IMAGE MOSAIC CONSTRUCTION ON DSP

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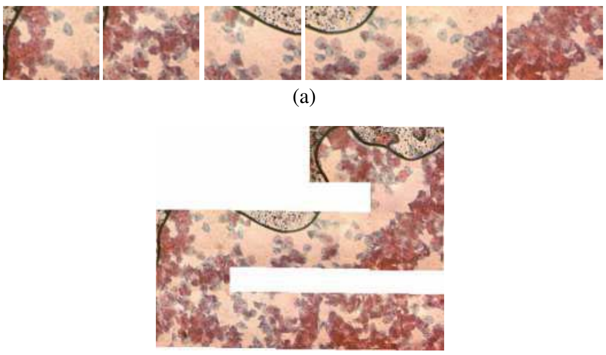
ABSTRACT

Digital medical image processing is based on images acquired by video cameras. The limited vision field restricts the analysis either made by an operator or by a computer. However, depending on the application, it may be important to have a continuous image of a larger region of the glass slide. The use of a higher resolution camera does not always increase the image's resolution sufficiently. In order to overcome this limitation, this work proposes the construction of a image mosaic of the images acquired sequentially by a standard resolution camera, returning a high resolution image representing an arbitrary slide area. The image mosaic construction algorithm uses the phase correlation method and the Discrete Fourier Transform to align and join the images precisely. Finally, in order to increase overall system performance, part of the algorithm is ported to a DSP.

1. INTRODUCTION

The Papanicolaou (also known as Pap) test [1] is an examination of the uterus inner and outer cells in order to detect pre-cancerous or cancerous mutations. In addition to automatic diagnosis, the screening of the glass slides images to be analyzed by a specialist can also be automated, increasing the amount of slides that can be processed in a certain time.

The first part of the automated screening consists on acquiring sequences of images, which contains a very small part of the slide but together represent the desired area, and processing them in order to obtain one continuous image, as in a mosaic. The process is named image mosaic construction (see Figure 1). After that, this larger image receives additional processing to determine its relevance to the exam.



(a)

(b)

Figure 1. (a) Example of acquired images; (b) mosaic including the images in (a).

2. THEORETICAL BASIS

The process of obtaining the exact translation between two displaced images is named image alignment, or image registration. Several different techniques are described in [2]. Phase correlation [3], a computational method based on the Fast Fourier Transform (FFT) is used because of its accuracy and noise insensitivity properties.

2.1. The Fast Fourier Transform

The FFT is the calculation of the Discrete Fourier Transform (DFT) of a function using fewer operations. In this case it is used the Cooley-Tukey FFT algorithm, which recursively divides an N point array into two smaller arrays, calculating one at each processing step. Thus, it can only be performed in arrays in which N is a power of two. To calculate the transform of a two dimensional array, the FFT is applied to all lines and after that to all columns, or the contrary. More information on Cooley-Tukey's and others algorithms can be found in [4].

2.2. Phase correlation

Consider an image to be a time-domain function $g_1(x)$, and an image of the same scene of $g_1(x)$ but translated by a certain amount L, named $g_2(x)$, as in (1).

$$\vec{g}_2(x) = \vec{g}_1(x - \vec{L}) \tag{1}$$

Because of the Fourier transform translation property, the transform of $g_2(x)$, is equivalent to the transform of $g_1(x)$ multiplied by a factor (2).

$$\begin{aligned} &F\{\vec{g}_1(x)\} = G_1(f) \\ &F\{\vec{g}_2(x)\} = F\{g_1(x - \vec{L})\} = G_1(f) \cdot e^{j \cdot 2\pi \cdot f \cdot \vec{L}} \end{aligned} \tag{2}$$

Subtracting the angles and performing the inverse transform results in a Dirac Delta function in the point of registration (3).

$$\begin{aligned} &\Delta\phi = \arg\{G_2(f)\} - \arg\{G_1(f)\} = 2\pi \cdot f \cdot \vec{L} \\ &F^{-1}\{e^{j \cdot \Delta\phi}\} = \delta(x - \vec{L}) \end{aligned} \tag{3}$$

3. ALGORITHM

3.1. Pre-processing

Generally, the microscopy images are not appropriate to perform image registration due to its low contrast and presence of multiple background artifacts. In order to minimize their influence, only the edges information is used. The Sobel filter is applied to the images, and the output is binarized having the threshold at a value in which most of the unwanted information is removed.

