SIFT descriptor to set landmarks on biological images

Van Linh LE[1,3], Marie BEURTON-AIMAR[1], Adrien KRAHENBUHL[1], Nicolas PARISEY[2]

[1]Laboratoire Bordelais de Recherche en Informatique (LaBRI)
351, cours de la Libération, F-33405 Talence cedex, France

[2]Institute for genetics, the environment and plant protection (IGEPP), INRA 1349
35653, Le Rheu, France

[3]Faculty of Information Technology, Dalat university
1 Phu Dong Thien Vuong, Dalat, Lamdong, Vietnam
van-linh.le,beurton,adrien.krahenbuhl@labri.fr, nparisey@rennes.inra.fr

Résumé – L'analyse d'images est une des étapes majeures du traitement d'images numériques, on l'applique aussi bien en imagerie médicale ou biologique, en vision par ordinateur ... Classiquement, l'image est très présente en biologie, les differentes techniques d'acquisition (photosdepuis l'imagerie microscopique pour étudier les structures anatomiques jusqu'au scanner, tomographie ou IRM pour étudier les tissu

Abstract – Image analysis is a large field of digital image processing and it has applied in practice with many application in the different majors such as medicine, machine vision, biology, ...

In biology, images are widely used from a long time, to study molecule structures or behaviors, tissus characteristics and in general to measure and to classify anatomical details. Classification of biological samples can be obtained from studying morphological features but at this time, setting morphological markers is done manually. In this work, we have focused on the problem to replace manual operations by automatic procedures to set landmarks which are point of interests on biological images. The presented framework, MAELab, allows to segment, to register and to apply a SIFT descriptor to set landmarks. In our procedure, we have specialized the way to compute and applied the SIFT descriptor by modifying the search area.

In the past of biology techniques, microscopic techniques were applied to study the structure details, but the current research requires more accuracy in the area, perimeter, localization of the object in the image by using the suitable features. In this content of this paper, we will focus on the problem of setting the landmarks on biological images which are used in many biological studies. The landmarks are indicated by applying a combination of SIFT and some techniques. Besides, we also show a difference way to use SIFT descriptor with another size of the sample region. The efficiency of the method is evaluated on two set of images: left and right mandibles of beetle. The complete work is implemented in MAELab and freely available as a library.

1 Introduction

Morphometry analysis is an important field of image analysis in biology. It is used to characterize the shape variations of the organisms. From obtained information, the biologists can evaluate the evolution of an organism or detect differences between several ones. Depending on the requirements of the application, the output of analysis process can be measures of shape, color ... or identificaton of pattern or landmark (points of interest) positions. Landmarks are points along an image outline that store a lot of important information about the shape of the image. The morphometric landmarks are precise points defined by the biologists. They are used in many biological studies and included into the classification tasks. Until now, the morphometric landmarks are manually identified mainly. The manual identification is time-consuming and could vary a lot depending on the operator.

In this paper, we focus on a specific part of our framework which consists of modifying the current way to compute SIFT descriptor to insert information about landmark area in the source image to reduce the size in one hand of the source patch and in the other hand in the target search space. The work is evaluated on the dataset of beetles from Brittany lands with a collection of 293 beetles. The first step of this work concerns the left and the right mandibles. For each beetle, a set of landmarks has been manually located by the biologists (see Fig. 1). In our study, we used that dataset as ground truth to evaluate the position of the automatically estimated landmarks. Our framework also contains steps of segmentation, registration, and descriptors comparison, these points will be discussed on the experiments results.

