AUTOMATED DIAGNOSIS OF MELANOMAS BASED ON GLOBULAR AND RETICULAR PATTERN RECOGNITION ALGORITHMS FOR EPILUMINISCENCE IMAGES

Andrés I. Gola, Begoña García Zapirain, Amaia Méndez Zorrilla and Ibon Ruiz Oleagordia
Telecommunications, University of Deusto
Avda. Universidades 24, 48007, Bilbao, Spain
phone: + (34) 944139000, fax: + (34) 944139101
Email: agola@tecnologico.deusto.es, {mbgarcia, amendez, ibruiz }@eside.deusto.es

ABSTRACT

In this paper an automated digital system for the diagnosis of melanomas is presented. The system is based on the standard Pattern Recognition dermatological protocol. Two automatic algorithms of digital image processing have been developed in order to detect the appropriate patterns. This allows one to calculate some quantitative features based on the inner patterns of the melanoma using simple-operations algorithms in order to minimize response time. The database used consists of 40 RGB images of 500x500; five (5) of each pattern images have already been catalogued by dermatologists and the results are successful according to the assessment of medical experts. The proposed algorithms presented a remarkable rate of Globular and Reticular Pattern recognition with 0% of false negative and an average of 7.14% of false positive. Thus, it proves to be a reliable system when performing a diagnosis.

1. INTRODUCTION

Around the 65 % of the deaths due to skin diseases are caused by malignant melanomas which are the most dangerous kind of skin cancer. Although it is less common than other types of skin cancer, its occurrence is increasing remarkably, having tripled in the last decade.

Early detection in every caner is fundamental for the patient's recovery. Statistics show that 90-95 % of cases, the patient, will achieve a full recovery if the melanoma is surgically removed when its thickness is less than 1 mm. However, when it is bigger than 1 mm, the prognosis is less optimistic and the mortality rate increases to around 10-15% for each millimetre that the tumour has grown. This is the reason why it is essential for tumours to be detected as soon as possible and parameterized in a quantitative way using certain features for defining the stage in the evolution of the sickness more accurately.

This research consists of a software solution designed to analyze photographs of the patient's injury by means of image processing techniques where the dermatologists will capture the image of a melanoma using a digital dermatoscope, and a stack of algorithms will process the image and provide an output diagnosis in an automated manner.

By means of this program, dermatologists will have the advantage of detecting melanomas, in its first phases of formation, in a rapid manner and prevent unneeded biopsies. Therefore the experience of the patients will be less obnoxious and the possibilities of preventing melanomas will increase.

The authors propose a software solution based on clinical medical protocol, epiluminiscence images, and pattern techniques. The system evaluates the lesions, providing an evaluation with quantitative parameters. The result is an integer output where the melanoma has the Globular and/or Reticular Pattern or not, using a simple-and-fast pattern recognition algorithm. The approach has taken into account the execution time so that it can be minimized.

The main goal of this project is to ease the daily practice of dermatologists, supplying a tool for an objective assessment of moles (melanoma in particular). This being the main aim, a number of secondary objectives could also be achieved:

- To create a complete database with records of dermatological images and their cataloguing by a dermatologists team.
- To develop image processing algorithms for the adequate segmentation of skin images for the calculation of the suspect cancer parts of the mole in comparison with specific patterns.

This paper is divided into the following sections: Section 2 describe methodology used by dermatologist and the state of the art in pattern recognition. Section 3 explains the proposed solution with a detailed description of the system design. In Section 4 the obtained results are shown, and Section 5 presents the authors' conclusions and future work.

2. METHODS

In this section the diagnostic methodology will be described in two parts: clinical and technical. Firstly, the method of "two-step diagnosis" used by dermatologists nowadays is explained in detail. After the clinical methods have been exposed, the explanation will move on to the technical field related to image processing algorithms, commenting on the strengths and weaknesses involved in research towards the development of reliable pattern recognition algorithms.

2.1. Clinical Methods

The method of two-step diagnosis in dermoscopy is the algorithm on which differential diagnosis is based.
The diagnosis' first stage is when the dermatologist must discern whether the lesion is melanocytic or not melanocytic. This classification is based on certain structures that, when present, help to correctly classify a lesion as a melanocytic tumour, spleen cell carcinoma, hemangioma, seborrheic keratosis or dermatofibroma. When a skin lesion does not meet any of the criteria of melanocytic and non melanocytic, the tumour should be considered of melanocytic origin. In case that a melanocytic lesion has few criteria, it should be considered as a potential melanoma, especially when there are irregular or pinpoint vessels.

