Image Processing Techniques for Assessing Contractility in Isolated Adult & Neonatal Cardiac Myocytes

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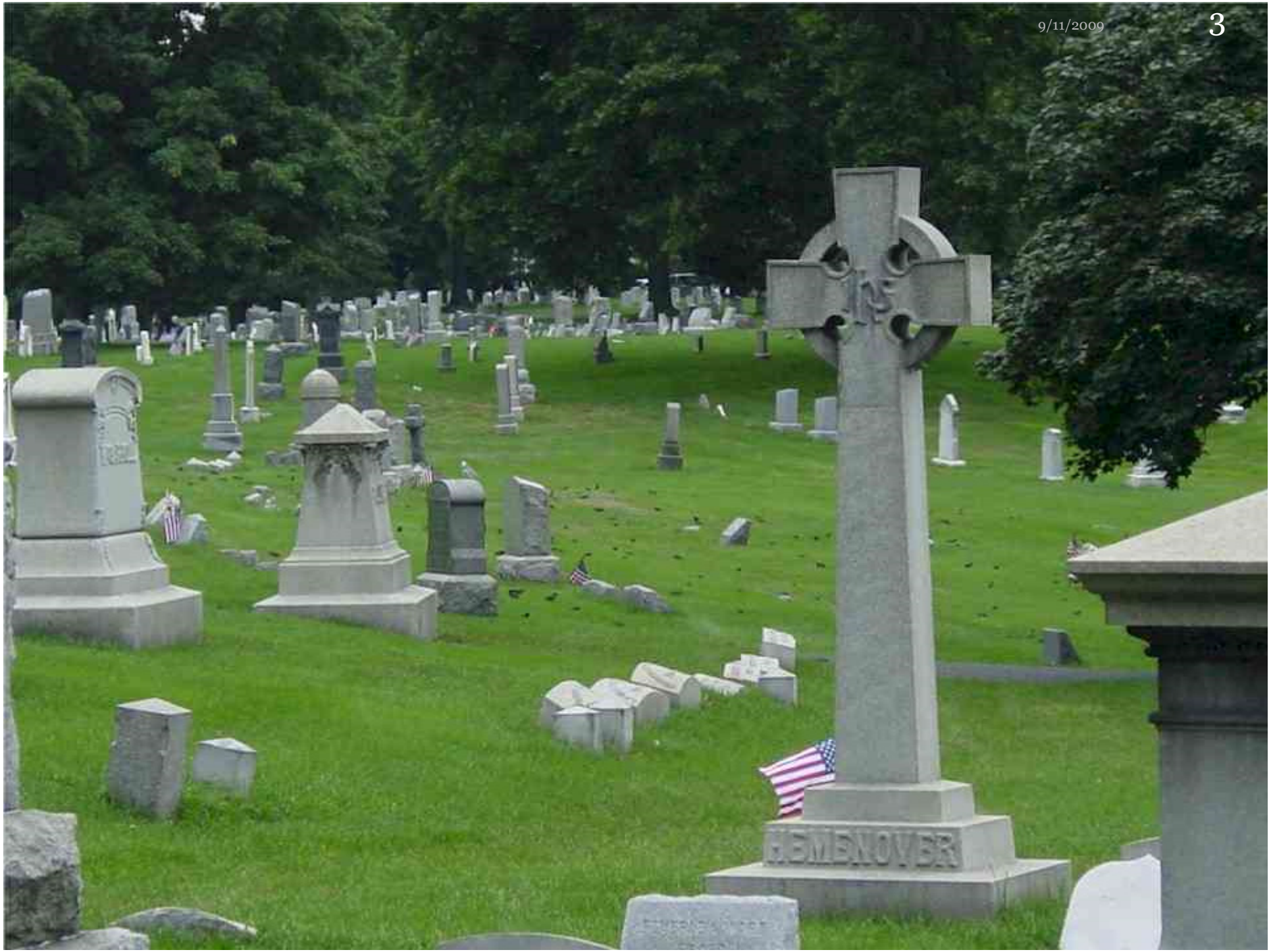
Hard facts (American Heart Association)

- 80.7 million Americans suffer from CVD
- CVD cost $448.5 billion in 2008
- 2,600 Americans die from CVD each day
- More deaths since 1900, except 1918


I.H.S.
I.B.M.E.N.O.V.BR

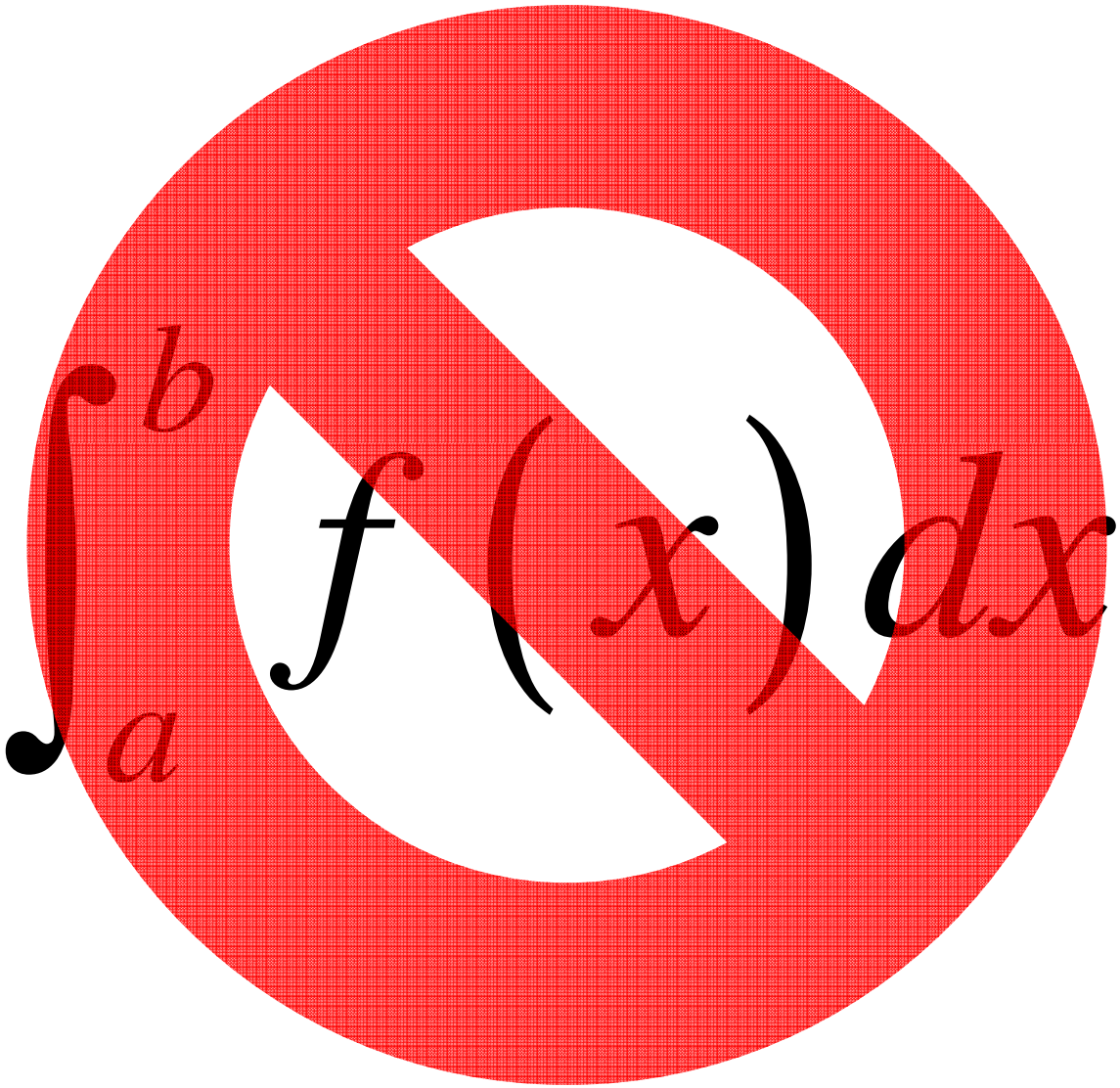
Why cardiocytes?

- Study cardiocyte contractile responses
- Analysis of cardiocyte mechanics for ECC
- Measurements
  - Calcium transient signals
  - Gene and protein expressions
  - Contractility
- Adult and neonatal cardiocytes are widely used

Agenda

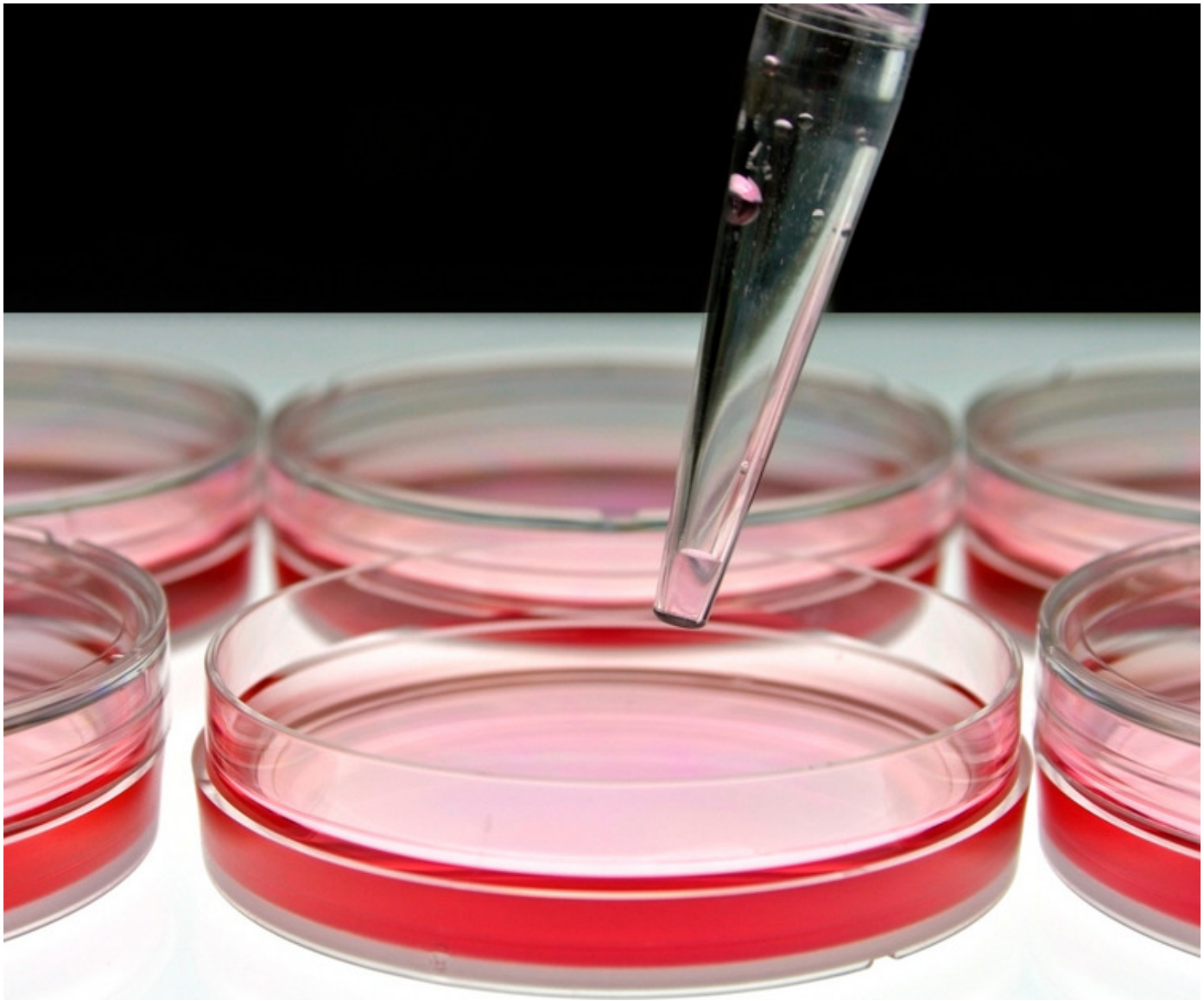
- Materials and methods
- Contractility in adult cardiocytes
  - Method and results
- Contractility in neonatal cardiocytes
  - Method and results
- Conclusions

