e-Science Institute

Multivariate Visualisation of Cardiac Virtual Tissue

James Handley

Thursday December 15th 2005
12.30 – 13.00

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e-Science Centre of Excellence

Integrative Biology
- exploiting e-science to combat fatal diseases

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Tackling two Grand Challenge research questions:

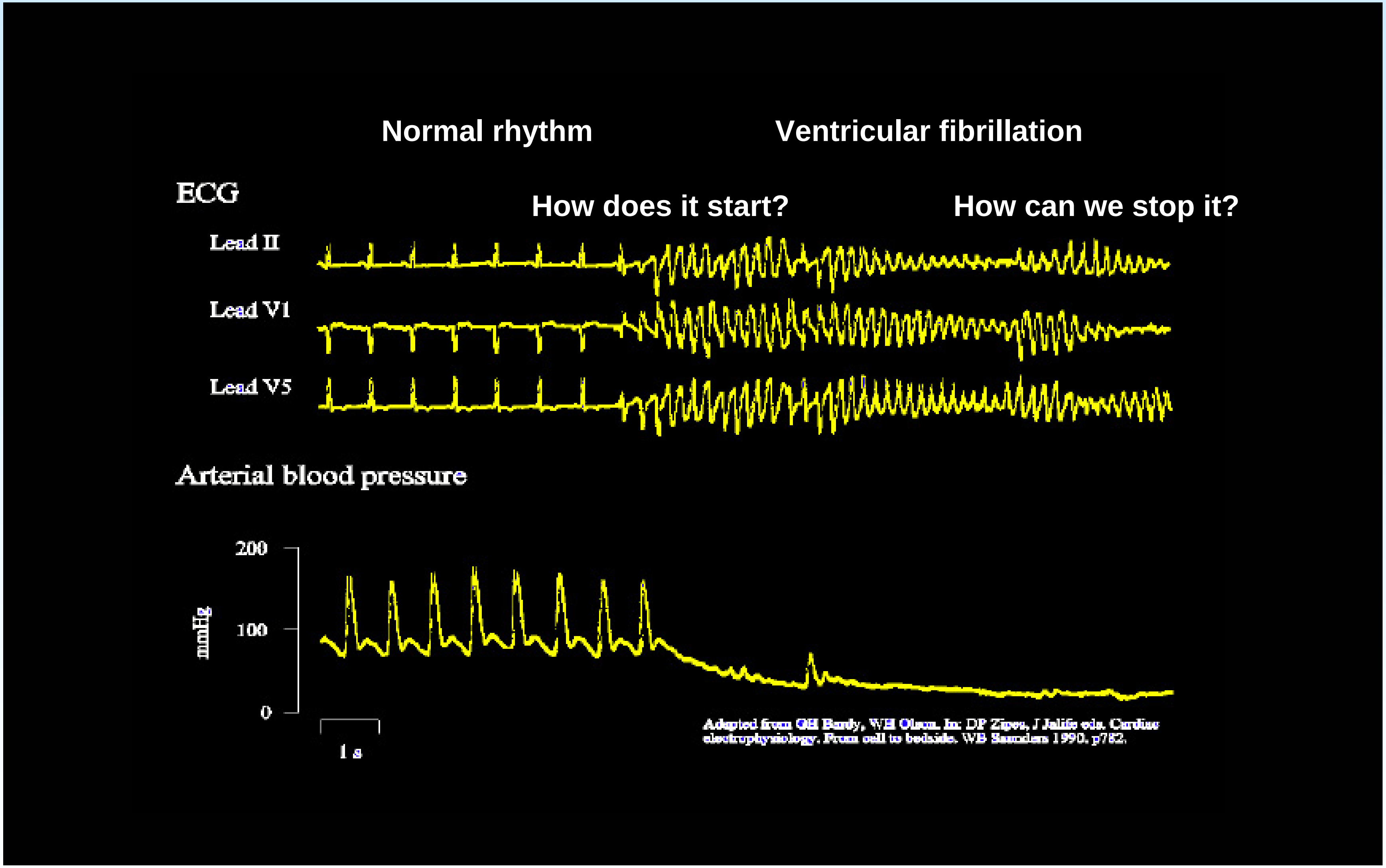
- What causes heart disease
- How does a cancer form and grow?

Together these diseases cause 61% of all UK deaths.

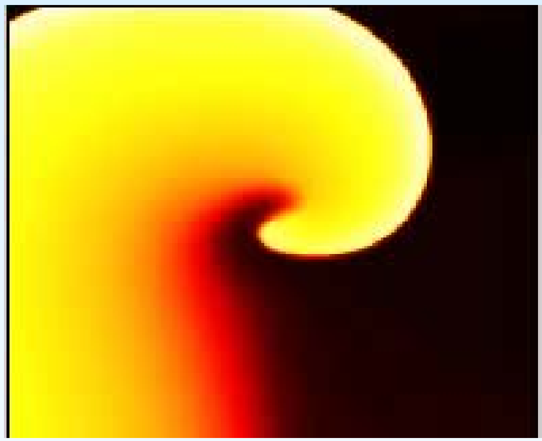
Why model the heart?

- Heart disease is an important health problem.
- Worldwide, cardiovascular disease causes 19 million deaths annually, over 5 million between the ages of 30 and 69 years.
- Spectrum of acquired and congenital heart disease, multiple disease mechanisms.
- All disease mechanisms are difficult to study experimentally.
- Heart is simpler (structurally and functionally) than other organs.

Ventricular Fibrillation – The Killer



Ventricular Fibrillation – Re-entry



Cardiac Virtual Tissue

Model cardiac tissue as a continuous excitable medium

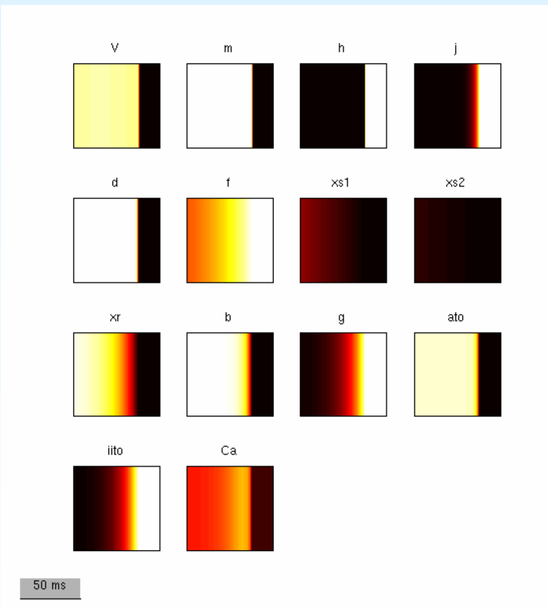
$$\frac{\delta Vm}{\delta t} = \nabla \cdot (\tilde{D} \nabla V_m) - \frac{I_{ion}}{C_m}$$

Solve using finite difference grid. At each timestep

- Compute dV due to diffusion
- Compute dV due to dynamic response of cell membrane
- Update membrane voltage at each grid point

The Visualization Challenge

Standard Visualization techniques of 2D and 3D models use a single variable…



…but sophisticated models may have dozens of variables.

Can we visualize the entire state of the heart model in a single image (or figure?)

