

Whole-Heart-FSI

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A whole-heart model of multiscale soft tissue mechanics and
fluid structure interaction (FSI)
for clinical applications

Principal Investigator: Xiaoyu Luo

Co-Investigator: Dirk Husmerer

Research Assistants: Liuyang Feng & Arash Rabbani

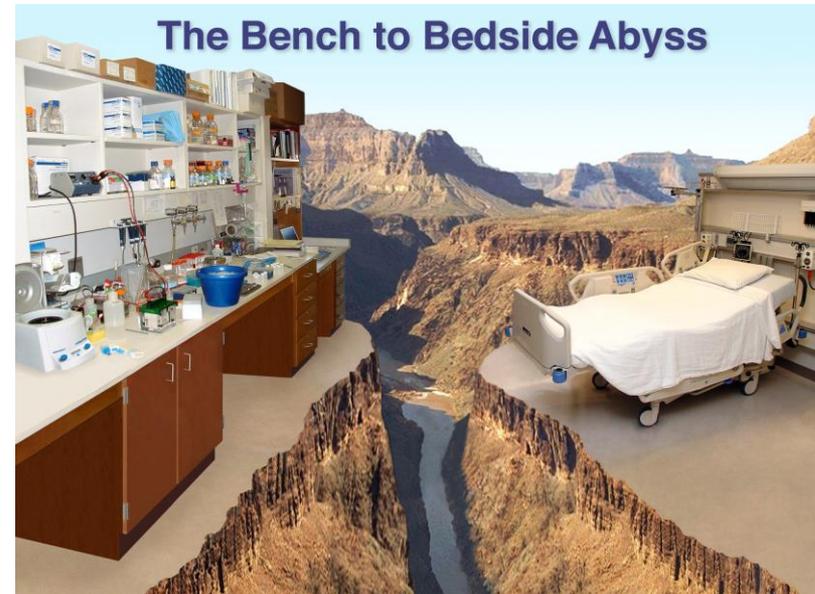
PhD student: TBA

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The vision

Heart diseases -> $\frac{1}{4}$ all deaths.
Inc. MI (heart attack) & MR.

Huge gap between clinical
demands and Healthcare
Technologies (HT).

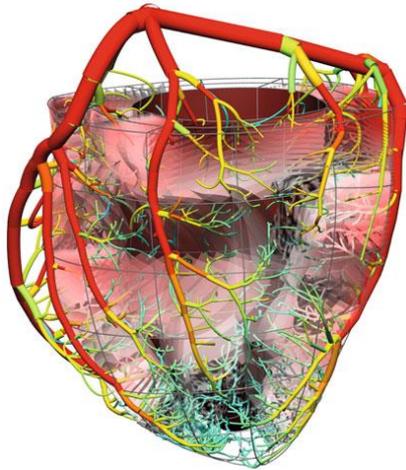


- ❖ Need to develop **mathematics base** to support Healthcare Technologies.
- ❖ **Grand challenges:** models too simple for clinical needs, yet too expensive for real time clinical support.
- ❖ **Cutting edge modelling + emulation** – no compromise between model sophistication & applicability.

Develop

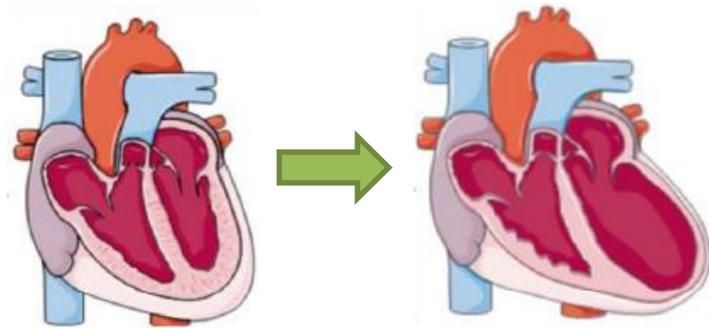
New mathematical and computational models

3-phase poroelasticity
(Cardiac perfusion)



Heart is a porous medium with
coronary circulation and FSI

Growth and remodelling
(Longer time effects)

