SEGMENTATION OF NUCLEI IN CONFOCAL IMAGE STACKS USING PERFORMANCE BASED THRESHOLDING

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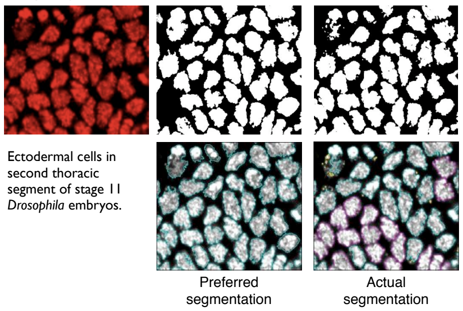
Problem



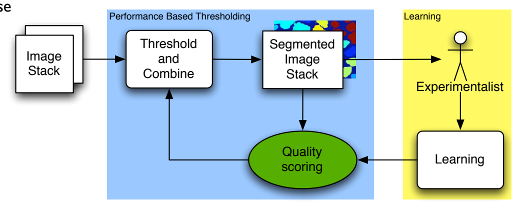
Ectodermal cells in second thoracic segment of stage 11 *Drosophila* embryos.

Challenge

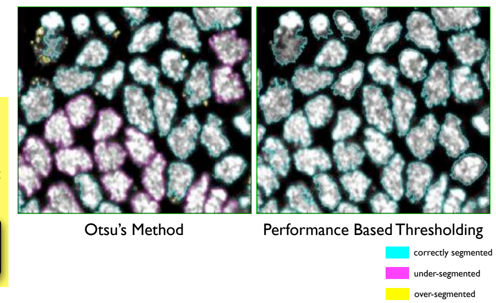
- Tuning required for computer vision algorithms (for both initial use and as experimental conditions change)
- Tuning requires computer vision expertise
- experimentalist ≠ computer vision expert (typically neither side wants =)

Our Approach

- use machine learning to *mimic* biologist
- intuitive interface engages biologist in training machine



Results

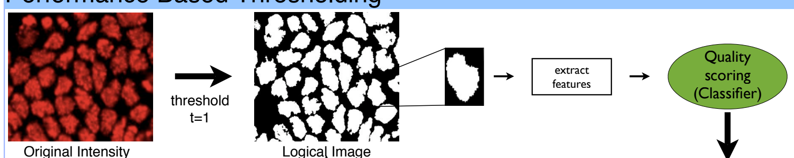


method	count	diff	% found	US	Conn
Mean	2535	-1126	69%	7572	347
Otsu	2741	-920	75%	4134	186
PBT	3505	-156	96%	20	173

Performance of various thresholding algorithms in detecting objects vs. ground truth segmentation from CT-FISH confocal image stack of DAPI. The actual number (ground truth) of 2D nuclei segments in tested 18 frame stack containing approximately 600 nuclei, each spanning about 9 frames, is 3661.

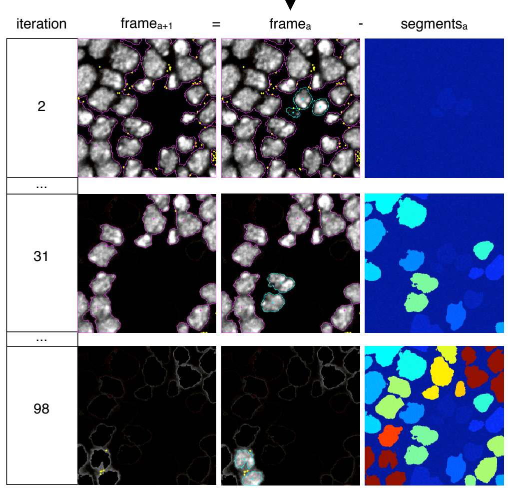
diff = difference from ground truth,
US = under-segmentation
Conn = Connected (nucleus not detected as a separate segment but combined with another nucleus.)

Performance Based Thresholding

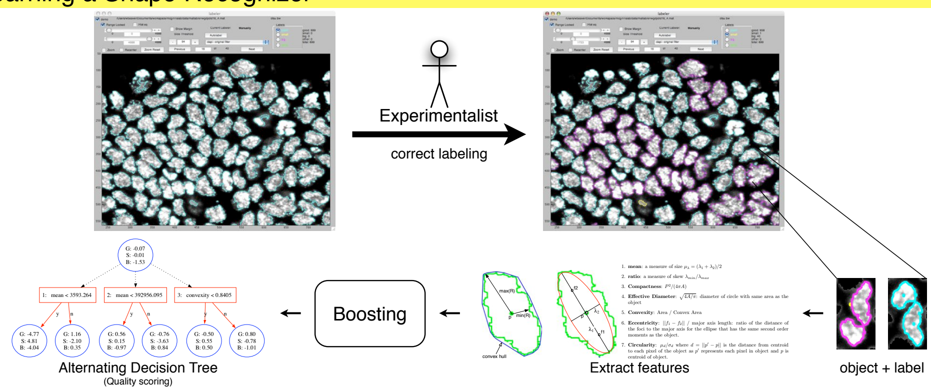


for all frame_a, in stack **do**
  $\text{segments}_a = \{\}$
  for all thresholds t from low to high **do**
    $B = \text{frame}_a > t$
    CE = 2D connected elements in B.
    for all ce_j in CE **do**
      p = F(ce_j)
      if p ids "good" **then**
        mask (remove) ce_j from frame_a.
        add ce_j to segments_a.
      end if
    end for
  end for
  Connect segments between segments_a and segments_{a-1}
end for

Pseudocode for Performance Based Thresholding (PBT)



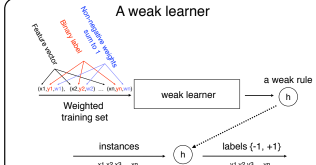
Learning a Shape Recognizer



Boosting Details

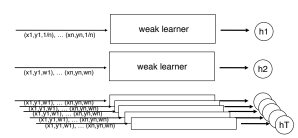
for more information see: www.cse.ucsd.edu/~yfreund/papers/IntroToBoosting.pdf

A weak learner



The weak requirement: $\left|\frac{\sum_{i=1}^{n} y_i \hat{y}_i w_i}{\sum_{i=1}^{n} w_i}\right| > \gamma > 0$

The Boosting Process



$$F_T(x) = \alpha_1 h_1(x) + \alpha_2 h_2(x) + \ldots + \alpha_T h_T(x)$$
$$f_T(x) = sign(F_T(x))$$

AdaBoost

$F_0(x) \equiv 0$

for $t = 1..T$

$w_i^t = \exp(-y_i F_{t-1}(x_i))$

Get h_t from $weak-learner$

$\alpha_t = \frac{1}{2}\ln\left(\sum_{i:h_t(x_i)=1, y_i=1} w_i^t \Big/ \sum_{i:h_t(x_i)=1, y_i=-1} w_i^t\right)$

$F_{t+1} = F_t + \alpha_t h_t$

[Freund, Schapire 1997]