Cell Tracking by Normalized Cross-Correlation with Image Processing

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Abstract - Here, cell tracking task involves normalized cross correlation of the cell target and microscope images. The sensibility of this method was improved applying image processing algorithms prior to the cross correlation task.

I. INTRODUCTION
Cell tracking is a problem that many authors [1] have faced using different procedures. In vitro experiments have shown important features that allows image processing analysis. Major problems presented in cell tracking image analysis involves cell migration and cell variations. Cell variations include change of shape, mitosis or even different behavior caused by drugs. Another problem can be the similitude between cells and image background does not permit a good performance of the tracking process.

Different computer methods to track cells have been applied by many authors [2]-[4]. To face this problem first it is analyzed a single frame from all the video sequence. Some of the main issues performing cell tracking are related with the number of numerical operations and with computer time consumption. Both of these parameters rise considerably as either results precision or period of time analysis need to be increased.

Even the light efficiency problems of these systems, optical correlator systems have several advantages compared with the traditional image processing. Without doubt, the best of them is that these systems can execute Fourier transforms at light speed, reducing in several magnitude orders the time delay of the data processing. This can be done, because the transform image correlator can use either a charge-coupled device (CCD) interfaced with a binary spatial light modulator (SLM) or a high contrast optically addressed SLM at the Fourier plane. In the former case, the interference between the Fourier transforms of the reference and input signals is produced by Fourier transform lens, and intensity distribution of the Fourier transform interference is obtained by a CCD array located at the Fourier plane. The CCD array is connected to a thresholding network interfaced with a binary SLM, also at the Fourier plane, that reads out the binarized joint power spectrum in real time. A second transform lens is used to obtain the inverse Fourier transform of the threshold interference intensity pattern, which yields the desired correlation results. A high contrast optically addressed SLM can also be used at the Fourier plane to obtain the Fourier transform interferences intensity and then threshold the interference intensity according to the characteristics of the device.

II. RESULTS
The images used in this work were obtained from the frames of a video sequence, Figure 1 shown one of these images. These sequences were provided by Debeir [1] and they were taken at a rate of 1 picture every 4 minutes. These video sequences were acquired under phase-contrast microscopy and each frame is 700 x 500 pixels. Images are in gray scale, 256 levels of intensity, where black color is the lowest intensity value and white color is the highest intensity value.

Fig. 1. Image obtained from Phase-Contrast Video Microscopy.

Normalized cross correlation of a particular cell and the image showed in Figure 1, it results in a peak located in the original position of the target, Figure 2.

Fig. 2. Normalized Cross Correlation of the target and the image.
Even cross correlation able us to localize a target from a microscope image, this procedure is not robust and the target is lost after few sequences. Nevertheless, the inclusion of some image processing to the image prior to the cross correlation operation, can increase the sensitivity of the tracking process.

We characterized several of this operations against the tracking effectiveness and its robustness respect mitosis and cell shape change. Image normalization, equalization, dilation and erosion are some of the image processing procedures we tried in this work. In this sense, equalization shown to provide best tracking results.

A. Image Equalization

Image equalization is applied to obtain better image contrast and it can be defined as a uniform distribution of the image histogram. This is made to facilitate the tracking of the objects. Histogram equalization obtain the maximum value of intensity in the image, in this case white color, it allows threshold the image in two levels.

Image equalization is performance by Eq. 1

\[ E(m,n) = 255 \times \text{AcuHis}(I(m,n)) \]

where \( E(m,n) \) is the equalized image, \( m \) and \( n \) are the pixels in the image, \( \text{AcuHis} \) is the accumulated histogram of image \( I(m,n) \).

III. CONCLUSIONS

Because of the features of the original images, in the cell tracking process, the normalization constitutes an important step in order to save computer time. Later, gray level morphological gradient makes the cells detection, basically by using the background. The method separates the background and the probable areas that contain a cell or cells, so the cell tracking can be performed without considering the background, shape, size, etc.

Finally, this contribution consists in taking the contour cell obtained after previous calculations and feed an optical correlator in order to track a specific cell from the image frame. Time consuming required to obtain the desired results in this work does seems to be in the range of time image acquisition. Image equalization provided excellent tracking results and robustness for mitosis and cells joints conditions.

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Fig. 3. Final image sequence after tracking process

The tracking process using equalization procedure required a time delay of 5 sec for a size target of 60x90 pixels and 9 sec for size target of 89x100 pixels. Figure 3 shown the final stage of the tracking task for 900 images. The path in the image represents the point where the cell was located. The tracking was possible even for mitosis and cells joint conditions.