FieldML

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Te Whare Wānanga o Tāmaki Makaurau

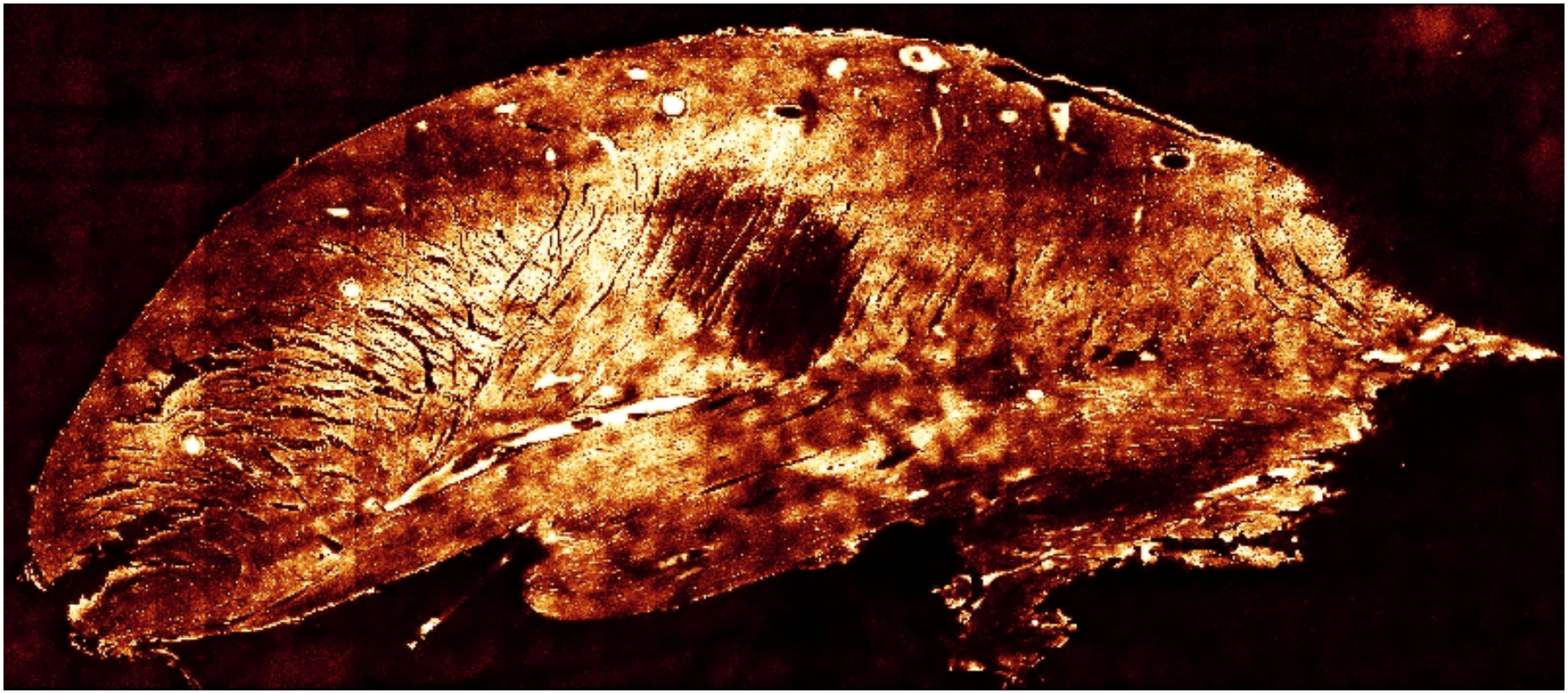
Modelling approaches

- Distributed parameter modelling at organ level:
  - Anatomy;
  - Constitutive relationships (typically nonlinear hereditary equations);
  - Mathematical description of physics (typically nonlinear partial differential equations).
- Lumped parameter modelling at the cellular level:
  - Typically systems of nonlinear ordinary differential equations.
  - Hierarchically embedding CellML models in distributed parameter descriptions.
- Stochastic modelling at the subcellular level:
  - Discrete particle/time simulations.

