CPS from EU-Science Perspective

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Joint work with

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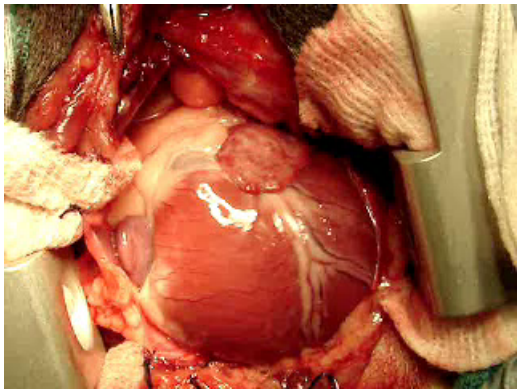
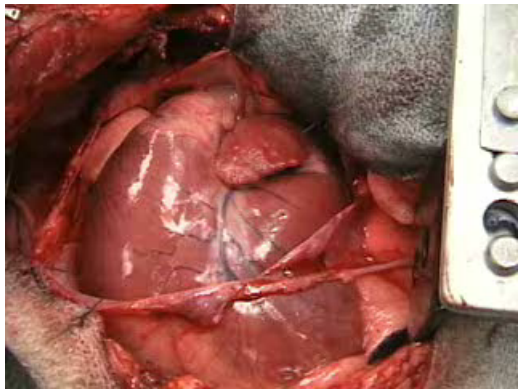
Consider the Following CP-EM-Systems



Error-Free System



Error-Prone System

Whose problem is this to solve?

It is a Medical Problem

National Vital Statistics Report, Vol.49, No.11, October 12, 2006
Deaths and percent of total deaths for the 10 leading causes of death: USA

Rank	Cause of death	Total Deaths	Percentage
	All causes	2,391,399	100.0
1	**Diseases of heart**	**725,192**	**30.3**
2	Malignant neoplasms	549,838	23.0
3	Cerebrovascular diseases	167,366	7.0
4	Chronic lower respiratory diseases	124,181	5.2
5	Accidents (unintentional injuries)	97,860	4.1
6	Diabetes mellitus	68,399	2.9
7	Influenza and pneumonia	63,730	2.7
8	Alzheimer's disease	44,536	1.9
9	Nephritis, nephrotic syndrome and nephrosis	35,525	1.5
10	Septicemia	30,680	1.3
	All other causes	484,092	20.2

http://www.cdc.gov/nchs/data/nvsr/nvsr57/nvsr57_14.pdf

What are the Fundamental Questions?

For cardiologists, pharmacologists and patients:

- What is the risk of a patient to develop the disorder?
- Under what circumstances will such a disorder arise?

Given a disorder-specification and a model of the ventricle:

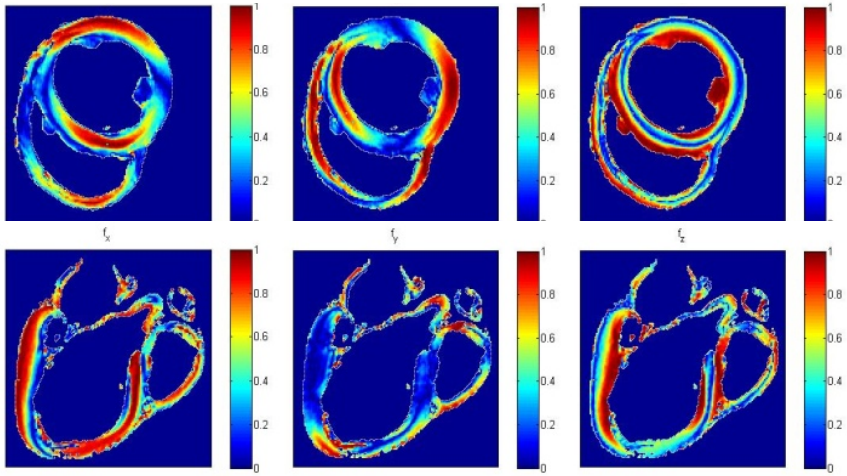
- What is the probability of the model to satisfy the specification?
- For what parameter-ranges does it satisfy the specification?

Whose problem is this to solve?