Equation-free zone

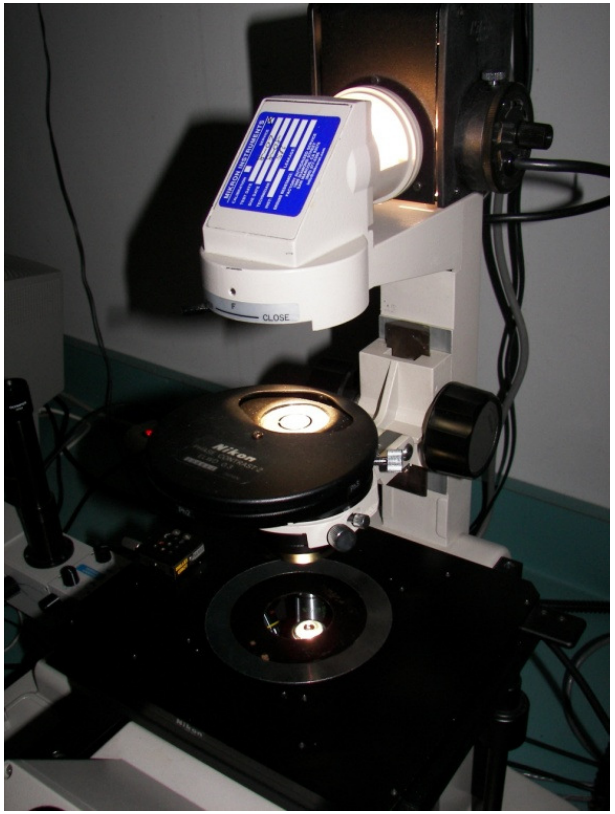


Materials and methods

Materials and methods (Cont'd)

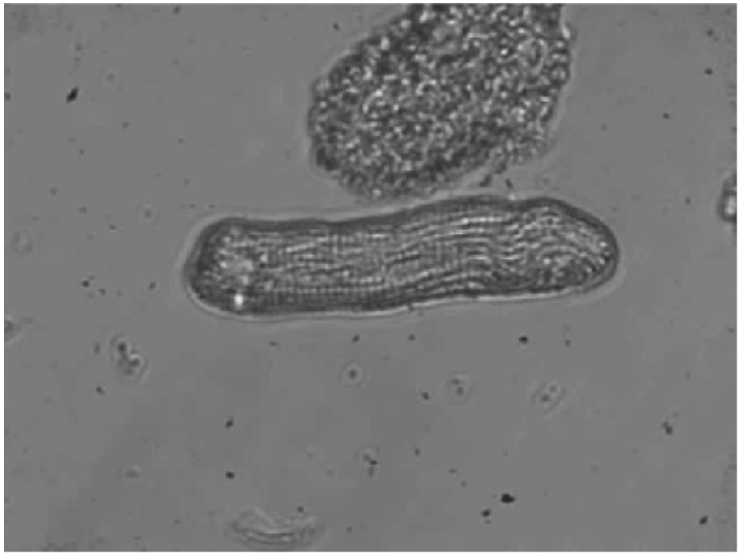


Materials and methods (Cont'd)

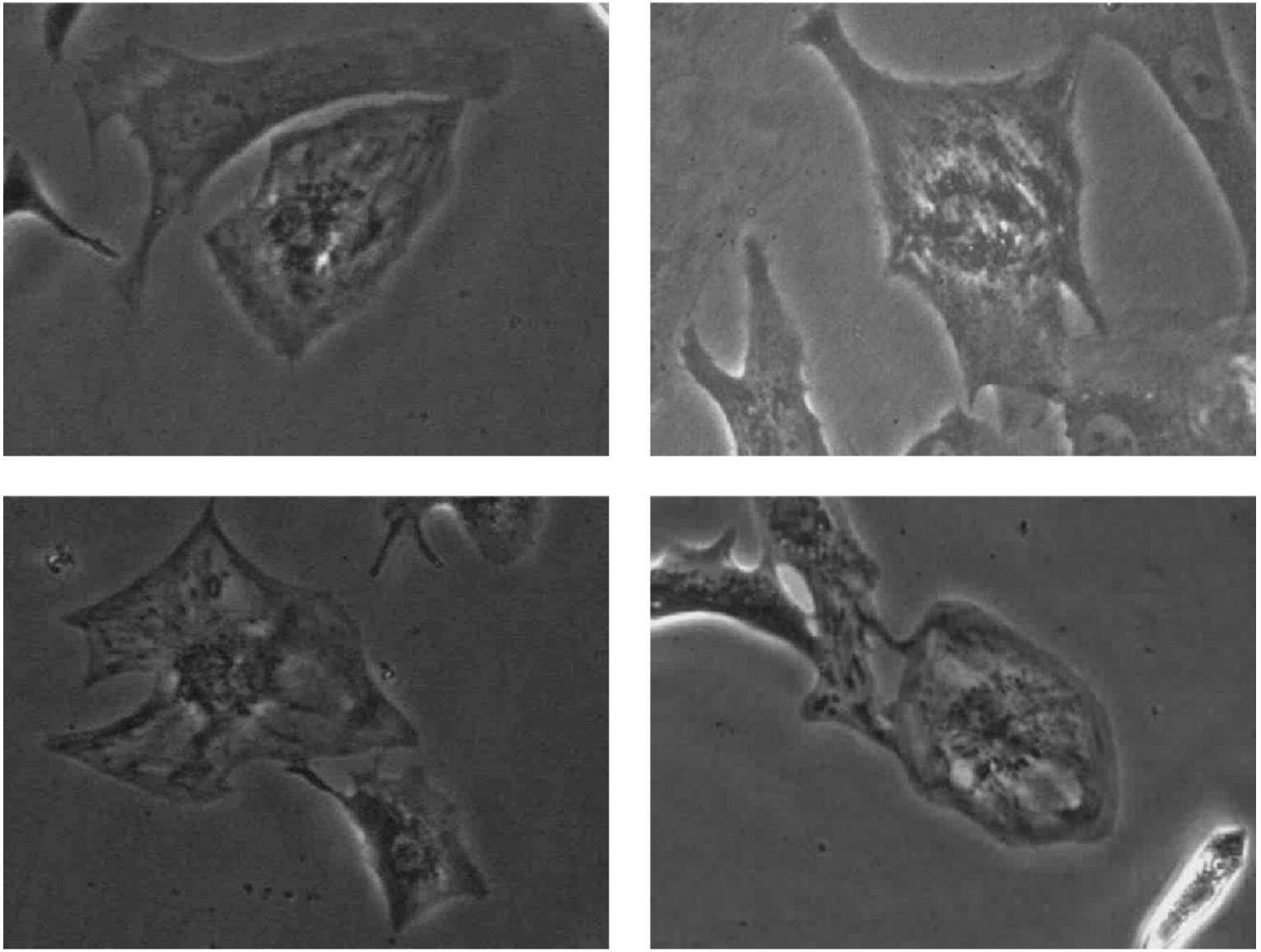


Adult movies

Adult cardiocytes



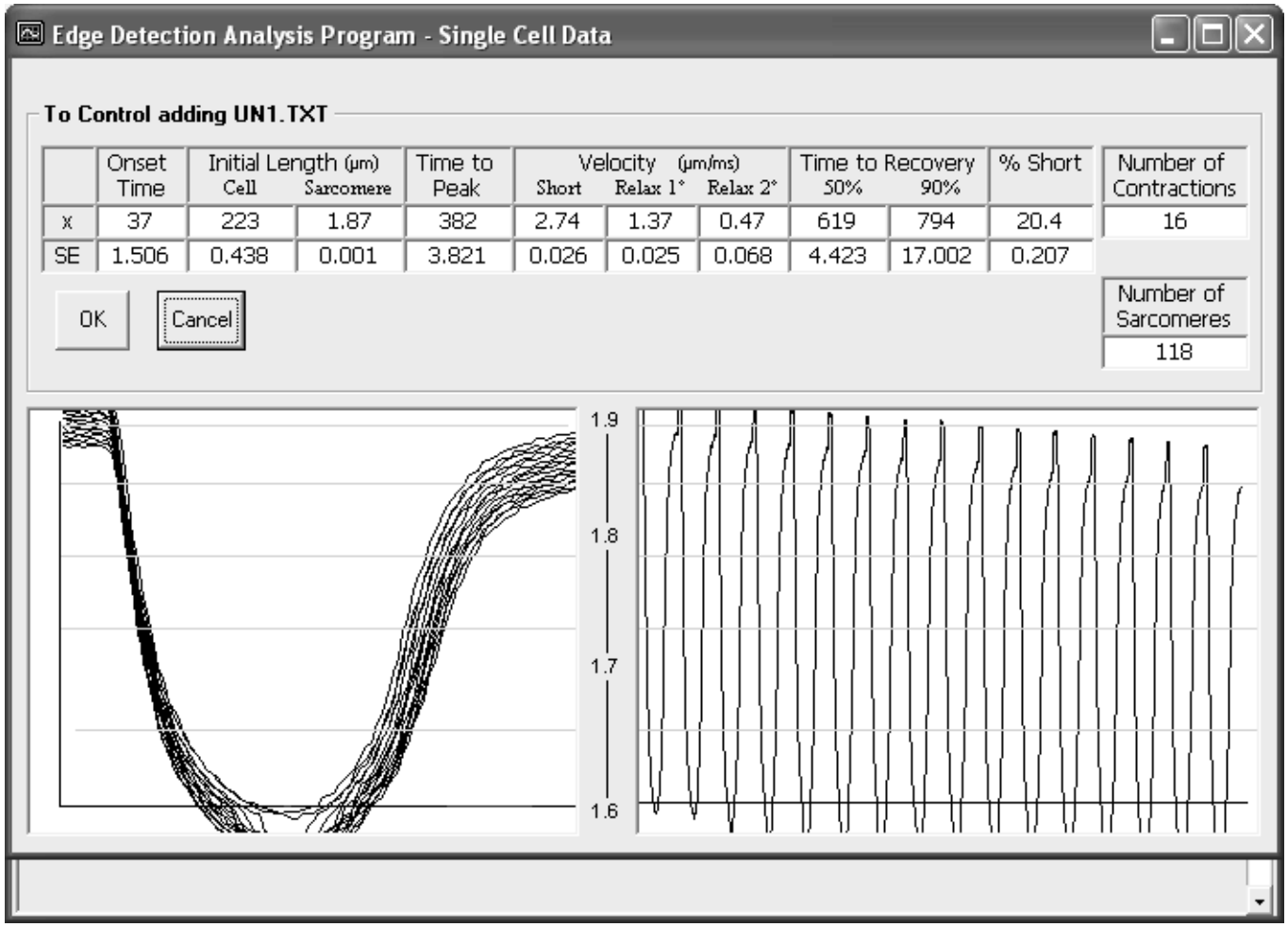

Neonatal cardiocytes



Contractility of adult cadiocytes

Edge tracking method

Edge tracking method (Cont'd)