The images are then placed in the real portion of a larger complex data array. Note in Figure 2 that each image is placed in a different location. Each array's dimension must be a power of two, since this is a condition to perform the FFT. The difference between the complex array and the image dimensions are the maximum negative distance between the images to be registered.

2.2. Image registration and mosaic construction

The process of image registration using phase correlation is applied to the images in pairs. Each image has its Fourier transform calculated only once, to be used in two consecutive pairs. So each time a new image is processed its position in the complex array is inverted. After the registration process the mosaic is constructed by placing the images of the sequence, one by one, in a larger new image, respecting its relative location.

3. EXPERIMENTAL RESULTS

3.1. Image acquisition

The images are acquired using a Sony SSC camera and a microscope equipped with a dc motor. While the motor moves the glass slide at low speed, a video is recorded at 3fps. That was chosen after tests to be the maximum acquisition rate that permits to capture the images without blurring. The video is converted into an image sequence in which every image is very similar to the next one, displaced by a certain amount in the direction of movement.

The acquired images have dimensions of 640x480 pixels. They are placed in a 1024x512 background, and the image correlation process is performed. All of the source code was implemented in C and the image handling was performed using the LaPSI Image Processing Library *lili*[5], which is open source and includes various filters and functions commonly used in image processing.

3.2. DSP Implementation

On the method proposed the FFT calculations represent from 60% to 80% of the total image registration time. The approach adopted to increase the speed of the mosaic construction is to port the image registration functions to a dedicated processor. The DSP architecture was chosen over HDL circuit development for its faster development time, since it requires only few modifications in the working C source code and not a full project of the system.

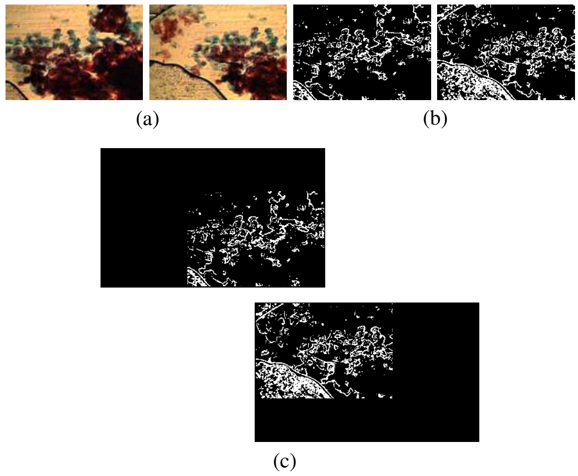


Figure 2. (a) Original Images; (b) images after applying the Sobel filter, and applying a threshold; (c) images placed in the complex array.

The target DSP is a TMS320C64XX, with 64Mb of RAM, working on a frequency of 1GHz. The performance was compared against a Pentium IV HT 3.2 with 1Gb of RAM. The sole porting did not result in a satisfactory processing time. Because of that a part of the FFT code used were replaced by Texas Instruments [6] C-compatible FFT libraries. These libraries are compiled with optimizations destined to specific DSP processors. The comparison table is shown below.

Table 1: Processing time of a 1024x512 point 2D FFT.

Hardware	Time
Pentium IV 3.2GHz	250 ms
DSP 64XX 1GHz, using FFT ported from C code	1790 ms
DSP 64XX 1GHz, using TI's FFT library	110 ms

4. CONCLUSIONS

This work proposed an algorithm to construct a mosaic of a glass slide. After that, part of the algorithm was ported to a DSP. Only recompiling the code increased the computation time. That is because the compiler is not prepared enough to recognize all the algorithm features and translate them to machine code.

However, the use of DSP with pre-compiled libraries represents an economy of more than 50% only on FFT calculations time, when compared to the Pentium IV. This is a very important result when constructing the mosaic of an entire glass slide, since it requires the processing of over 6500 images.

5. REFERENCES

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