Classification of Sperm Heads using Active Contours and Morphological Features

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Outline

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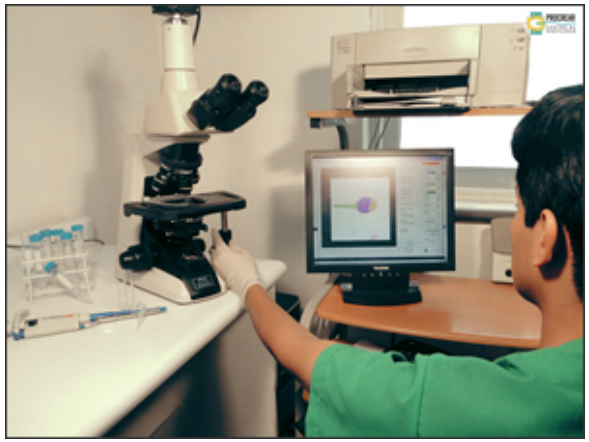
Introduction

Infertility is a clinical problem more common than is believed that affects up to 15% of couples,
with emotional and physiological implications.

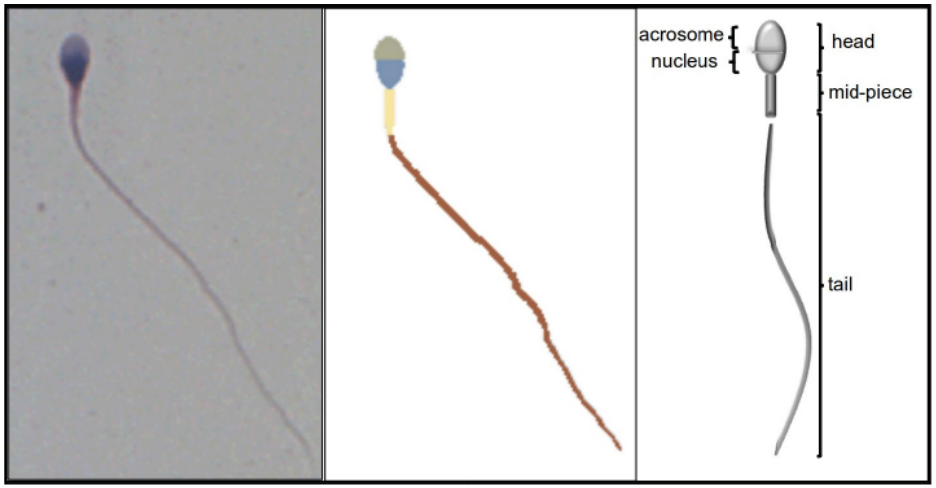
Introduction

A semen analysis according to standard criteria, is one of the first steps in the evaluation of male partner of an infertile couple.



Rigorous application of existing guidelines + high laboratory standards + emphasis on identifying categories of abnormal sperm heads –> significant clinical utility when deciding for an infertility treatment.

Our Problem



a) b) c)

Figure 1: **Morphology of the normal human sperm.** **(a)** Representative bright field image of a normal human sperm (Image size: 277×144 pixels $\approx 58 \times 31$ μm). **(b)** Manually segmented ground-truth of the sperm: Head, acrosome, nucleus, mid-piece and tail of stained spermatozoa. **(c)** Schematic drawing of the principal components of a normal human sperm. Oval head: 5μm long and 3μm wide. Acrosome: $40 - 70\%$ of the head area. Mid-piece: 5μm. Tail: 55μm.

Our Problem

The computer assisted sperm morphology assessment has been fueled by:

- Inherent lack of objectivity in the evaluation of human sperm morphology
- Difficulty in standardizing, implementing and controlling manual methods
- High degree of variation within and between laboratories and technicians

Outline

Previous Approaches to Morphological Analysis

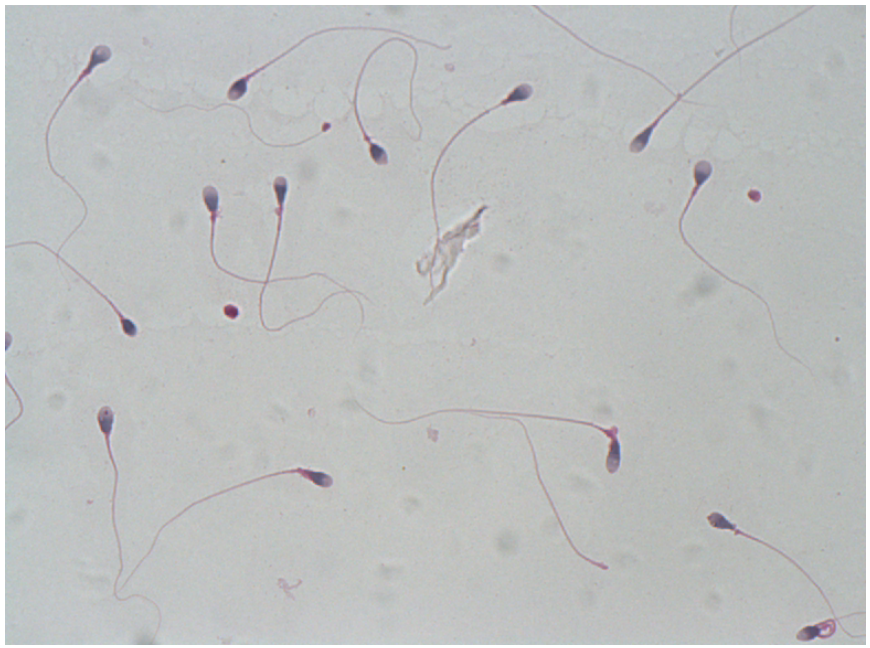
There are few approaches to evaluate semen samples automatically, even though none of them proposes a complete framework:

- Park et al. (1997): segmentation of sperm heads using the strategic Hough Transform.
- Nafisi et al. (2005): detection of sperm cells (including tail) using best-fit ellipses.
- Carrillo et al. (2007): segmentation of sperm heads and mid-pieces using thresholding and morphological masks.
- Bijar et al. (2012): segmentation of sperm acrosome, nucleus, mid-piece and identification of tails using a Bayesian classifier with entropy based expectation maximization and a Markov random field.