2 Landmark descriptor

For each beetle, the morphometric landmarks have been manually set on mandibles images by the biologists : 16 and 18 landmarks for each left and right mandible, respectively. The

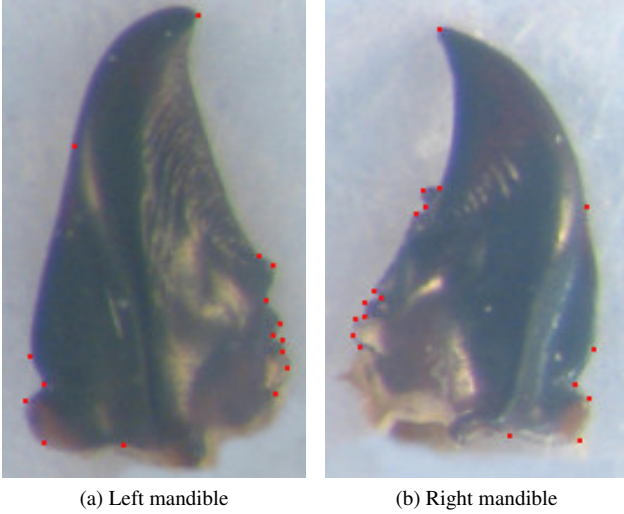(a) Left mandible   (b) Right mandible

FIGURE 1 – Example of beetle mandibles from the studied data set with manual landmarks.

considered problem is how to detect automatically the landmarks on the mandible image to replace the manual ones. In the whole of the process, the landmarks will be estimated on a target image by using the manual landmarks of a source image. Note, the source image is chosen randomly from the set of images.

In this section, firstly, we have a summary about the general usage of SIFT. Then, we will discuss detail about our method to estimate the landmarks.

2.1 SIFT method

SIFT method has been proposed by Lowe [7, 8]. It is used to extract distinctive invariant features from the images. Besides, the features from SIFT can be used to match between different views of source and target images such as rotation, scale, noise. SIFT method includes four stages : (1) scale-space extrema detection, (2) keypoint localization, (3) orientation assignment, and (4) keypoint descriptor.

In the first stage, a difference of Gaussian (DoG) [3] function is applied to identify the interest points on all scale and orientation of image. The keypoints are taken as the maximal and minimal of the result of DoG function at mutliple scale.

The scale-space extrema detection produces too many kepoint candidates, some of them are unstable. In the second stage of SIFT, the key point candidates are localized and refined by suppress the key points which have the low contrast or are poorly localized along an edge.

Then, the orientation and gradient magnitude of key points are calculated by considered the 4-neighborhoods of them.

At the end, the descriptor is computed for each key point based on the orientation and gradient magnitude. This is the descriptor of a region 16×16 pixels around the key point. By applying the original SIFT into our problem, we have succeeded indicating the keypoints in the image (see Fig. 2). But we do not have the result when we try to extract keypoint cor-

respondences between the source and target image. The problem is carried from choosing the best points from the large set of the candidates. To solve this problem, we have modified the method in order to limit the search space before applying the SIFT computing. We have also change the size of the gird to calculate the SIFT descriptor.
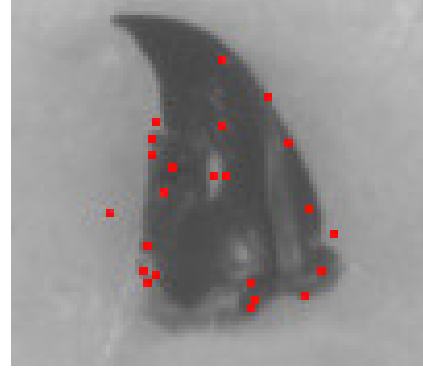

FIGURE 2 – SIFT keypoints in a right mandible

2.2 SIFT using into landmark area

As mentioned in section 2.1, we have tried to use original of SIFT to detect the landmarks. But the result contains a lot of candidates for the estimated landmarks. Additional, when we compare the position of the detected points with the ground truth (manual landmarks), they are very far. Last, searching in whole image is very time consuming. To hope for a better result, we use the SIFT method with another way.

Firstly, two images are segmented. Then, we register two lists of contours points. After that, the area (called patch) around each source landmark is defined and a larger patch is extracted in the target image at the same position. The SIFT descriptor is then calculated as usual. But we have reduced two first stages of SIFT and have changed the size of the sample region as 9×9 (instead 16×16). This size has been obtained after several tests. The SIFT descriptor for the patch is also an histogram containing the sum of pixel gradients for each consider direction. The comparison between two SIFT-descriptors is done by L2-distance with following equation (Eq. 1) :

$$L(D1, D2) = \sum_{i=0}^{n} \sqrt{(D1_i - D2_i)^2} \qquad (1)$$

Where :
— n is the number of directions
— $D1$ and $D2$ are two descriptors of size n,
— $D1_i$ and $D2_i$ are the ith descriptor values.

