

Automated Analysis of Ultrasound Images

by

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Category:

Biomedical

Products Used:

LabVIEW software

IMAQ Vision Toolkit

PCI-1407 board

The Challenge:

To improve the speed, precision, and objectivity of the analysis of video tapes containing ultrasound images which document changes in blood vessel diameter.

The Solution:

Use National Instruments' LabVIEW software to build an application that combines the automated analysis of video frames with control of the video recorder drive so that video sequences of interest can be accessed quickly and analysed objectively.

Abstract

The Cardiac Transplant Unit at a client hospital uses ultrasound imaging to monitor the effect of different drugs on the diameter of blood vessels in the arm. The vessel diameter is typically monitored in a series of 2-5 minute bursts over a period of about half an hour. An ultrasound image of the area of interest is combined with an ECG trace and stored on S-VHS tape for off-line processing. ICON Technologies was asked to develop an application for the automated analysis of the stored data to replace the existing time consuming and subjective method, which involved taping a grid to the replay screen and manually measuring the diameter as the tape was advanced frame-by-frame. The system achieves continuous analysis at a rate of up to 17 frames per second, with an increase in the precision of measurement of the vessel diameter from 24.8 percent to 6.7 percent.

Background to the Application

The Cardiac Transplant Unit at a client hospital uses ultrasound imaging to monitor the effect of different drugs on the diameter of blood vessels in the arm. This research has implications for both the diagnosis and treatment of endothelial dysfunction, which can be a precursor to diabetes, atherosclerosis, and other conditions. In a typical experiment the vessel diameter is monitored in 2-5 minute sequences over a period of about half an hour. An ultrasound image of the area of interest is combined with an ECG trace in a proprietary commercial instrument, and the composite image is output to S-VHS tape for later processing (see Fig. 1).

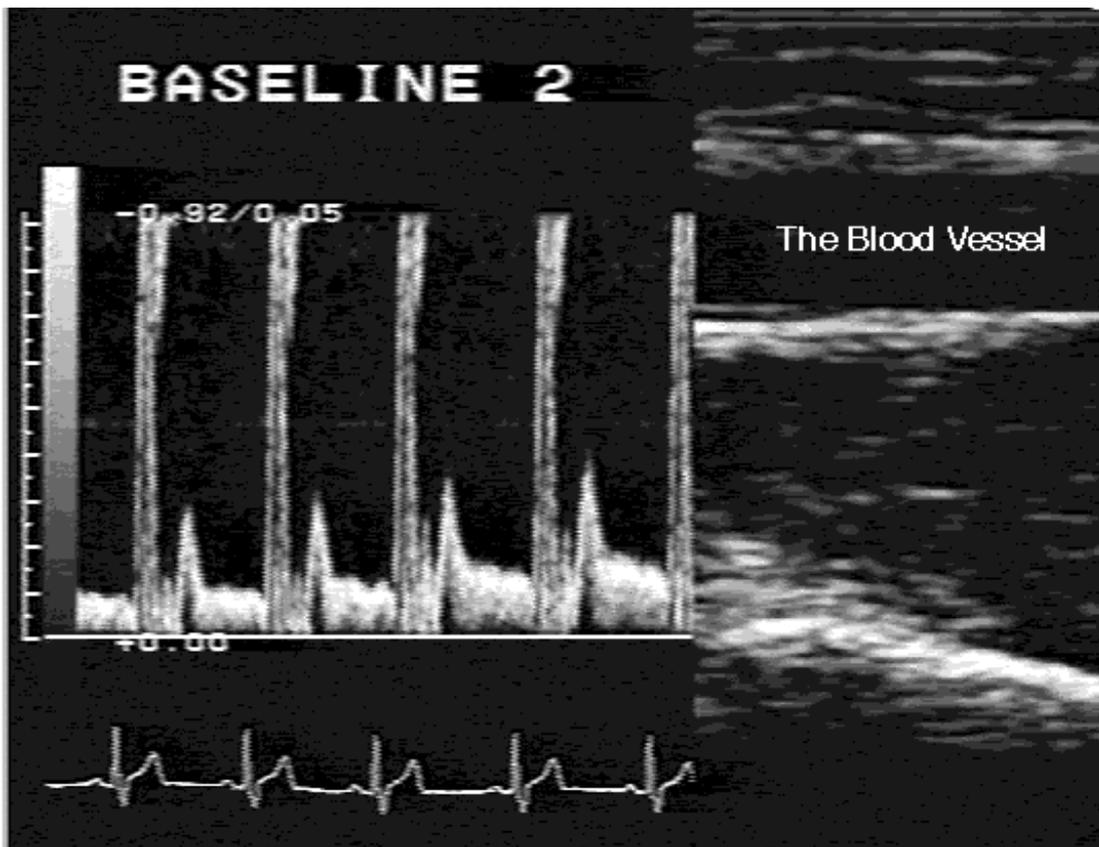


Fig. 1 – A video frame showing a composite image of the blood vessel and the ECG trace.