When a tumour has melanocytic lesion criteria, the dermatologist proceeds to the second stage of the algorithm to differentiate between a benign lesion (melanocytic nevi) and melanoma. For this purpose, various diagnostic methods that have been developed for this aim can be used, including the "ABCD rule" (which today is considered old-fashioned) and "pattern analysis" which provides a more reliable diagnosis.

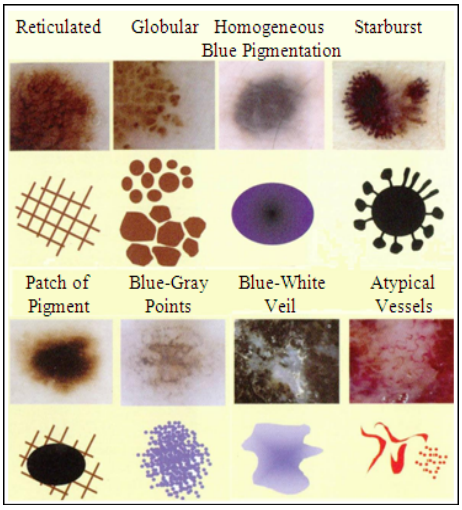


Fig. 1. Dermatoscopic Structures

One or more types of shapes and colors of *Fig. 1* can be present in melanocytic tumors. The location and distribution of shapes and colors can often create different visual patterns that are characteristic for certain injuries [1].

2.2. Database

The database was created with the collaboration of the Dermatology Department of Basurto Hospital in Bilbao, Spain. The images provided by the dermatologist Ana Sanchez were captured with a Molemax II digital dermatoscope and a dermatology application from Diagniscan, S.A Bolton Medical Group and a Canon Power Shot A630 digital camera with 8.0 megapixels and a Dermlite Photo lens. The result is a 40 RGB of 500x500 pixels image database catalogued by a certified dermatologist. This database was used for the algorithm development process.

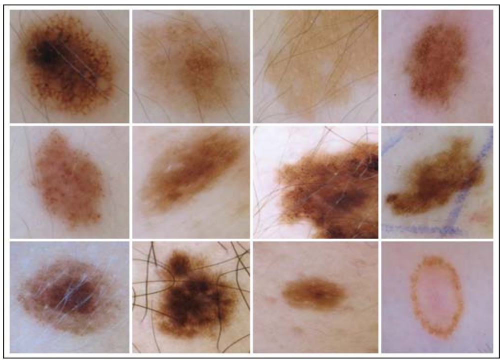


Fig. 2. Dermatoscope Images Samples

The images, as shown in *Fig. 2*, were carefully selected taking into account the quality, resolution and patterns of the melanomas. However, due to the standardized protocol followed to capture epiluminiscence images, the explanation of the technique is out of scope in this paper since this application will be handled by certified dermatologists.

2.3. Technical Methods

Nowadays, there are numerous applications which implement algorithms intended images processing and performing biometric pattern recognitions, such as face, veins, iris, fingerprint and so on. Nonetheless, there is no dermatology software that provides pattern recognition to help with the diagnosis of melanomas. These algorithms are usually based on Pattern Matching and Artificial Neural Network.

Neural networks are high complex system used for a broad variety of fields, but one of the most important applications is pattern recognition. Pattern recognition can be implemented by using a feed-forward neural network that has been trained accordingly. During training, the network is trained to associate outputs with input patterns. When the network is used, it identifies the input pattern and tries to produce the associated output pattern. The disadvantage is that they are notoriously slow, especially in the training phase and also in the application phase. Another significant disadvantage of neural networks is that it is very difficult to determine how the net is making its decision. Consequently, it is hard to determine which of the image features being used are important and useful for classification and which are worthless [2].

Thus, an eigenvectors-based face recognition algorithm has been modified specifically for Globular and Reticular patterns recognition. The displays of the images created by eigenvectors appear as light and dark areas that are arranged in a specific pattern. This pattern shows how different features of a face are singled out to be evaluated and scored [3].