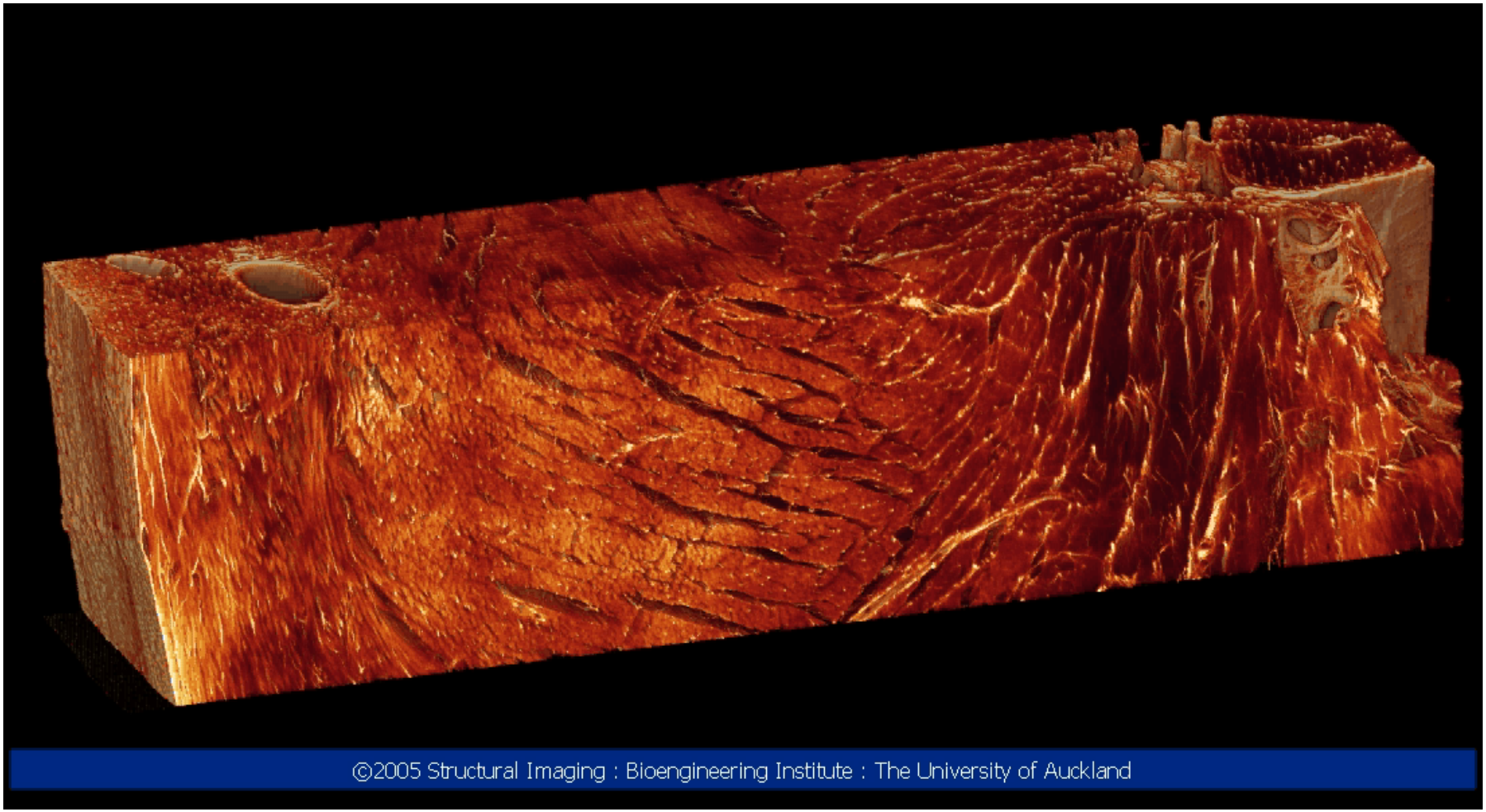
Research interests

- Soft tissue mechanics
  - Breast mechanics
  - Mechanics of childbirth
  - Skin
  - Shaken baby
- Bioinstrumentation
  - Micromechanocalorimetry
  - MRI exercise
  - Microrobotics
  - Wireless motion sensing
- Knowledge representation
  - CellML
  - FieldML