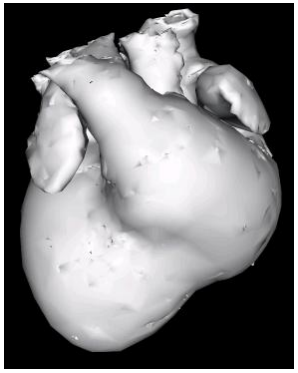
It is a Communication-Structure Problem

Complicated structure

Canine heart: slices
(DTMRI @ 250 microns resolution)

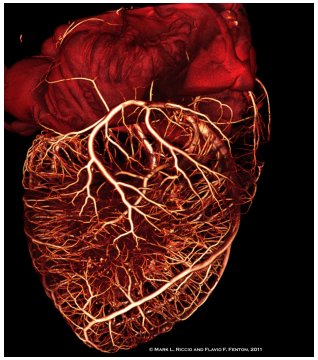


Anatomy



Fibers

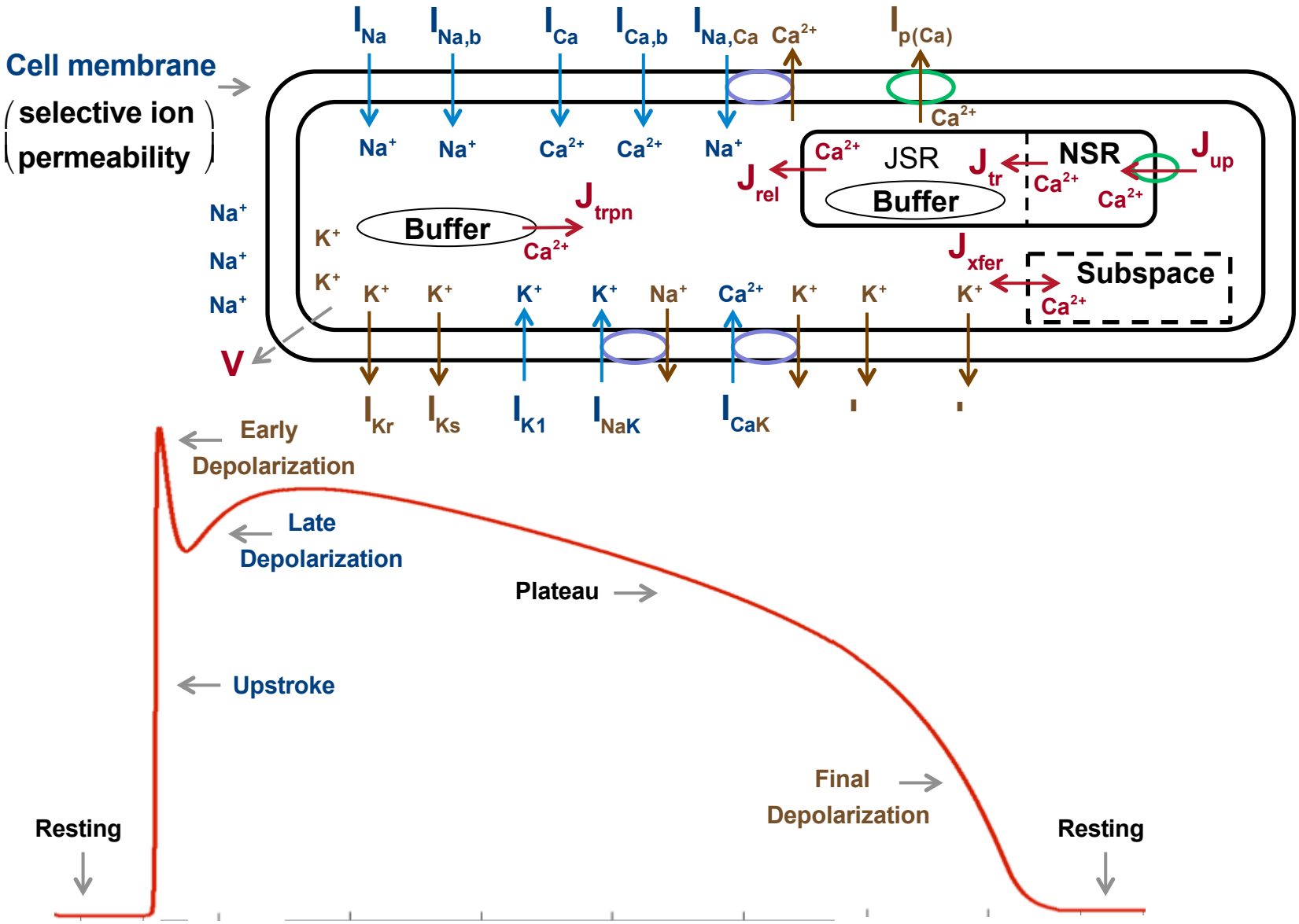
Vessels



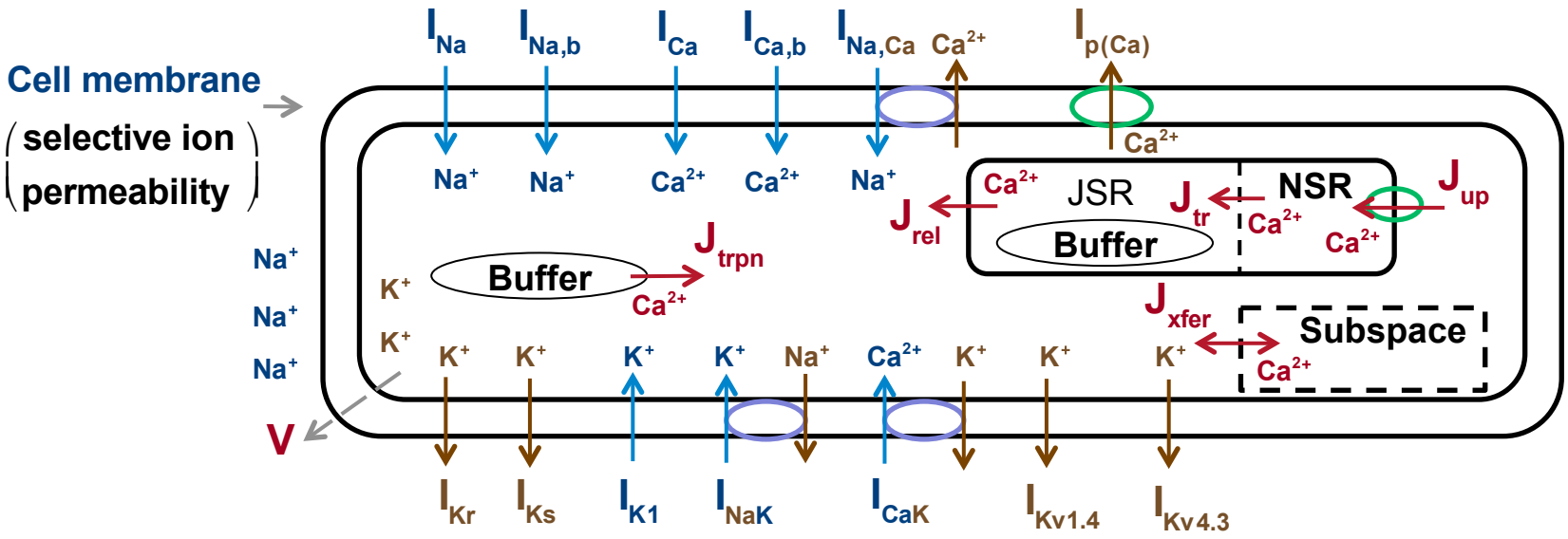
