Coagulation Time Detection by means of a Real-Time Image Processing Technique

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Abstract - Several techniques for semi-automatic or automatic detection of coagulation time in blood or in plasma analysis are available in the literature. However, these techniques are either complex and demand for specialized equipment, or allow the analysis of very few samples in parallel. In this paper a new system based on computer vision is presented. An easy image processing algorithm has been developed, which leads to an accurate estimation of the coagulation time of several samples in parallel. The estimation can be performed in real time using transputer architecture supported by a PC.

I. INTRODUCTION

One of the most important features in clinical analysis of blood and of plasma is the determination of their coagulation time. That is, in a laboratory of clinical analysis this parameter has to be estimated many times per day. So, it is important to carry out such computation in an automatic way, with a robust equipment and, if possible, with several detectors working in parallel.

Actually, there are already different kind of procedures and commercial coagulometers that perform an automatic or semi-automatic determination of this parameter. The current procedures of examining the clotting process are based on measuring the time between the start reagent and fibrin formation.

Among others, the most usual coagulometers are either optical or mechanical [1]. Optical techniques are based on the fact that clotting of a plasma sample is associated with a change in its optical density. Meanwhile, mechanical techniques are based on the change of viscosity, which is measured in a mechanical way after formation of the clot.

The so-called sphere coagulometer belongs to this last category. This instrument is set by a tube containing the preparations and a metallic sphere, in an oblique position, which rotates around the longitudinal axis of the tube. The coagulometer is calibrated in such a way that, to the onset of coagulation, the sphere moves exactly along a given site. The change in position is detected by a magnetic sensor. This system is interesting because it allows a certain kind of parallelism when testing samples.

However, in all these automatic systems there are strong constrains, either in space or in time, in order to process

several samples in parallel. This is the case, for instance, of the sphere coagulometer which requires one detector for every sample to be measured.

The solution presented in this paper is based on computer vision techniques. The initial idea is similar to the sphere coagulometer in the sense that the clotting is also detected by means of some change of movement of a sphere which is rotating inside a tube. However, in this case, neither special detectors for each sample nor even special position of the tube are necessary. After digital image adquisition, the detection process is performed by image analysis techniques. A quite simple algorithm, which is discussed in the next section, has been developed in order to get the coagulation time. Due to its simplicity, the process can be performed in real time supported by commercial hardware. This hardware, which is presented briefly in section III, is controlled by a PC, and has an architecture that allows flexibility to increment the number of samples to be processed at the same time.

II. DETECTION ALGORITHM

The image of the scenario (tubes containing the plasma samples, each one with a sphere in it) is taken by means of a commercial video camera. Every image is digitalized by an image adquisition board, and processed. The system is shown in figure 2. The goal of the designed algorithms is to analyze every image in order to extract a characteristic of the movement of the sphere. This characteristic has to be related with the change of the viscosity, inherent to the formation of the clot.

Depending on the method used for detection a binarization of the image is not necessary. Nevertheless, it is a very simple preprocessing technique which leads to a simpler detection and saves memory. Therefore, the first step is a binarization of the input image. For simplicity the illumination of the scenario is supposed to be good enough, so that a high contrast between the sphere and the rest is obtained. In these conditions, a constant threshold can be fixed. Otherwise, the histogram must be calculated at the beginning of a session and, by using it, so must be the threshold. Different solutions can be used to perform the binarization: from a binary CCD camera (with constant illumination and fixed contrast conditions), up to an input LUT (look-up table).

Different parameters may be computed to detect the change of movement of the sphere, e.g.: linear velocity, angular velocity, or position of the sphere (radius of

rotation). Linear or angular velocity leads to perform a tracking of the sphere (of course, preceded by a detection process in the first image). This tracking is not necessary in the position case, as it will be seen. Therefore, the computational load is lower in the last case.