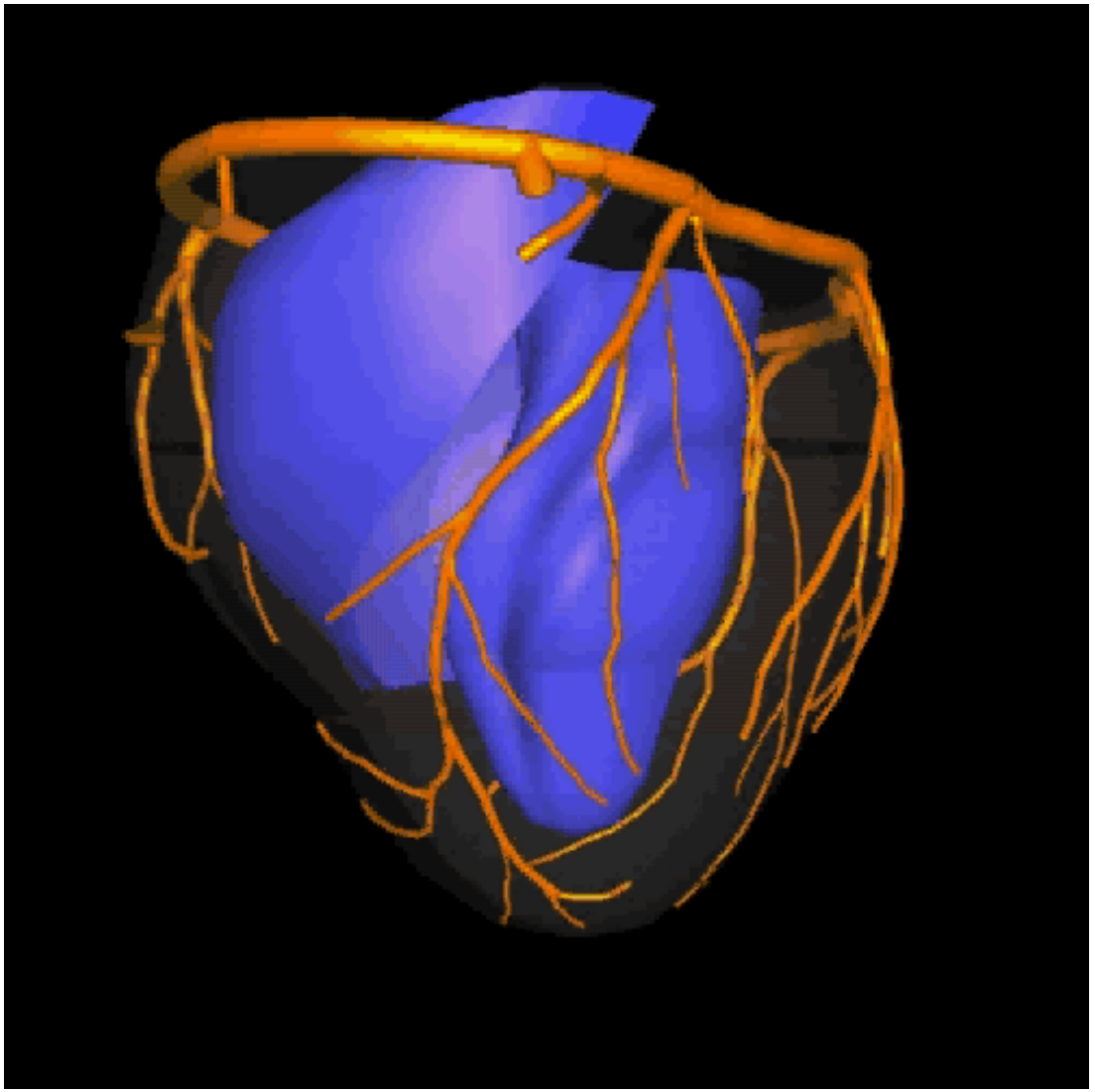
High resolution 3D imaging



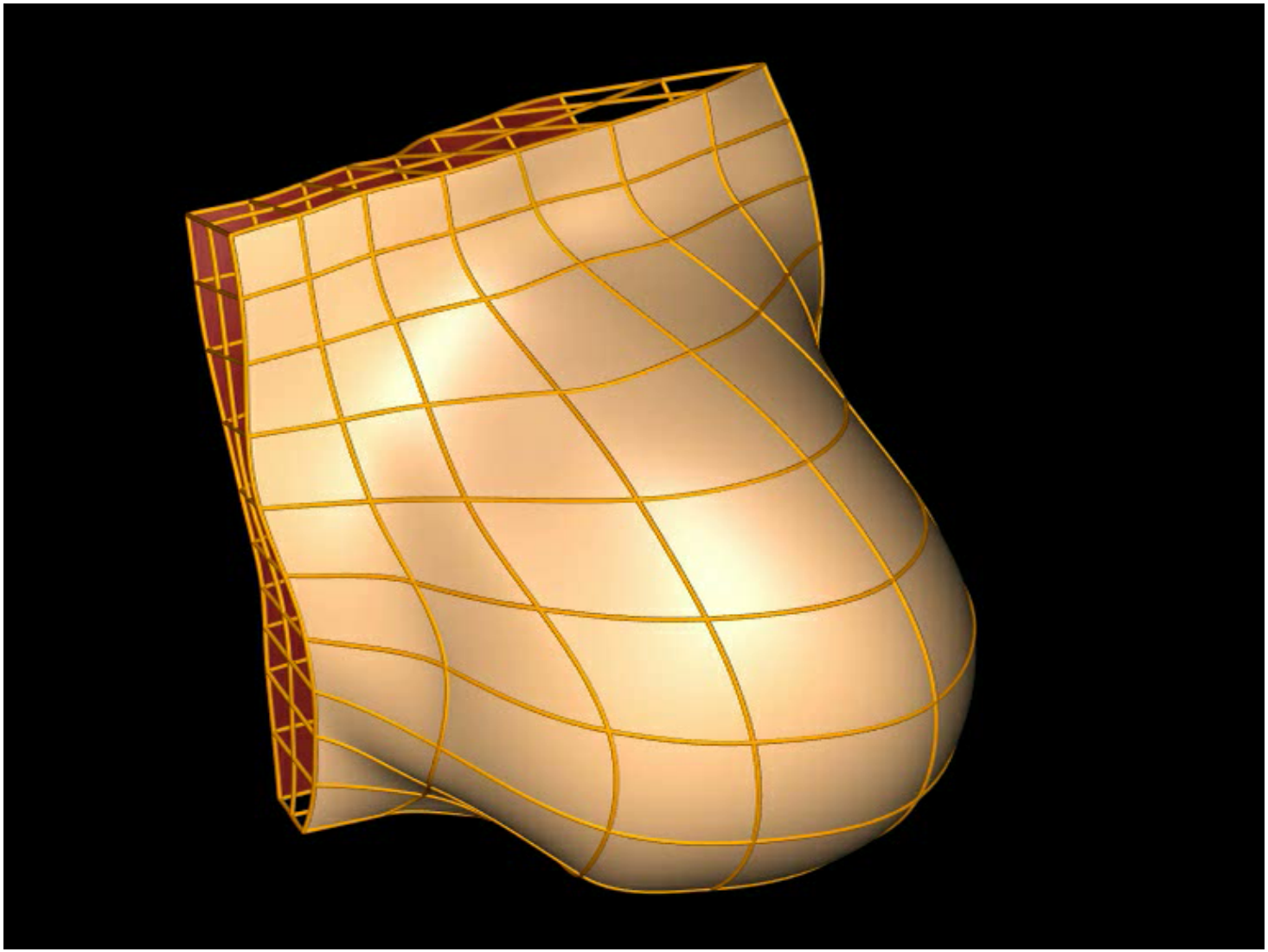
Structural anisotropy and inhomogeneity



Blood vessels embedded in heart



3D co-location from 2D mammograms



Chung J-H, Rajagopal V, Nielsen PMF, Nash MP 