Pittsburgh NMR Center

MicroCT Cornell

It is a Cellular Problem

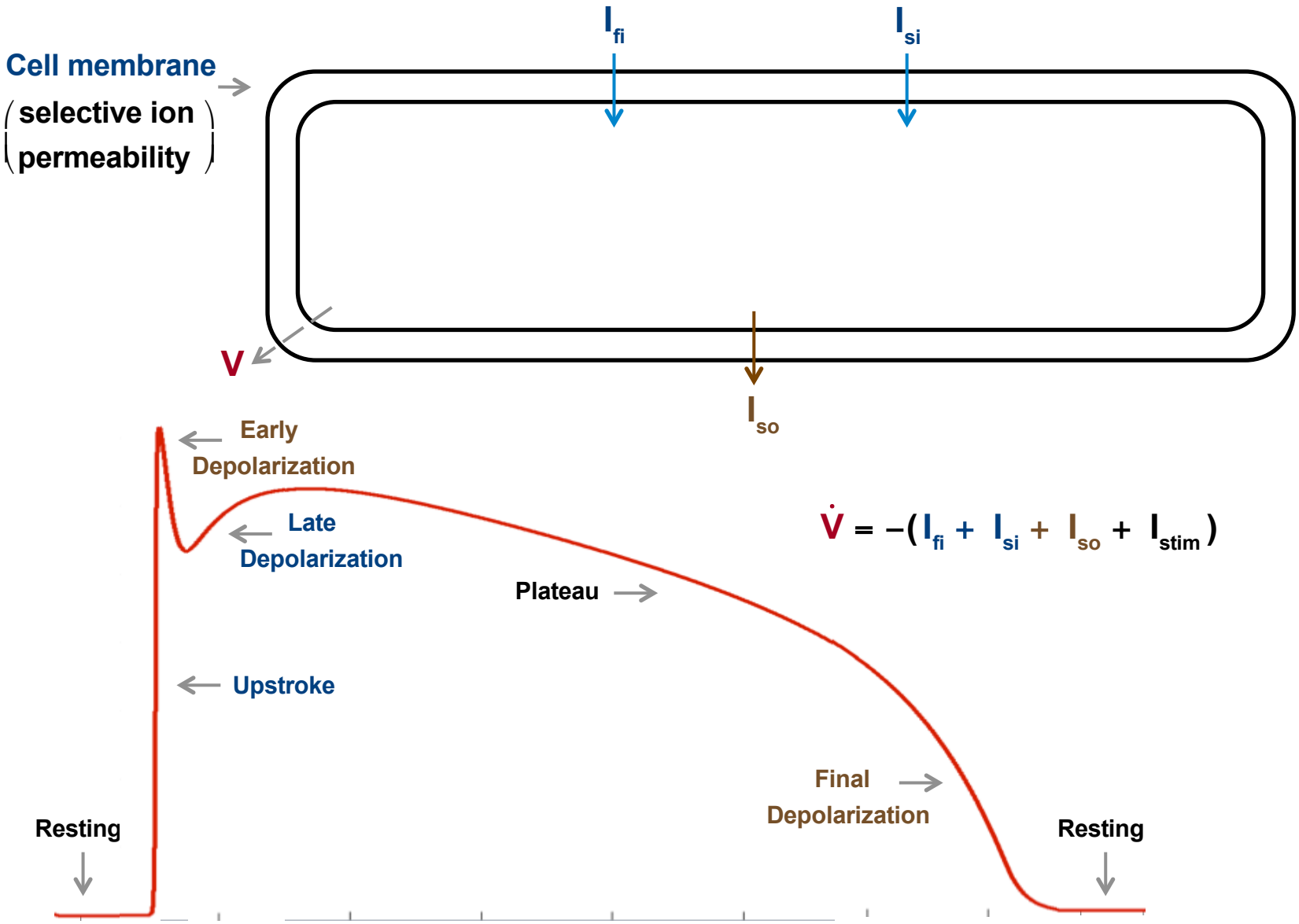


It is an Electrical Problem



$$\dot{V} = -(I_{Na} + I_{Ca} + I_{CaK} + I_{K1} + I_{NaCa} + I_{NaK} + I_{Cab} + I_{Nab} + I_{Kr} + I_{Ks} + I_{Kv1.4} + I_{Kv4.3} + I_{p(Ca)} + I_{stim})$$

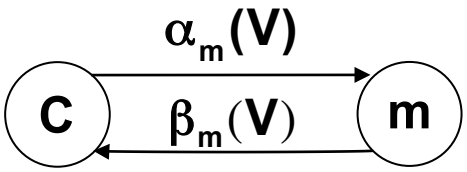
It is an Abstraction Problem



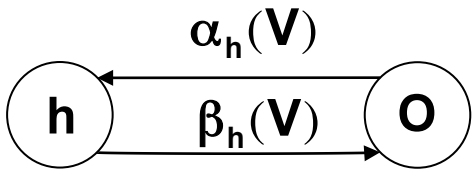
It is a Molecular Problem

$$I_{Na} = g_{Na}(V - V_{Na}) = \bar{g}_{Na} m^3 h (V - V_{Na})$$

- $\bar{g}_{Na}$: Na Channel Conductance
- V_{Na}: Nernst Potential
- $m^3 h$: 3 m-units, 1 h-unit

