Object recognition techniques in real applications
Fernandez Robles, Laura

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Chapter 6

Conclusions and outlook

6.1. Work summary

Three main applications have guided the work presented in this dissertation: the classification of boar spermatozoa according to the integrity of their acrosome heads; the localisation of cutting tools and identification of broken inserts in edge profile milling tools; and the retrieval of images containing certain objects for the Advisory System Against Sexual Exploitation of Children (ASASEC) project. Object recognition and image classification techniques, which have had a huge activity in the last years in the computer vision field, are required to provide a solution for these applications. In particular, in this thesis we have focused on the proposal of appropriate object recognition methods and retrieval techniques in these real applications.

The proportion of damage acrosomes in semen samples is usually estimated manually. Veterinary experts stain sperm samples and count the number of intact and damage acrosomes using a fluorescence microscope. Thus, the current process faces many drawbacks such as human mistakes or the requirement of expensive equipment. In this work we have analysed the integrity of boar acrosome spermatozoa describing their heads using invariant local features for the first time, as opposed to previous works that relied on global texture description.

Broken cutting tools may go on working without being detected and can cause a breakage of the head tool or even the milling machine itself. Tecoi utilises milling tools that contain a high number of inserts and that work under very aggressive conditions. Therefore, the identification of broken inserts is critical in this industrial process. We have proposed a method for the localisation of inserts and the identification of broken ones in such edge profile milling machines based on the specific geometry of these tools. Moreover, we have also presented a more general method for the localisation of inserts that can be automatically configured regardless of the appearance of the cutting tools and milling head tool.

In the ASASEC project, the retrieval of images and videos where some specific objects are present is one of the most challenging and important task to help fighting against sexual child exploitation. On the one hand, we have evaluated different clustering configurations of SIFT keypoints for object matching in relation with their pose parameters: coordinates location, scale and orientation. On the other hand, we
have presented a trainable keypoint detection operator, called colour COSFIRE filter, that firstly adds colour description and discrimination power to COSFIRE filters and, secondly, it provides invariance to background intensity.

The study of object recognition in different fields allows a knowledge transfer from one application to another. The lessons learned in one application context have influenced the design of solutions in other applications. We studied COSFIRE filters with the intention to develop an improved method for object retrieval in ASASEC project. From this expertise, we could infer how to apply COSFIRE filters for a more knowledge independent and versatile method to localise inserts in milling head tools. Furthermore, we have extended the knowledge about ILF acquired in spermatozoa description for object retrieval in ASASEC project. Moreover, some experiments carried out and the metrics used for an appropriate evaluation of the methods are also common in different contributions.

In the rest of the chapter, the main conclusions of this work and future work lines are presented.

6.2. General conclusions

This dissertation has provided solutions to real applications using object recognition and image classification techniques.

Some specific conclusions that can be extracted from this work are:

1. We have successfully applied invariant local features, for the first time, in the assessment of sperm acrosome integrity. We have used SURF (Speed Up Robust Features) to describe the state of boar sperm acrosomes as intact or damaged. We have carried out the classification using $k$-NN algorithm. We have obtained an averaged accuracy of 94.88%, 92.89% for the intact class and 96.86% for the damaged one. This method is more efficient than global texture descriptors and any other related work presented to the date this work was published as a conference paper. Moreover, we have achieved higher accuracy rates for the damaged class using SURF and SIFT (Scale-Invariant Features Transform) whereas we have generally obtained better results for the intact one using global texture descriptors. Thus, a combination of both types of descriptions could improve the results obtained separately.

2. In the same line of work, we have proposed an approach to classify SURF features, which produce several descriptors per image, with traditional SVM classifiers and without the use of BoW. We have yielded an accuracy of 90.91% (94.94% and 86.87% for the intact and damaged classes respectively). We have obtained a higher accuracy for the intact class than the damaged one and the opposite situation has been yielded for the classification of points. We have concluded
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that keypoint descriptors detected in the damaged parts of the acrosome are more distinctive than the ones coming from the intact parts. However, damaged spermatozoa contain acrosome areas where the damage is not noticeable that could lead to keypoint mismatches. This approach can be easily extended to other Invariant Local Features (ILF) methods and classifier algorithms.

3. We have proposed an early fusion of ILF with global texture descriptors for the classification of the integrity of the acrosomes that has outperformed the individual methods. We have achieved an accuracy of 95.56% (93.63% and 97.48% for the intact and damaged classes respectively) using a concatenation of SURF with Legendre descriptors and \( k \)-NN classification algorithm.

4. We have presented a highly effective and efficient method for the localisation of cutting edges in milling machines. Its output is a set of regions surrounding cutting edges, which can be used as input to other methods that perform quality assessment of the edges. It is based on applying first a circular Hough transform to find the screws that fasten the inserts, then edge detection and finally standard Hough transform to localise the cutting edge. We have obtained an accuracy of 99.61%, defining accuracy as the average of the fractions of the ground truth segments that lie inside ROIs of 20 pixels wide in images of 1280×960 pixels.