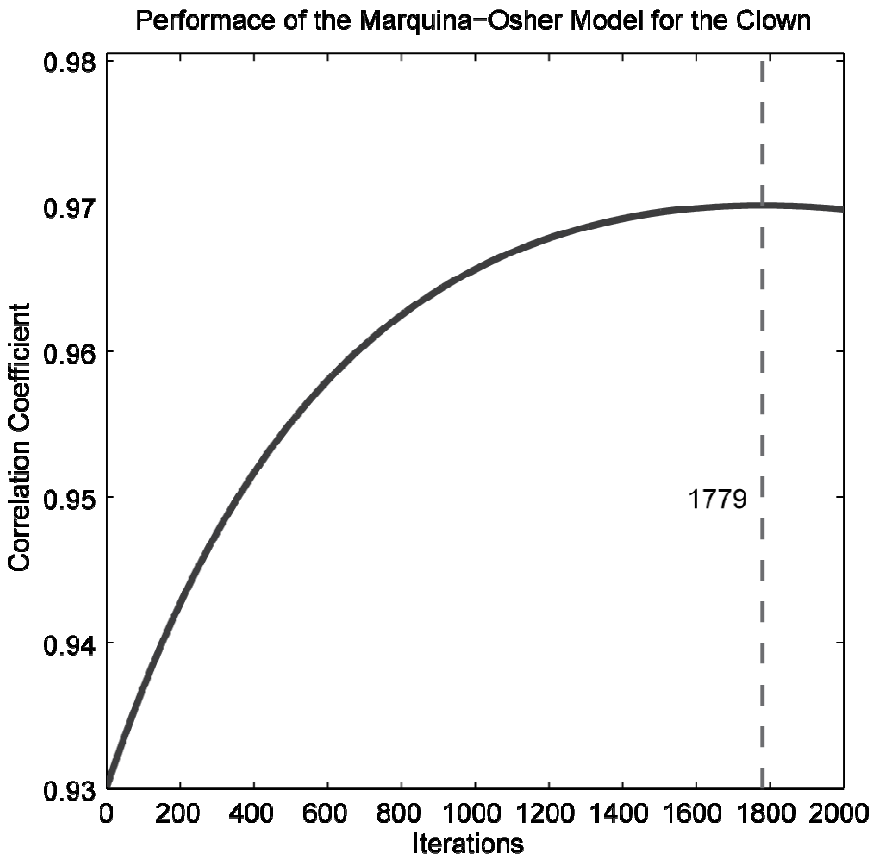


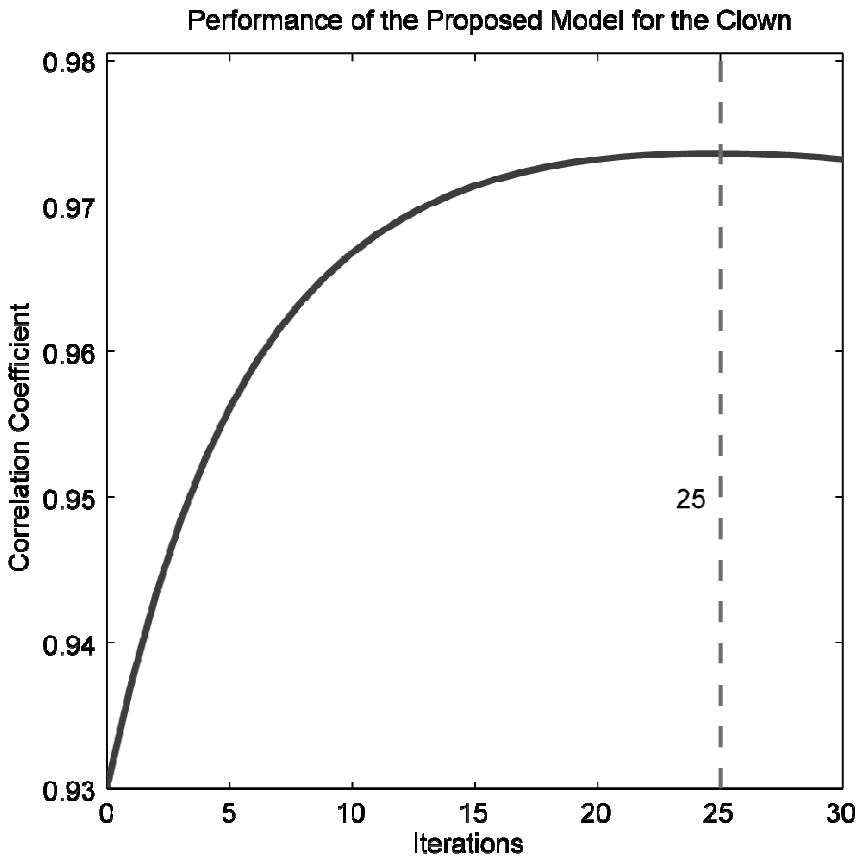
	Onset Time	Initial Length (µm) Cell	Initial Length (µm) Sarcomere	Time to Peak	Velocity (µm/ms) Short	Velocity (µm/ms) Relax 1°	Velocity (µm/ms) Relax 2°	Time to Recovery 50%	Time to Recovery 90%	% Short	Number of Contractions
x	37	223	1.87	382	2.74	1.37	0.47	619	794	20.4	16
SE	1.506	0.438	0.001	3.821	0.026	0.025	0.068	4.423	17.002	0.207	