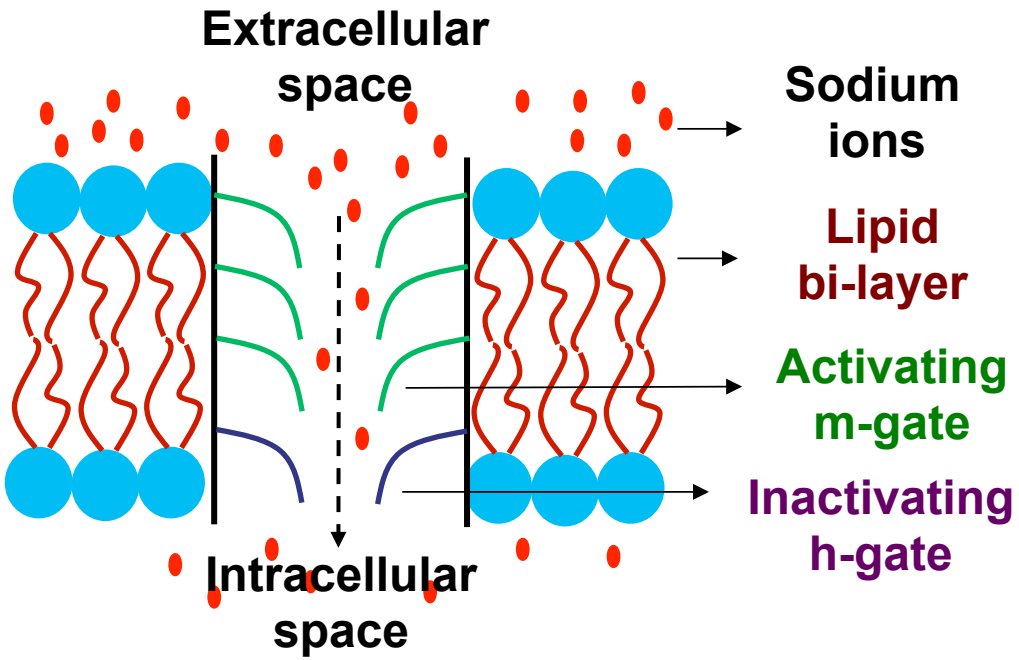


$$\dot{m} = \alpha_m(V)(1 - m) - \beta_m(V)m$$

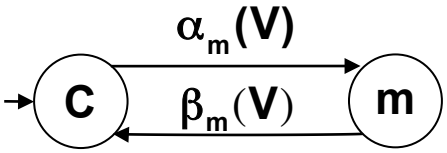


$$\dot{h} = \alpha_h(V)(1 - h) - \beta_h(V)h$$

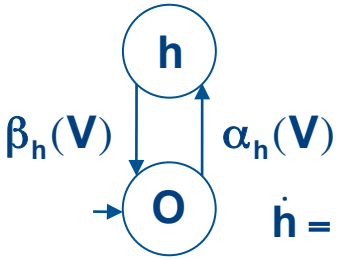
The Sodium Channel



It is an Abstraction Problem



$$\dot{m} = \alpha_m(V)(1-m) - \beta_m(V)m$$