5. We have introduced a novel method to describe and classify inserts as broken or unbroken with respect to the state of their cutting edges. It computes the gradient magnitudes around the cutting edges and the deviation between the ideal and the real edges. The time required by this method for the inspection of the head tool is below the resting time of the machine. We have obtained an averaged F-Score of 0.9143(±0.079) with a precision 0.9661(±0.073) and a recall 0.8821(±0.134) in a publicly available dataset with 180 inserts by taking average results in 20 random validation sets.

6. We have presented another domain knowledge independent and more versatile method for the localisation of inserts. It is more general than the previous one since it considers independently each image of the dataset. It is based on COSFIRE filters and it can be automatically configured regardless of the appearance of the inserts. We have introduced a new metric, soft geometric mean, for the computation of the response of the COSFIRE filter, that is more efficient than the previous ones. This metric is based on geometric mean but it adds a small value to all entries and thus it provides tolerance to non-found contour parts. We have obtained a F-Score of 89.89%, with precision 92.39% and recall 87.52%, improving results of preceding works based on template matching.

7. We have evaluated different clusterings of SIFT keypoints in relation with their pose
parameters: coordinates location, scale and orientation. On the one hand, we have used the similarity measure of the closest pairs of keypoint descriptors. On the other hand, we have used a Hough transform, with different parametrisation values, to identify clusters of at least three points voting for the same pose of an object. We have verified the consistency of the pose parameters with the least squares algorithm. We have obtained higher precisions at small cuts of the ranked list of retrieved images with the first approach, whereas we have yielded better precisions at high cuts with Lowe’s clustering. We have computed the results for a dataset of 614 images that simulates sceneries of ASASEC database.

8. We have proposed colour COSFIRE filters have been proposed. They add colour description and improve the discrimination power to standard COSFIRE filters as well as provide invariance to background intensity. We have presented colour COSFIRE filters both for patterns made up of colour lines and for patterns that are colour objects. Colour COSFIRE filters are more efficient for CBIR and classification tasks on COIL dataset than standard COSFIRE filters.

6.3. Outlook

In this section, we summarise the main research lines that remain open for each studied application.

First, we discuss the classification of boar spermatozoa according to the acrosome integrity. The last work in the topic up to our knowledge, which I co-author, has been presented in (García-Olalla et al., 2015). It combines local and global texture descriptors and contour descriptors. Global texture description was obtained from the GLCM of the original image and the four sub-images of first level of decomposition with the DWT based on Haar wavelets. LBP and Fourier shape descriptors provided the local texture and the contour descriptions, respectively. An early fusion by concatenation of the descriptors was performed and the 10-fold classification using SVM backed by a least squares training algorithm and a linear kernel yielded an accuracy of 99.19% (harmonic mean equals to 99.12% of precision 99.42% and recall 98.84%). The solution for this application has already been delivered to the requesting company, Microptic.

Secondly, several lines of work are open for the development of a tool wear monitoring (TWM) system in edge profile milling machines:

1. The method for the localisation and identification of broken inserts that relies on the information of the several snapshots that capture the same insert under different poses can be improved by increasing the number of inserts localised in each individual image. This could be achieved by using, for example, a
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Modification of the Hough transform for finding ellipses. The screws have a circular shape when the insert is placed in the centre of the image, but as the insert is placed on a side of the image the screw is seen as an ellipse. Another option is to perform the localisation of the inserts with COSFIRE filters and then the localisation of cutting edges by edge detection and standard Hough transform. Having more views of the same insert could help to improve results since in some views there is low contrast of the inserts with respect to the background.

2. The results could be also improved with a better illumination system. Our method relies on edge detection and therefore achieving a good contrast is highly important. One possible solution would be to follow Pfeifer and Wiegers (2000) who captured the same insert under several lighting positions to combine contour information of all images. Otherwise, different settings of the illumination and capturing system could be evaluated.

3. Even though the breakage of the inserts is the most critical aspect to evaluate, it would be interesting that the TWM system also assesses the wear level of the inserts. In this way, we could predict possible future breakages of inserts or decide to change the inserts when they reach a high level of wear.

Finally, ASASEC project has been already delivered with satisfactory results. We put the effort in the appropriate programming of the product by following an object-oriented analysis and design making use of design patterns. Hence, future decisions of changing specifications will affect the programme in a limited way. However, the approach followed in the computer vision field was quite straightforward, with a more restricted development of new vision techniques. Colour COSFIRE filters can be exploited for many other applications related with object retrieval and object recognition in colour images or videos. The main drawback of colour COSFIRE filters is that they require a quite high number of convolutions, which depend on the application at hand, that are time consuming. Nevertheless, the implementation of the filters can be done in a parallel or distributed mode since most of the computations are independent from each other. Moreover, COSFIRE approach is not limited to the use of Gabor filter responses. In future, we will study object recognition using a combination of colour SIFT (Van de Sande et al., 2010) responses instead of Gabor filters responses. Previous tests using COSFIRE with SIFT for gray scale images are very promising. This approach can be very interesting for objects that contain distinctive blobs but less appropriate for objects in which contours are determinant.