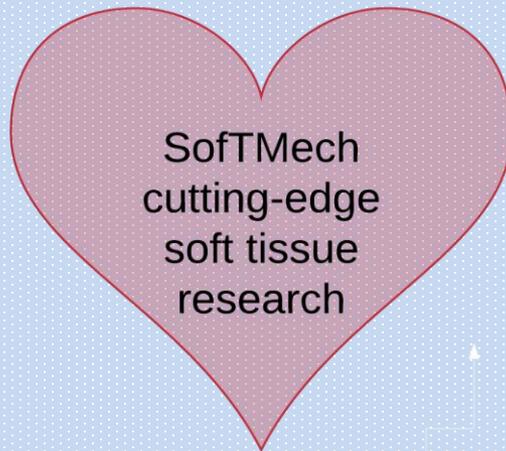


Normal heart

Heart failure

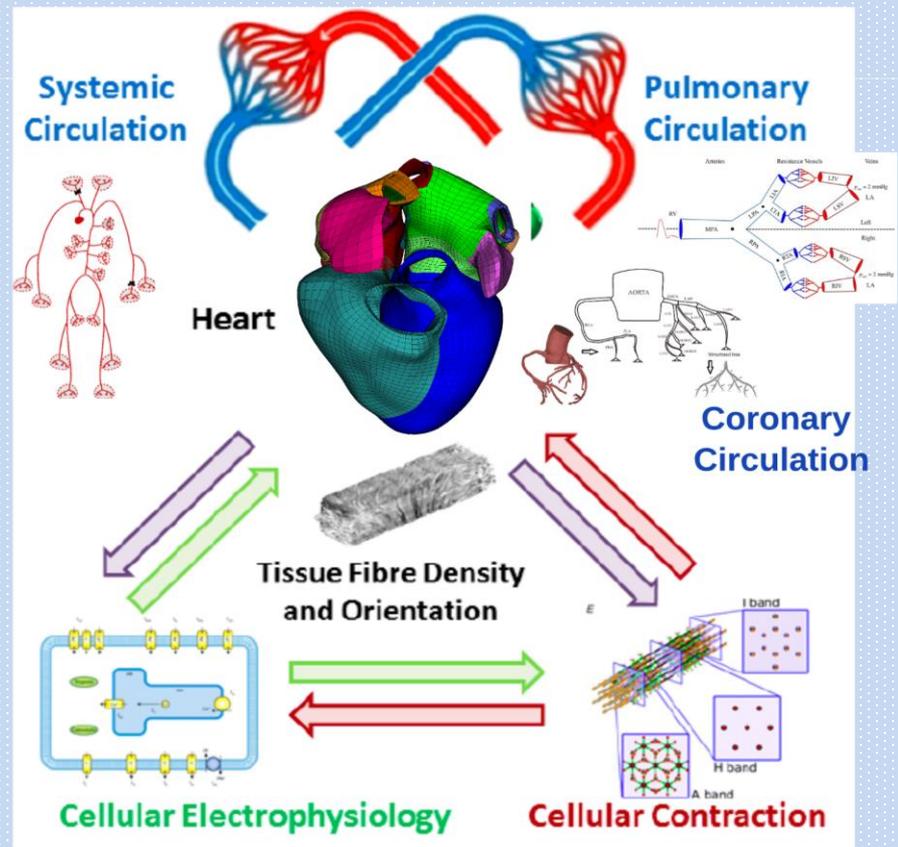
Build

A multiscale whole heart model for cardiac diseases



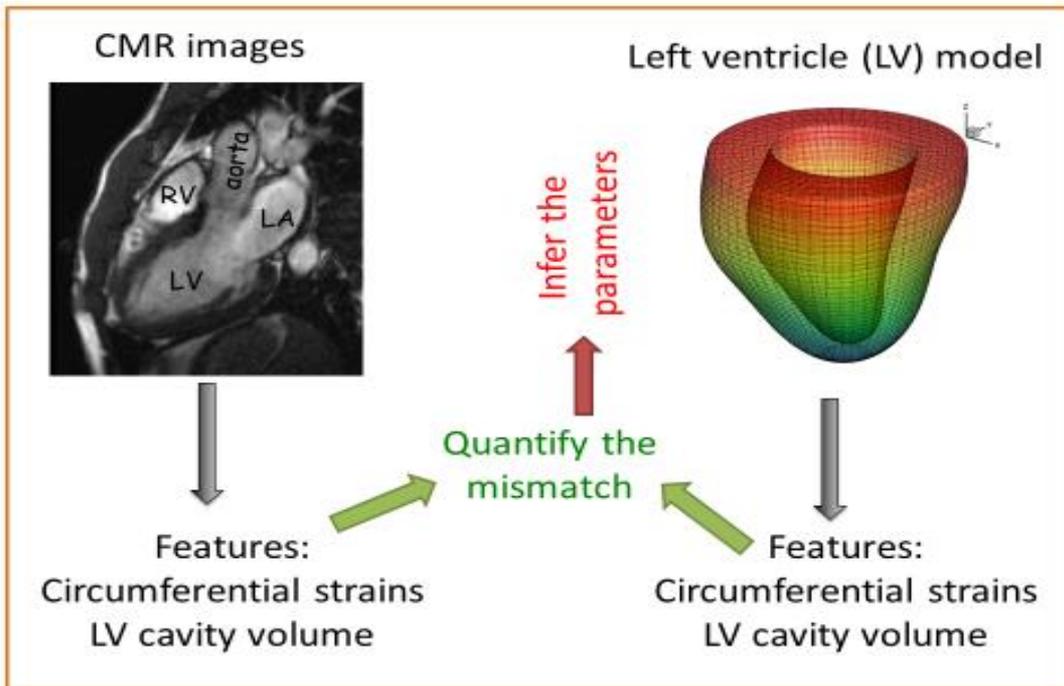
Most existing models are parts.