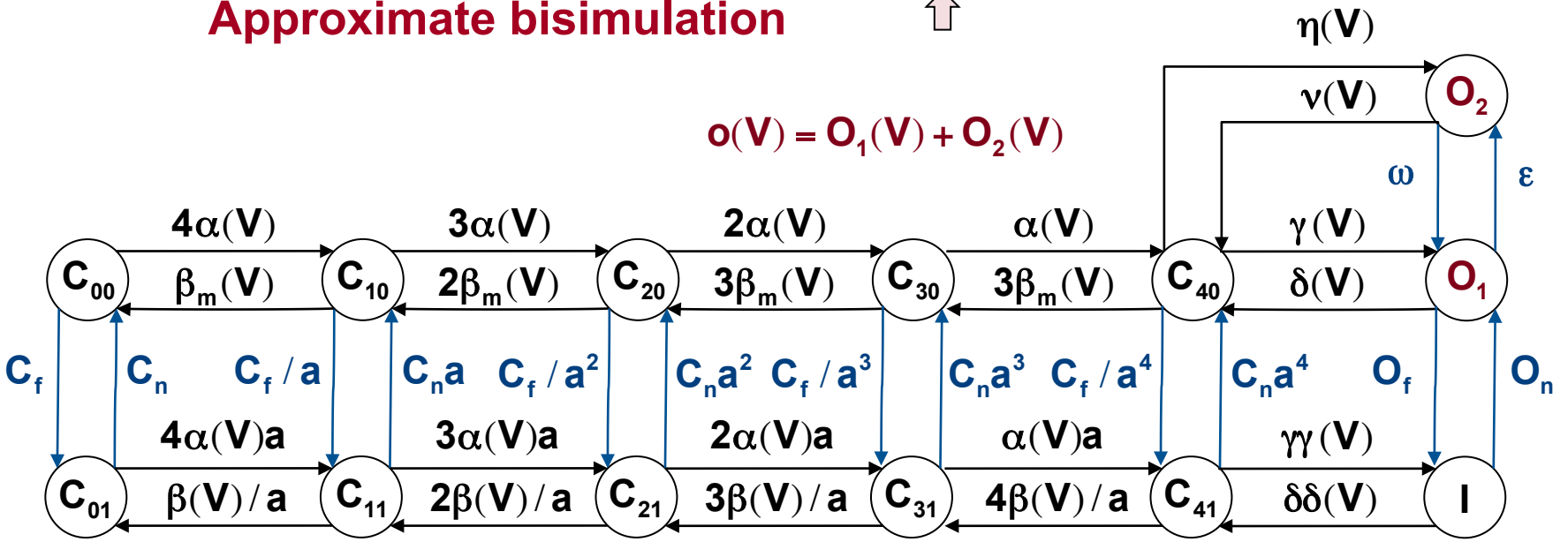


$$o(V) = m^3(V)h(V)$$

$$\dot{h} = \alpha_h(V)(1-h) - \beta_h(V)h$$

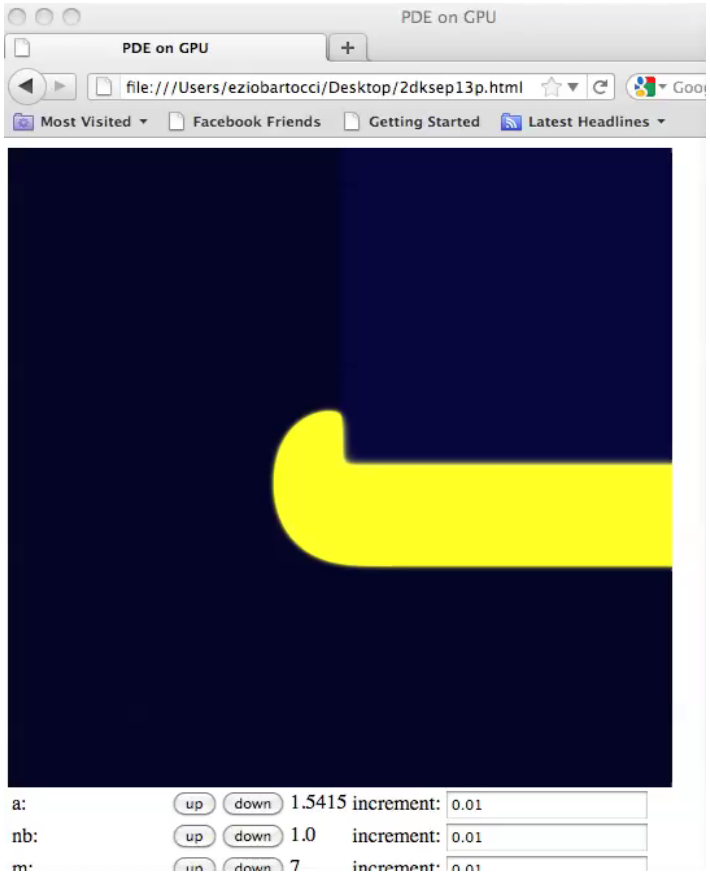
Approximate bisimulation

$$o(V) = O_1(V) + O_2(V)$$



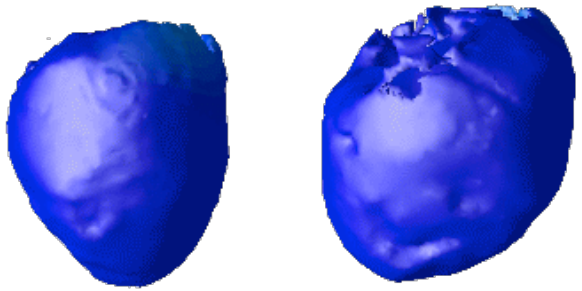
It is a Simulation Problem

Web Graphics Language (Fenton-Karma 2V)