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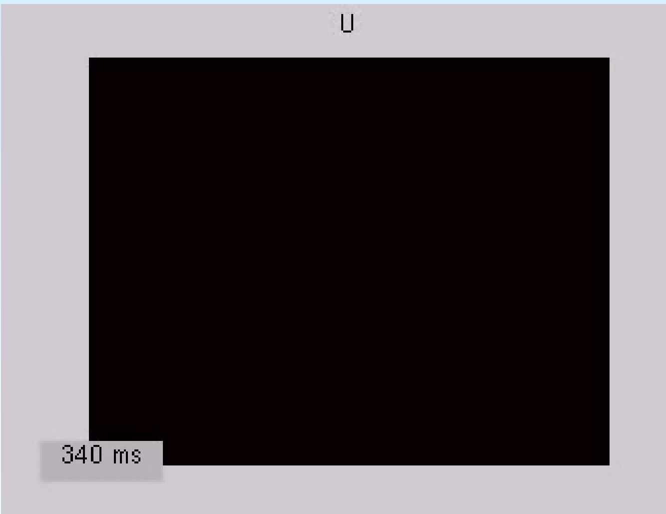
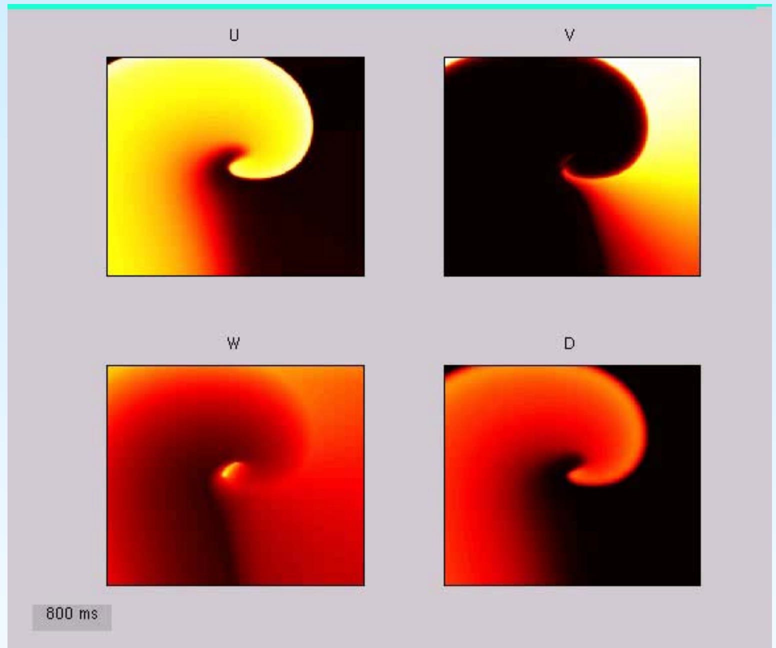
Multivariate Visualisation of Cardiac Virtual Tissue



Action Potential



Fenton Karma 4 variable

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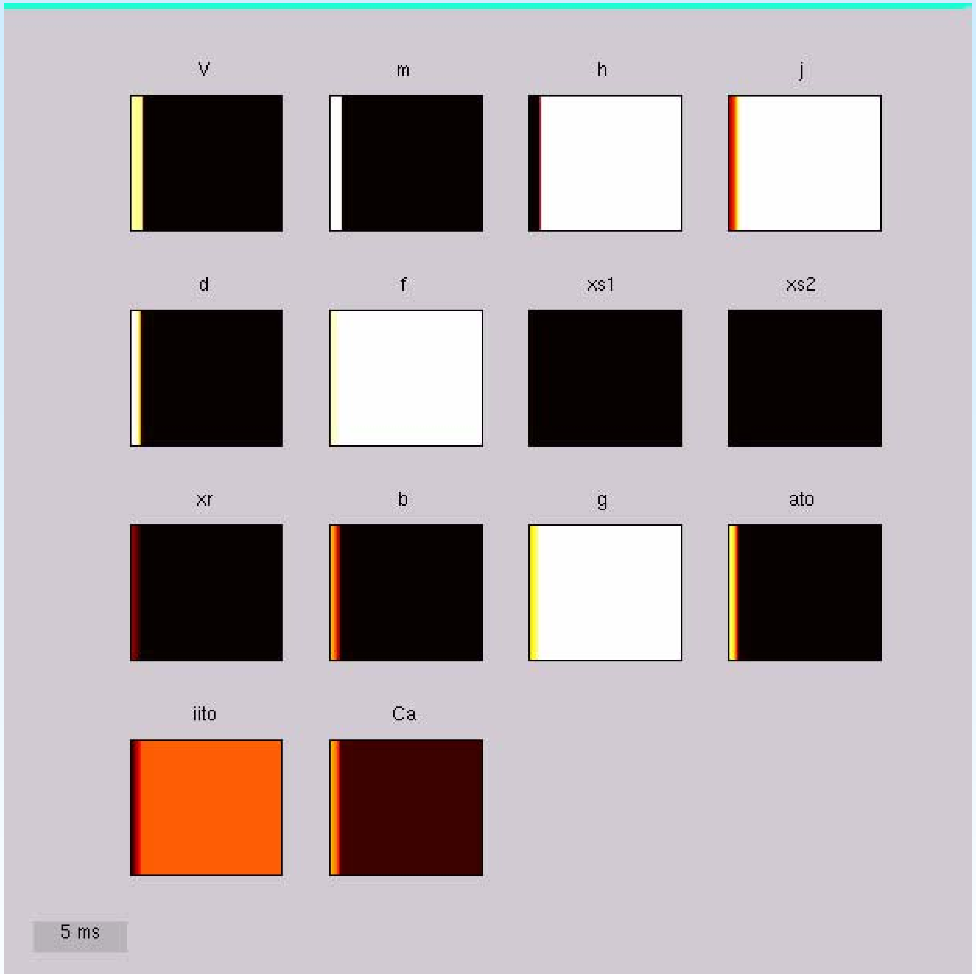


LuoRudy2 – 14 variable

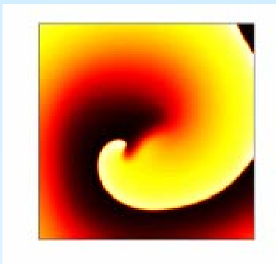
The Visualization Challenge

Impossible!

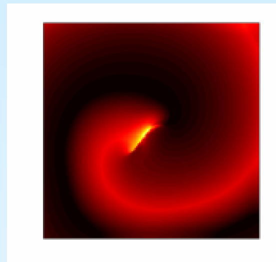
(3+1) dimensional 14+ variate data *cannot* be perfectly visualised on a (2+1) dimensional computer screen…

.. but we just might be able to make a meaningful image!