But integration of the parts is key to disease progression.



Infer

Patient-specific parameters from clinical Images



Log likelihood:

Simulated (depending on constitutive parameters)

$$\sum_{i=1, \dots, n} (\epsilon_i - \epsilon_i^*)^2 + \left(\frac{V - V_0}{V_0} \right)^2$$

The equation shows the log likelihood function. The first term, $(\epsilon_i - \epsilon_i^*)^2$, represents the squared difference between the measured strain ϵ_i (red box) and the simulated strain ϵ_i^* (blue box). The second term, $\left(\frac{V - V_0}{V_0} \right)^2$, represents the squared difference between the measured volume V (red box) and the prior estimate V_0 (blue box). Red arrows point from the text 'Simulated' to the ϵ_i^* and V_0 terms. Blue arrows point from the text 'measured' to the ϵ_i and V terms.

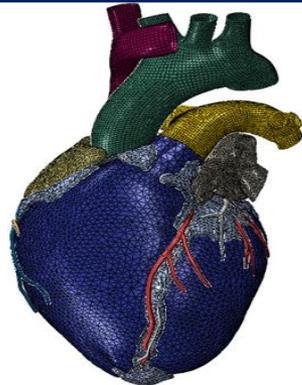
Prior estimate from in vitro tests & literature

Translate to clinical applications



$\sim O(10^3)$
saving

Gao et al.
2017, Noe et
al. 2019



Model

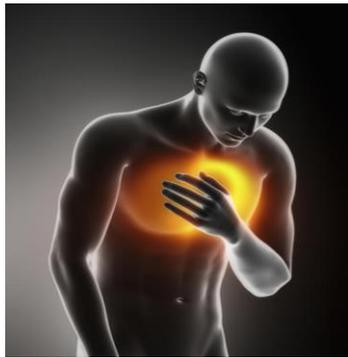


Simulation

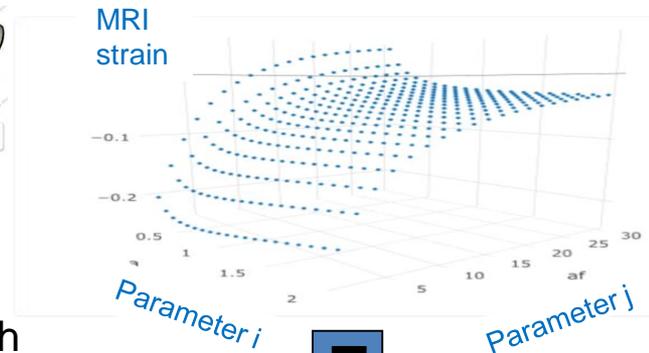
Repeated simulations with
different parameter settings
using parallel computing
in weeks

Emulator

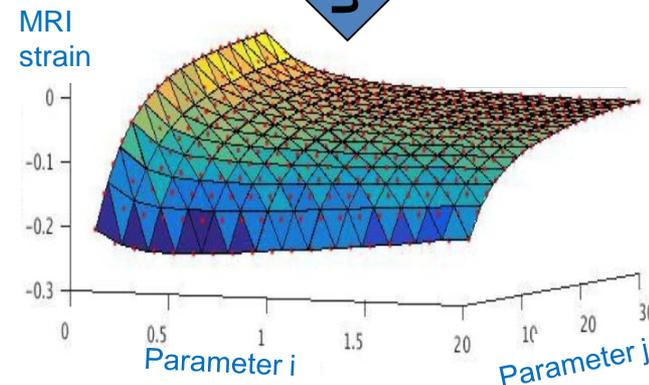
Patient information
matched to high
dimensional
parameter space
in minutes



Clinical support



Interpolation



- **A leap forward** in cardiac research.
- **Biomarkers** for MI and MR progression.
- **Top quality** research papers (inc. clinical journals).
- **Maths framework** for more general applications.
- Tools for **real-time** clinical assessment & trials.
- **Impact & outreach** through two international workshops, various networking activities.

- [Back to Whole – Heart](#)