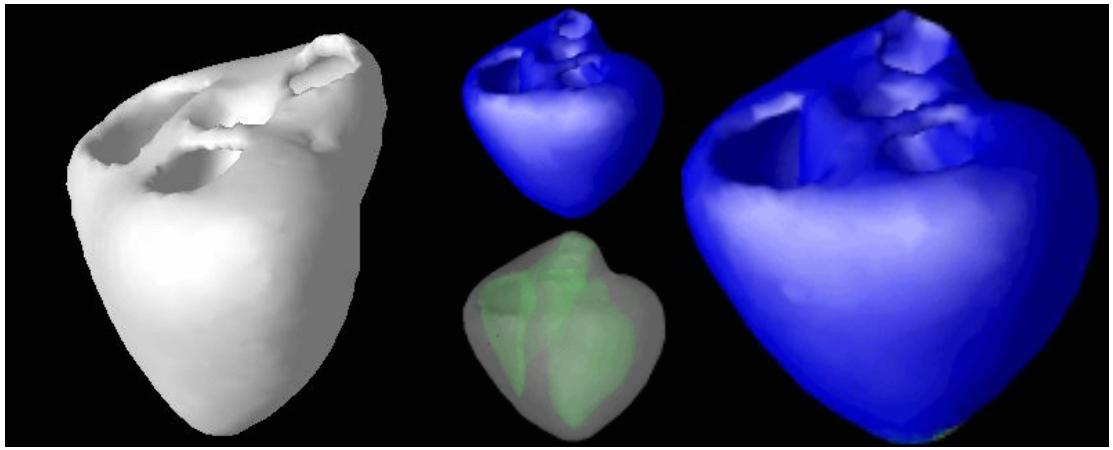


Runs in your Browser and Uses your own GPU

3D Model of a Mouse Heart (Fenton-Karma 3V Model)

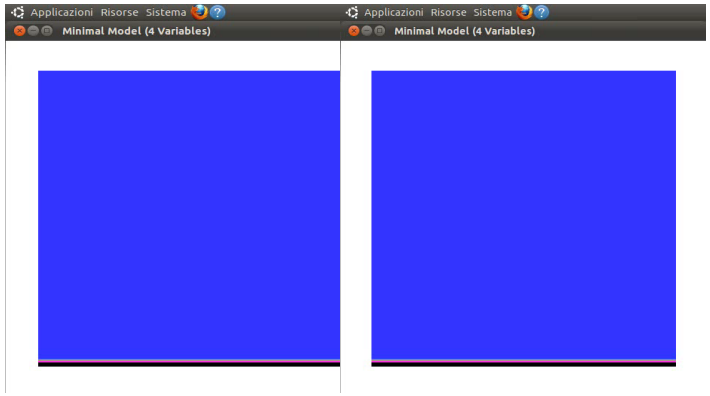


3D Model of a Pig Heart (Fenton-Karma 3V Model)