The results of the techniques explained above highlight the difficulties encountered in detecting shapes inside melanoma due to the unpredictable low similarity that exists between samples and the randomness of the patterns, in comparison with the predictable structure of faces and the tardiness in producing a result.

3. SYSTEM DESIGN

Segmentation is a low level task that aims at partitioning an image into different homogeneous regions, according to various properties like colour, texture, shape, motion, etc. It is useful for many high-level applications in such diverse fields as remote-sensing, medical imaging, video coding, image restoration, and so on [4]. Therefore, it has been concluded that image-processing algorithms must be developed to enable a basic and simple operation that will have the advantage of providing results in a short period of time.

Due to the nature of melanomas, two or more patterns can be present in the same skin lesion. As a consequence, a pattern recognition algorithm should be designed for each type of pattern so that the image can be processed by those algorithms in parallel, and later a diagnostic subsystem should develop the diagnosis on the basis of the 8 outputs from the stack of algorithms, as shown in *Fig. 3*. Pattern recognition algorithms will be specifically designed for each type of pattern in *Fig. 2*.

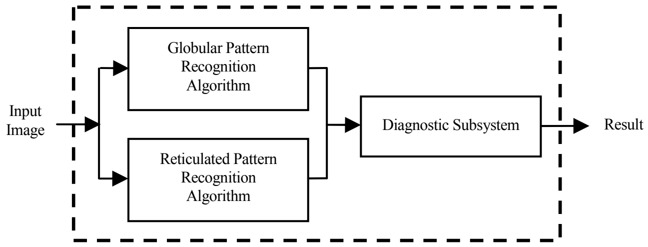


Fig. 3. Diagnosis System Scheme

Real world applications, it is evident that images not only contain instances of the objects of interest, but also large amounts of background pixels. If no elementary shape features are available for the input data, one has to rely solely on the information provided by colour and textures attributes [5].

As it will be seen in *Fig. 5* and *Fig. 6*, the processing consists of extracting the useful and desired part of the melanoma and detecting the shapes corresponding to the Globular and Reticular pattern.

Nonetheless, the complete diagnostic system is designed to shelter a post-processing; in which dermatological data should be loaded, in order to perform a correct diagnosis based on the outputs of the detection algorithms (As shown in *Fig. 3*).

A graphic user interface was developed taking into account the usability and the representation of results. As seen in *Fig. 4*, the screen is dived in two regions: the qualitative (image representation) and the quantitative (numerical results). On the image representation panel the application will display: the original epiluminescence photograph, a representation of the lesion's shape, and two other processed images where the Globular and Reticulated patterns are extracted and highlighted. On the other panel, dermatologist will be able to adjust the threshold which will determine the number of shapes that have to be detected in order to have a 100% probability regarding the presence of each pattern.

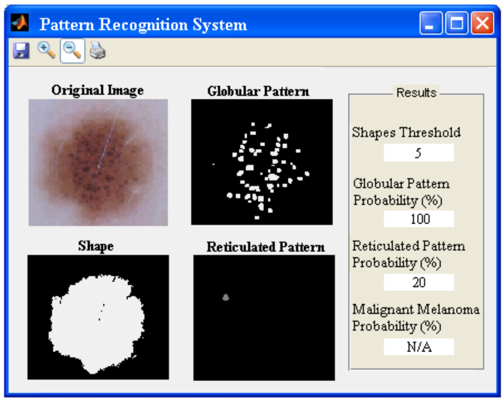


Fig. 4. Diagnostic System Prototype Interface

The window explained above (*Fig 4.*) is a prototype that will be extended in accordance with the addition of new features and more pattern recognition algorithms.

3.1. Globular Pattern Recognition Algorithm

The following algorithm was developed with the aim of detecting the shapes that correspond to the Globular Pattern.
The process is as follows, based on *Fig. 5*:

Step 1: The input is an epiluminescence RGB image of 500x500 pixels captured with a dermatoscope and downloaded to the computer. It will be called *I*.

Step 2.1: In this stage a filter is applied to image *I* in order add blur, thus removing details that are not necessary for the detection of the melanoma's shape. This resulting image is *IBR*.

Step 2.2: This step is to convert the input image, to a 256-bit greyscale image of the same size. This image is *IG*.

Step 3: The image *IG* is equalized and then converted to a binary image *IB* where the differences in the intensity of the image is represented with white pixels and the rest with black, 1s and 0s respectively.