Number of Sarcomeres: 118

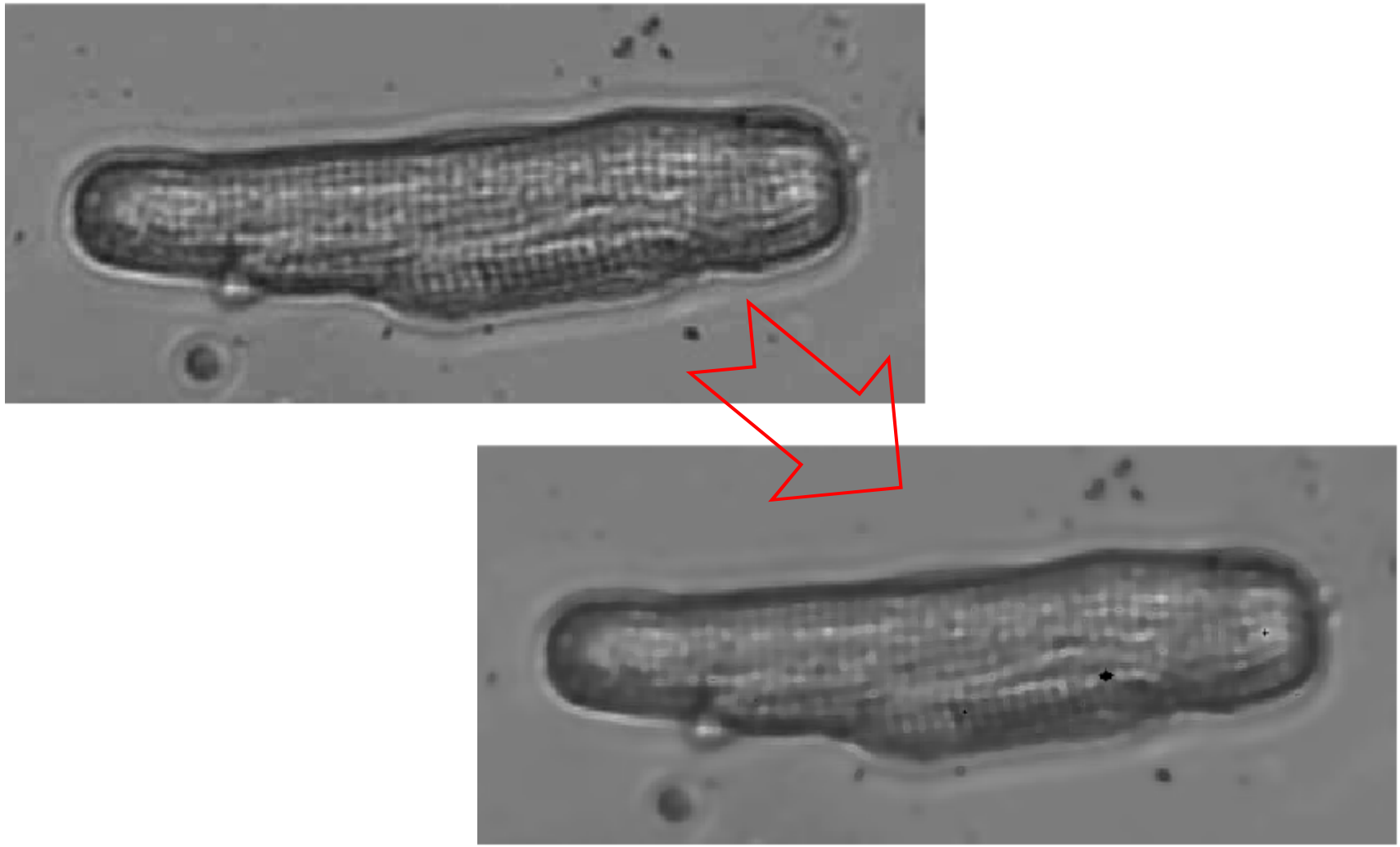
Image processing techniques

TV smoothing

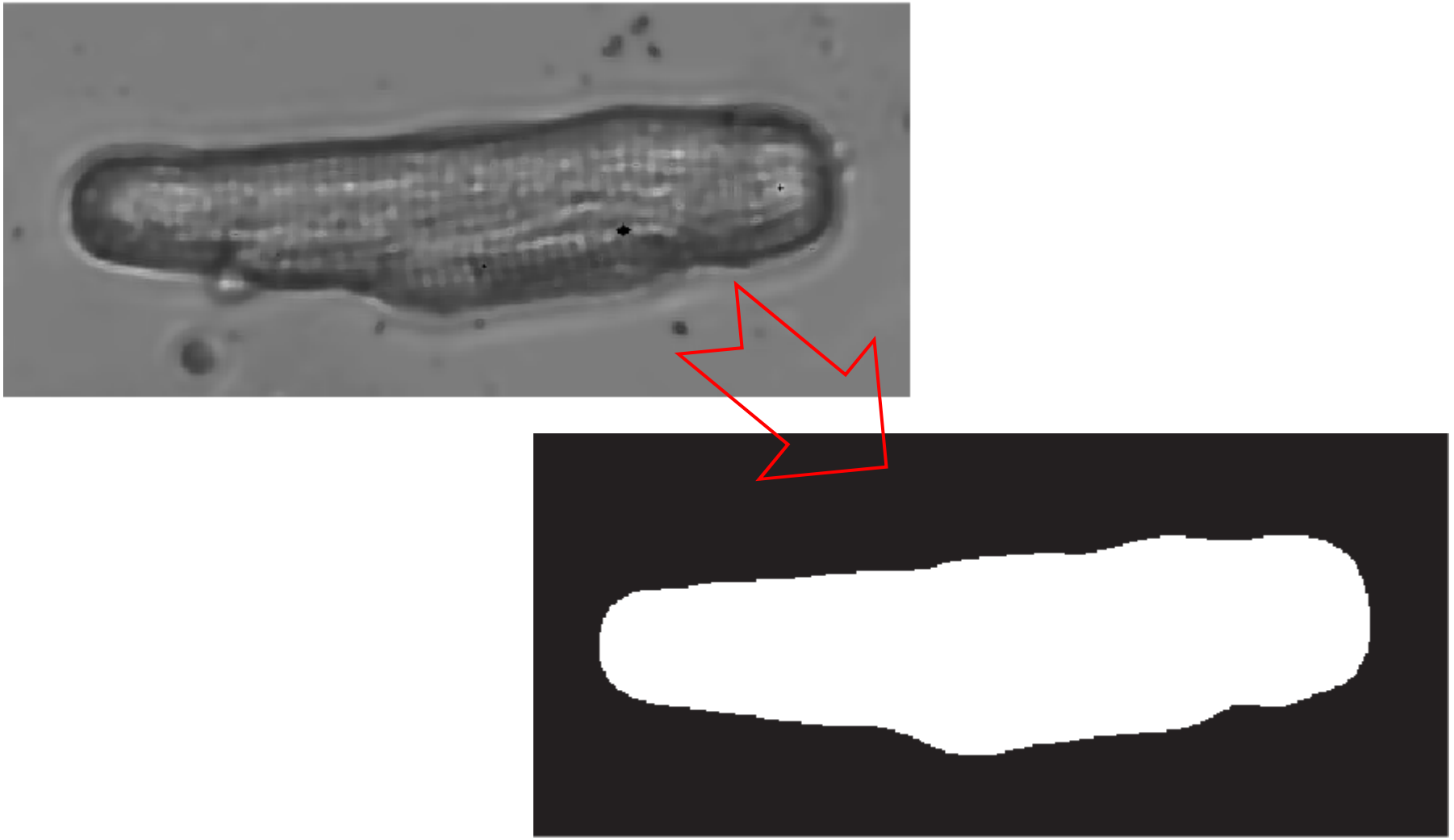




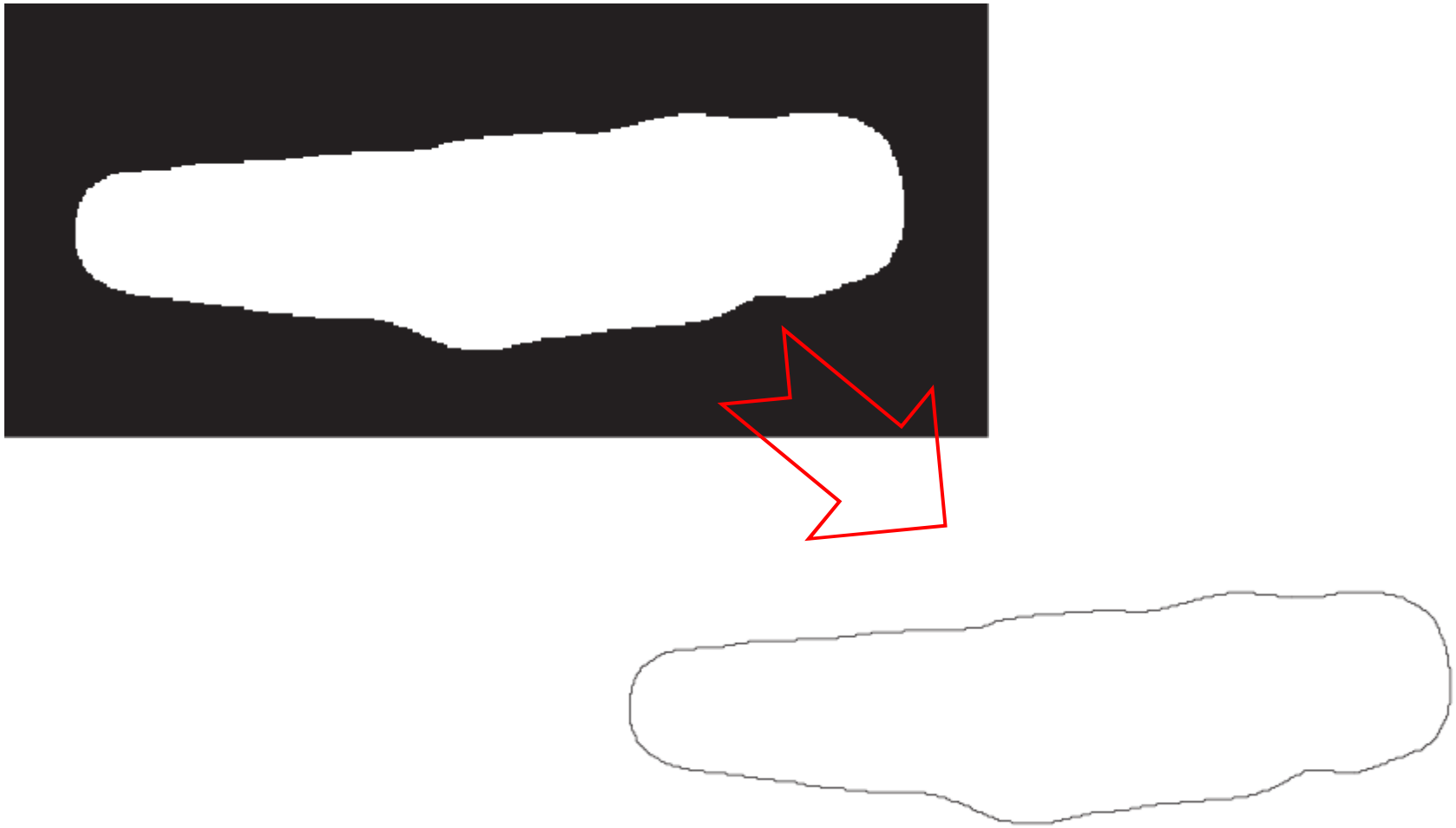
TV smoothing (Cont'd)