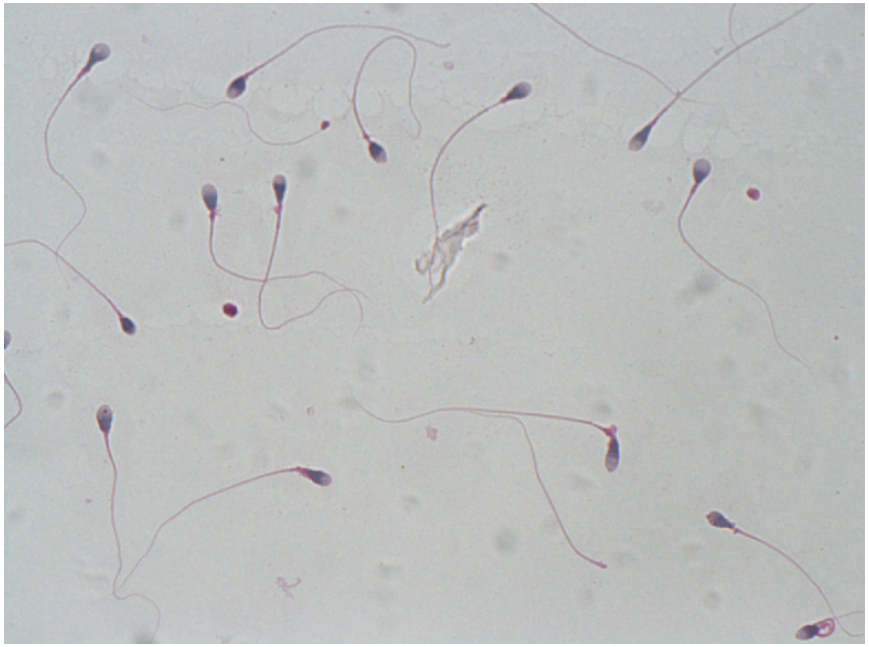
Outline

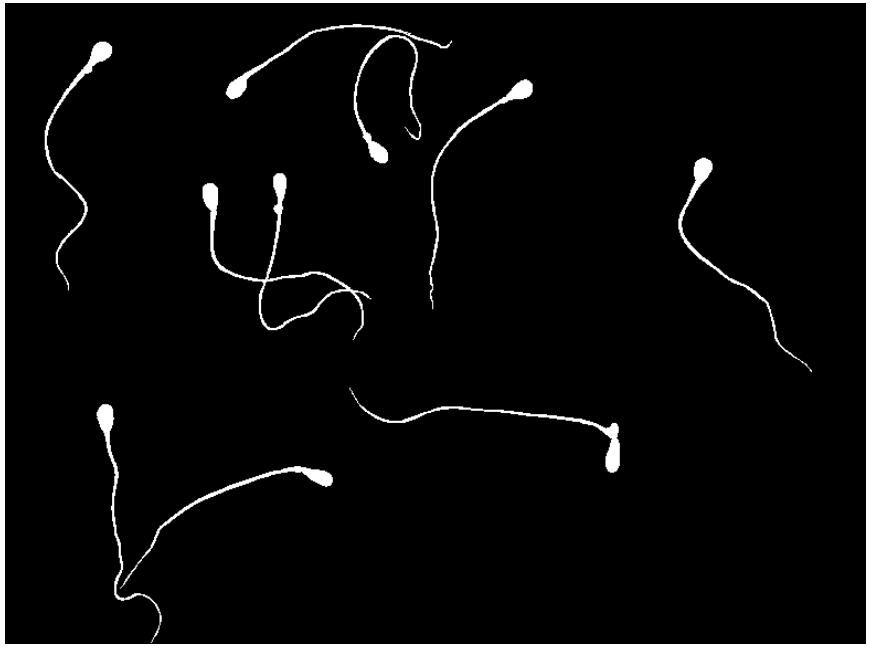
Sperm Segmentation Gold-standard

- Built with the cooperation of a referent expert in the field.
- Twenty images with more than two hundred sperm cells plus hand-segmented masks.
- morfologia.cedai.cl/public



Sperm Segmentation Gold-standard





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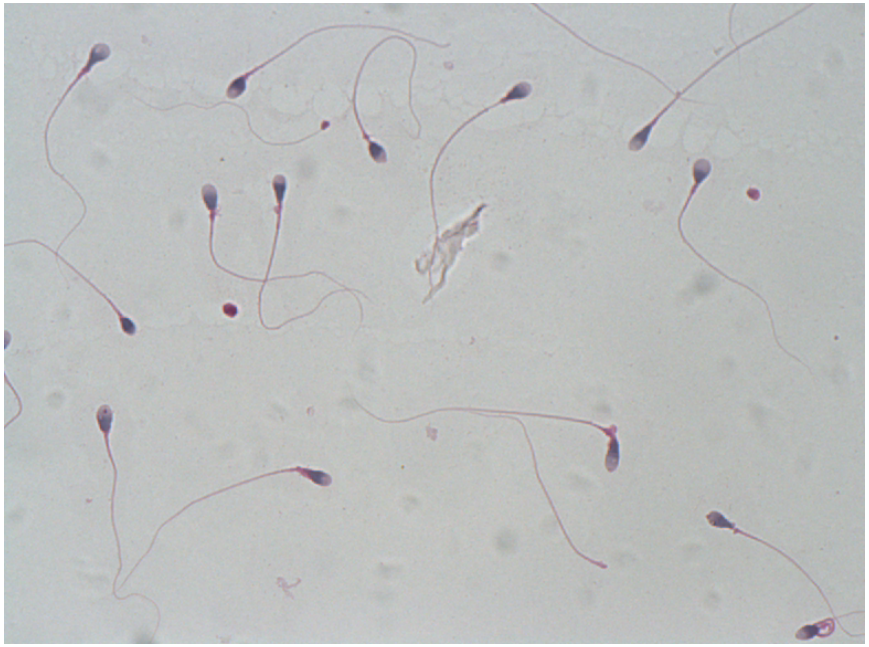