Reduce the data


U


V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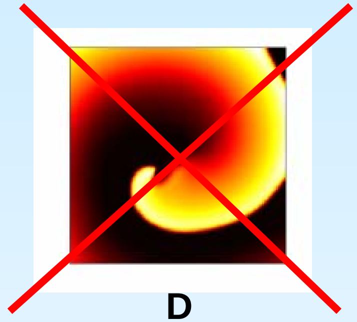
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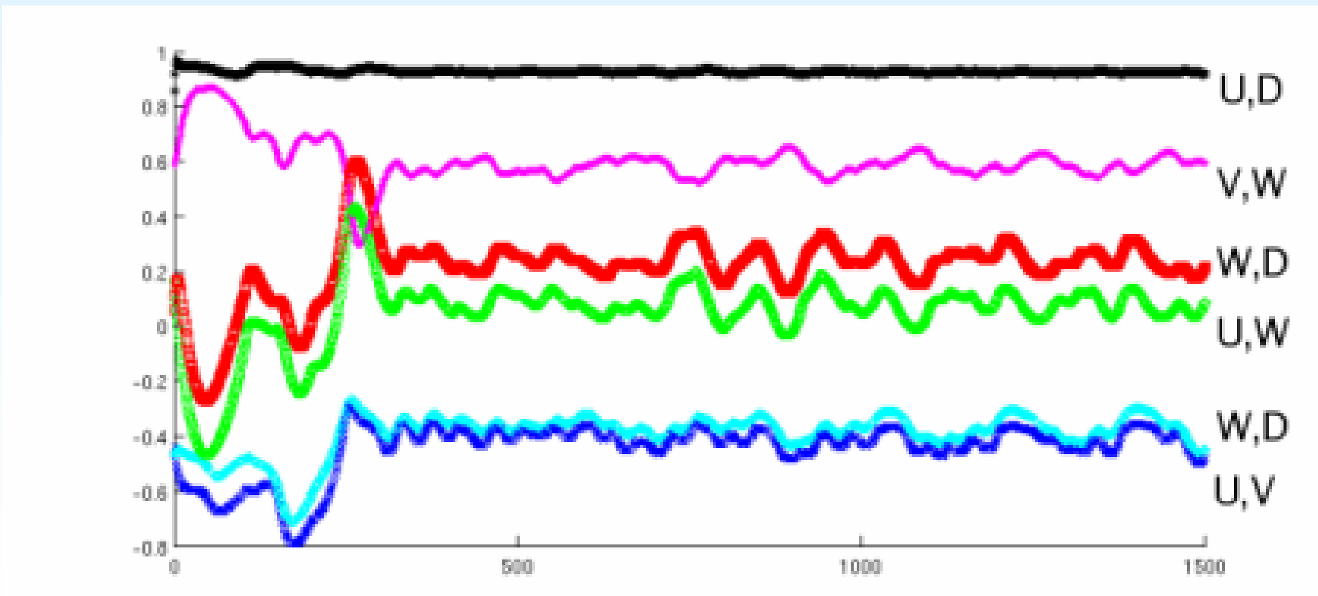

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Reduce the data (2)

• Apply domain specific knowledge to *collapse* state variables.

For instance, several current parameters to do with Na might be collapsed in a single 'Na Current' parameter

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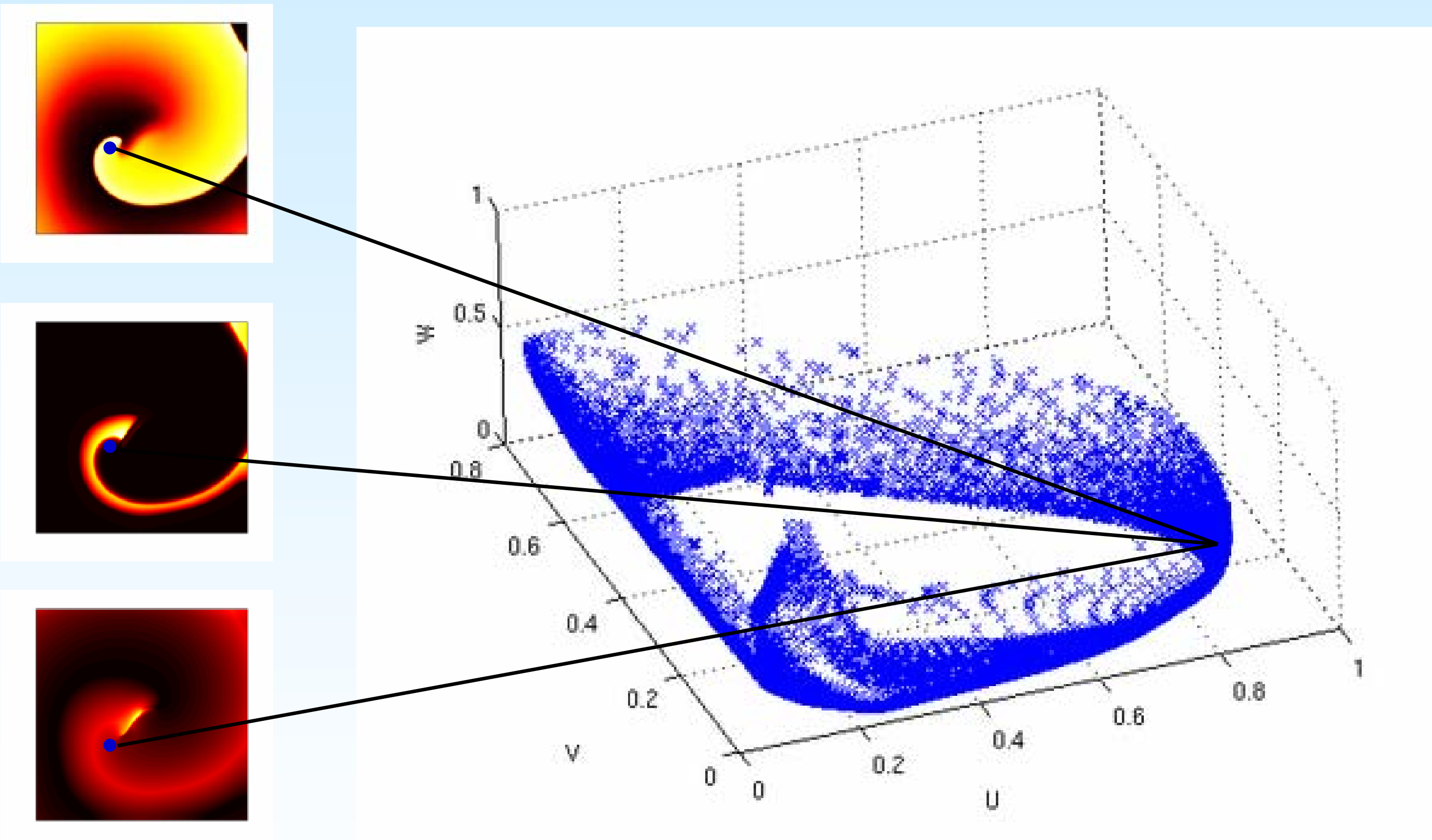
Move into ‘Phase Space’