Step 4: The melanoma's shape is extracted from image *IG,* which is *IB* filtered, and placed on a binary image *–IM-* using equation *(1)*.

$$IM(i,j) = \begin{Bmatrix} 1 \rightarrow IG(i,j) < mean(IG) \\ 0 \rightarrow else \end{Bmatrix} \quad (1)$$

Step 5: In this step, a subtraction between *IB* and *IM* takes place in order to delete the unwanted information from outside the melanoma from *IB*. The result is the image *I2*.

Step 6 (Optional): Image *IM* is eroded with a flat disk-shaped structuring element *B* with radius 2 (equation *(2)*) in order to create a smaller shape of the melanoma in a new image: *IM2*.

$$IM2 = IM \ominus B = \bigcap_{b \in B} IM_{-b} \quad (2)$$

Step 7 (Optional): In order to delete the inner area that is over-pigmented, thus the globular pattern is not visible, *I2* is subtracted with *IM2*

Step 8: In this step, the lines in *I3* are dilated with a flat disk-shaped structuring element *B* with radius 2 (equation *(3)*) in order to close possible open shapes which correspond to the Globular Pattern. The resulting image is called *ID*.

$$ID = I3 \oplus B = \bigcup_{b \in B} I3_b \quad (3)$$

Step 9: A fill function is implemented in order to assign white pixels to those surrounded by closed shapes in image *ID*. The result is *IF*.

Step 10: *IF* is eroded with the aim of removing the lines and leaving only medium-size shapes. This image is *IE*.

Step 11: The remaining pixels of *IE* are dilated in order to make the result more visible for the user: the *IU* image.

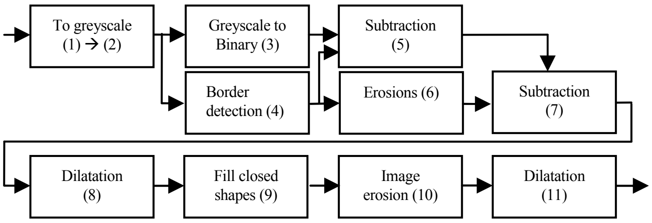


Fig. 5. Globular Pattern Algorithm's Block Diagram

The system is based on a modular architecture where the aims of each block are clearly separated.

3.2. Reticulated Pattern Recognition Algorithm

The following algorithm was developed with the aim of detecting the shapes that correspond to the Reticular Pattern. The process is as follows, using *Fig. 6* as reference:

Step 1: The input (*I*) is loaded in the application.

Step 2: The second step is to convert the original image *I*, which is a 500x500x3 matrix (or 500x500 RGB), to a 256-bit greyscale image of the same size. This image is *IG*.

Step 3: In this stage a Gaussian Lowpass Filter, which matrix is LPF (size=8,σ=10), is applied to image *IG* in order to add blur (as shown in the equation *(4)*), thus removing details that are not necessary for the detection of the melanoma's shape. This resulting image is *IBR*.

$$IBR = IG \otimes LPF \quad (4)$$

Step 4: The image *IG* is equalized and then converted to a binary image *IB* where the differences in the intensity of the image is represented with white pixels and the rest with black, 1s and 0s respectively.

Step 5: The melanoma's shape is extracted from image *IG,* which is *IB* filtered, and placed on a binary image *–IM-* using the edge detection equation *(1)*.

Step 6: In this step, a subtraction between *IB* and *IM* takes place in order to delete the unwanted information from outside the melanoma from *IB*. The result is the image *I2*.

Step 7: A fill function is implemented in order to assign white pixels to those surrounded by closed shapes in image *I2*. The result is *IF*.

Step 8: Image *IF* is eroded using equation *(2)* to create a smaller shape of the melanoma in a new image: *I3*.

Step 9: The remaining white pixels of *I3* are dilated with equation *(3)* in order to have a similar size of the former shapes: the *IU* image.

Step 10: The image *IU* is inverted creating image *IUI*.

Step 11: An overlay is applied with *IUI* and *IG*, in order to delete all the information of *IG* except the shapes of interest. The result is *IS*.

Step 12.1: The mean value of the melanoma's intensity is calculated.