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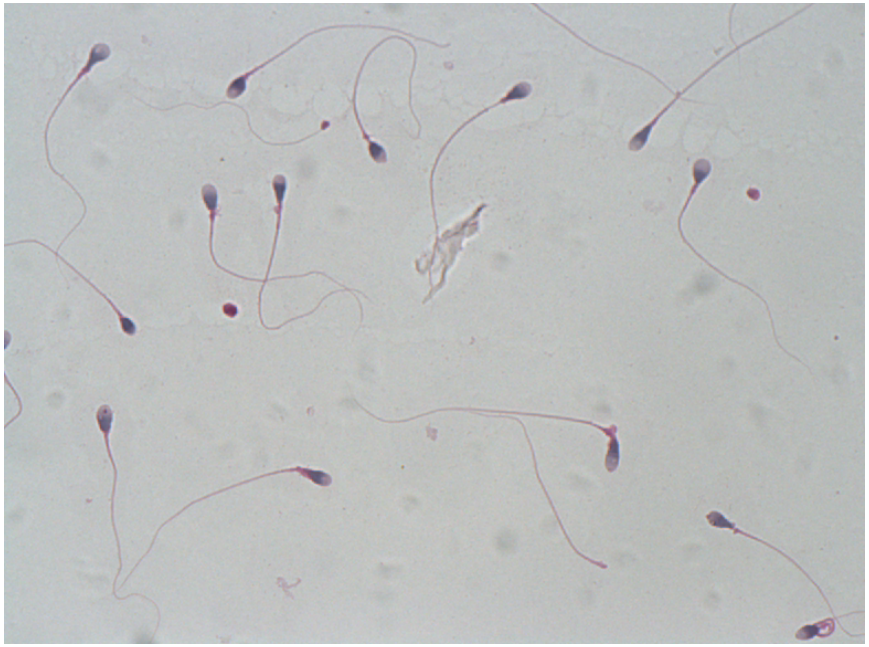

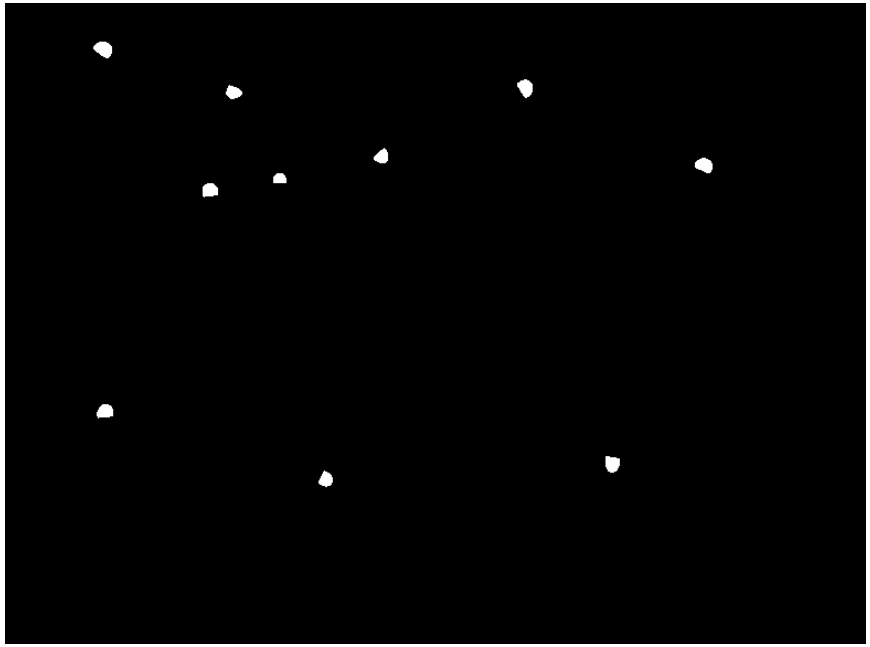

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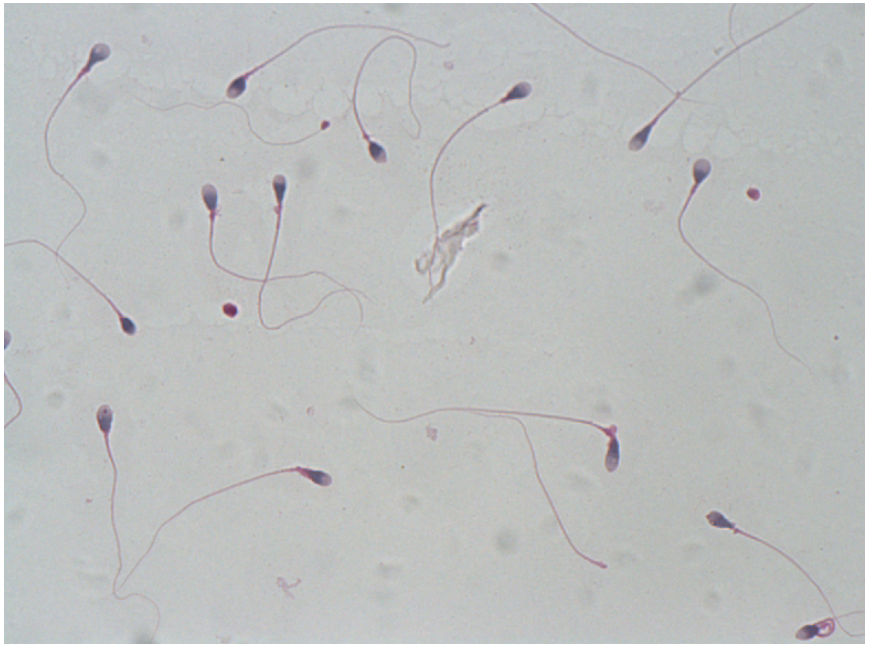