The way that we apply SIFT into our work is painted in Fig. 3. To detect the target landmarks, a registration is computed between the source and target images. This step is described in the experiment results. Then, the patch P_s of source and P_t of the target are created with the size of P_s is smaller than the size of P_t. For each pixel in P_t, a sub-patch P_t' is extracted with

the same size of P_s. When the P'_t have a part outside of P_t, the pixels do not belong to the patch will be considered. Then, the distance $L(P_s, P'_t)$ is computed by using Eq. (1). This work is finished when all the pixel in patch P_t are considered. The position of estimated landmark corresponds to the position of the sub-patch P'_t with smallest distance $L(P_s, P'_t)$. Finally, the position of the estimated landmark is set in the original position of the target image.
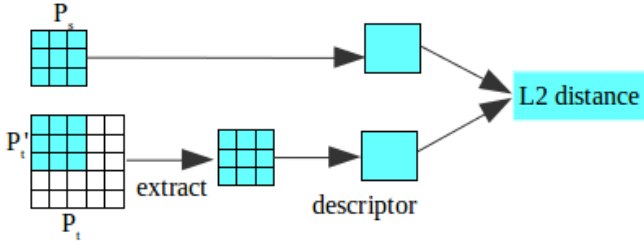

FIGURE 3 – Steps of SIFT descriptors comparisons between the patch P_s of the source image and the patches P'_t of the target image.

By experiments, a patch sample of 9×9 pixels centered in each landmark on the source and the size of 36×36 is kept for the patch on the target image.

3   Experiments and results

The method is tested on two sets (left and right mandible) of beetles. After verifying the dataset and suppressing of same unusable images (broken or hidden mandible), it remains 290 images of right mandibles and 286 left mandible images. In all valid images, the position of a set of manual landmarks is indicated by biologists : 18 for each right mandible, 16 for each left mandible.

As discussed, before applying the SIFT descriptor to estimate the landmarks on the target image. We have estimated the search space that contains the landmarks.

Firstly, the segmentation is applied on both of source and target image. The Canny algorithm [2] was chosen to finish this step. To use the Canny algorithm, two thresholds value must be provided (T_{lower}, T_{upper}). As mentioned in [5], indicating the threshold values is a difficult problem. If the threshold values are unsuitable, the contours could be far with ground truth (fewer contours or more noise). In our case, the lower threshold value is indicated by analysis the histogram of the image [6]. The ratio of two threshold values that we have chosen as $1 : 3$ to consider a wide range of the values. During Canny computing, the direction of the gradient of each pixel belonging to the contours is kept and will be used later. At the end of segmentation step, a simple algorithm is applied to remove edges inside the main contours.

Then, the Principal Component Analysis (PCA) is applied to register two lists of contours points from the source and the target [9, 4]. The lists of contour points are used as the input.

For each list of contours points, the centroid point and principal axis are computed. The centroid point coordinates are computed like the average coordinate of all contours points. The principal axis is a line connecting the centroid point to a contour point which has the minimum of average perpendicular distance to remaining contour points. Then, two lists of contours points are registered by computing the translation and rotation parameter values. The translation is computed as the distance between the centroid points of the source and the target. The rotation angle is the angle between the principal axes of two images. However in some case, the result of the segmentation step could exist the noise, it could affect to the registration step. To improve the registration, we have built up the PCA by iterating until stabilization (PCAI). Finally, the SIFT descriptor is achieved to determine the estimated landmark on the target image.

