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Suggested Project Title:
Reducing the uncertainty in miaging when using sensor array data

Suggested Project Summary:
An array of sensors (for example, acoustic, ultrasonic, or light based) can be used to position and image an object in its field of view. However, one source of uncertainty that arises in this exercise (when considering large scale propagation of waves in a heterogeneous medium) is due to wave refraction. Our approach will be to use sensor data to reconstruct this heterogeneous spatial map of the local wave velocity. This knowledge will then be used to discount the refractive effects and thereby reduce the uncertainty of this imaging problem. In particular, we will approach this inverse problem using Voronoi tessellations to spatially parameterise the localised velocity map and the Fast Marching Method to track the wave through the medium. A Bayesian approach, namely the reversible jump Markov Chain Monte Carlo method (rj-MCMC), is proposed to be used as the optimisation method in the inversion. This is an iterative stochastic approach and is used to create samples from a probability density; the moments of the posterior distribution containing the sought after information. Once the map is recovered it can then be used to adjust the imaging algorithm by including the localised time of flight and wave refraction as the wave travels through the (now known) heterogeneous medium. Note that to support and inform any experimental investigations it is sensible to generate some synthetic data via a finite element code. This provides complete groundtruth on the spatially localised velocity maps that are to be recovered, complete control over the placement and number of the sensors, and is a quick and affordable way to produce a large volume of test data samples of increasing complexity. It is also possible to investigate the role that the number and positions of the sensors have on the ability to recover the localised velocity map and hence on the improvements to the imaging problem. The Fisher Information Matrix describes the sensitivity of the sensor measurements to changes in the localised velocity map parameterisation. There are various measures of this matrix (such as the determinant) that can be used to form a utility function that depends on the sensor distribution. So an optimal experimental design can be devised that produces an optimal sensor distribution (position, number) such that the uncertainties in the recovered heterogeneous velocity map and in the reconstructed image are minimised. The outcome from the project is an improved imaging system with better images and perhaps cost savings associated with the number and type of sensors.

Collaboration Sought for the Project:
The industrial partner would need to have an interest in using multiple sensors to image an object and this object should be in a medium that is preventing the system from achieving the desired levels of image quality/accuracy. The partner should have data from sensors - which the project intrinsically relies upon - and also be able to contextualise the work and describe the practical side of the problem.

Benefit to the Industry Sponsor:
We have a global lead in using these techniques in the area of ultrasound array imaging and the generic nature of the methodology should mean that it can be quickly translated to a new field. It may be that the new application has not benefitted from an approach of this type before and so a step change in capability might be achieved for the industry partner. This could help them achieve a higher market share by having a more able system than their competitors.

Published or Private?:
Yes