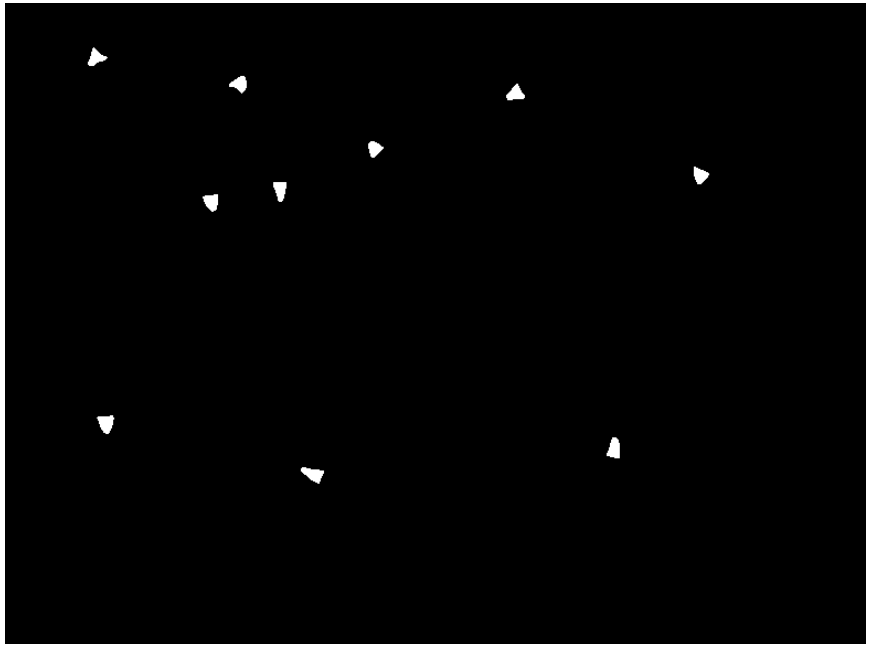

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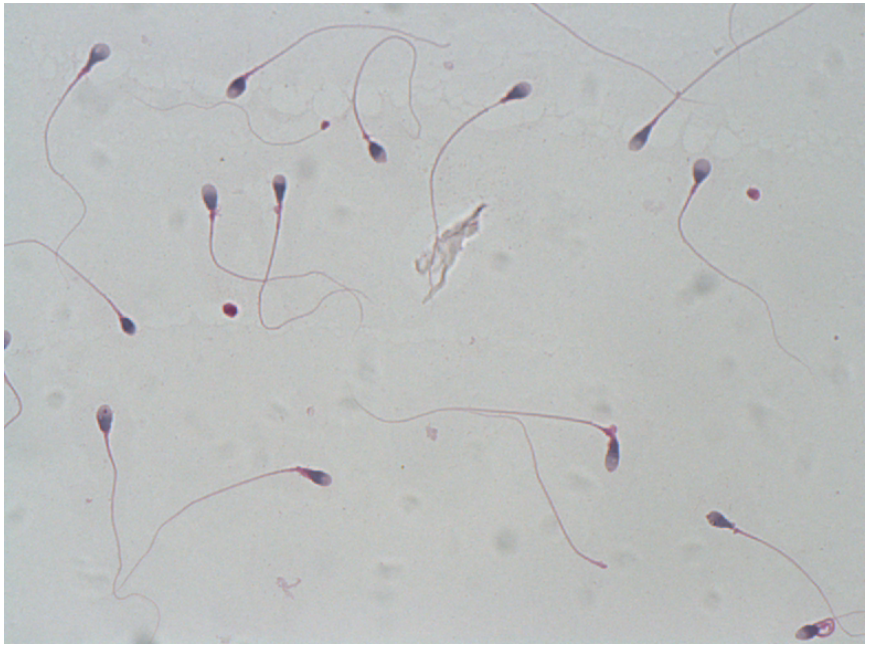

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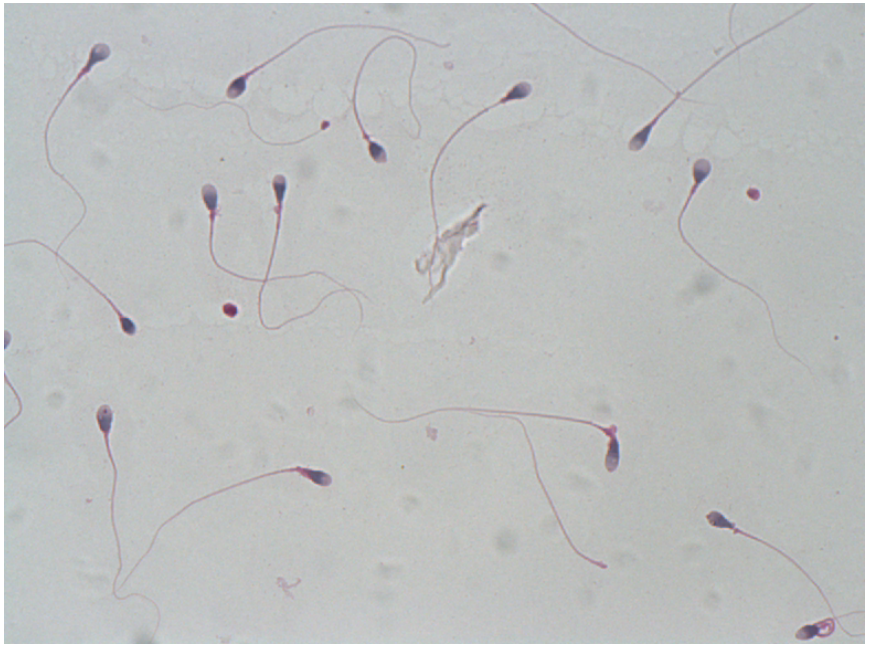
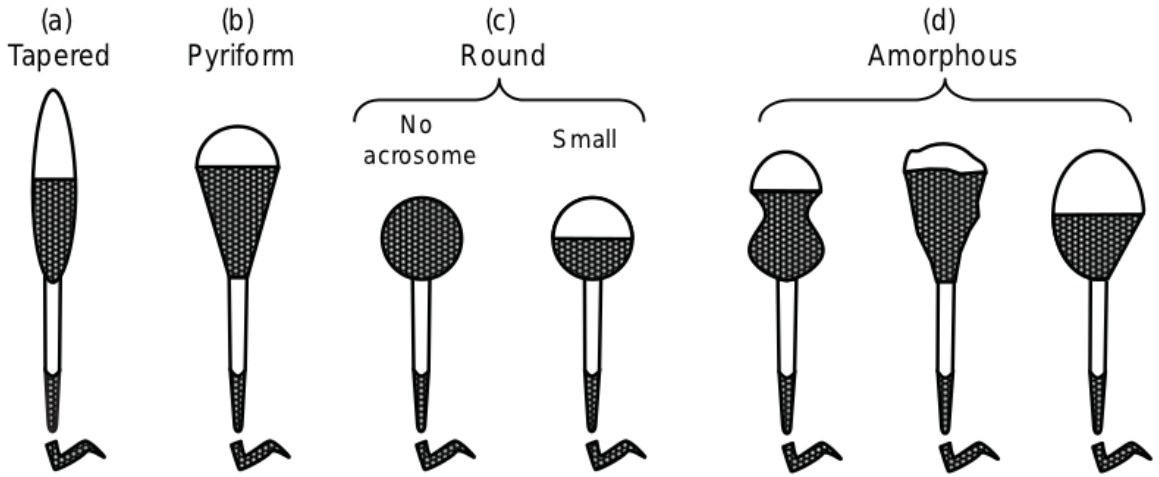
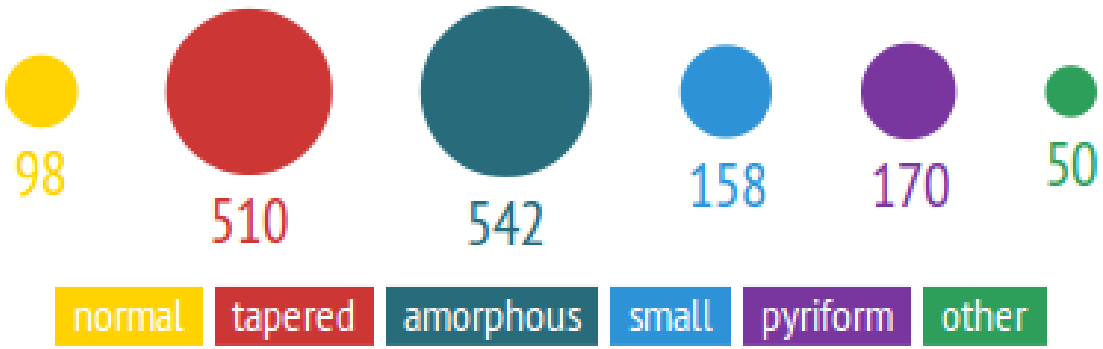