2008. A biomechanical model of mammographic compressions. *Biomechanics and Modeling in Mechanobiology* 7(1): 43-52.

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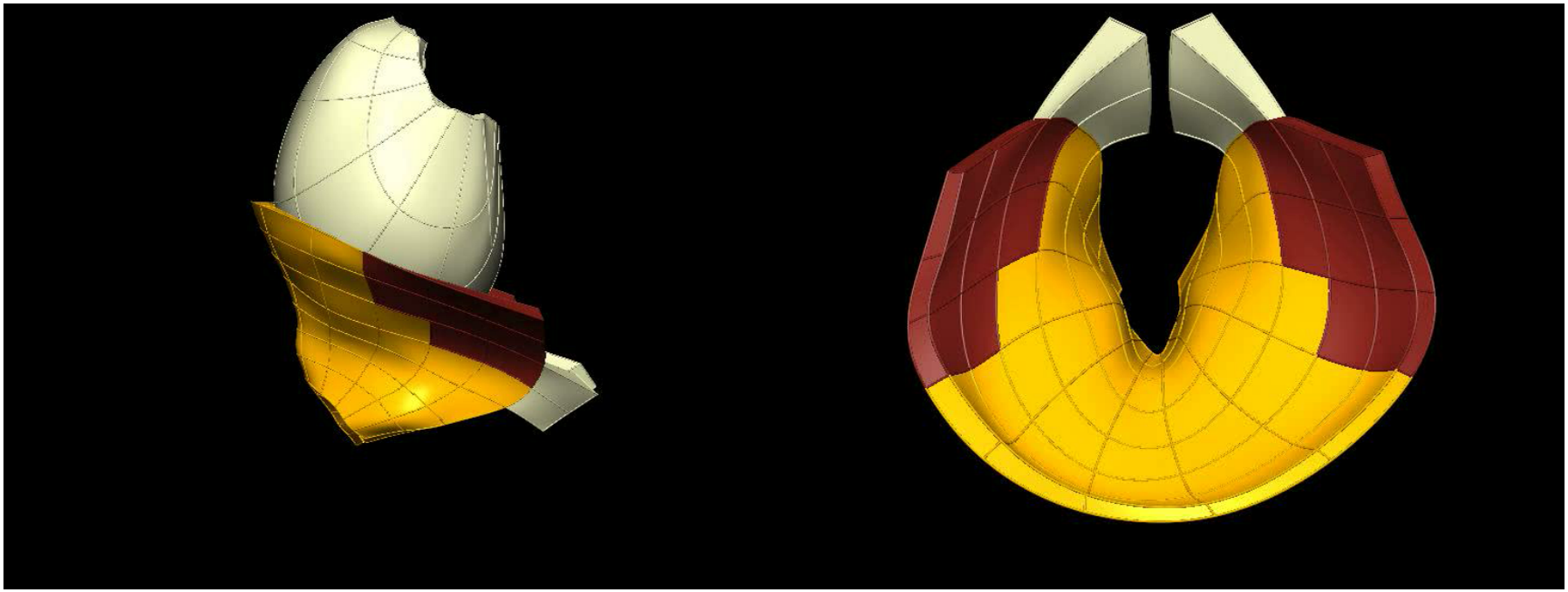
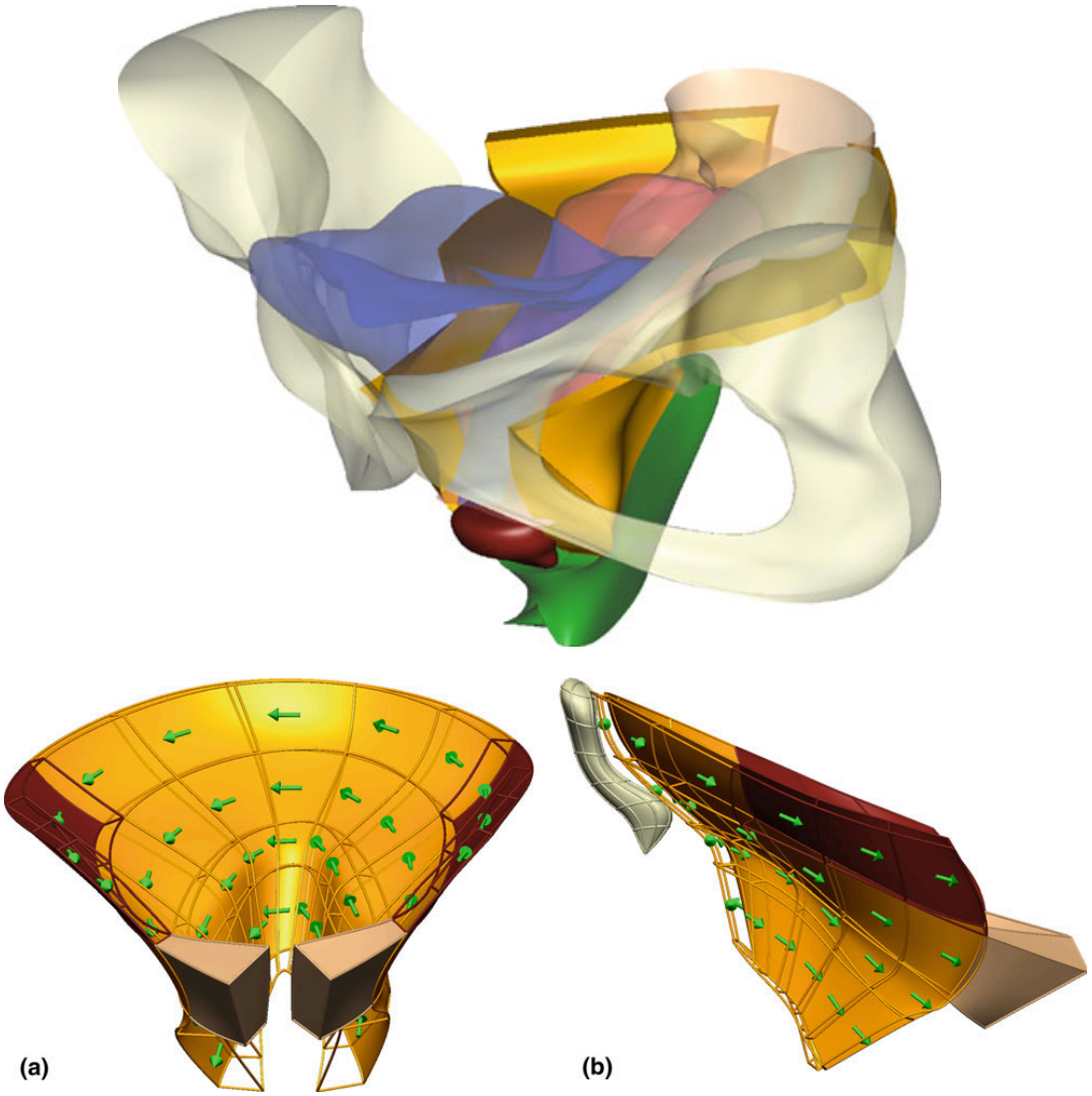
Modelling childbirth

