ML methods for Edge detection and Tracking for Drosophila Dorsal Closure

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Objectives

- Develop fast and efficient methods to analyse Dorsal closure in Drosophila
- Structured decision forests to make accurate and fast edge detection
- Tracking vertices in amnioserosa using Kalman filter equations

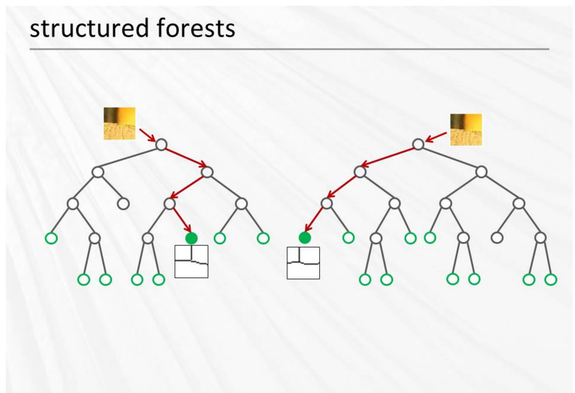
Introduction

Biologists have analysed the change in the area of cells as it closes, or Dorsal closure for the larger understanding of [1, 2] the forces that drive cell shape changes. Kinematic models and dynamic models[1] have been developed to this end. Recently [2] well-understood tools in Vision have been used to analyse the problem.

However, these methods need the detection and tracking to be optimized over several variables and need explicit point correspondences between consecutive frames. Such methods are not only computationally intense but also slow.

We analyse the system from a purely visual perspective, using machine learning techniques such as structured decision forests and Kalman filter equations (which in fact bear a striking resemblance to biologically motivated state equations) that are very fast and cheap to compute. We hope that this intuitive framework can enable biologists to infer useful information about the system.

Structured Random Forests[3]



Structured Random Forests

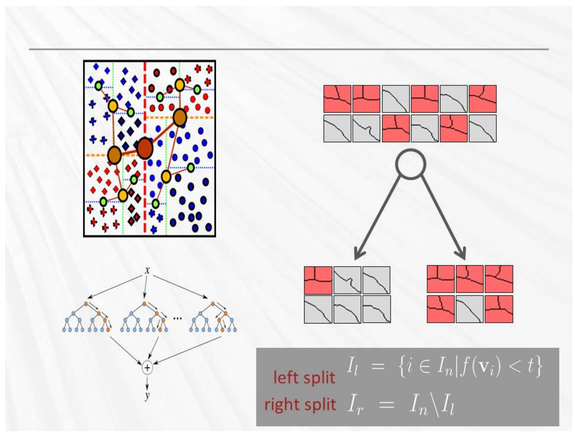


Figure 1: (left) Training and Testing modules (right) The information gain at each node

Important Result

The edges in Drosophila outside the amnioserosa can be detected effectively with low noise and high accuracy at very high speed by modifying the Structured Random forests. The Kalman filter can be used to track the vertices inside the amnioserosa efficiently and allows to define a constant velocity model for each vertex separately.

Mathematical formulations

Information Gain formula:

$$\Delta E = -\frac{|I_l|}{|I_n|}E_(I_l) - \frac{|I_r|}{|I_n|}E_(I_r) \quad (1)$$

Kalman Filter equations:

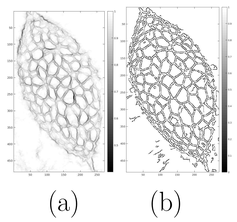
$$x_{t+1} = Ax_t + Bu_t + w_t \quad (2)$$

$$y_t = Cx_t + v_t \quad (3)$$

where $w_t \sim N(0, \Sigma_w)$, $v_t \sim N(0, \Sigma_v)$, and $x_0 \sim N\left(x_{0|-1}, P_{0|-1}\right)$. Note that $x \sim N(\mu, \Sigma)$ means

$$P(x) = \frac{1}{(2\pi)|\Sigma|^{1/2}} e^{-\frac{1}{2}(x-\mu)\Sigma^{-1}(x-\mu)}.$$

Qualitative Results



(a) (b)

Figure 2: (a) General structured forest (b) Canny Edge detector

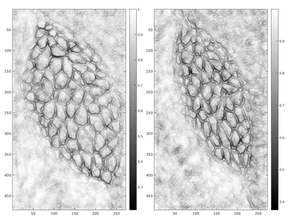


Figure 3: Edge detection on frames 5 and 100. The edges outside the amnioserosa overlap to a good extent and are trackable.

Qualitative Results

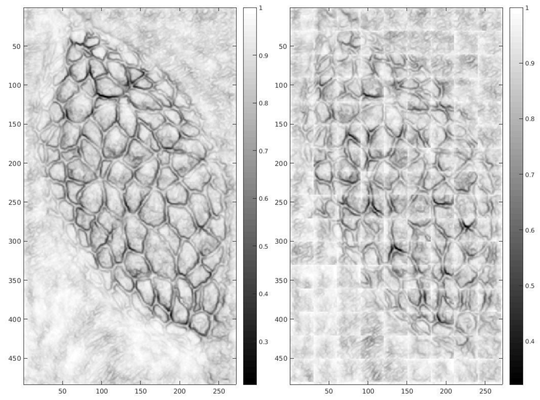


Figure 4: Two variations of our method, where even faint edges appear visible

Results

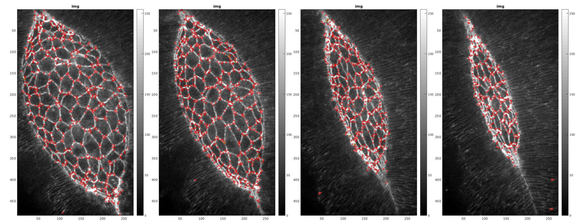


Figure 5: Tracking results at frames 1, 50, 180 and 280 as the cell closes

Edge detection		Tracking	
Canny	Ours	SOTA	Ours
0.3262	**0.09**	1.739	**0.76**

Table 1: Timing results in seconds per frame (SOTA is unpublished)

Conclusion

We have developed faster methods to enable biologists to infer the kinematics of Dorsal closure in Drosophila using efficient and accurate image analysis aided my machine learning tools.

References

[1] Adam Sokolow, Yusuke Toyama, and Daniel P et al Kiehart.
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[3] Piotr Dollár and C Lawrence Zitnick.
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