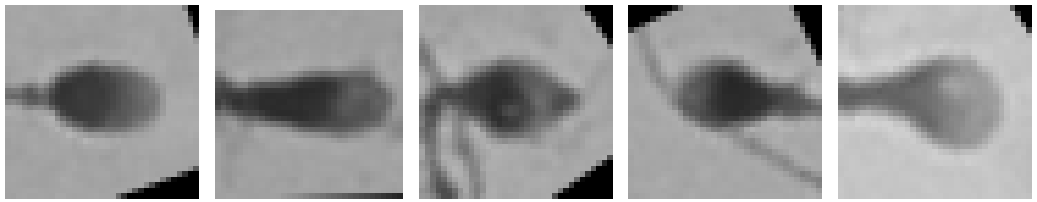
Sperm Classification Gold-standard

- In process with the cooperation of four referent expert in the field
- 152 images with more than 1500 sperm cells classified.
- morfologia.cedai.cl/



Sperm Classification Gold-standard



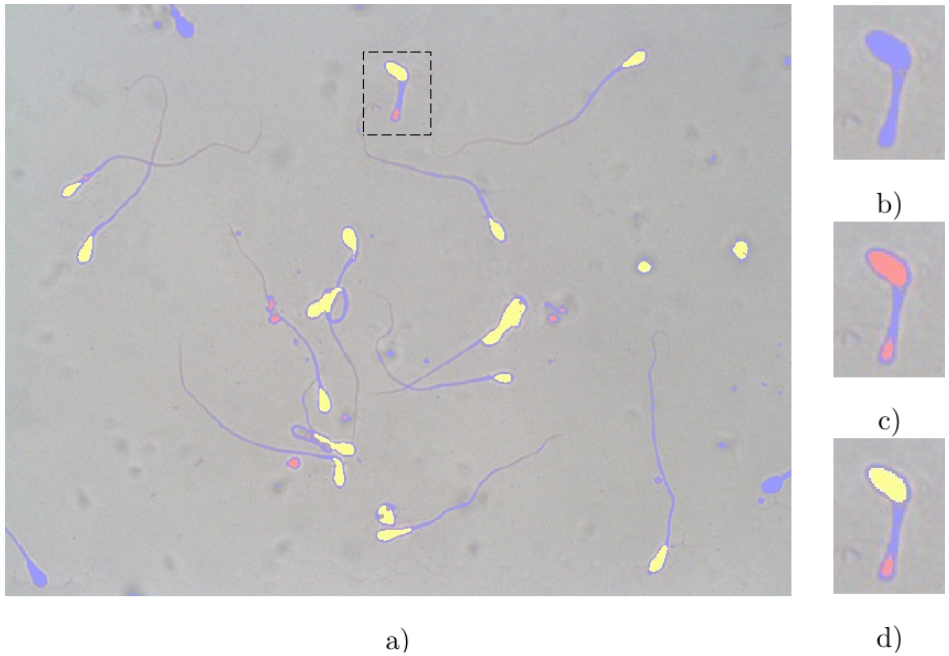


Outline

General Ideas of Our Framework

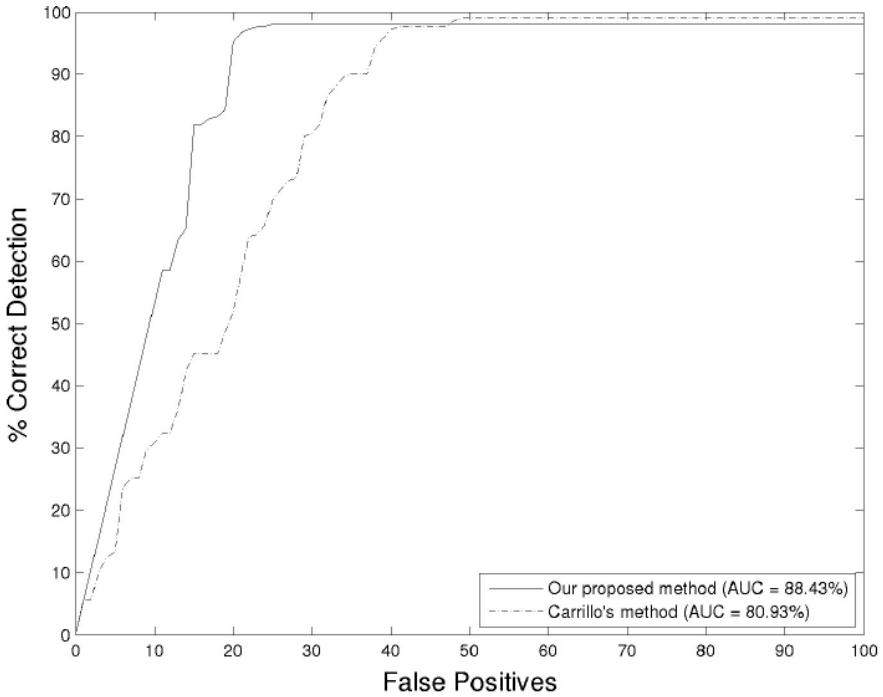
- Use of color space combinations
  - RGB withdraws: high correlation among components, no representation of color differences in uniform scale
  - RGB + YCbCr + L*a*b* : intensity and chromatic components easily and independently controlled
  - L*a*b* : perceptual uniformity, efficient in measurement of small color differences (Euclidian distance)
  - YCbCr : Euclidian distance for color space
- Use of clustering method
  - k-means : illumination variation problem
- Identification of sperm head direction