It is a Verification Problem

Spiral Wave Induced by Unexcitable Myocytes

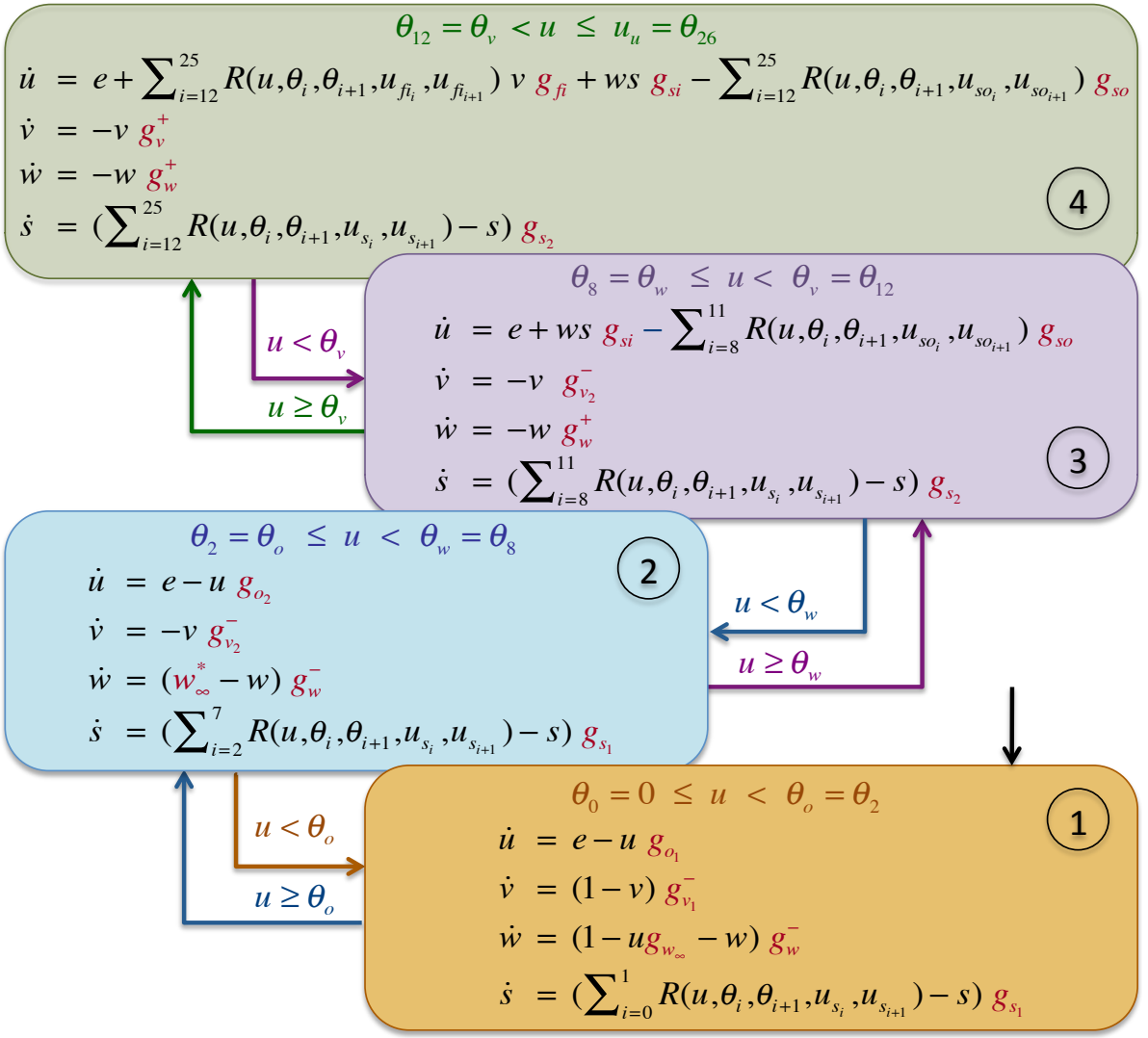


Property to Check

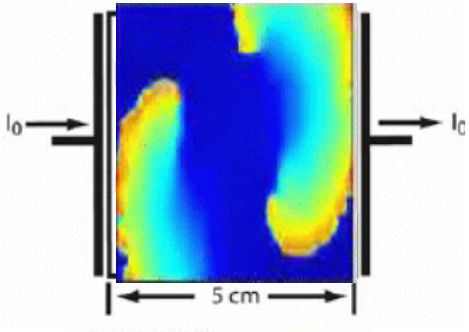
$$G(u < \theta_v)$$

Uncertain Parameters

$$g_{o_1} \in [0,180], \quad g_{o_2} \in [0,10]$$
$$g_{si} \in [0.1,100], \quad g_{so} \in [0.9,50]$$

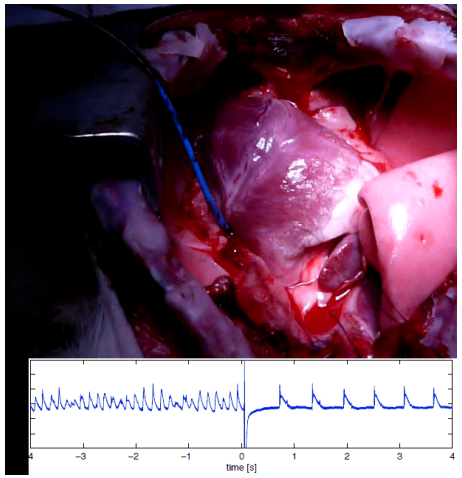


It is a Control Problem

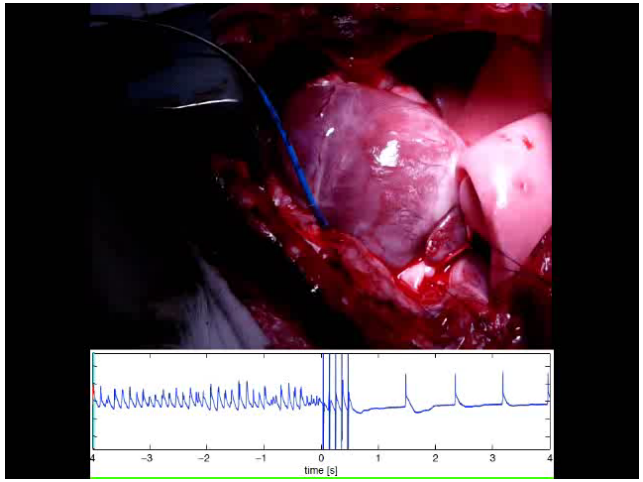


Computer simulation

1 Shock



5 Low Energy Shocks



Defibrillation with 90% energy reduction

It is a EU-CPS Problem

We are on the brink of a paradigm shift in the Diagnosis and treatment of cardiac disorders

It is up to us in to make it happen!

This is a World-CPS Problem