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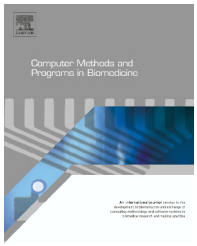

Acrosome integrity assessment of boar spermatozoa images using an early fusion of texture and contour descriptors

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ABSTRACT

The assessment of the state of the acrosome is a priority in artificial insemination centres since it is one of the main causes of function loss. In this work, boar spermatozoa present in gray scale images acquired with a phase-contrast microscope have been classified as acrosome-intact or acrosome-damaged, after using fluorescent images for creating the ground truth. Based on shape prior criteria combined with Otsu's thresholding, regional minima and watershed transform, the spermatozoa heads were segmented and registered. One of the main novelties of this proposal is that, unlike what previous works stated, the obtained results show that the contour information of the spermatozoon head is important for improving description and classification. Other of this work novelties is that it confirms that combining different texture descriptors and contour descriptors yield the best classification rates for this problem up to date. The classification was performed with a Support Vector Machine backed by a Least Squares training algorithm and a linear kernel. Using the biggest acrosome intact-damaged dataset ever created, the early fusion approach followed provides a 0.9913 F-Score, outperforming all previous related works.

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1. Introduction

Herd fertility is critical to the prosperity of any breeding animal company. Artificial insemination is both a fertility treatment for humans and a typical method in breeding of pigs or dairy cattle, dominating the reproductive process of many farms. It brings superior species, mainly for human consumption, requiring that mating is performed using viable sperm.

Computer Assisted Semen Analysis (CASA) systems are more and more present in sperm analysis centres [1]. CASA system is used to assess the semen quality of many species such as bulls [2], pigeons [3] or cats [4], not only humans. It is an automatic or semi-automatic and standardised equipment which allows to assess sperm concentration [5], motility [6] or morphology [7] in a semen sample [8]. However, the major cause of function loss is damage of acrosome due to the leakage of cellular components and inactivation of crucial

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proteins [9]. Up to our knowledge, the only way of automatically measuring the state and vitality of a sperm sample is using fluorescence images in combination with Cell Counters or fluorescence microscopy which is a very expensive device. Otherwise, the stained samples have to be manually assessed which requires the use of veterinary experts and specialised equipments leading to an expensive and non-objective task. This work deals with the automatic and reliable assessment of the state of the boar acrosome using phase contrast images, so just a phase contrast microscope, a high-featured digital camera and a computer are needed.

There are few works related with this topic and in most of them the texture description makes up the basic operation. González et al. [10] proved that the texture features derived from the Discrete Wavelet Transform (DWT) allow to classify the acrosome integrity with an accuracy of 92.09%. Following this idea, Alegre et al. [11] used the first order statistics derived from the co-occurrence matrix of the image, both computed from the original image and from the coefficients yielded by the DWT. They affirm that this approach outperforms moments-based descriptors (Hu [12], Zernike [13,14] and Legendre [15]) in terms of the classification accuracy they provide yielding the 94.93% which suggests that the edge and some shape features are not enough to describe the state of the acrosome. Besides texture and moments, the gradient magnitude along the contour of the sperm head has been used to describe the acrosome integrity. Learning Vector Quantification (LVQ) has been applied in 2007 with only three prototypes and a hit rate of 83.5% [16] and more recently in 2012 [17] with four prototypes reaching a hit rate of 93.2%. Alegre et al. in 2013 [18] improved this approach by using 7 inner contours and computing a local texture descriptor for each point of the seven contours and classifying with Relevance LVQ, obtaining the best result so far with a hit rate of 99%. As we can see, global and local texture description of the head of the spermatozoa and contour description of the shape of the acrosome have been considered in previous works. Here we present a comparison and combination of the three approaches with different methods applied in a bigger dataset.

Not only the description of the cells is important but the segmentation of the heads, if any, and the classification step can be critical. González-Castro et al. [19] proposed a novel and intelligent segmentation method based on a changing threshold and on a Watershed with which 90.96% of 763 spermatozoa images have been correctly segmented. Bijar et al. [20] segmented the acrosome of human spermatozoa through a method based on a Bayesian classifier which utilizes the adaptive mixtures method (AMM) and Markov random field (MRF) model to obtain and upgrade the class conditional probability density function (CCPDF) and the a priori probability of each class. As regard to the classification, unsupervised classification methods proved to have better performance than supervised ones [21]. However besides this experiments, it is very important to yield an accurate classification. [22] and [23] estimate the true and unknown proportion of damaged cells in a sample with help of the Hellinger distance by quantifying the unknown a priori probabilities of test sets.

The assessment of the vitality of a spermatozoon is a close related topic which has also been studied recently. Most of the works are also based on texture description. Sánchez et al. [24] used the intensity distribution of the cytoplasm densities of the cells whereas [25] adds standard deviation information to the Local Binary Pattern (LBP) descriptor, [26] presents a new textural descriptor called NCSR and [27] shows the performance of LTP texture descriptor.

The rest of the paper is organized as follows: Section 2 describes the methodology used to determine the spermatozoa description. The dataset, experimental setup and experimental results are presented in Section 3. Finally, Section 4 shows our conclusions.

2. Methodology

In this work, we have assessed boar sperm integrity by describing images that contain spermatozoa heads. In particular, global and local texture and the contour of spermatozoa heads have been chosen to describe and classify them as acrosome-intact or acrosome-damaged. For obtaining the global texture, 13 Haralick features computed on the GLCMs of the original image and on the images obtained in the first Haar DWT decomposition were used. Regarding contour, Fourier Shape Descriptors were calculated whereas rotation invariant uniform LBPs were obtained in order to describe the local texture of the heads. Moreover, some different early fusion approaches of the aforementioned descriptors have been evaluated to thoroughly describe the heads. Here we propose the use of WFLP (Wavelet Fourier Local Pattern) as we have named the new descriptor obtained with the specific combination of the three previous approaches that yielded the better performance. A general diagram of the steps followed can be viewed in Fig. 1.

2.1. *Segmentation of the spermatozoa heads*

Previously to carry out the description of the spermatozoa it is necessary to segment the spermatozoa heads so that the computed descriptors for texture and contour correspond only to the region of interest. We used the ideas presented in the González-Castro et al. [19] work, where images of alive and dead spermatozoa in positive phase contrast are segmented. We have followed the same steps but modifying the validation criteria in such a way it works when the purpose is to segment acrosome-intact and acrosome damaged spermatozoa heads. The González-Castro et al. [19] method combines a first segmentation step, where some morphological operations and Otsu's thresholding is carried out, with a second segmentation using a Watershed transform, in cascade. After the first step, the images that do not fulfil the validation criteria explained below are segmented again and, if they do not accomplish them again, they are rejected.

The criteria for rejecting a wrongly segmented image are based on specific values that have been obtained experimentally and that are the following ones:

1. The area, measured in pixels, of the obtained head can not be smaller than the 75% of the average area of the whole dataset. This average area was computed using a ground truth where the heads were segmented manually. As long as the camera resolution, and the magnification of

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