x = 55, y = 91

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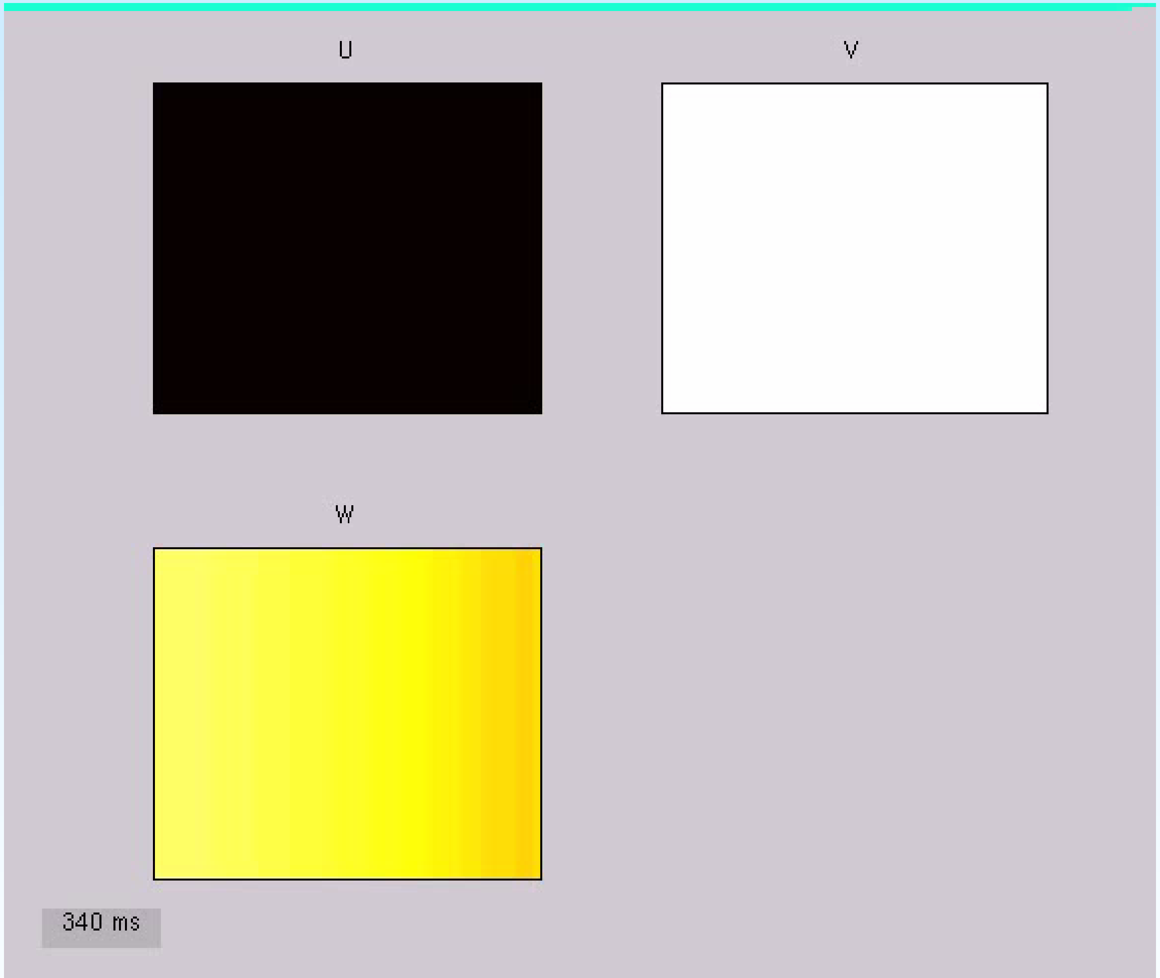
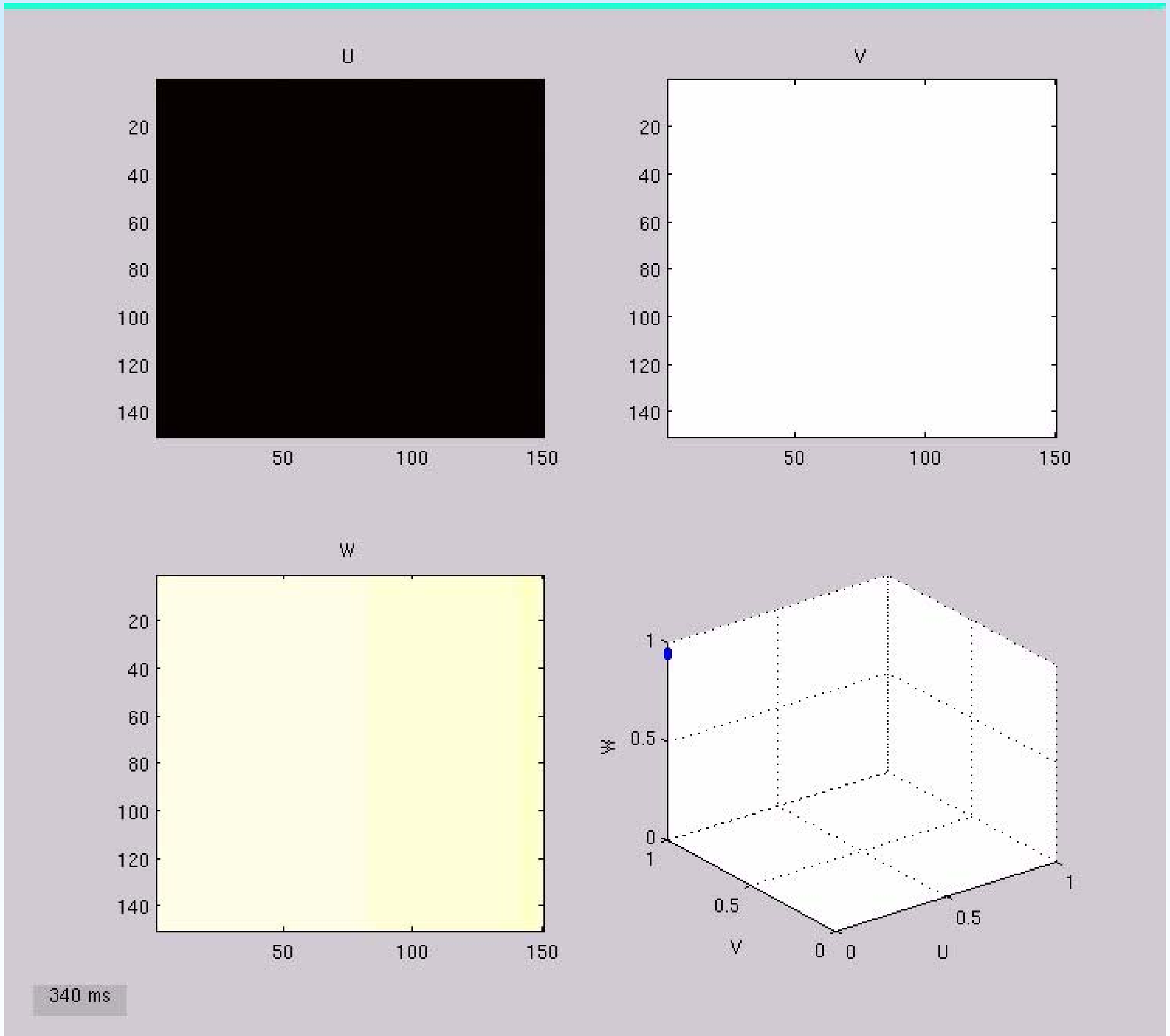
CVT data sets

Using a 2D slice of Fenton Karma 3 variable CVT

1. Normal action potential propagation through homogeneous tissue
2. Abnormal propagation through heterogeneous tissue
3. Re-entrant behaviour in heterogeneous tissue



