Electronic Letters on Computer Vision and Image Analysis 13(2):19-21, 2014

Adaptive Texture Description and Estimation of the Class Prior Probabilities for Seminal Quality Control

Víctor González-Castro

Dep. of Elect., Systems and Automatic Engineering, University of León, Campus de Vegazana s/n, 24071, León, Spain
Advisor/s: Enrique Alegre and Rocío Alaiz-Rodríguez
Date and location of PhD thesis defense: 29 June 2011, University of León

Received 30th January 2014; accepted 25th May 2014

1 Motivation of the PhD thesis

Semen quality assessment is a crucial task in artificial insemination processes, both for humans and animals. Animal artificial insemination allows farmers to save time and money (e.g. working with a limited number of animals). They purchase semen samples to companies devoted to their production and commercialization, but they need these samples to be optimal for fertilization. As a result, semen production centers have to carry out rigorous quality control procedures to guarantee good standards

A semen sample with a high proportion of (i) dead spermatozoa, or (ii) sperm heads with damaged acrosomes* will have low fertilization potential. Therefore, sperm vitality and acrosome integrity are two of the parameters evaluated by veterinaries in semen quality control processes. Currently, both are assessed manually, by means of a visual process which entails expensive equipment, such as stains and fluorescence microscopes. Moreover, they may be a source of errors, as any manual process is.

The goal is to develop an automatic system to estimate the proportions of damaged acrosomes and dead spermatozoa using just a computer and a digital camera connected to a phase contrast microscope, which is affordable by any laboratory. The contributions made on this PhD thesis in the fields of Image Processing and Machine Learning [1] can be helpful for this goal. Concretely, several texture description approaches have been evaluated for this task. Furthermore, a new intelligent segmentation process, an *adaptive* texture description method, and two robust approaches for estimating class proportions of unlabeled datasets have been proposed. All these methods are applied to automatic boar semen quality estimation.

2 Contributions

2.1 Intelligent boar sperm segmentation using thresholding and Watershed

A bad segmented sperm head could lead to further errors in description and classification stages. Therefore, it is necessary to minimize the number of bad segmentations and to detect when a head is not well segmented, thus avoiding its further processing. To accomplish that, in this thesis an approach which combined (i) classical Otsu

Correspondence to: <victor.gonzalez@unileon.es>

Recommended for acceptance by <Alicia Fornés and Volkmar Frinken>
ELCVIA ISSN:1577-5097
Published by Computer Vision Center / Universitat Autònoma de Barcelona, Barcelona, Spain

*The acrosome is a membrane that covers the anterior part of the sperm head and makes possible the penetration into the ovum thresholding and morphological operations, (ii) the Watershed transform and (iii) a method to automatically detect the bad segmented heads using criteria based on area and eccentricity is presented.

This method obtained rates of correct segmentations of around 97%. The reader interested in more details is addressed to the PhD thesis manuscript and to [2].

2.2 Texture Descriptors for Boar Semen Quality Assessment

In this PhD thesis, multi-resolution texture analysis has been assessed with the goal of characterizing the integrity of boar sperm acrosomes. Concretely, these texture descriptors are:

- The Curvelet Statistical Features (CSF) and Wavelet Statistical Features (WSF) consist on the Mean and Standard Deviation computed from (a) the grey levels of the original texture and (b) the coefficients yielded by the discrete Curvelet (in the CSF) or Wavelet (in the WSF) transforms.

- The Curvelet Co-occurrence Features (CCF) and Wavelet Co-occurrence Features (WCF) are some of the Haralick Features computed from the Grey-level Co-occurrence matrix of (a) the original texture and (b) the coefficients of the Curvelet (in the CCF) or Wavelet (in the WCF) transforms.

These descriptors have been compared with some shape descriptors: the Hu, Flusser, Legendre and Zernike moments. The reader interested in further details is addressed to [3] or to the PhD thesis manuscript.

Classification was carried out by means of a back-propagation neural network. Results show that all texture descriptors are better than the shape descriptors for this particular problem. In addition, the best descriptor was the CCF, with an overall accuracy of 97% and an area under the ROC curve of 0.995.

2.3 Adaptive Geodesic Pattern Spectrum (AGPS)

The third contribution of this thesis is an adaptive Mathematical Morphology approach which uses a Geodesic distance criterion to make the shape of the structuring element (SE) change at each pixel of the image. Therefore, morphological operations are adapted to the local features of each point with no need of a priori information about the images. This method has been used to compute the Adaptive Pattern Spectrum of textures with the goal of characterizing them [4].