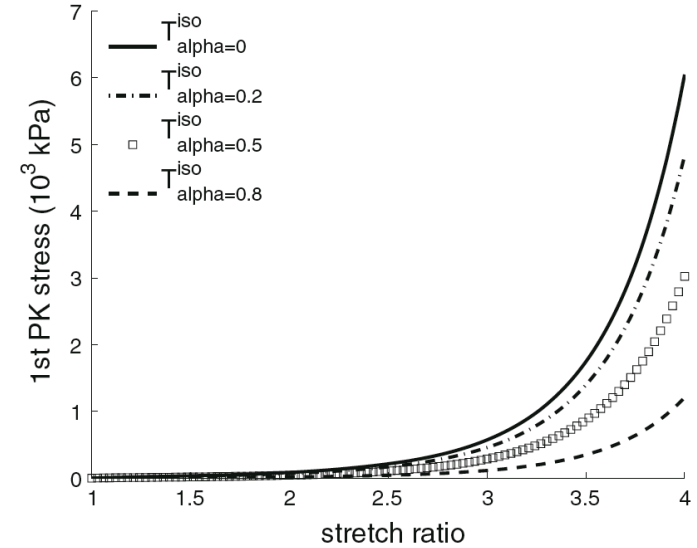
- Model second stage of labour:
  - Complicated geometry, fetal head moulding;
  - Very large deformations;
  - Nonlinear anisotropic tissue;
  - Soft/soft and soft/hard tissue contact mechanics;

