COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 108 (2012) 873–881

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

Texture and moments-based classification of the acrosome integrity of boar spermatozoa images

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ARTICLE INFO

Article history:
Received 13 May 2010
Received in revised form
28 December 2011
Accepted 11 January 2012

Keywords:
Acrosome integrity
Boar semen
Texture descriptors
Discrete Wavelet Transform
Invariant moments
Neural Networks
k-Nearest Neighbours

ABSTRACT

The automated assessment of the sperm quality is an important challenge in the veterinary field. In this paper, we explore how to describe the acrosomes of boar spermatozoa using image analysis so that they can be automatically categorized as intact or damaged. Our proposal aims at characterizing the acrosomes by means of texture features. The texture is described using first order statistics and features derived from the co-occurrence matrix of the image, both computed from the original image and from the coefficients yielded by the Discrete Wavelet Transform. Texture descriptors are evaluated and compared with moments-based descriptors in terms of the classification accuracy they provide. Experimental results with a Multilayer Perceptron and the *k*-Nearest Neighbours classifiers show that texture descriptors outperform moment-based descriptors, reaching an accuracy of 94.93%, which makes this approach very attractive for the veterinarian community.

1. Introduction

Proper semen quality assessment is an important problem in medical and veterinarian research fields. It plays an important role in dealing with human fertility problems or with breed improvement of some species such as boars. The porcine industry is one of the most important fields where it is applied and it is focused on obtaining better individuals for human consumption in each generation.

In the last decade, several computer assisted approaches have been developed to evaluate the quality of semen samples. These approaches were first designed for human semen analysis [1], but they have been currently adapted to other species [2]. These systems are essentially based on parameters such as motility or morphometry [3–6], as they are directly related to the semen quality. However, up to our knowledge, the evaluation of the acrosome integrity of the spermatozoon heads is carried out manually, using stains and there are not any computer assisted tools for that analysis. This manual assessment has several drawbacks such as its high cost in terms of time, its lack of objectivity, or the requirement of specialized veterinarian staff and equipments. Hence, it would be very interesting to get an automatic classification of the acrosomes (intact or damaged). It would only require a high-featured digital camera and a computer, and it would let veterinarian experts save a lot of time when determining the proportion of damaged cells within a sample.

Texture analysis and classification have been applied to biology and medicine in the literature (e.g. to distinguish ulcer

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doi:10.1016/j.cmpb.2012.01.004

regions from normal regions in capsule endoscopy images [7], to classify human embryonic stem cell nuclei [8] or to recognize leukocytes [9]), providing quite good results. Other examples are the works carried out by Morales et al., who apply texture analysis to the selection of human embryos for in vitro fertilization [10] or Perner et al., who classify Hep-2 cells into 6 different classes [11]. Sørensen et al. extract quantitative measures of emphysema severity computing Local Binary Patterns from CT images of lungs [12]. All of these works show accuracies around 90%.

One of the most powerful techniques is the multiresolution texture analysis. A successful example is the Discrete Wavelet Transform (DWT), which is widely employed for several applications. For instance, Zhou and Peng use the DWT to extract some features from fly embryo images in order to recognize various gene-expressed structures within them [13], providing accuracies near to 100%. Tsantis et al. [14] extracts some morphological and wavelet-based features from ultrasound images in order to evaluate malignancy risk of thyroid nodules. Quellec et al. proposed in [15] a content-based image retrieval method for diagnosis aid in medical image which compares signatures built from the wavelet transform of the images by means of a distance criterion. Wavelet textural properties are also used for breast cancer analysis applications [16], or in order to analyze the images captured by a wireless capsule endoscope, in the examination of diseases of small bowel [17].

Computer-based systems designed for semen analysis tasks should reliably segment the heads of the spermatozoa [18], extract the patterns which characterize them and finally classify those patterns in order to estimate how many damaged acrosomes contain each semen sample. There are few computer vision works that deal with boar sperm analysis. Furthermore, there are not any commercial tools at all that classify the spermatozoon heads in terms of their membrane integrity, although there are a few experimental works that address this problem.

A classification of the acrosome in terms of its integrity is performed in [19,20], using Learning Vector Quantization (LVQ). This work considers images of boar spermatozoa obtained with an optical phase-contrast microscope and tries to automatically classify single cells as acrosome-intact or acrosome-reacted. This approach uses the gradient magnitude along the outer contour of the sperm head as descriptor. The minimum error rate achieved in this work was 6.8%. Despite this reasonable result for semen quality control, it is very important to improve the accuracy of the classification, according to veterinary experts. Alaiz-Rodríguez et al. use texture descriptors with the aim of estimating the true – and unknown – proportion of damaged cells in a sample [21]. They quantify the unknown a priori probabilities of test sets using the outputs of a classifier trained with an image dataset with class prior probabilities that may not match those of the operational conditions.

Other related – although not similar – proposals are the works carried out by Sanchez et al. [22,23]. They classify the images of the spermatozoa according to its intracellular intensity distribution.

Our proposal is to describe the texture of the acrosomes by computing some first-order statistical and co-occurrence features proposed by Haralick in [24]. These features are computed from both the original image and the coefficients yielded by the DWT, to assess the power of multirresolution texture analysis. We hypothesized that descriptors based on the shape of the head or on its internal intensity would provide good results, but the experiments conducted classifying with Hu [25], Legendre [26] and Zernike [27,28] moments and histogram-based descriptors did not yield good results, as we will show.

The rest of the work is organized as follows: Section 2 describes how the different features have been obtained. The classification and the empirical results are evaluated and compared in Section 3. Finally, some concluding remarks are given in Section 4.

2. Methods

The goal of this work is to classify images of boar spermatozoa in terms of their acrosome integrity. The first step to achieve it is to extract the region of interest (ROI) – the head of each spermatozoon – from the whole image and then, some descriptors are extracted from it.

We have computed some features derived from the co-occurrence matrix proposed by Haralick et al. [24] and, additionally, some first order statistical descriptors both from the ROI and from its wavelet coefficients [29]. We have also extracted some moment-based descriptors in order to compare them with the texture descriptors in terms of the classifier performance. In particular, we have extracted the Hu, Legendre and Zernike moments.

Once the images are described, we classify them by means of two methods: the k-Nearest Neighbours and a Multilayer Perceptron with a log-sigmoid transfer function both in the hidden and in the output layer. Classification results are estimated taking the 70% of the images for training and the remaining 30% of the samples as the testing set.

2.1. *Preprocessing and segmentation*

Using a digital camera connected to a phase-contrast microscope, boar semen images are captured with a resolution of 780×580 pixels. The magnification of the microscope is $100\times$, so each image contains no more than 2 or 3 cells. Hence, most of the spermatozoa come from different takings, which means that illumination is not completely constant, and therefore the method will be robust to light changes. Information about the sample preparation can be found in [30].

The process of acquiring the images is the following: First, we take a snapshot in real color under the fluorescent illumination. Then, we capture another image in grey scale of the same spermatozoa under positive phase contrast illumination, with the sample in the same position. The images have been obtained in CENTROTEC, a veterinarian research centre interested in this problem.

The spermatozoa heads on the phase contrast images are then cropped and labelled as damaged or intact using the information provided by the snapshots taken under fluorescent illumination. Overlapped heads cannot be analyzed, so they are discarded. Fortunately, due to the conditions under