FK3, Homogenous tissue, no re-entrant behaviour



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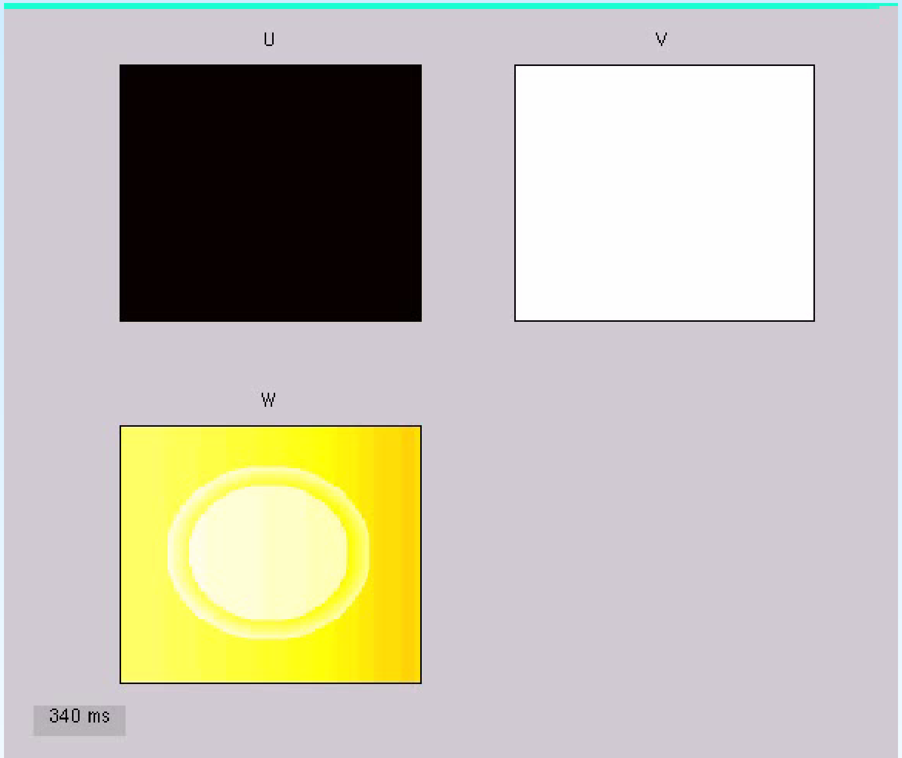
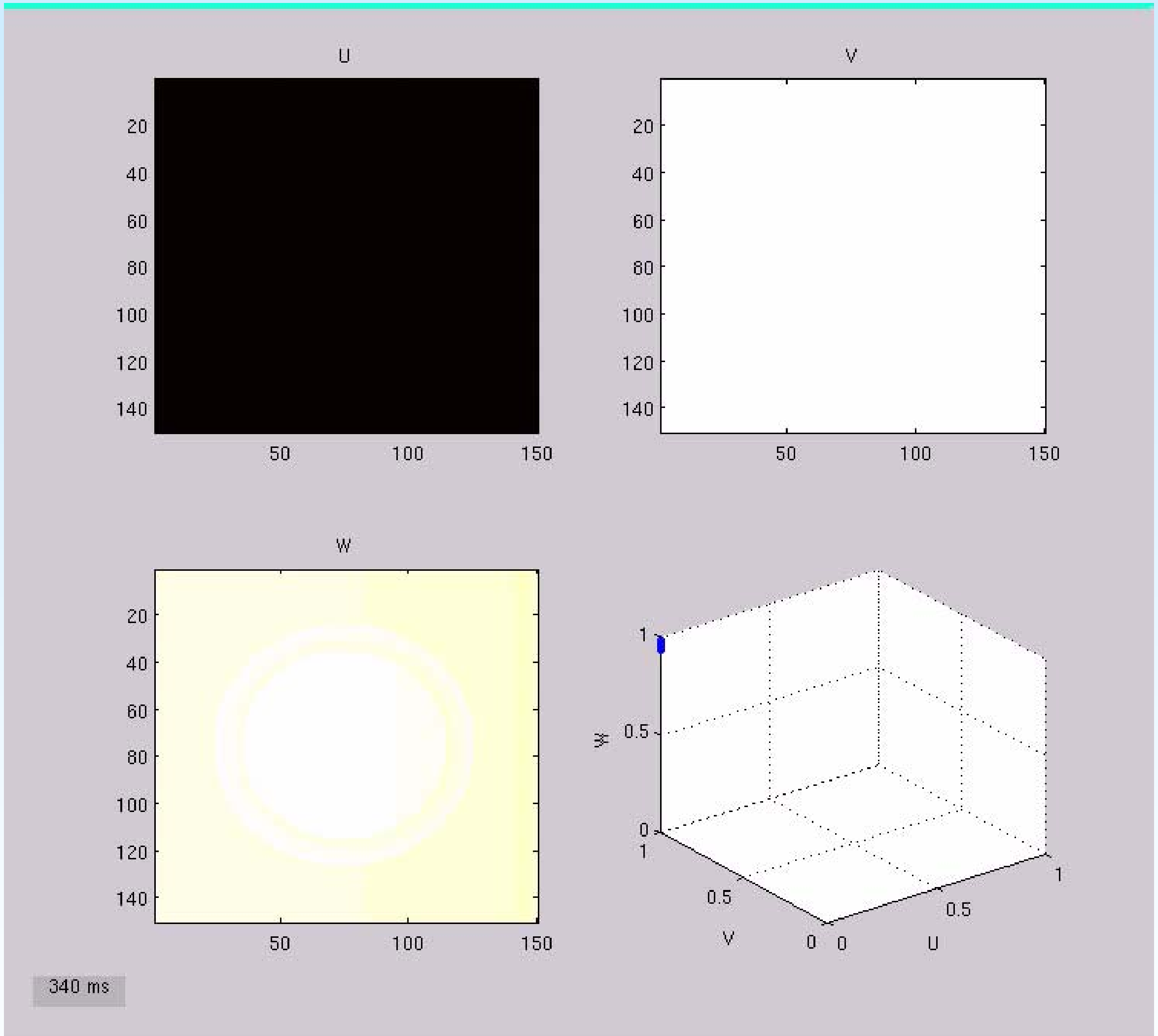