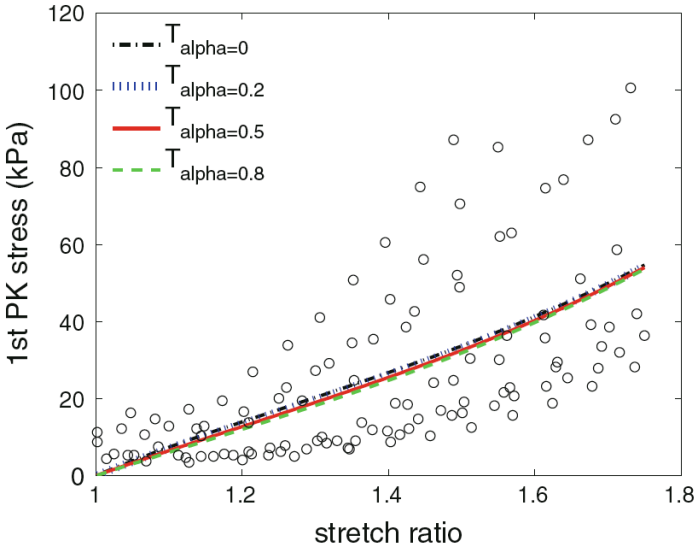


Li X, Kruger JA, Nash MP, Nielsen PMF 2010. Modeling childbirth: elucidating the mechanisms of labour. *Wiley Interdisciplinary Reviews: Systems Biology and Medicine* 2(4): 460-470.

Effects of tissue anisotropy







Li X, A. KJ, Nash MP, Nielsen PMF 2010. Anisotropic effects of the levator ani muscle during childbirth. *Biomechanics and Modeling in Mechanobiology*.

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FieldML

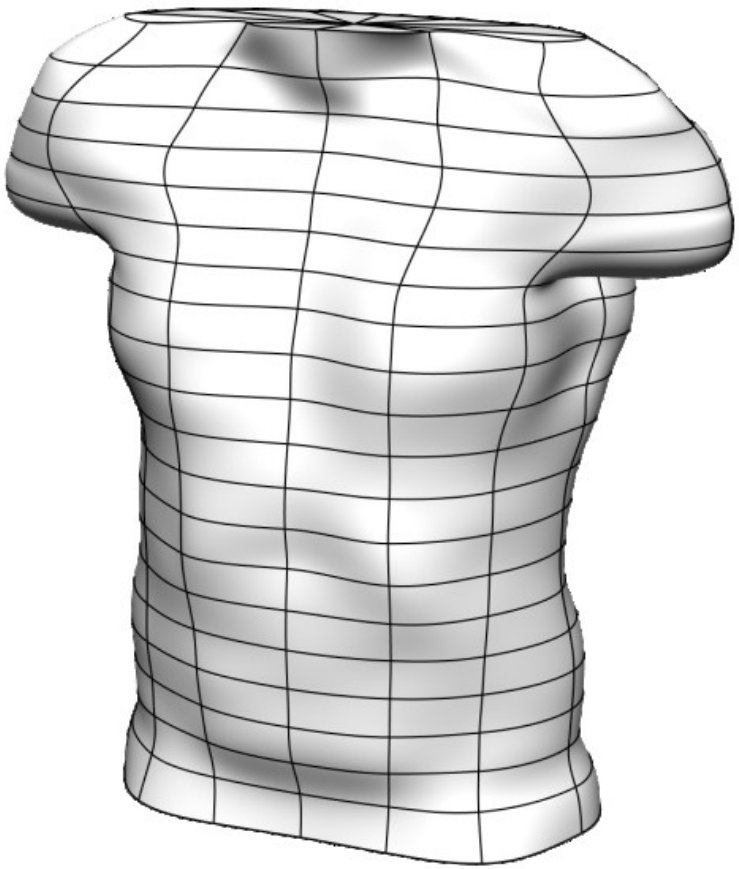
- A format for storing and interchanging field descriptions and data between different software.
- Extensible and able to describe fields of arbitrary complexity…
- … defined over arbitrary domains: spatial, temporal, continuous, discrete… , and their product spaces.
- Reusable model components.
- Efficient.
- XML serialization.