We have run the method on all usable images. The results are given in difference : estimated landmarks are well positioned on some target images but not pleasing on others. As raised, the mandible images can be exist difference sizes because beetles have also difference sizes. We detected that our method is sensible to this parameter. To improve the result, we have inserted a pre-process step before the computing of the SIFT descriptor to estimate the scale between source and target image. The bounding box of contours in source and target are defined by checked the coordinate of the contour points. The scale between two images is the ratio of two bounding boxes.

The Fig. 4 shows the final result for a right and a left mandible with manual and estimated landmarks. The estimated landmarks are quite near with the manual ones.

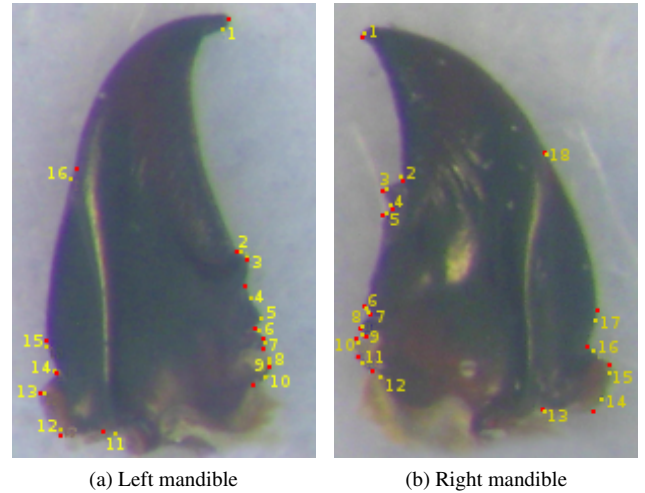(a) Left mandible   (b) Right mandible

FIGURE 4 – The manual (in red) and estimated (in yellow) landmarks on a mandible.

First statistics are done on the mean accuracy of all landmarks on the target images. The error is computed as the distance between the manual and corresponding estimated landmark on the target image with an error accepted from 1% to 2% of bounding box's size (when we consider the scale of the

image). According to this way, the result is shown in Fig. 5 ; following that, the good score of well-positioned landmarks equal to **87.03%** for the set of right mandibles and **78.82%** for left mandibles.

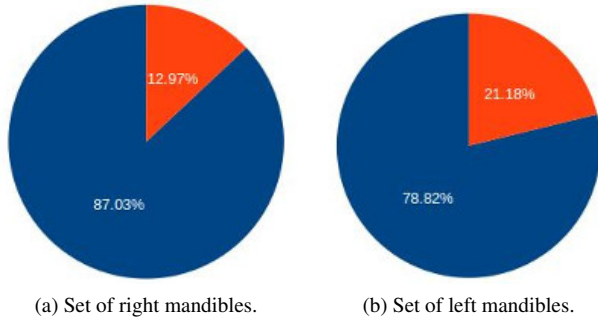(a) Set of right mandibles.   (b) Set of left mandibles.

FIGURE 5 – The mean proportion of well and bad landmark locations of the two sets of left and right mandibles.

Beside the global results, we are also interested by the accuracy of each estimated landmark. The error measure is the same with the first one (distance between manual and corresponding estimated landmark) but the acceptance is done with standard deviation of the distances [1]. Figs 6 and 7 show the proportion of well estimated landmarks on each dataset. With 18 landmarks of right mandible, the highest proportion is belong to the 1st landmark with **98.62%** ; the lowest proportion is **74.48%** for the 14th landmark. The remaining landmarks are also estimated with a high accuracy greater than **75%**. For left mandibles, the highest and lowest success rate are **93.01%** for the 1st landmark and **60.14%** for the 16th landmark. In this evaluation, we can see that the correct proportion on the 11th and 12th landmark of the left mandible and the 13th and 14th landmark of the right mandible are less than other landmarks. The reason is come from the noise of the contours at the base of mandible is higher than the top of the mandible. Currently, using SIFT to estimate the landmarks is implemented in MAELab. It was written in C++. MAELab is distributed as free library on the Github.
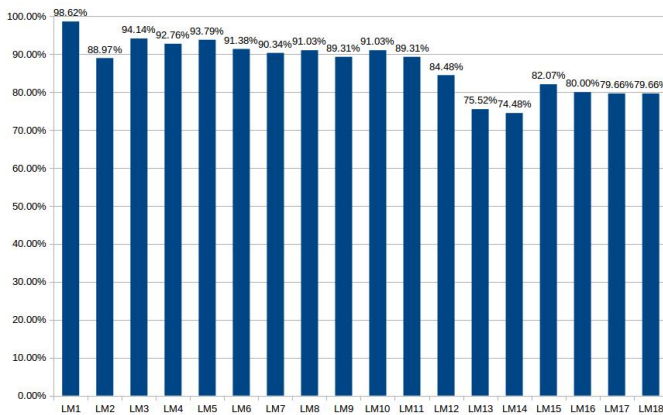