FK3, Heterogeneous tissue, re-entrant behaviour



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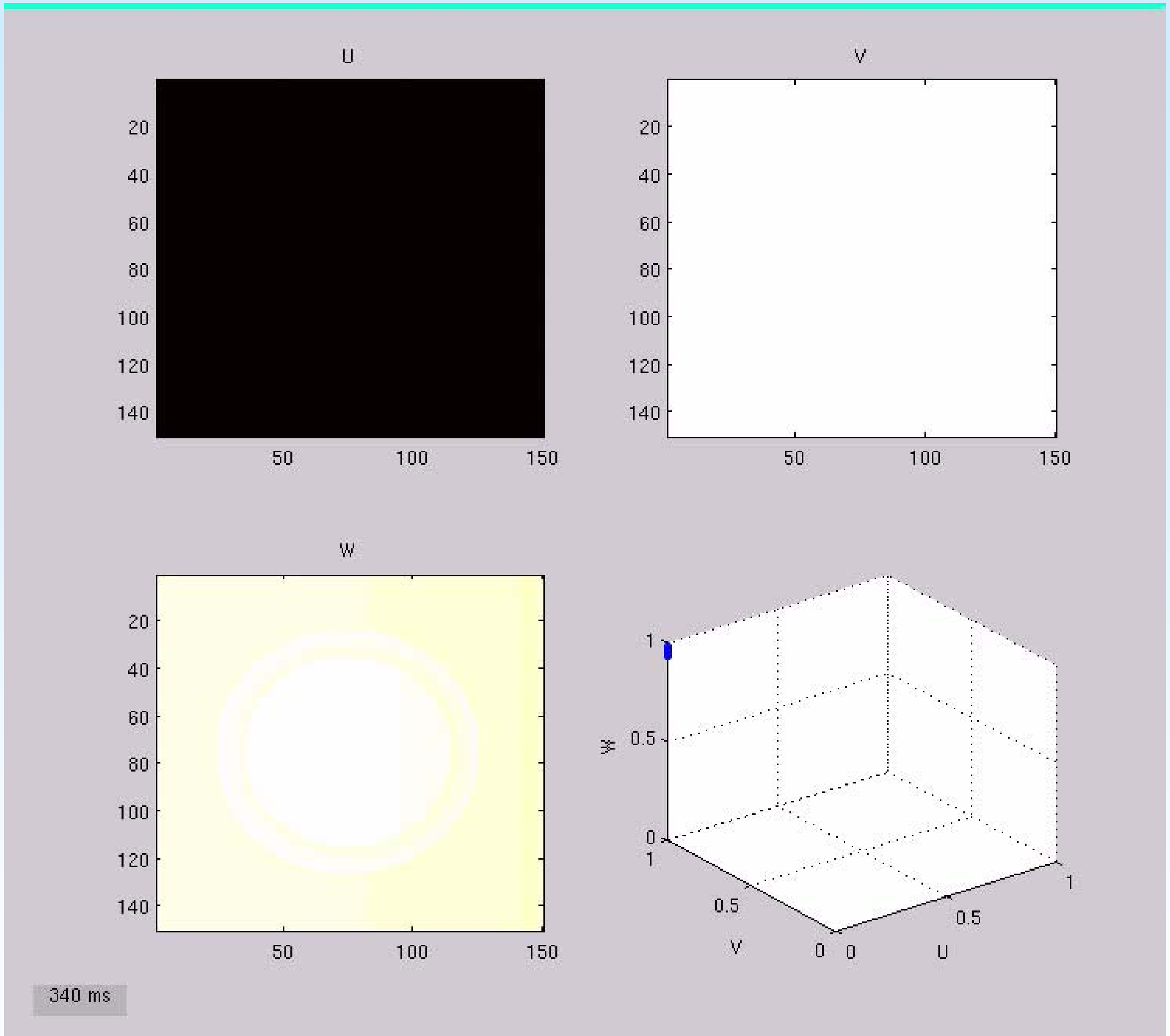
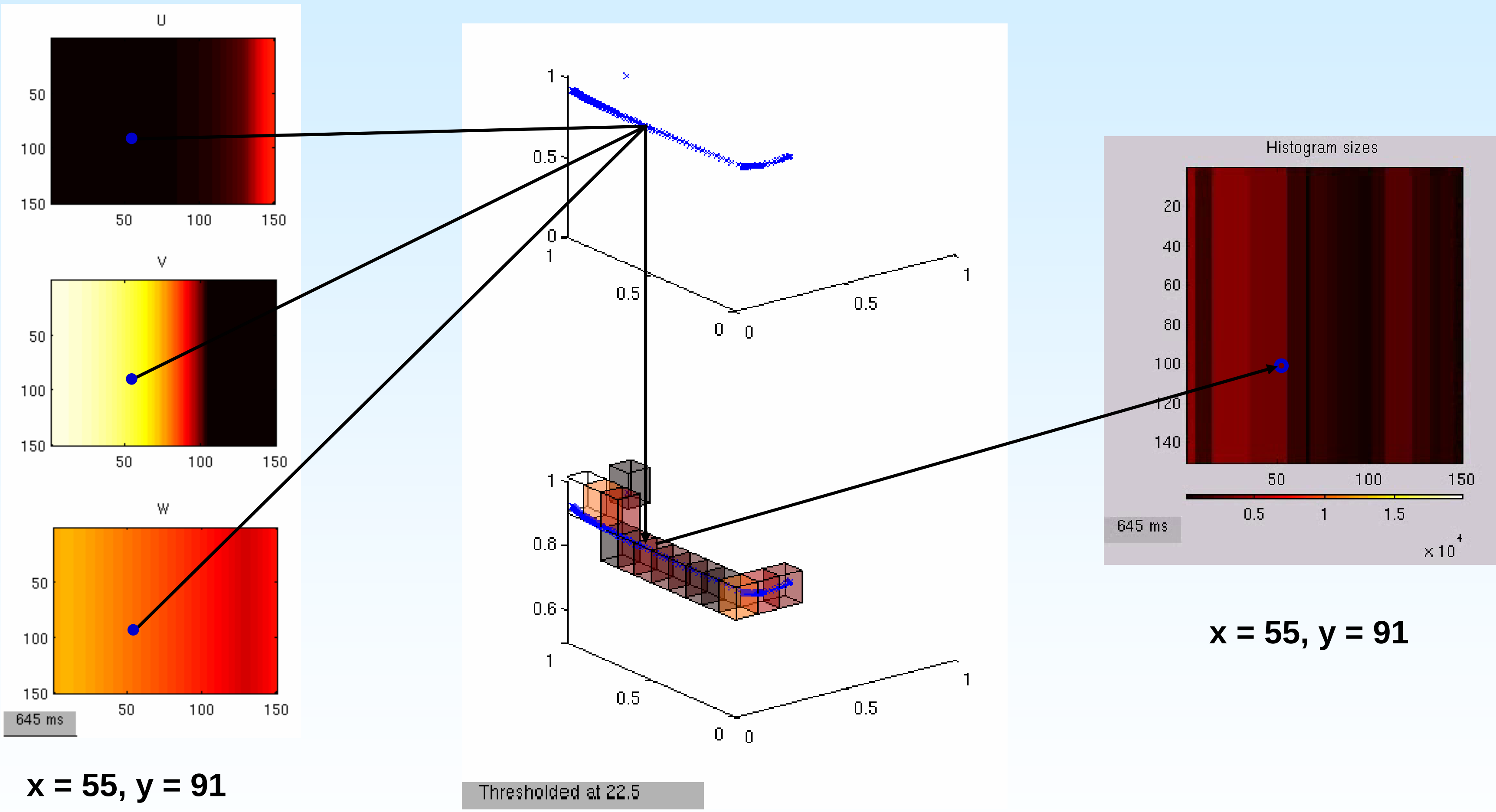


