. The location estimation component is used to isolate a fetal heart in any given 4-D image. Its main use is to ensure that the correct structure of interest (fetal heart) is analyzed. It uses a region of interest segmentation approach which considers the local image characteristics around each image voxel to estimate the outer walls of a fetal heart. The segmentation component uses a novel motion estimation and feature extraction method where features describing the motion of a fetal heart during a cardiac cycle is used in a kernel learning framework to segment the individual fetal heart chambers. The added dimensionality of a four-dimensional image is leveraged to improve on results associated with two-dimensional and three-dimensional segmentation. The classification component is a simple binary classifier that discriminates the segmented fetal heart chambers based on diagnostics features such as relative sizes, relative orientation, etc. Initial tests of the detection system on clinical data produced 80% success rate for fetal heart with hypoplastic left heart syndrome, a congenital heart defect.

In addition to my dissertation research, I have also done some research work on sensor signal analysis, and nonlinear signal processing. In particular I worked on a project that aimed to optimize sensor placements on an airplane through analysis of the sensor signals. I utilized digital filtering, statistical signal processing and machine learning techniques to extract feature that best represented these sensor signals. These features were used in a constrained objective function to minimize the number of sensors. The application of this project was for structural health monitoring of an airplane to detect faults.

From the two brief project descriptions provided, it is evident that I am interested in diverse and interdisciplinary applications of signal processing and image processing. My training has equipped me with the material needed to add knowledge to the field of signal processing. There are still many research projects out there that signal processing can be used to solve, and I hope to be at the forefront of discovering solutions to these problems.