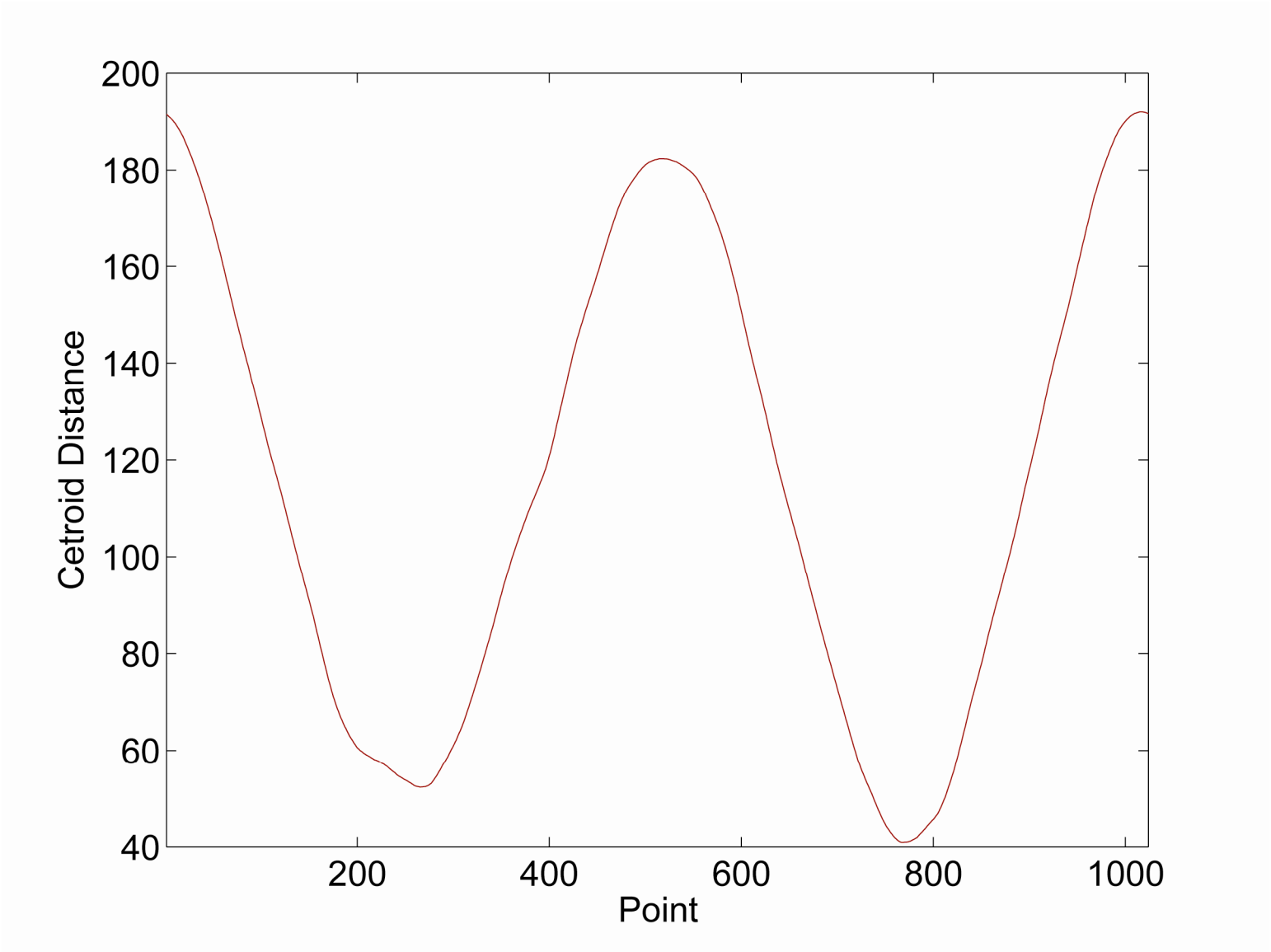
Segmentation



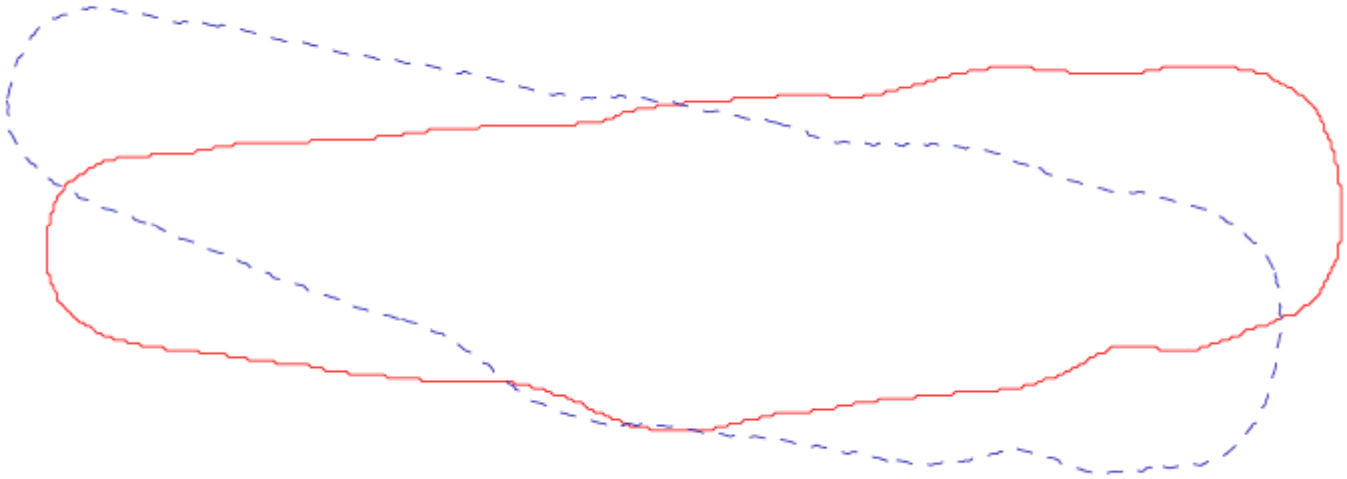
Contour extraction



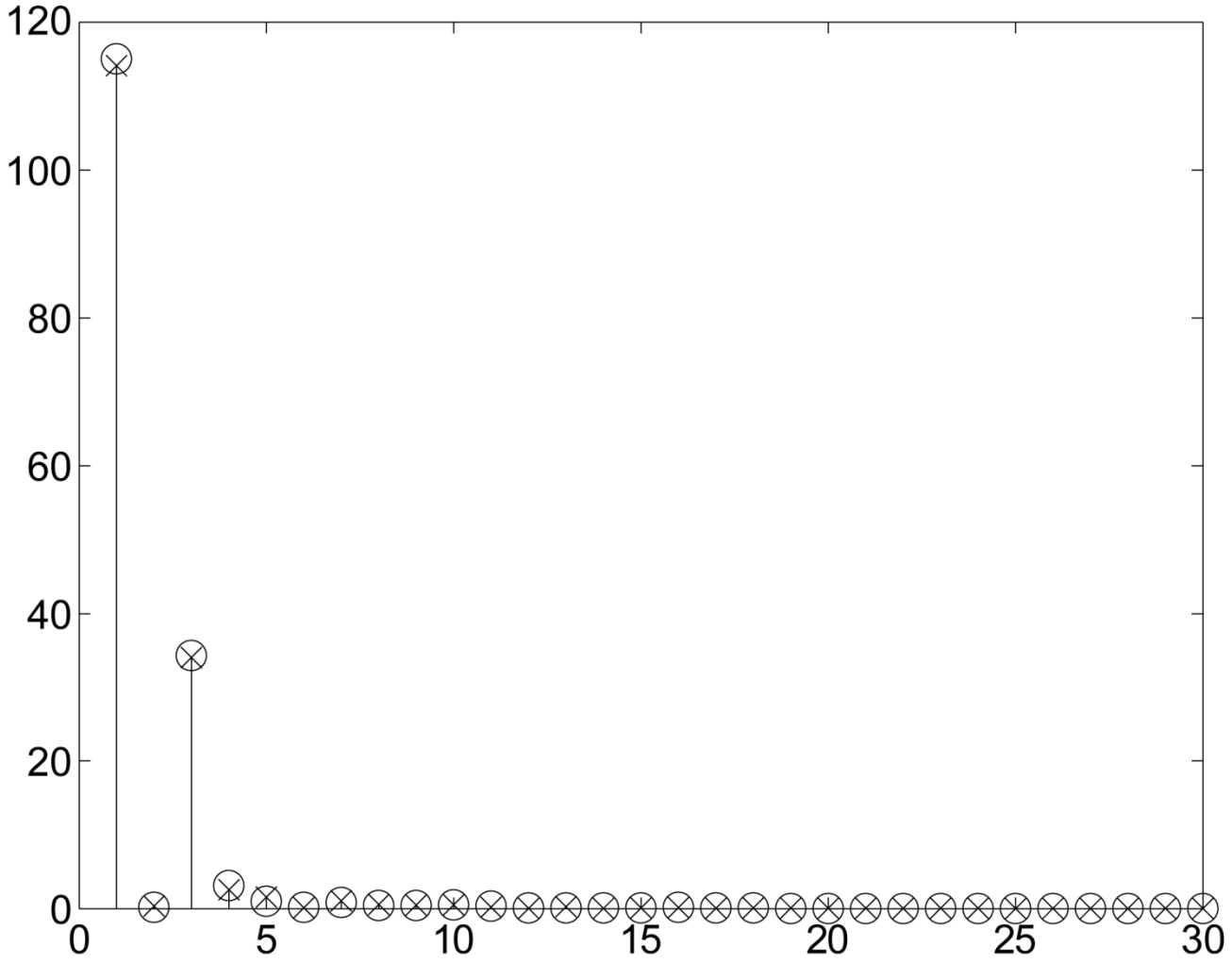
Shape signature



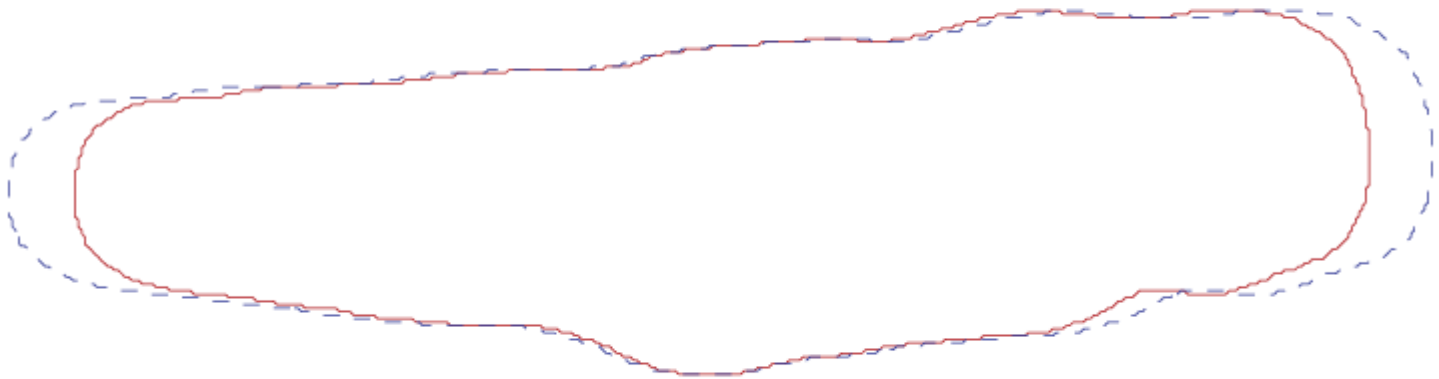
Fourier descriptors



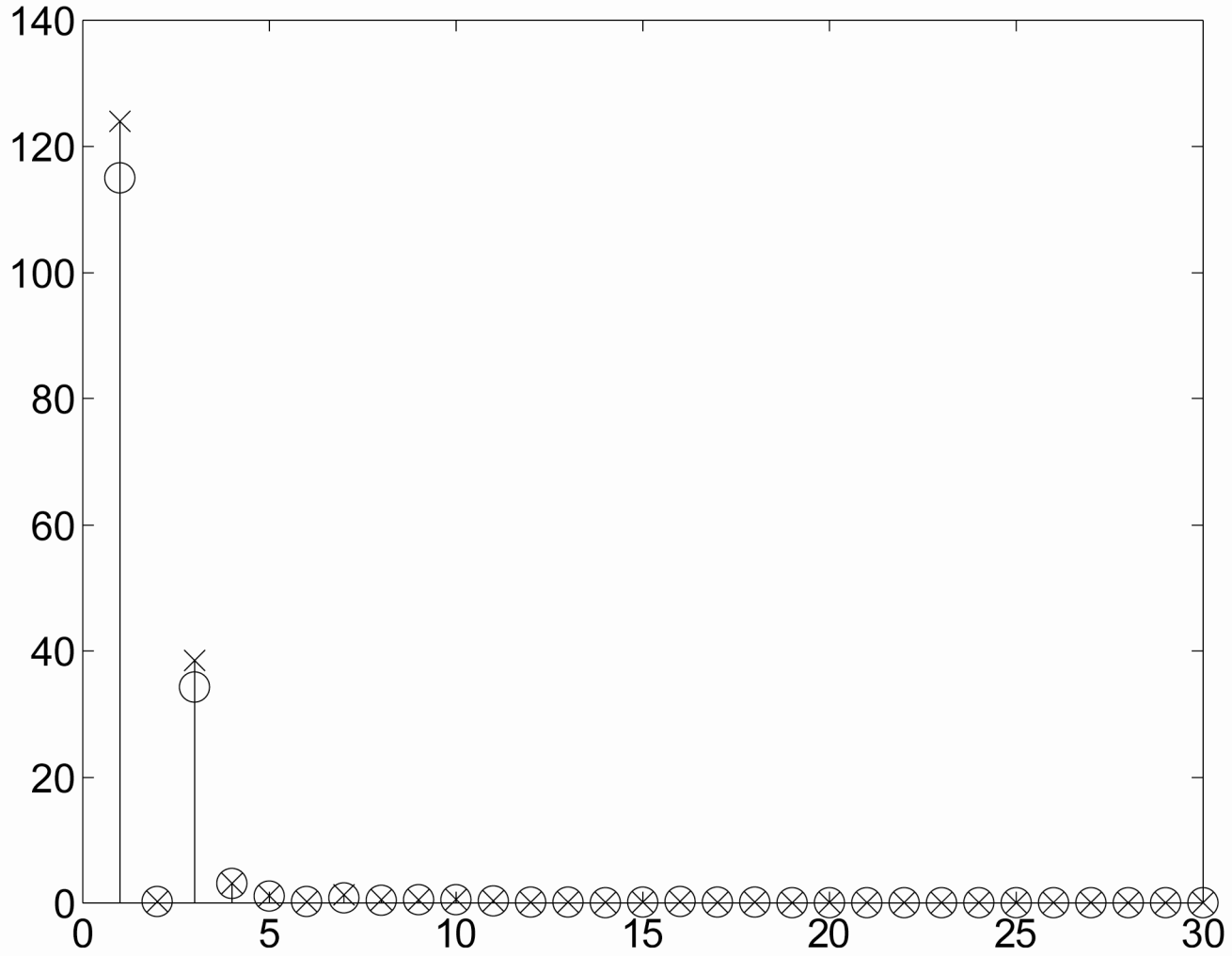
Fourier descriptors (Cont'd)



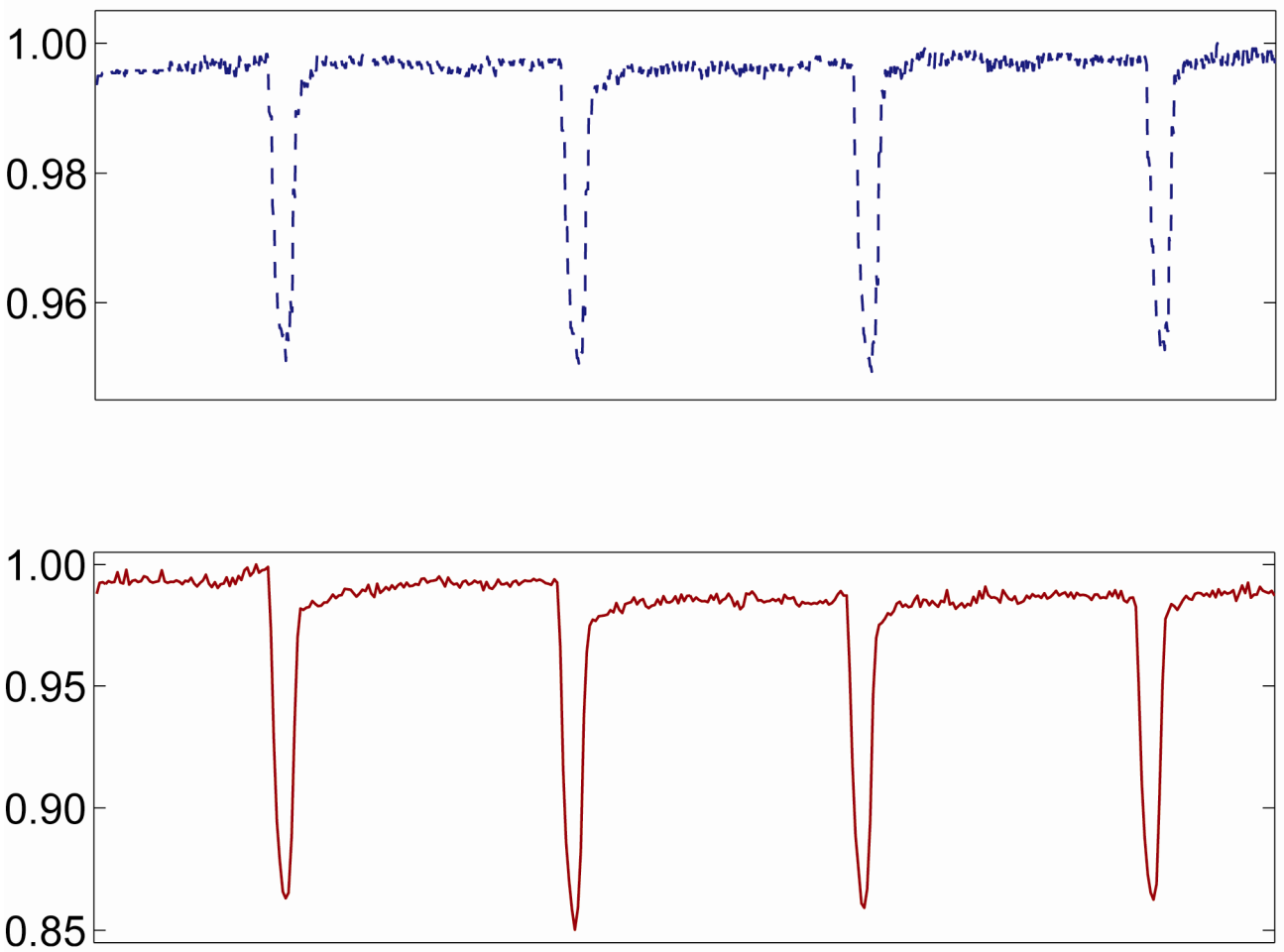
Fourier descriptors (Cont'd)