Detection of Sperm Heads



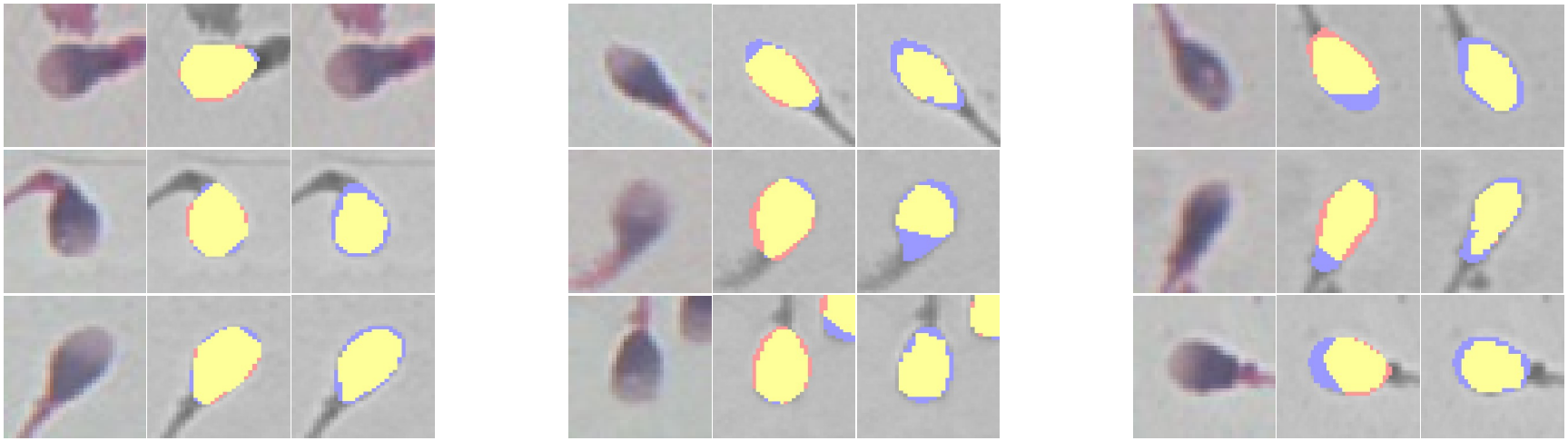
Detection of sperm heads. **(a)** Original image in RGB color space with resulting ROIs marked on it. **(b)** Blue color represents ROIs after applying *k-means* in RGB and L*a*b* color spaces. **(c)** Red color represents ROIs after erasing tails and sperm cells at border. **(d)** Yellow color represents ROIs after erasing by size. Yellow pixels constitute the final ROIs of this stage. Image size: 780×580 pixels $\approx 164 \times 122 \mu m$.

Detection of Sperm Heads



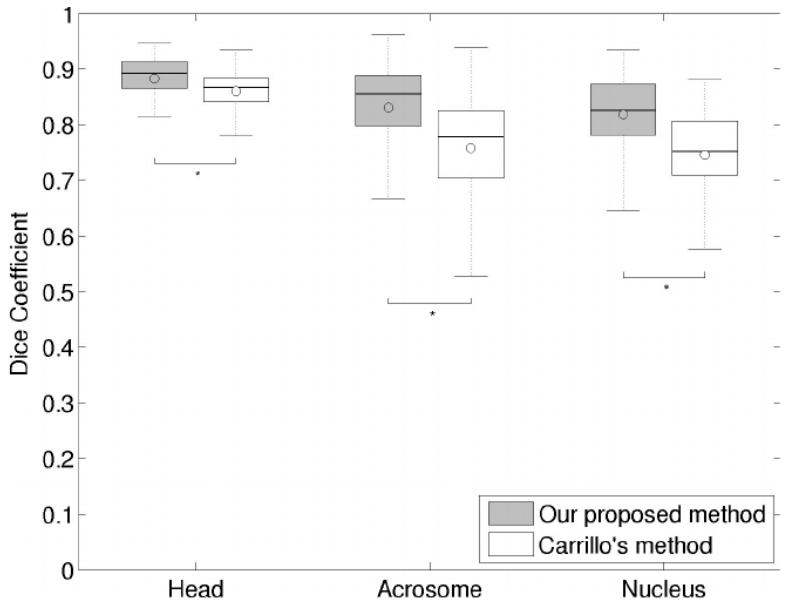
ROC curves for sperm head detection. Detection rate and number of false positives according to the results of our proposed method (continuous line) and Carrillo's method (dotted line), versus hand-segmented masks.

Segmentation of Sperm Heads



Results of head segmentation. We show representatives for best results (left section), center section for average results, and right section for worst results. For each section, we present the original (first column), our result (second column) and Carrillo's method result (third column). The blue color represents the gold-standard, red presents our proposed/Carrillo's method and yellow the overlap between gold-standard and our proposed/Carrillo's method.

Dice Coefficient

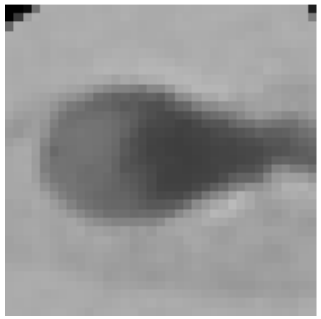
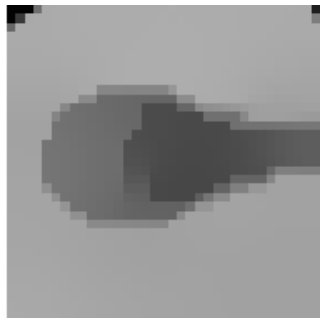


Dice coefficient for head, acrosome and nucleus. On each box, the edges are the $25th$ and $75th$ percentiles and the whiskers extend to the most extreme data points that are not outliers. For each box, we show the median value (horizontal line) and the sample mean ($\circ$). Statistically significant differences between our proposal (grey) and Carrillo's method (white) using Wilcoxon rank sum test are indicated ($*p < 0.05$).

