Abstract

Before inverse algorithms can accurately reconstruct non-invasive electrical images of the heart, patient specific data must be gathered and processed. Three-dimensional generic male and female human and porcine models have been constructed from CT and MRI images using a non-linear fitting procedure. Prior to realising the ultimate goal of using such models in an inverse procedure, several issues must be addressed.

The ability to customise a generic model to a given individual in the absence of full MRI/CT data is required. This can be achieved by manipulating a mesh with a number of control points. The generation of a continuous potential field must be created from discretely sampled ECG signals. We present a new approach of finite element field fitting to reconstruct the signals. The appropriate computational mesh resolution required to achieve a converged solution must also be determined.

The three issues identified above in preparing a process for use in electrical inverse studies have been successfully addressed. These procedures are now being used as part of an experimental program to validate inverse procedures.

Patient Specific Modelling for Non-Invasive Cardiac Electrical Imaging

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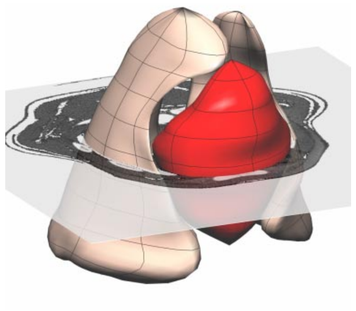
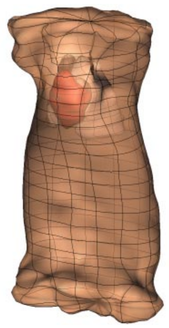
Computational Model

- Three-dimensional male and female human and porcine models have been constructed from CT and MRI images using a non-linear fitting procedure (see porcine model below).

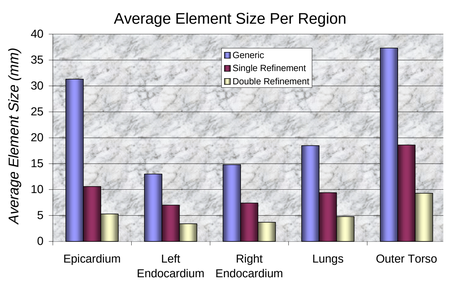


Epicardial and lung surfaces with a CT image (from which the model was digitised) overlayed.



Full porcine model with outer torso layer, lungs and epicardial surfaces. Left and right endocardial surfaces are not displayed.

- Using a constant current heart source, a simulation was used to generate potentials. The mesh was then refined until convergence was obtained.
- For a converged solution, the epicardium was refined twice and all other regions were refined once in each direction.
- Numerical results were compared using multiple measures: RMS, relative RMS, Similarity Index, changes in maxima and minima.
- The resulting mesh required for a converged solution has 2538 nodes and 4142 elements with 10116 degrees of freedom.



Increasing mesh resolution as the model is refined. A single refinement is defined as an element division once in a given direction.

Patient Specific Models

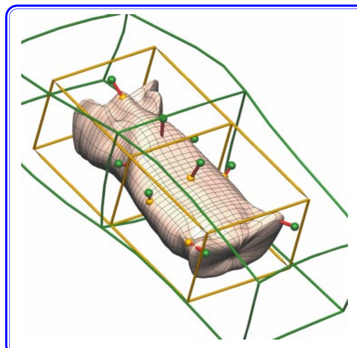
- When applying an inverse procedure to a subject a patient specific mesh is required. The ability to model the geometry of the torso and position of the heart accurately are crucial for accurate results.

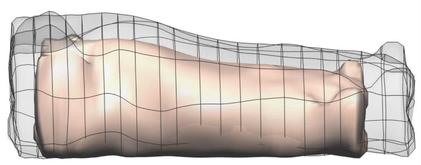
Digitisation & Geometric Fitting

- Geometric fitting from digitised MRI or CT cross-sectional image slices creates an accurate model.
- However, this method is slow and labour intensive.

Host Mesh Customisation

- Host mesh customisation is a faster but less accurate method by which a generic model can be transformed to a specific subject. This is for use when MRI or CT data is not available or as an initial mesh for the non-linear fitting procedure when MRI or CT data is present.
- Using a small number of control points on both the generic model and the subject, a host mesh is deformed to minimise the differences.
- The slave mesh (the generic model) is embedded within the host mesh and moved accordingly.
- Ultrasound, CT or MRI data can be used to more accurately position the heart model.

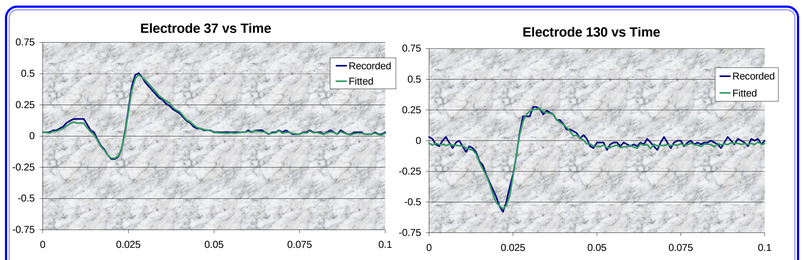




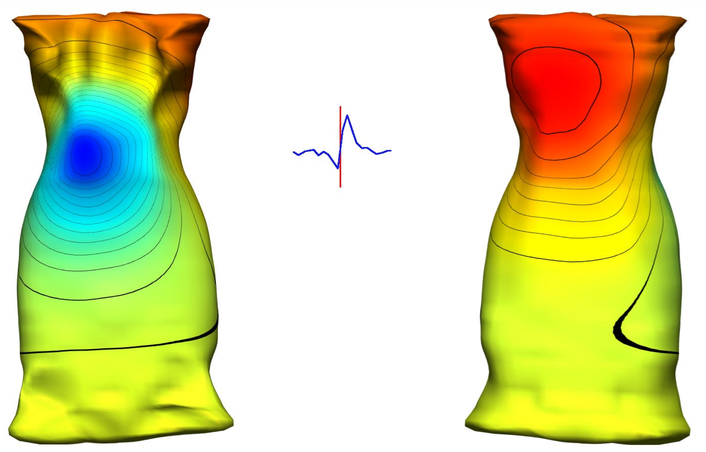
Customising a smaller generic model to a larger specific subject with the use of 9 control points. On the left, the generic mesh and data (gold) is customised to the measured data (green).

Signal Interpolation

- Experimentally, data is acquired at discrete, non-uniform locations. These must then be manipulated to a form which can be used in inverse procedures.
- Traditionally, this is achieved by cubic-splines or triangulation. These techniques force the field to pass directly through each noisy data.
- Finite element field fitting creates a continuous potential field and has the advantage of smoothing out noisy data.



Comparison between experimentally measured and fitted signals. Electrode 37 is on the right upper posterior while electrode 130 is on the anterior over the heart.



Potentials on torso surfaces created by finite element field fitting from 240 electrode locations. Blue indicates minimum and red indicate maximum potential. An electrode recording is display with the red marker indicating current time in heart cycle.