Step 12.2: The remaining shapes of *IS* are filtered and those whose mean value doesn't exceed the mean value of the melanoma are removed as shown in equation *(5)*.

$$IS = \sum_{i=0}^{n} S_i\{mean(S_i) > mean(IG)\} \quad (5)$$

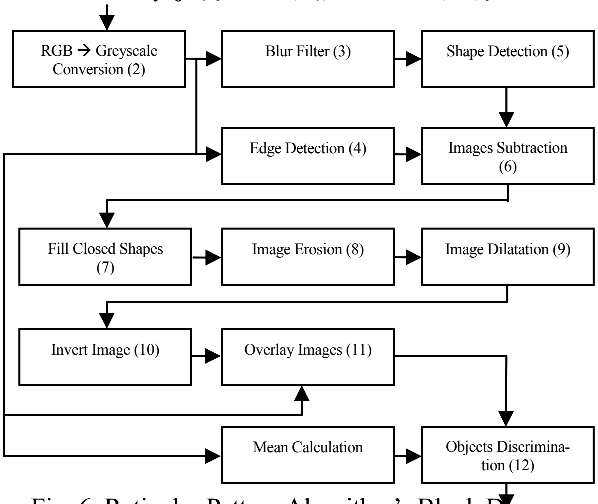


Fig. 6. Reticular Pattern Algorithm's Block Diagram

The system has been developed to process images in a fast manner in order to be comfortable for the users.

4. RESULTS

The next sequence of images in *Fig. 7* and *Fig. 8* represent the Globular and Reticular pattern recognition, respectively, of four of the images from the evaluation database.

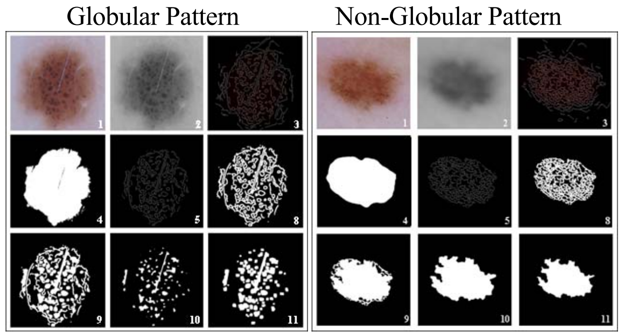


Fig. 7. Pattern Recognition Image Processing

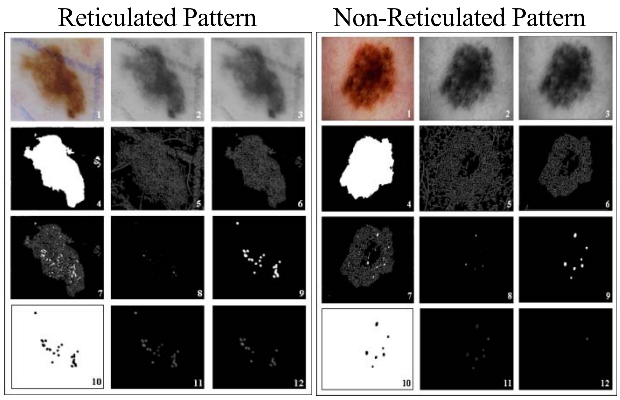
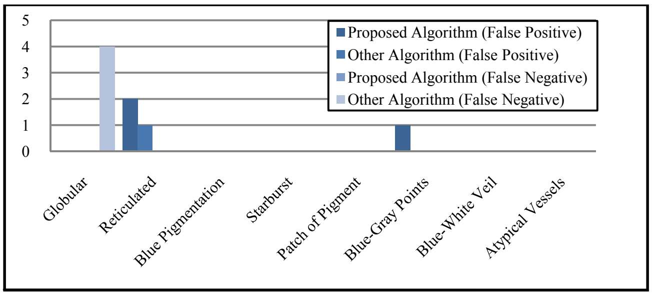


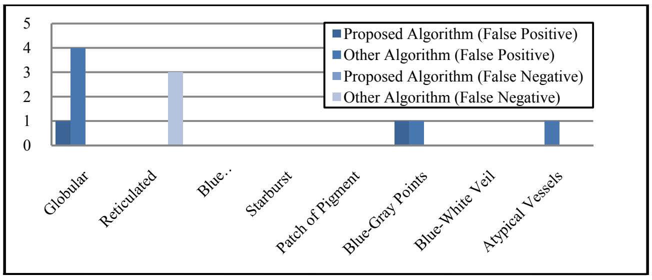
Fig. 8. Reticular Pattern Recognition Image Processing

The results that will be shown in the next graphics and tables are the outcome of the tests performed to the algorithms with RGB images of 500x500 pixels. The size was determined as the best one after evaluating the algorithms with different resolutions.