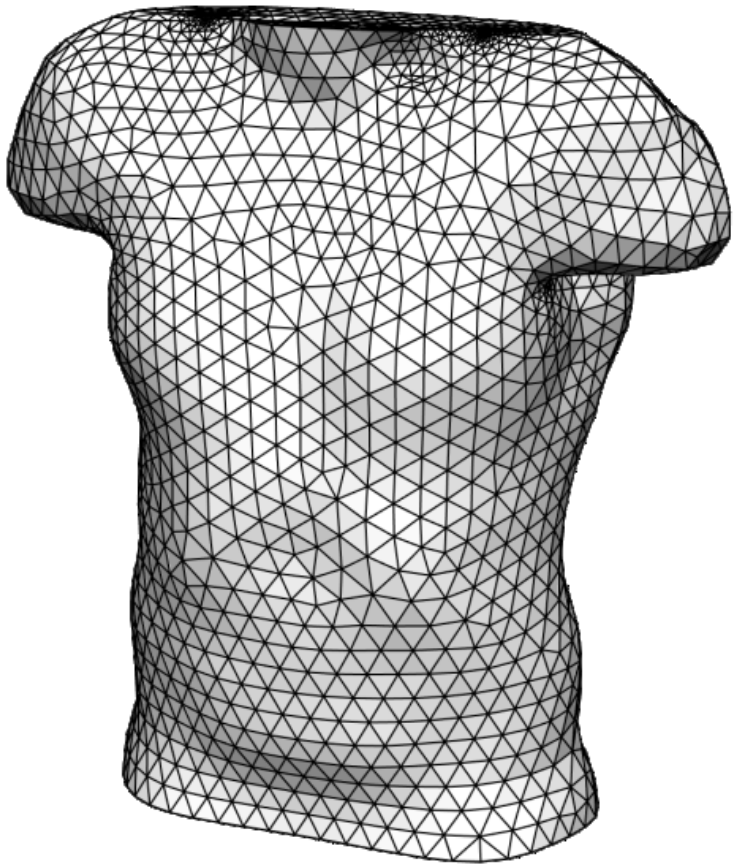
FieldML concepts – domains & charts

- Abstraction based on concepts of differential geometry.
- Domains are generalised spaces over which fields are defined.
- Have a fixed dimension (0, 1, 2, 3, 4, …).
- Have a set of coordinate charts that cover the domain to uniquely identify locations.
- Domains can embed subdomains of same or lower dimension.
- Can thus create hierarchies of domains within domains - essential for reuse and preservation of spatial relationships.
- Domains may be constructed as unions, intersections, projections, and outer products of other domains.

FieldML concepts – domains & charts

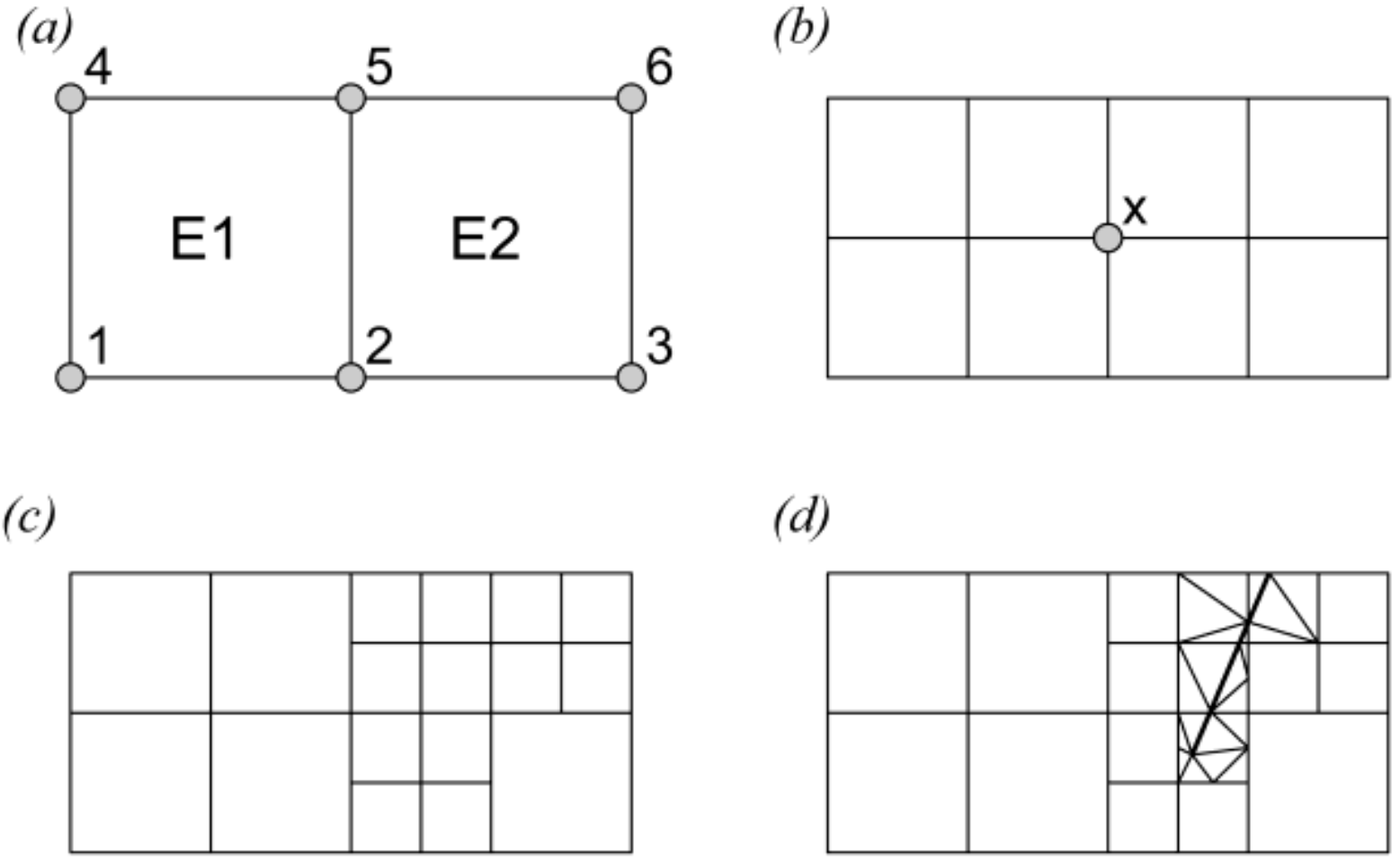
- Multiple atlases/meshes covering the same domain