FK3, Heterogeneous tissue, no re-entrant behaviour

Form images using hyper-dimensional histograms using histogram sizes



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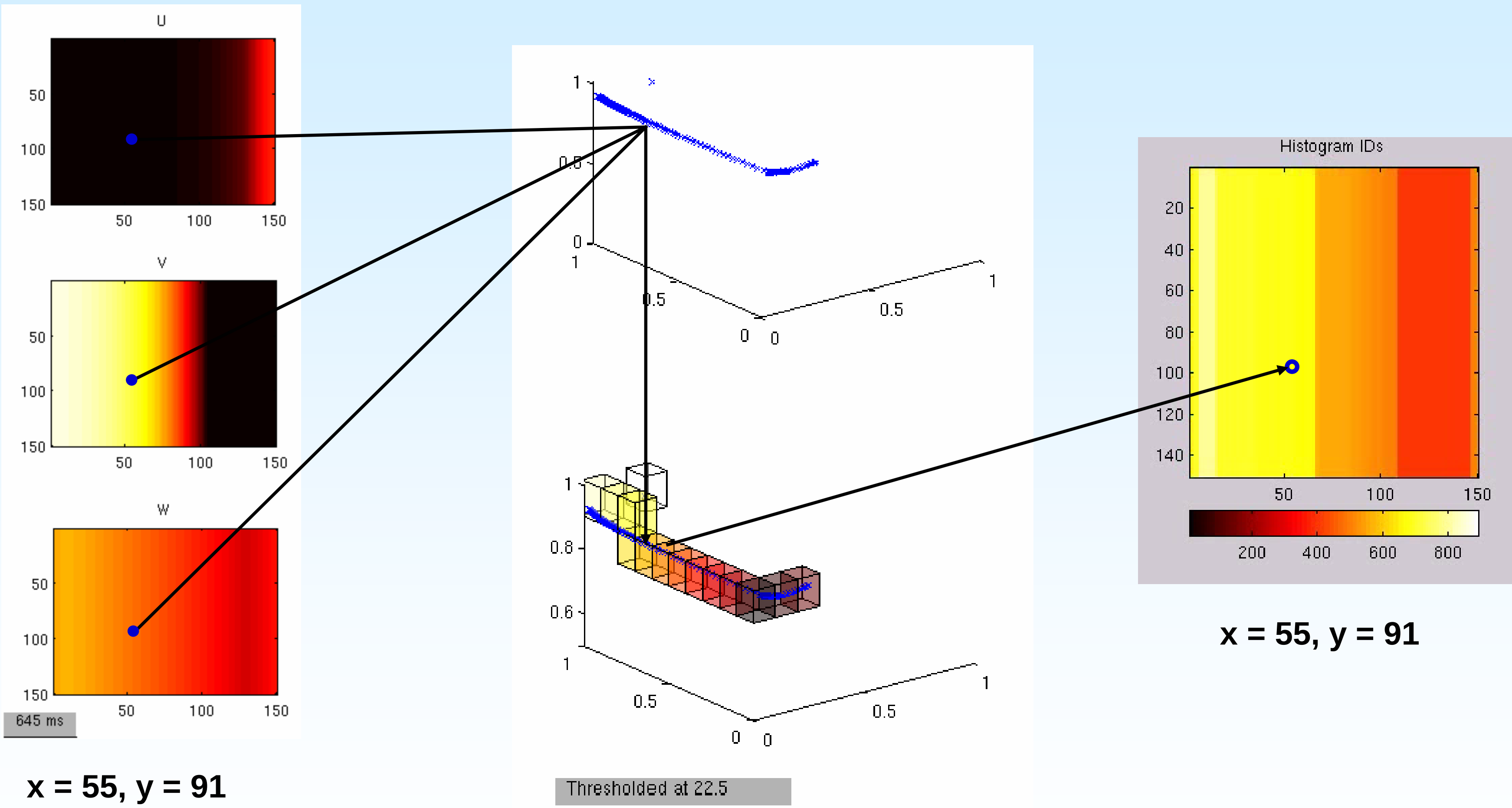
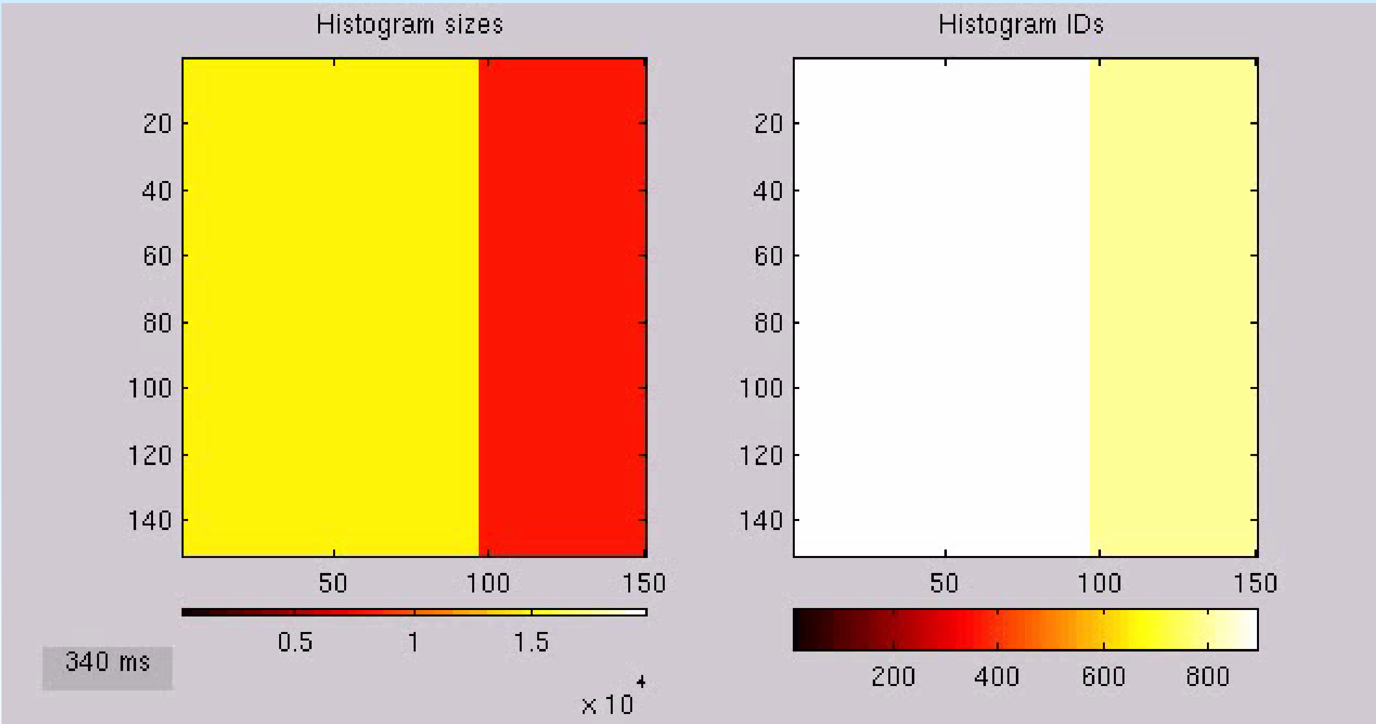
Form images using hyper-dimensional histograms using histogram IDs





