2-D Colposcopic Image Registration in Cervical Cancer Detection

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Introduction

Cervical cancer is the first cause of death in women in Mexico [1]. However, if it is detected early, the probability of healing is very high. With the aim to contribute to an opportune diagnosis, an automated system for the classification of cervical injuries based on colposcopic image segmentation using temporary aceto-white patterns is being developed. The main parts of the system are depicted in Figure 1.

Figure 1. Image Segmentation Project
This work focuses in the 2-D medical image registration part required after the colposcopic sequences were acquired. The image registration phase is the basis for a successful cervical diagnosis. Therefore, its accuracy is critical in the performance of the whole automated system.

**2-D Image Registration Proposed Approach**

Image registration is the process of overlaying two or more images of the same scene taken at different times, from different points of view or by different sensors [2].

There are too many approaches for image registration according to the needs of each working or researching group. In this work we propose two complementary ways to perform the image registration process, the first one is a 'global registration' and the second one is a 'local registration'. Both processes are complementary in such a way that it is possible to firstly apply the global registration with the aim to improve the movement (noise) of the image sequence (colposcopy video), and then applying the local registration (which requires more processing time), with the goal to further improve the quality of the registration process.

In the global image registration algorithm it is necessary to select a region of interest (ROI), which can be chosen by taking any area where remarkable changes in intensity values are observed in the images sequence. The selected region can be the opening of the cervix or the mark set in the colposcopy test. The algorithm requires as input parameters the set of images in grayscale and the selected region of interest (ROI).

The results from the global registration algorithm heavily depend on the ROI selection, because if it is not well appreciated in the entire sequence of images, the effect will be an increasing error value. The output of this global registration process is the globally-based registered images sequence.

In order to obtain better results in the image registration process, we propose to perform a locally-based image registration conceived as an optimization problem solved with a local search strategy. Unlike the previous algorithm (i.e., global image registration), for the local registration algorithm it is necessary to select little groups of pixels (i.e., windows of 9 or 25 pixels) from a basis image, and compare them across the entire set of images according to the time series of intensity values of each pixel in the window. This local registration process is very exhaustive because one image may contain thousands of pixels.

The optimization phase is very important for the local registration algorithm because the accuracy of the results and processing time depends on it. In this work, the optimization consists in a local search strategy and it is directly applied when the algorithm looks for the correspondence of the window of the defined number of pixels in each frame across the sequence. The algorithm also looks for either the best result or the best correspondence among pixels in the window.
A model to adjust the time series was implemented with the objective to reduce the noise observed. This model was experimentally obtained by analyzing the behavior of the signals, whose values allowed to approximate the shape of the linear model with explanatory variables as shown in Equation 1.

\[
Model(t) = \theta_0 + \theta_1 t + \frac{\theta_2}{t^2} + \frac{\theta_3}{t^3}
\]  

(Eq. 1)

The parameters \( \theta_i \) are a compact representation of the time series.

The accuracy of the optimization algorithm depends on the time series calculation for each pixel in the image and its corresponding polynomial approximation. Figure 2 shows the time series of one pixel (blue line) and its polynomial approximation (red line).

![Figure 2. Polynomial approximation of a time series in a pixel](image)

**Preliminary results**

For our experiments we processed data from ten women with abnormal Papanicolaou results, with ages ranging from 22 to 35 years. All of them gave written consent.

Images were acquired using a colposcope dfv Vasconsellos model CP-M7 with magnification 16 X without any optical filter. The viewing distance was 20 cm. This data resource was funded by the Mexican National Council for Science and Technology for the economic support of this project under the research grant: Fondo Sectorial de Investigación en Salud y Seguridad Social SSA/IMSS/ISSSTE-CONACYT (Salud-2003-C01-06).
Experiments where both, global and local image registration processes were applied, suggest that they complement very well in the samples tested. However, when applied separately and compared, local image registration clearly provides the best results (for the entire search radius and for the entire sizes of the windows of pixels defined in each experiment). The main shortcoming of the local registration process is its high processing time, mostly when the radius increases considerably.

If a greater search radius is employed, there is a greater possibility that the algorithm finds near-optimal values. On the other hand, windows of nine pixels are sufficient to obtain satisfactory results because the algorithm searches for temporal patterns, regardless of the spatial patterns.

After the application of both registration processes, the error from the original set of images in our experiments was reduced by up to 70%, which shows the good performance of our proposed approach.

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