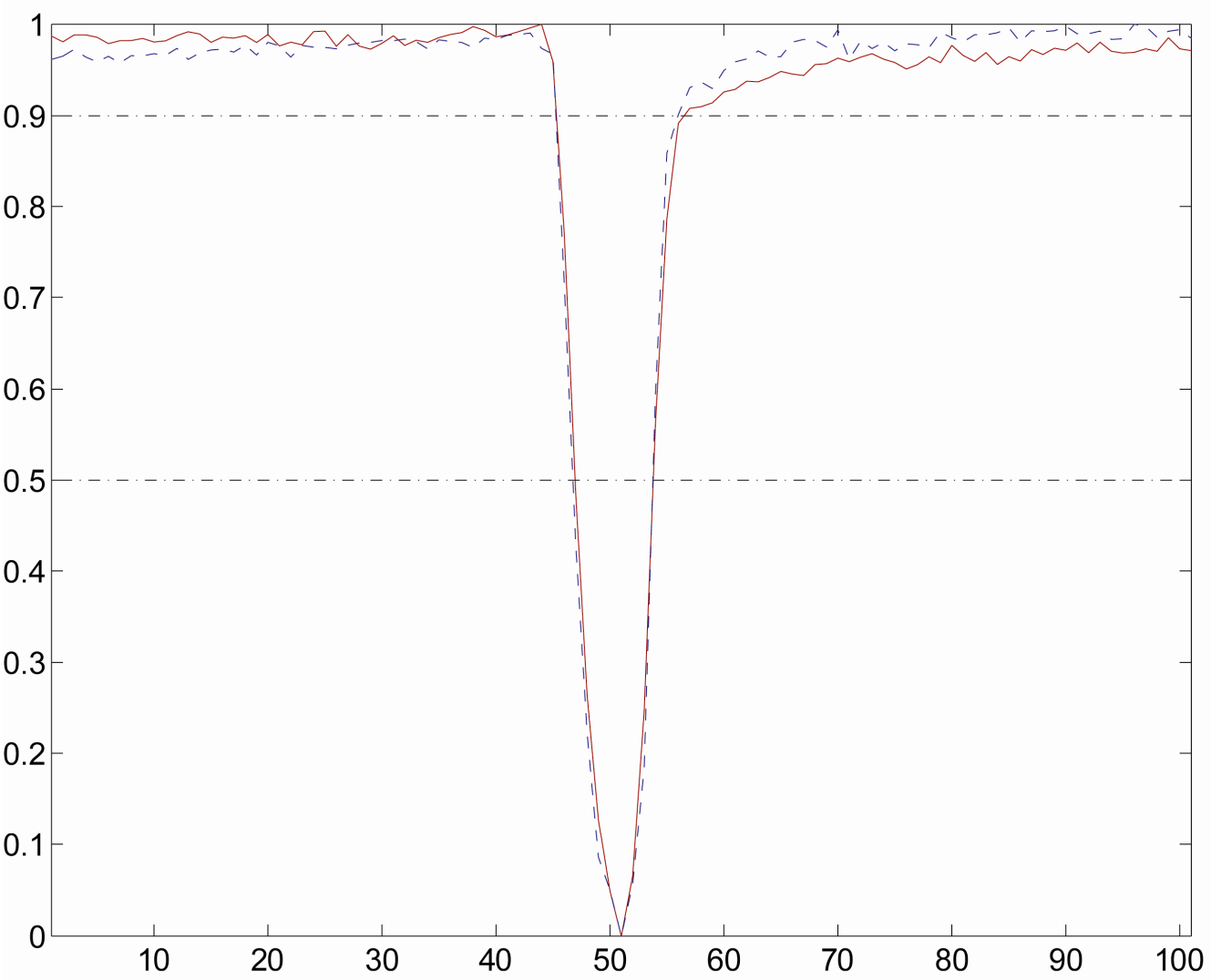
Fourier descriptors (Cont'd)



Results



Results (Cont'd)



Neonatal cardyocyte

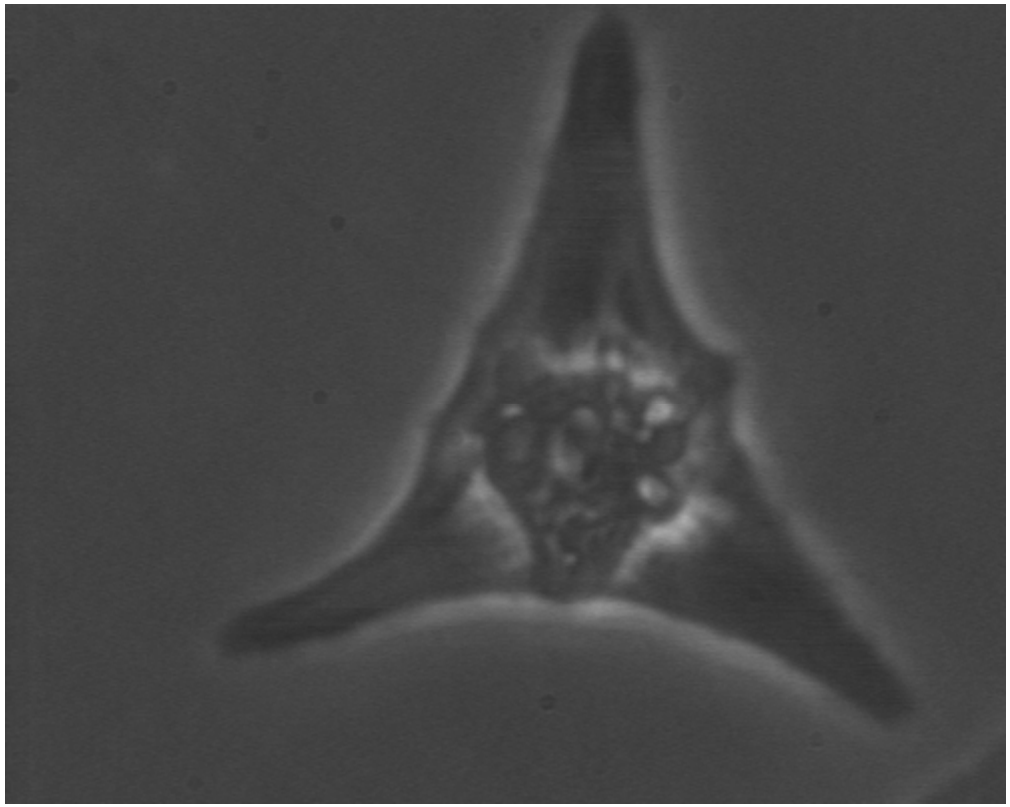
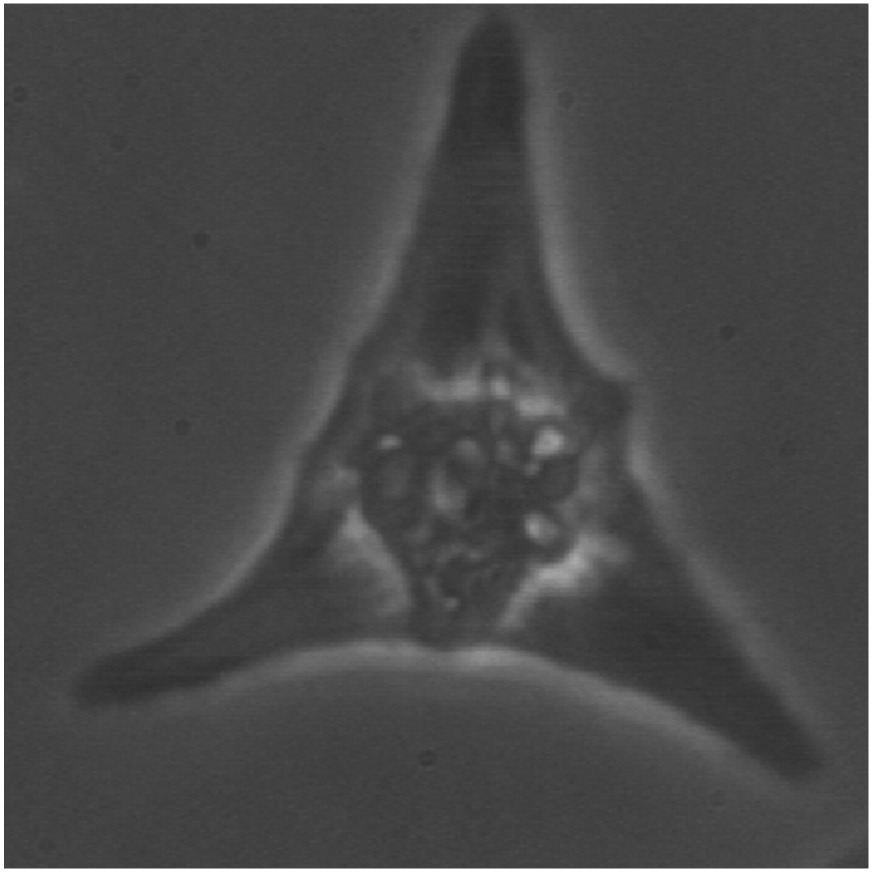
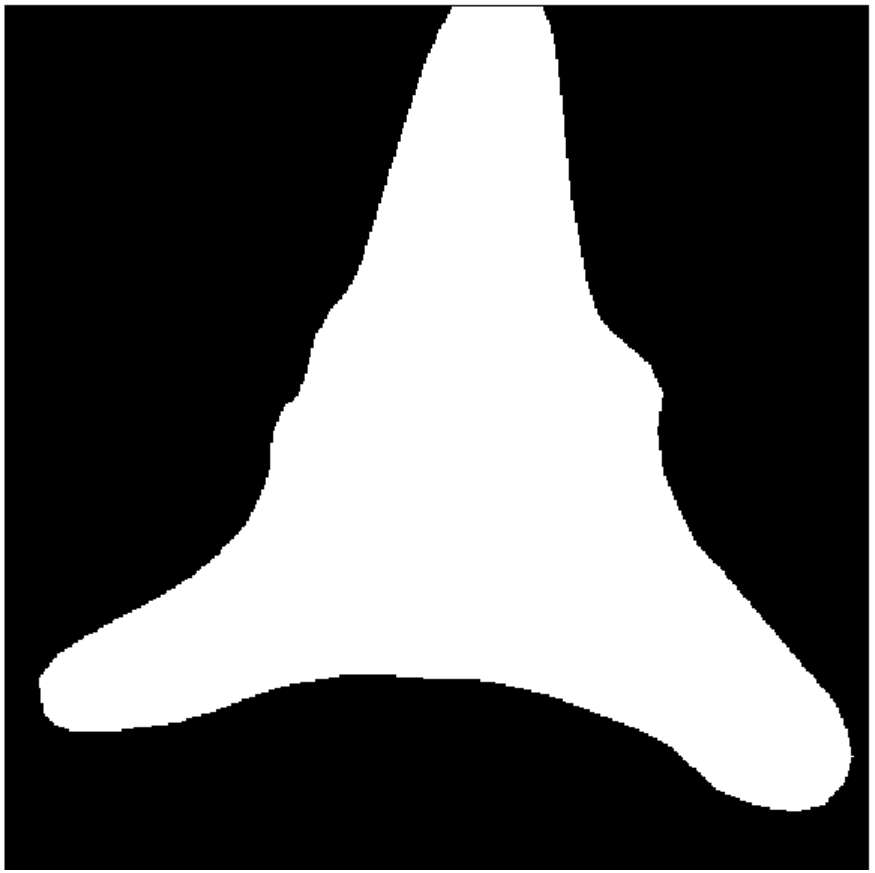