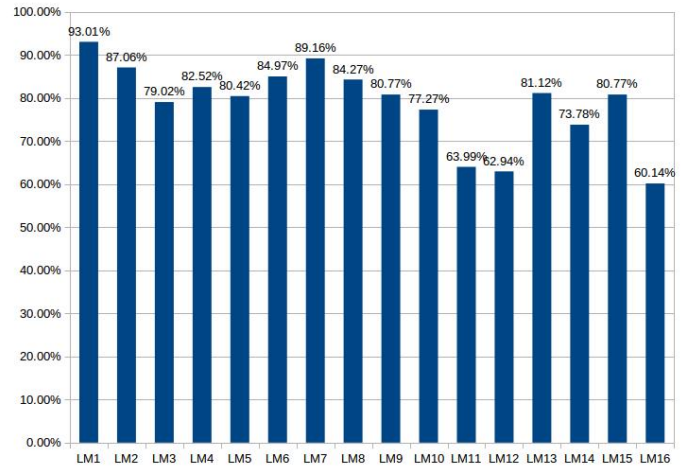FIGURE 6 – The proportions of well estimated landmark for each model landmark of right mandibles.

FIGURE 7 – The proportions of well estimated landmark for each model landmark of left mandibles.

4   Conclusion and discussion

The landmarks setting is the main way to analysis image in biology. In this paper, we have described a difference way to use the SIFT descriptor along with the segmentation and registration processes to estimate the landmark on the beetle. Firstly, each mandible has been segmented. Then, two contours are registered. Finally, SIFT descriptor is applied to find the best matching position of estimated landmarks. The results show that our method succeeds in locating all the landmarks of the image. The accuracy of the method is sufficient to be proposed to biologists as a replacement of the manual measures. Moreover, considering with previous work [6], the position of the estimated landmarks are improved a little bit. From now, the next stage consists the improving to increase the correct accuracy of the landmarks in the bottom of the mandible.

Références

[1] J Martin Bland and Douglas G Altman. Statistics notes : measurement error. *Bmj*, 313(7059) :744, 1996.

[2] John Canny. A computational approach to edge detection. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, (6) :679–698, 1986.

[3] Michael W Davidson and Mortimer Abramowitz. Molecular expressions microscopy primer : Digital image processing-difference of gaussians edge enhancement algorithm. *Olympus America Inc., and Florida State University*, 2006.

[4] Ian Jolliffe. *Principal component analysis*. Wiley Online Library, 2002.

[5] Dehua Li Jun Zeng. An adaptive canny edge detector using histogram concavity analysis. *International Journal of Digital Content Technology and its Applications*, 5, 2011.

[6] L Lê Vãnh, M Beurton-Aimar, JP Salmon, A Marie, and N Parisey. Estimating landmarks on 2d images of beetle mandibles. *WSCG*, 2016.

[7] David G Lowe. Object recognition from local scale-invariant features. In *Computer vision, 1999. The proceedings of the seventh IEEE international conference on*, volume 2, pages 1150–1157. Ieee, 1999.

[8] David G Lowe. Distinctive image features from scale-invariant keypoints. *International journal of computer vision*, 60(2) :91–110, 2004.

[9] Jonathon Shlens. A tutorial on principal component analysis. *arXiv preprint arXiv :1404.1100*, 2014.