In the detection process, different approaches can be carried out. So, using a video camera with interlaced is possible to compute, from a frame to the next one, the linear or angular velocity of the sphere. This approach gives a more accurate estimate of the coagulation time, but such degree of accuracy is not necessary. Moreover, this procedure asks for a tracking of the sphere (in fact, of a significant point of it, e.g.: its center), which, as it has been said, is time demanding operation.

Better results, from a computational cost viewpoint, are obtained by controlling changes on the position of the sphere. An approach, close to the sphere coagulometer method, is the use of stroboscopic effects. That is, the radial velocity of the sphere is to be the same or a multiple of the image sampling velocity, which is fixed (normally 25 image/sec.). In this way, the sphere is expected to be found always in the same position before clotting. This technique is not computational demanding, but a very accurate precision in the mechanical equipment is required.

By observing the images, one can realize that there is another way to detect changes in the position of the sphere. With spheres of fair size and uniform velocity, a sphere rotates in the largest possible circle within the tube, as it is shown in figure 1 a) (in this example the binarized sphere does not look circular since there was low contrast in the scenario). However, due to the fibrin formation, sphere speed decreases. That means less centrifugal force and therefore, the sphere goes, following a random path, towards the center of the tube, as it is shown in figure 1b. This fact can be detected

in a very easy way from the image. The algorithm developed computes firstly the ring in which the sphere is rotating before clotting. This ring can be computed at the very beginning of the session (when there is no problem in computational time) using boolean functions over the input binary images, and it can be smoothed using morphological operators [2]. In fact, if scenarios were always in the same conditions, this computation would be done only once.

This external ring can be used as the boundary of the internal circle where the sphere goes when clotting. This means that the detection is performed by looking for pixels inside this inner region, which are the whitest pixels in figure 1 b). This detection is very simple and it is the only task that it has to be done in real time for every collected image.

III. HARDWARE ARCHITECTURE

In figure 2, a diagram of the hardware implemented for this applications is shown. It has to be pointed out that the video camera is a standard model that gives 25 image/sec. This figure is high enough since it leads to a detection tolerance between 0 and 40 msec., which is much better than usual clinical requirements. In fact, for actual applications, one over three images can be used; that is, a precision of 120 msec. in the worst case.

Due to the algorithm simplicity, the detection process of one sample can be managed straight by typical image boards. This is not possible when working with several samples in parallel. In this case, the use of fast processors with fast links is necessary . A structure with transputers has been chosen because it allows a great flexibility. This method has been implemented on two transputers in order to process 100 samples in parallel. The same structure can be increased if more parallel detections are wanted.

REFERENCES

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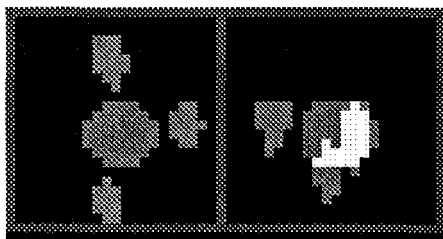[2]   J. Serra, "Image Analysis and Mathematical Morphology", Academic Press, 1988.

Figure 1. Overlapping of 3 consecutive images. a) Before clotting. b) During the fibrin formation. The central circle is the region of interest for detection purposes.
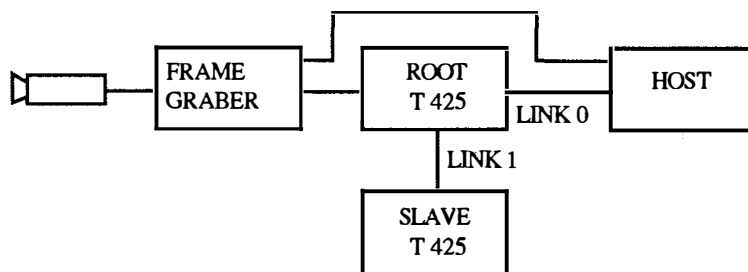

Figure 2. Block diagram of the hardware architecture.