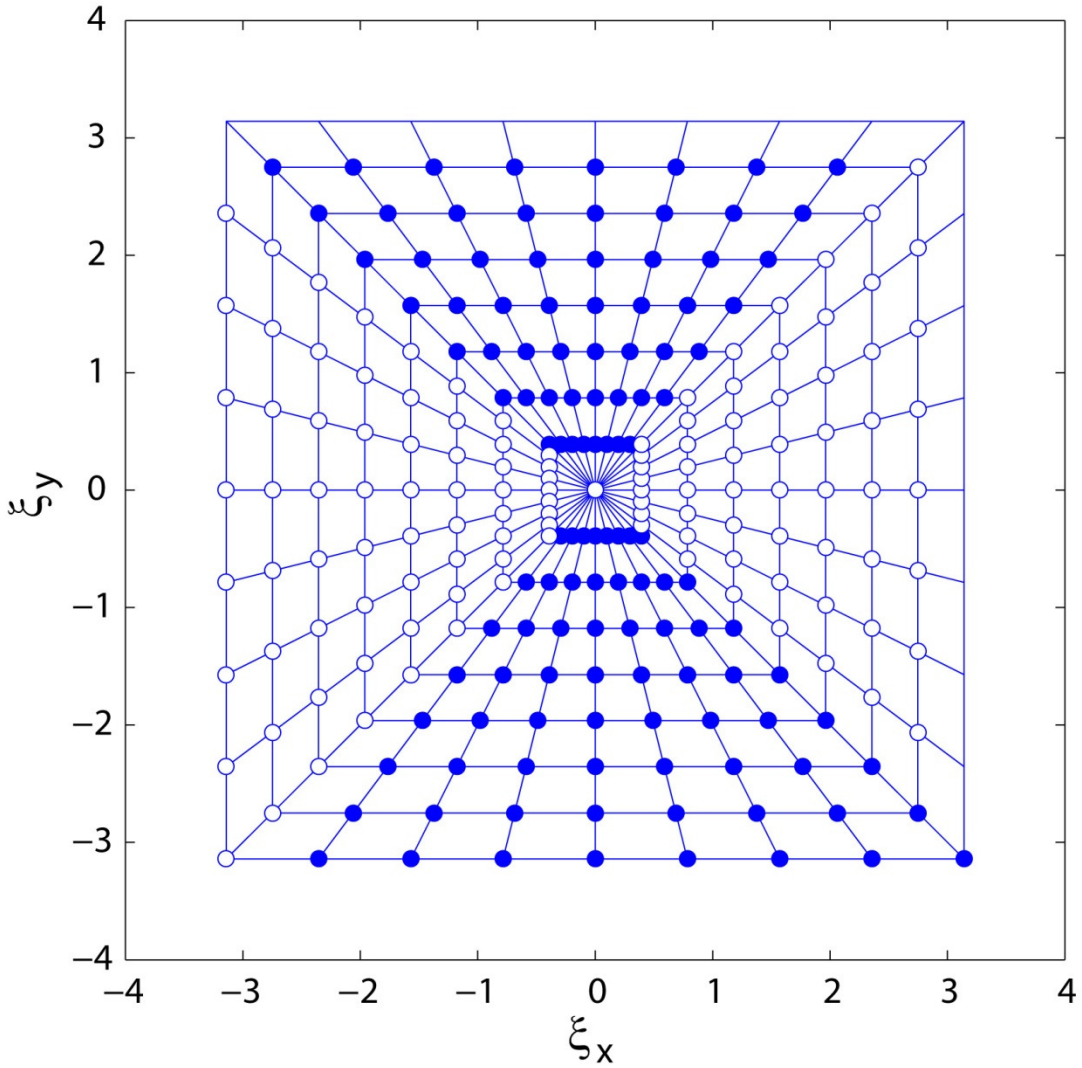
Image processing techniques

Apply mask

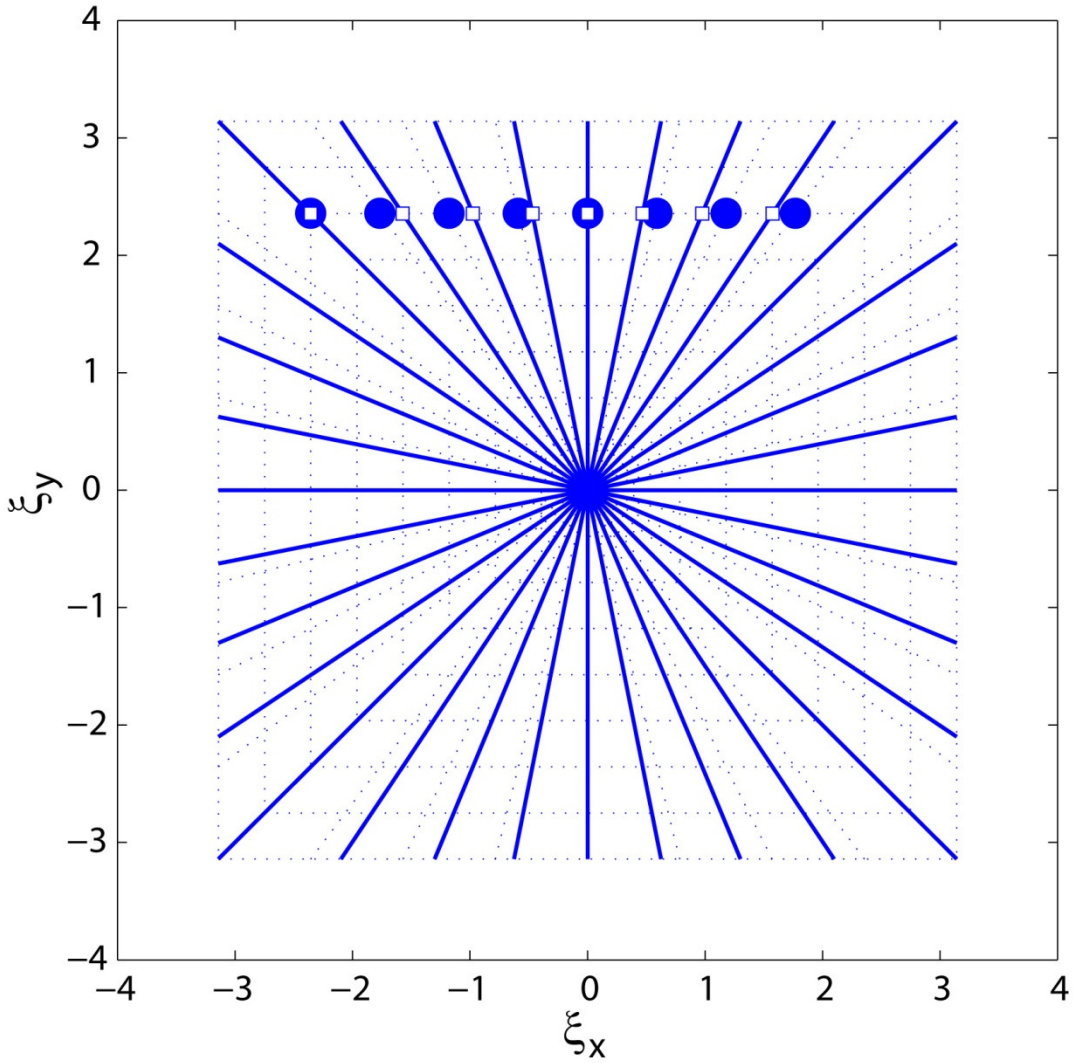




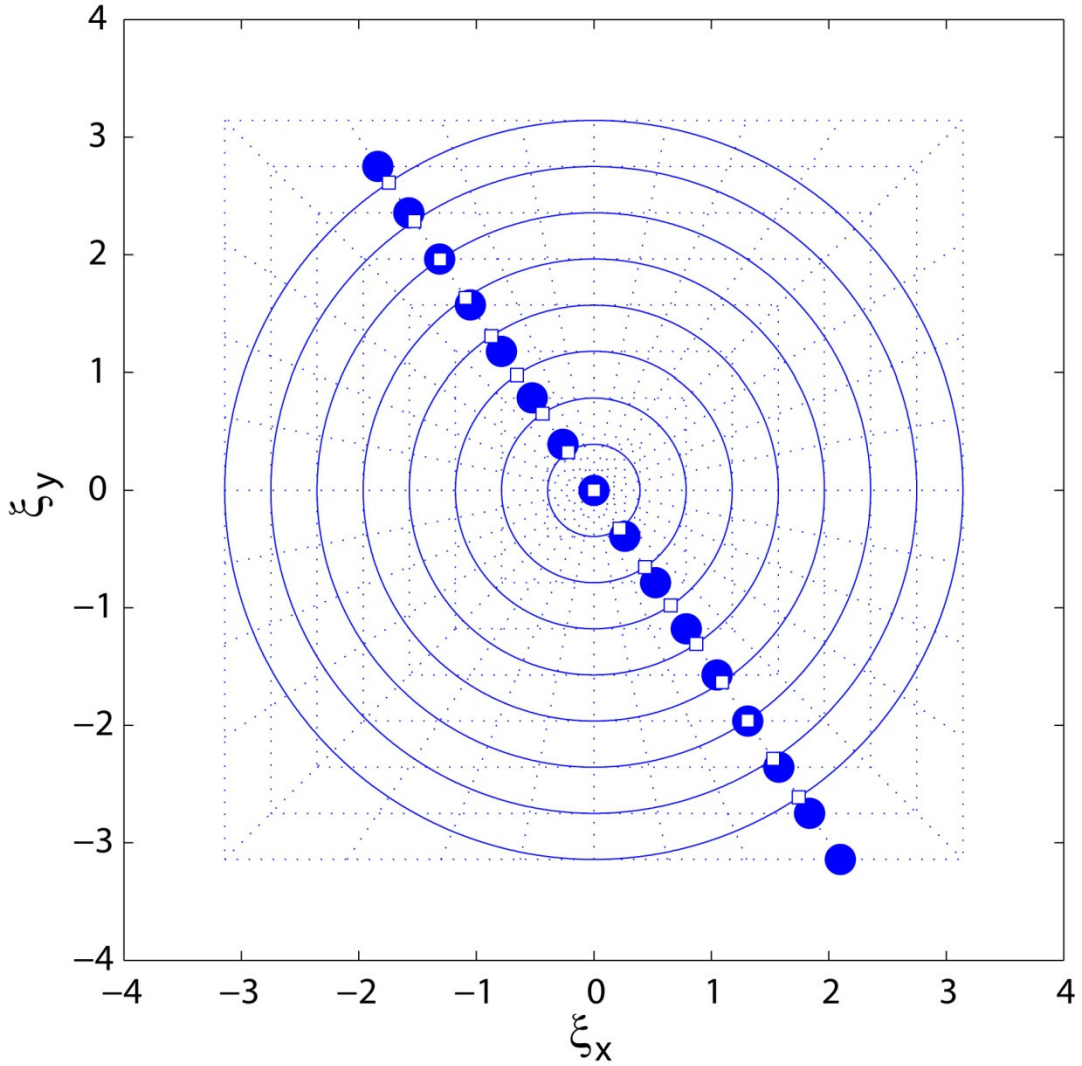
Polar Fourier Descriptors (Averbuch et al., 2006)



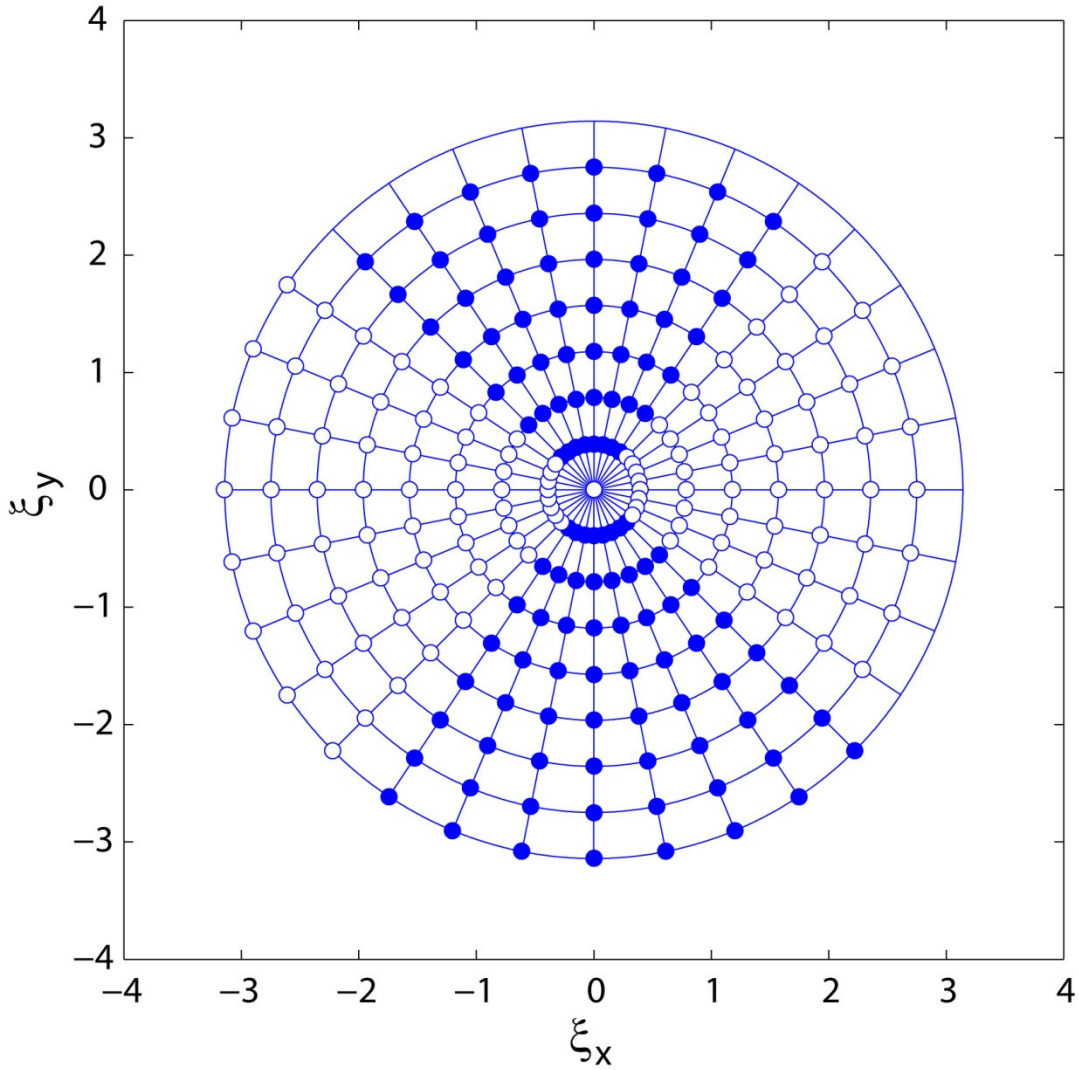
Polar Fourier Descriptors (Cont'd)