Graph 1 and *Graph 2* shows a comparison between the false positives and false negatives of the proposed Globular and Reticulated, respectively, pattern recognition algorithms and the modified face recognition algorithms [3].



Graph 1. Globular Pattern Algorithms False Positives and False Negatives Results



Graph 2. Reticulated Pattern Algorithms False Positives and False Negatives Results

In *Table 1* we can see the average results of the algorithms' performance in reliably detecting the patterns that they were conceived for and contrasting it with the other algorithms.

	Proposed Algorithms		Other Algorithms	
Pattern	**False Positive**	**False Negative**	**False Positive**	**False Negative**
Globular	*8.57%*	*0%*	*2.85%*	*80%*
Reticulated	*5.71%*	*0%*	*17.14%*	*60%*
Average	*7.14%*	*0%*	*11.42%*	*70%*

Table 1. False Positives and False Negatives Results

The proposed algorithms are remarkably more accurate in detecting the specified patterns, in spite of their higher False Positive rates. Nevertheless, the scope of this research is the development of a new tool rather than the improvement of existing techniques.

5. DISCUSSIONS AND CONCLUSIONS

On the one hand, after testing the proposed algorithm and comparing the result with the ones from the generic pattern recognition technique that was modified to detect patterns in skin lesions, it can be said that the proposed algorithms are virtually 100% accurate in Globular and Reticular pattern identification from the images (with those patterns). As regards false positives, the proposed Globular and Reticulated algorithms are maintained at an average of 8.57% and 5.71%, respectively. However, this data should not be a cause for concern because the global system (which will house the set of algorithms to recognize patterns listed in *Fig. 1*) will not make the final decision by only taking into account one algorithm, but will correlate partial outputs of each subsystem so as to recognize each specific pattern. Therefore, the end result will be well below 10%. On the other hand, the false negatives average of the proposed algorithms is 0%. This average must be as low as possible to prevent a doubtful diagnosis of a malignant melanoma.

On the other hand, focusing on the images that the algorithm delivers as the final result, specialists in dermatology collaborating in this research have shown that the result is helpful for subjective diagnosis of the original images as it provides confirmation of the specific identified patterns. This is helpful in the early years of dermatologists' practice, when they do not have enough experience to draw patterns visually within the melanoma.

Currently, the developments of algorithms aimed at detecting reticulate, starburst and blue veil pattern are taking place. Once the research and development of all the algorithms required to detect all existing patterns has been completed, a system integrating all the algorithms will be developed. This system will help dermatologists to deliver a fast and non-invasive diagnosis. Thus, it will help prevent skin cancer and treat it in its early stages, because patients will be more comfortable when tracking their lesions.

6. ACKNOWLEDGMENTS

The authors wish to acknowledge the University of Deusto and Basurto Hospital, especially dermatologists Dr. Ana Sanchez and Dr. Mª Dolores Boyano from the University of the Basque Country, for kindly lending their infrastructures and material for this research work, which was partially financed by the Department of Industry and Department of Education, Universities and Research from the Basque Government.

7. REFERENCES

[1] J. Malvehy, S. Puig, R.P. Brown, A.A. Marghoob, and A.W. Kopf, Manual de Dermatoscópia. Address: Zriltiam S.L., 2006.

[2] R. White, "Object Classification in Astronomical Images", Space Telescope Science Institute [Online] http://sundog.stsci.edu/rick/SCMA/node2.html

[3] M. Turk and A. Pentlad, "Eigenfaces for Recognition", *Journal of Cognitive Neuroscience, Vision and Modeling Group*, vol. x, pp.71-86, 1991.

[4] R.Gaetano, G.Poggi and G.Scarpa, "Identification of Image Structure by the Mean Shift Procedure for Hierarchical MRF-based Image Segmentation", *European Signal Processing Conference*, September 4 - 8 2006, Florence, Italy

[5] T. Zöller and J.M. Buhmann, "Robust Image Segmentation Using Resampling and Shape Constraints", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 29, pp.1147-1164, July 2007.