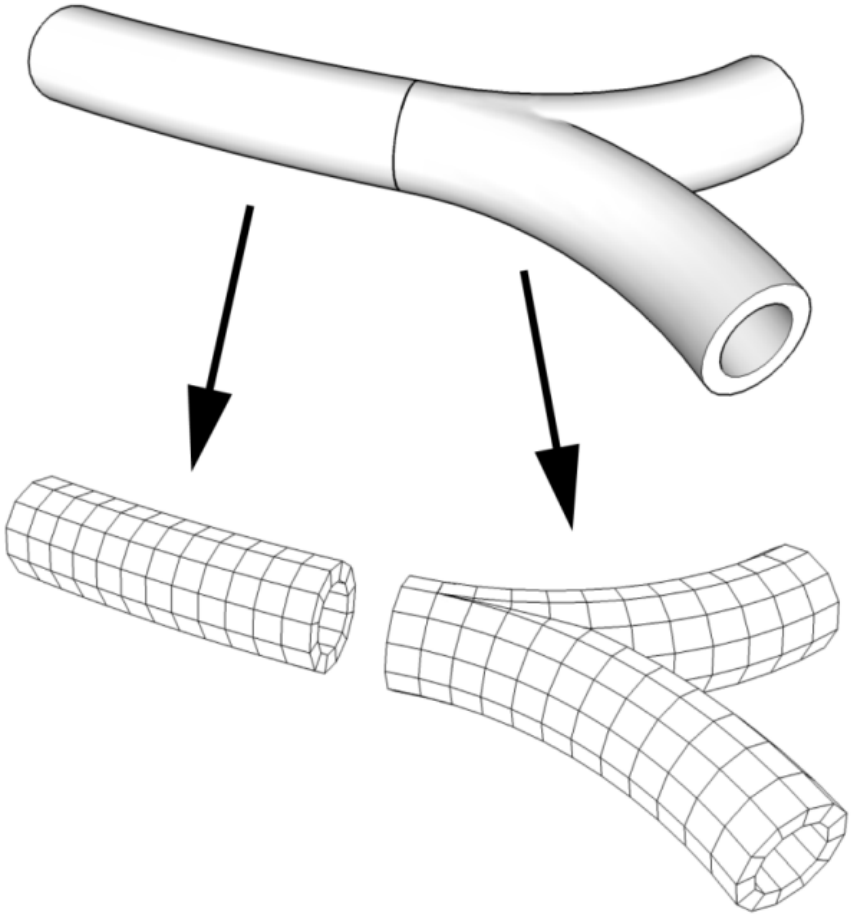
FieldML concepts – domains & charts

- Chart embedding for local mesh refinement, topology change.



FieldML concepts – domains & charts

- Domain composition to create new domain from union of domains



FieldML concepts - fields

- Fields are functions defined over domains.
- Types of fields are arbitrary (e.g. logical, real, vector, tensor, string, structure…).
- No fundamental distinction between geometric fields and any other field (same methods available for definition/evaluation).
- Few restrictions on how fields are evaluated, but must be defined explicitly (e.g. mathematical description).
- Many common basis functions are available in standard library (e.g. constant, *n*-linear, *n*-monomial, Lagrange, Hermite, spline, rational, radial, etc over simplex/rectangular domains).
- Fields may be defined as functions of other fields on the intersection of their domains, via evaluation pipelines.

FieldML concepts - fields

- Field operators available (algebraic and differential). e.g. gradient operator maps scalar real field over a domain to vector field over the tangent space of that domain.
- User-defined functions are created as compositions of field operators to create evaluation pipelines that produce new fields.
- Can create arbitrary basis functions over complicated domains – essential for principal component analysis of shapes and eigensolution model reduction.
- Large data sets may be stored efficiently by linking to external files in a similar fashion to how images are referenced in HTML. e.g. Hierarchical Data Format HDF5 <http://www.hdfgroup.org/HDF5/>

FieldML concepts

- Specification is currently at version 0.4
- Have API in C, but will shortly have C++ and support for other language bindings.
- API provides reader and writer objects for working with external or inline data resources.
- API validates XML documents against the XSD and reports both validation errors and a variety of FieldML logic errors.
- FieldML 0.4 support in CMGUI and OpenCMISS.
- Limited number of FieldML models available in Physiome Model Repository (PMR2).

FieldML developments

- Currently working on 0.5 specification.
- Concepts of domain calculus being added in this version.
- Keeping API release in synchrony with specification.
- Try to maintain generality, simplicity, and reusability (promote the creation of generic library components of useful topologies and field collections).
- Explicit definition of entities.
- Still evolving…

FieldML resources

- Latest documentation available on request:
  "*FieldML 0.4 Concepts and Serialisation*"
- Website:
  www.fieldml.org
- FieldML API releases:
  sourceforge.net/projects/fieldml/files
- FieldML source, prototypes, mock-ups:
  code.google.com/p/fieldml
- Model repository:
  models.fieldml.org
- E-mail:
  fieldml-developers@lists.sourceforge.net

People

- Chris Bradley
- Randall Britten
- Richard Christie
- Peter Hunter
- Caton Little
- Andrew Miller
- Poul Nielsen

- *Martyn Nash*
- *Andrew Taberner*.

www.abi.auckland.ac.nz

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Where in the world?