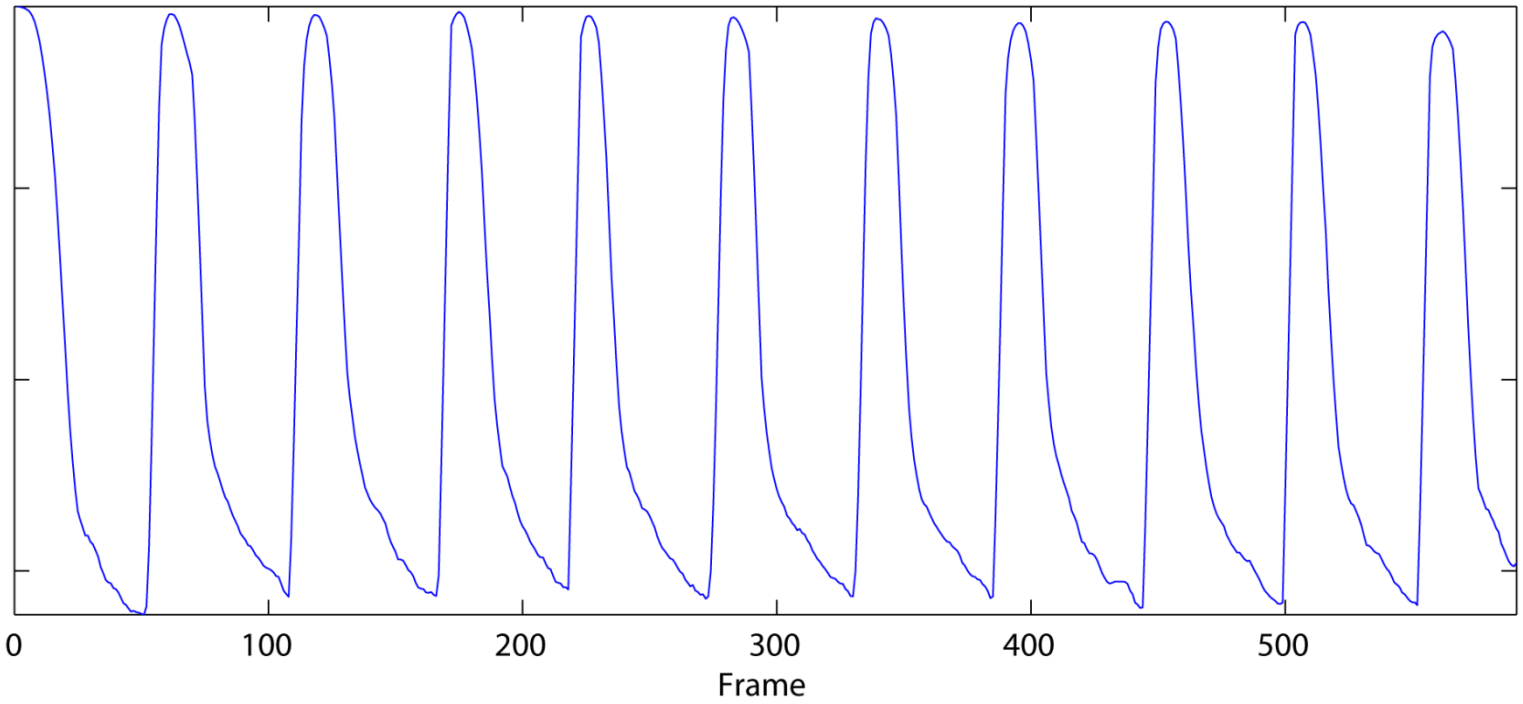
Polar Fourier Descriptors (Cont'd)



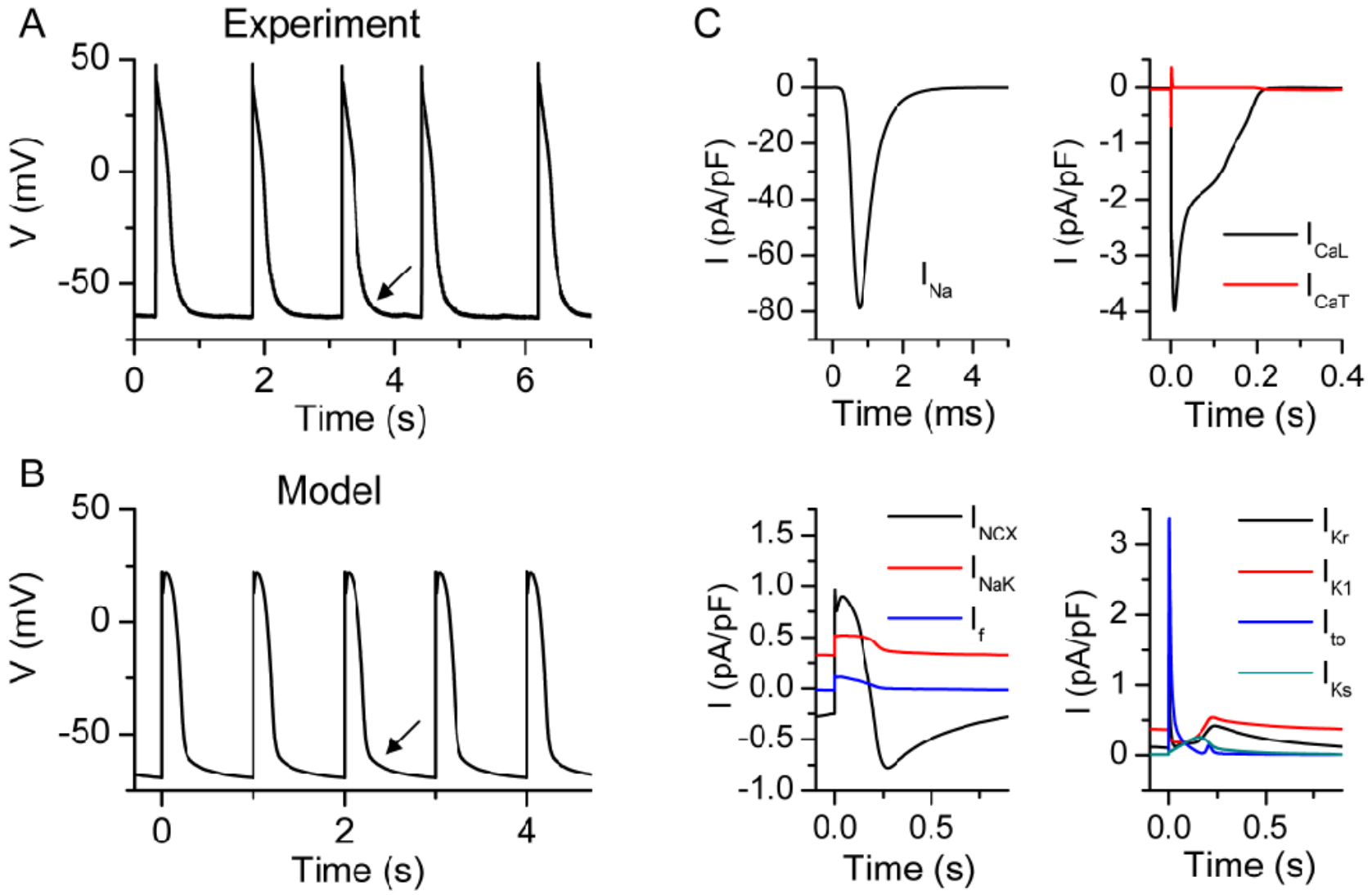
Polar Fourier Descriptors (Cont'd)



Results



Results (Cont'd) (Korhonen et al., 2009)



Conclusion

- Framework for assessing contractility
- HD in time analysis
- Contractility of cells under treatments

References

- Y. Mingqiang, K. Kidiyo, R. Joseph. *A Survey of Shape Feature Extraction Techniques, Pattern Recognition Techniques*, Technology and Applications, Book edited by: Peng-Yeng Yin, ISBN 978-953-7619-24-4, pp. 626, November 2008, I-Tech, Vienna, Austria.
- T. Korhonen, S.L. Hänninen, P.Tavi. *Model of Excitation-Contraction Coupling of Rat Neonatal Ventricular Myocytes*, Biophysical Journal, Volume 96, Issue 3, 1189-1209, 2009, doi:10.1016/j.bpj.2008.10.026.
- A. Averbuch , R.R. Coifman , D.L. Donoho , M. Elad , M. Israeli. *Accurate and Fast Discrete Polar Fourier Transform*, Applied and Computational Harmonic Analysis, vol. 21, pp. 145-167, 2006.

TV-based methods

$$u_0 = f + \eta$$

$$u \approx f$$

$$\min_{u \in \mathrm{BV}(\Omega)} \mathrm{TV}(u) = \min_{u \in \mathrm{BV}(\Omega)} \int_\Omega |\nabla u| \, d\mathbf{x}$$

$$\frac{1}{2} \int_\Omega (u - u_0)^2 \, d\mathbf{x} = \frac{1}{2} |\Omega| \sigma^2$$

$$\frac{1}{|\Omega|} \int_\Omega u_0 d\mathbf{x} = \frac{1}{|\Omega|} \int_\Omega u d\mathbf{x}$$

TV-based methods (Cont'd)

$$u_t - |\nabla u| \nabla \cdot \left(\frac{\nabla u}{|\nabla u|} \right) + \Lambda (u - u_0) = 0, \qquad \text{on } \Omega \times [0, \infty)$$

$$u(\mathbf{x}, 0) = u_0(\mathbf{x}), \qquad \text{on } \Omega$$

$$\langle g \cdot \nabla u, \mathbf{n} \rangle = 0, \qquad \text{on } \partial\Omega \times (0, \infty)$$

TV-based methods (Cont'd)

$$\Lambda = -\frac{1}{2\sigma^2}\nabla u^{\mathrm{T}} \cdot \left(\nabla u - \nabla u_0\right), \qquad \forall t$$

$$\mathrm{var}\left(\eta^{t+1}\right) = \mathrm{var}\left(u^t\right) - \mathrm{var}\left(G_\sigma * u^t\right), \qquad \forall t$$

$$\delta t = \frac{\varepsilon}{5} + \left(\frac{1}{4} - \frac{\varepsilon}{5}\right)\left(\frac{\max\left(\left|\nabla u\right|\right) - \left|\nabla u\right|}{\max\left(\left|\nabla u\right|\right)}\right), \qquad \forall t$$