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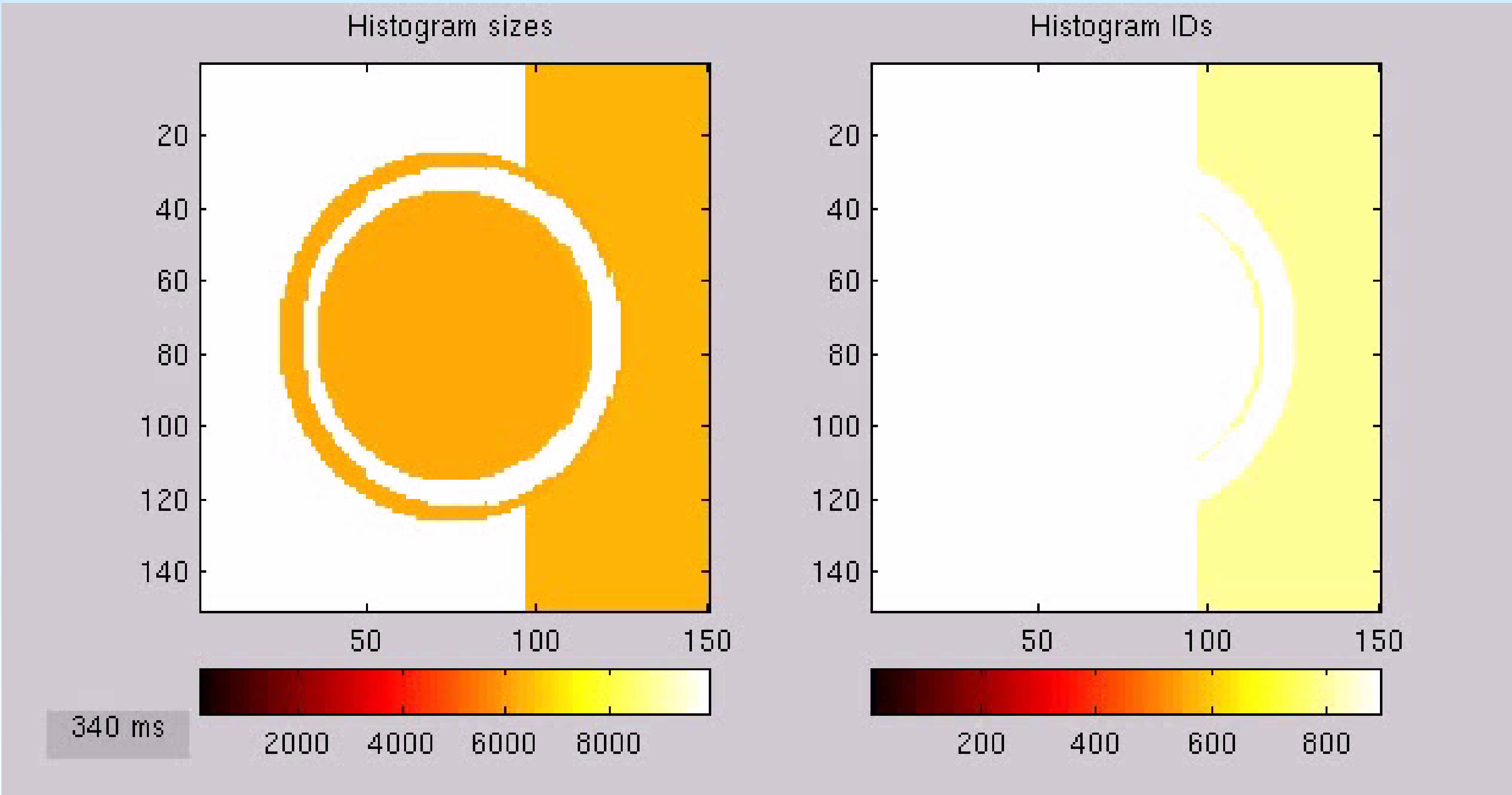

FK3, Heterogeneous tissue, re-entrant behaviour

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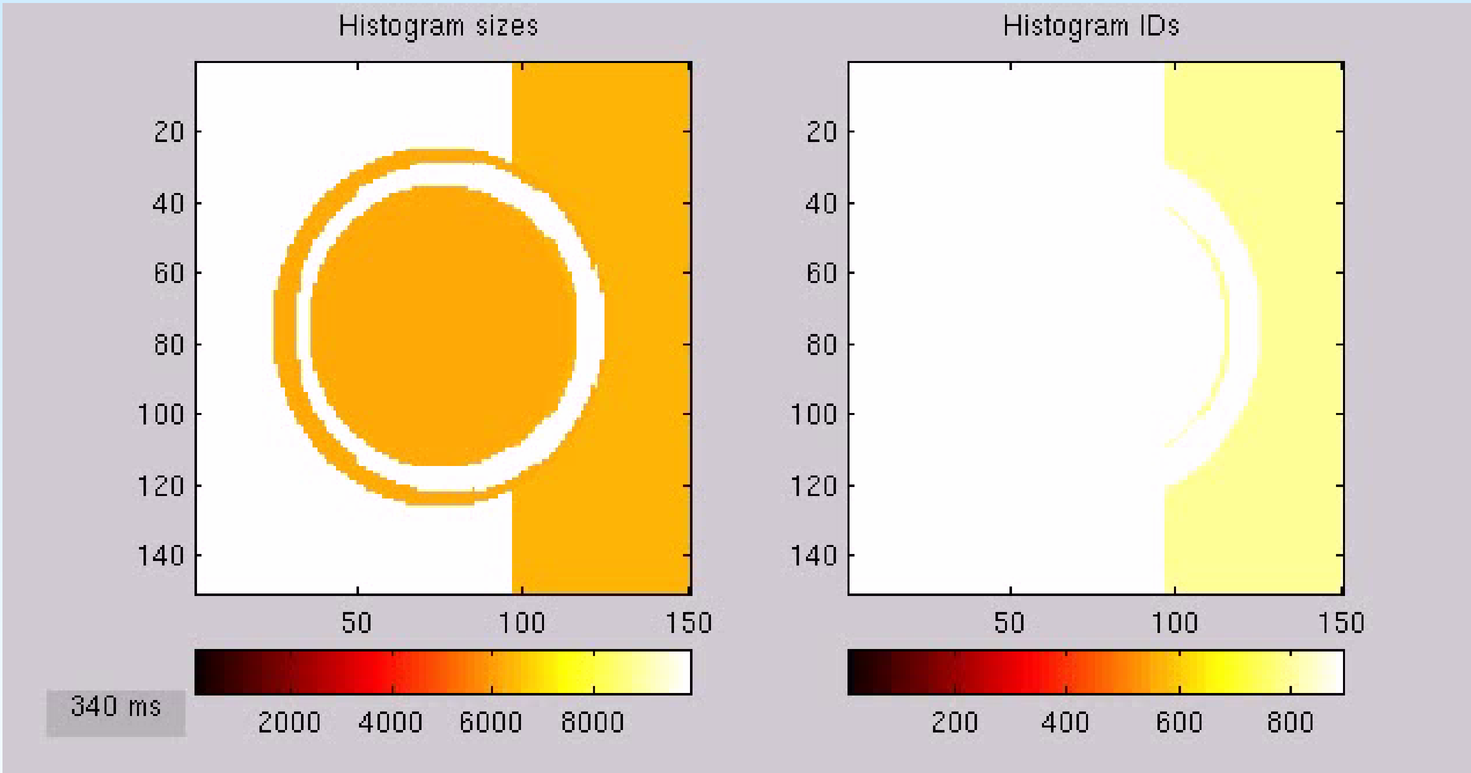

FK3, Heterogeneous tissue, no re-entrant behaviour

Hyper-dimensional histograms

- Cheap, easy, deterministic, unconstrained numbers of variables
- Meaningful? Especially with large numbers of variables…
- 3D in principle.
- Possibly better clustering methods; k-means, PCA, neural networks, ….

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Thanks to…

Richard Clayton
The University of Sheffield

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