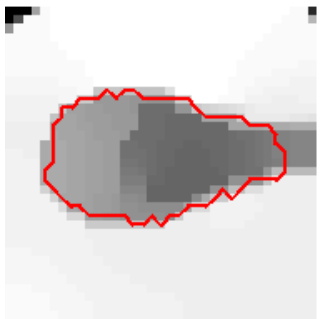
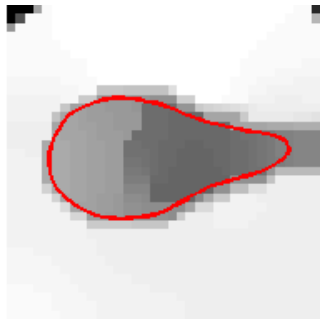
Outline

General Ideas

- Use of anisotropic diffusion

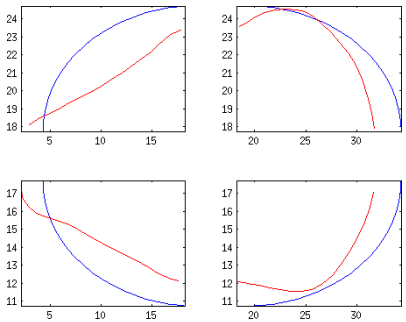



- Use of active contours over anisotropic diffusion results with our segmentation result as initial curve

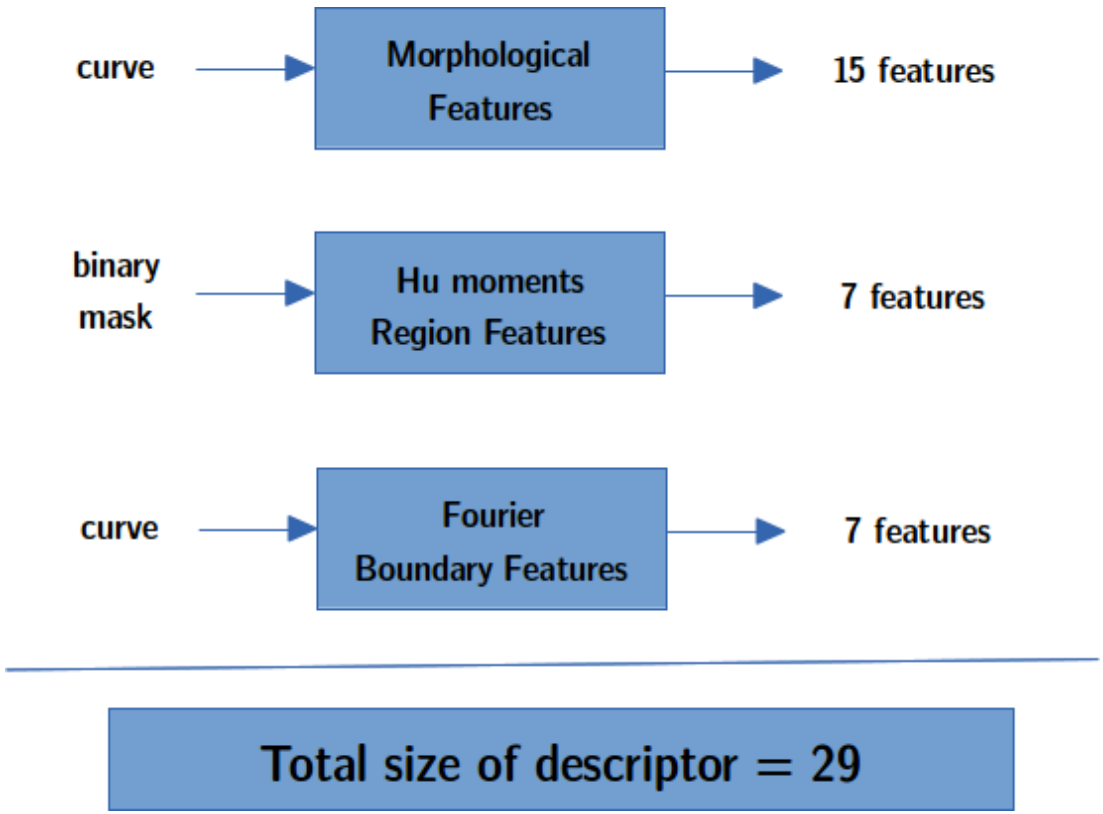



Morphological Features

- Based on seed characterization ideas
- Basics: area, elongation, perimeter, maximun curvature, minimun curvature
- Complex: roundness, rectangularity
- Ellipse-Fitness: quadrant-fitness