Experiments were carried out using (1) textures of different materials extracted from the MIT Medialab Vision Texture (VisTex) database and (2) a dataset of alive and dead boar spermatozoa. In the first case, results suggest that the adaptive pattern spectrum is more powerful than the classical (i.e. non-adaptive) one when textures have similar texel shapes. In the detection of alive and dead spermatozoa, the adaptive approach also yields better results than the classical one (achieving an area under the ROC curve of 0.74 against 0.66). It is true that these results are not good enough to encourage the use this descriptor in a commercial system but, according to veterinary experts, recognizing alive and dead spermatozoa is much more complex than classifying intact and damaged acrosomes (indeed, it is still an open problem).

2.4 Going Beyond Classification: Class Distribution Estimation

Regarding semen quality assessment tasks, veterinaries are not interested in the classification of each individual spermatozoon, but in the estimation of the *a priori* probability (i.e. the proportion) of the class of interest (i.e. damaged acrosomes or dead cells). The most straightforward approach to estimate it is to count the labels assigned by the classifier. This naïve method is known as *Classify and Count* (CC). However, this estimation is not reliable, as the classifier performance drops when there is a difference between the a priori probabilities of the actual (test) set and the set the classifier was generated with. This is the case in this particular application, due to several issues such as animal/farm variability, conservation conditions of the semen samples, etc.

Two methods have been proposed in this PhD thesis:

- The first one, called *Posterior Probability* (PP), is based on the posterior probability estimates provided by the classifier.
- The second one is based on measuring distributional divergences by means of the Hellinger distance. Two versions of the method have been presented: one measures the Hellinger distance using the input data as-is (HDx), and other one which relies on the outputs of a classifier (HDy).

These approaches have been compared with the naïve method CC, and with other approaches based on the confusion matrix of the classifier. Theoretical aspects about them are given in [5], as well as in the PhD thesis manuscript.

The methods have been validated by means of three experiments, using (i) 15 datasets from the UCI database, (ii) data from sperm heads with intact/damaged acrosomes and (iii) alive/dead spermatozoa. The first one showed that the HDy method outperforms the other proposals, being the differences in performance statistically significant.

In the second experiment 10 different scenarios were assessed, where the proportions of damaged acrosomes in the test set varied between 5% and 50%. The PP and HDy approaches got Mean Relative Errors which ranged from 13.92% to 1.55%, depending on the scenario. According to veterinaries, these error rates are low enough to use this method in commercial systems, as the proportions of damaged acrosomes are low in real semen samples (usually under 20%).

Moreover, these proposals have proven to be robust to drops in the quality of the classifier.

Finally, in the alive/dead sperm experiment, quantification results with PP, HDx and HDy achieved absolute errors around 0.05 and 0.06 for any proportions of dead cells in the test set. These error rates are quite interesting, considering the poor classification accuracies achieved in the classification of these images (see section 2.3).

References

[1] González Castro, V., 2011. Adaptive Texture Description and Estimation of the Class Prior Probabilities for Seminal Quality Control. URL: `https://www.educacion.gob.es/teseo/mostrarRef.do?ref=934893`.

[2] González-Castro, V., Alegre, E., Morala-Argello, P., Suarez, S.A., 2009. A Combined and Intelligent New Segmentation Method for Boar Semen Based on Thresholding and Watershed Transform. International Journal of Imaging 2, 70–80.

[3] Alegre, E., González-Castro, V., Alaiz-Rodríguez, R., García-Ordás, M.T., 2012. Texture and Moments-based Classification of the Acrosome Integrity of Boar Spermatozoa Images. Computer Methods and Programs in Biomedicine 108, 873 – 881.

[4] González-Castro, V., Alegre, E., García-Olalla, O., Fernández-Robles, L., García-Ordás, M., 2012. Adaptive Pattern Spectrum Image Description Using Euclidean and Geodesic Distance without Training for Texture Classification. Computer Vision, IET 6, 581–589.

[5] González-Castro, V., Alaiz-Rodríguez, R., Alegre, E., 2013. Class Distribution Estimation Based on the Hellinger Distance. Information Sciences 218, 146 – 164.