Sperm Head Descriptor

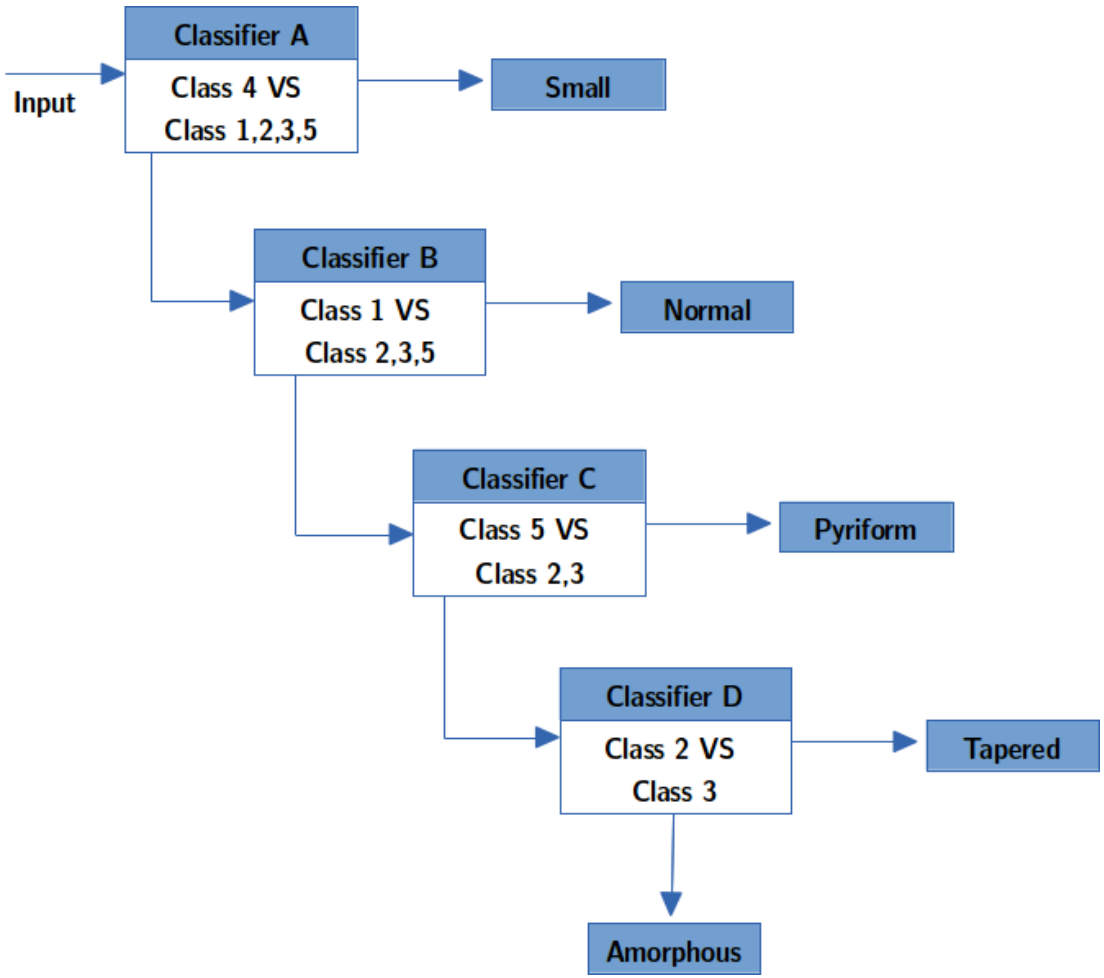


Outline

Classification of Sperm Heads

- Gold-standard for sperm head classification*
- One classifier for each class (two-class problem)
- Decision template to combine individual outputs
- Cascade-approach of individual classifier types:
  - 1-to-all
  - 1-to-1

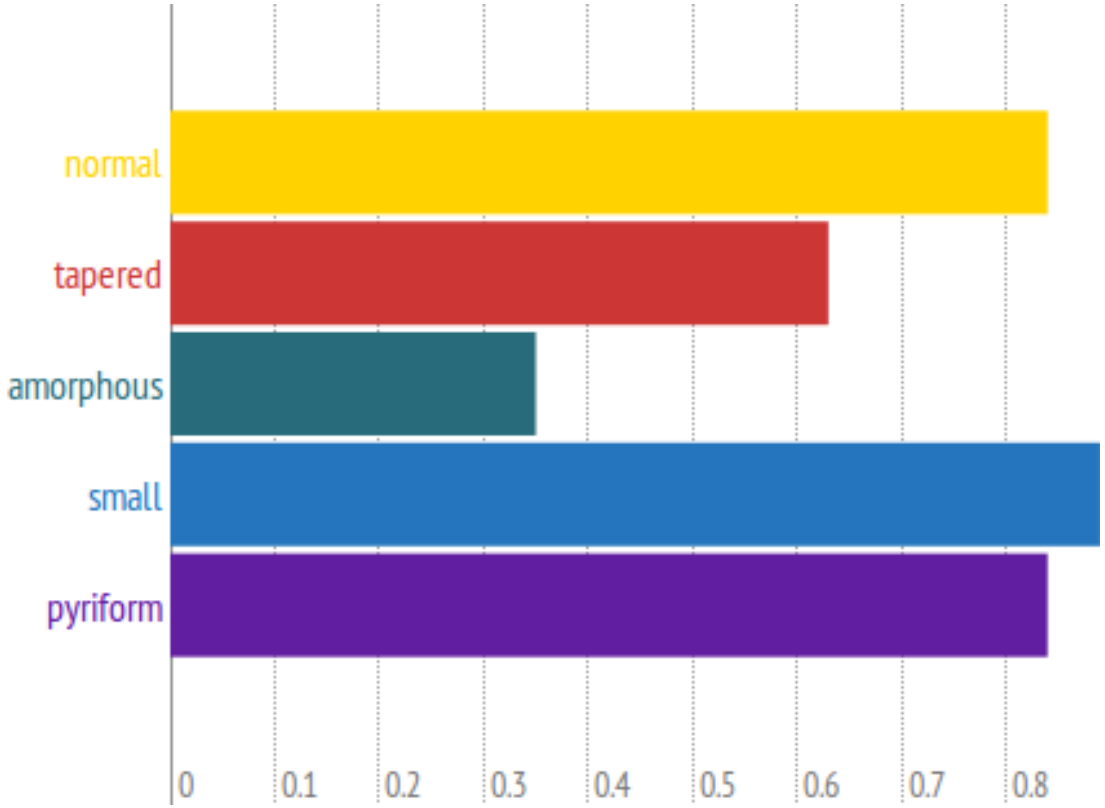
Classification of Sperm Heads



Our Dataset

- One expert classification (by now)

Our Results



Classification rate per class over a dataset with 338 sperm heads.

Summary

- Our work is aimed to propose a novel methodology to accurately characterize sperm components to facilitate the subsequent morphological sperm analysis with results similar to those of referent international experts in the field, focusing on a depth analysis of abnormal sperm for fertility diagnosis, prognosis, reproductive toxicology, basic research or public health studies.

Summary

- So far, we built a gold-standard for head sperm parts segmentation and sperm head classification.
- Also, we have developed an improved two-stage framework for detection and segmentation of human sperm head characteristics using color space combinations together with a clustering method, outperforming the-state-of-the-art method.
- Now, our work is focused in the characterization and classification stage, aiming to propose a new classification scheme with classification rate within the inter-expert variability.

Summary

- We need to reinforce the feature extraction stage.
- There are no good results using a single classifier, thus we will continue with combination of classifiers approach.
- So far, our average classification rate is 70% using 5 classes.