The conventional method of analysing these tapes in research groups throughout the world involves taping a grid to the replay screen, advancing the tape frame-by-frame, selecting images that are synchronised to a particular peak in the ECG trace (see Issues to Address, below), and manually measuring the blood vessel diameter. This process is subjective, extremely time consuming, and has a typical measurement precision around 25 percent. In many cases this precision is insufficient to quantify the effects under investigation. ICON Technologies was asked to develop an automated, objective method of analysing these tapes that would speed up the analysis times and improve the measurement precision.

Issues to Address

There were a number of critical issues that the application needed to address. To maintain objectivity there had to be minimum operator interaction with the application once an analysis sequence was initiated. The composite images were generally of poor quality, with the “grainy” appearance and high background noise levels typical of an ultrasound image. The client also had historical data archives that had been recorded on a previous instrument. The ultrasound image and ECG trace on the earlier tapes were of slightly lower quality, and located in totally different locations in the composite image.

Also, in a given sequence of frames, the image of the blood vessel was not fixed in place. Even though every effort was made to keep the patient’s arm immobile, there was always some translational movement of the vessel image from frame-to-frame.

Finally, it was necessary to synchronise the measurement of the vessel diameter to the R-wave spikes in the ECG trace, to eliminate the effects of periodic changes in diameter that are caused by normal surges in blood flow. By synchronising the measurement to the R-wave spike, it was being made at the same point in the blood flow cycle, and intra-cycle variations could be eliminated.

How It was Done

The tape was replayed through a JVC SR-S388E time-code video recorder under RS-232 serial control. The application includes a basic driver library for the SR-S388E that implements the most common control commands. Images are acquired from tape via a National Instruments’ PCI-1407 monochrome acquisition card.

Patient files include a tape index, and time-code ranges for the sequences of interest. The operator specifies the patient and the time-code range of the sequence to be analysed. The application auto-forwards to the starting time-code and

allows the operator to review the sequence. The operator uses the mouse to outline the general area on the screen that includes the blood vessel of interest, specifies the starting and ending time codes, and then initiates the analysis procedure. Once the procedure is activated there is no further input from the operator.

Video frames are acquired continuously from tape between the two operator defined time-codes. The application uses pre-defined masks to look for the ECG trace in different regions of the image depending upon the source instrument. The ECG trace is auto-thresholded, and a peak detection algorithm is applied to determine if the frame occurred within a specified (user-configurable) window of the R-wave in the ECG (see Fig. 2).

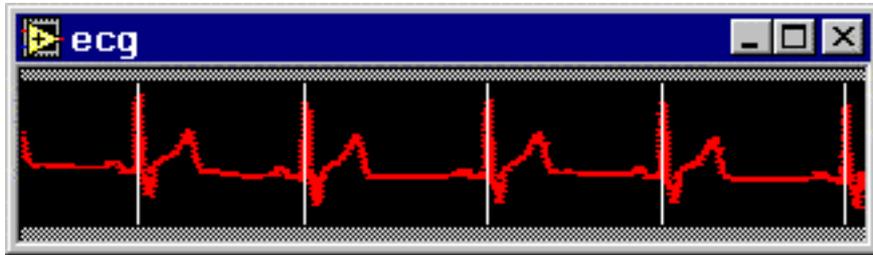


Fig. 2 – The auto-thresholded ECG trace with peak detection algorithm applied. The frame is valid if the rightmost peak occurs within a specified distance (time) of the edge of the trace record.

Frames that do not meet this criterion are discarded, and a new frame is grabbed and tested. Frames that do meet this criterion are passed to the second stage of image processing. In the second stage the operator-defined region of interest is thresholded to define the boundaries of the blood vessel. Approximately 200 measurements of the diameter are made by drawing perpendiculars between the vessel walls. The experimental diameter is taken as the median of these values (see Figs. 3 and 4). In this way diameters are taken at regular intervals between the starting and ending time-codes. At the end of the sequence the set of diameters is plotted to screen for post-processing.



Fig. 3 – A thresholded blood vessel overlaid with the envelope of all fitted diameters.



Fig. 4 – The thresholded vessel overlaid with a box drawn to the median diameter.

The operator can choose to run the analysis with the intermediate results of all thresholding and sizing operations displayed on screen, or for maximum speed, with the results of all these operations not displayed on screen. At

maximum speed the system achieves continuous acquisition and analysis rates of up to 17 frames per second in real time on a 450 MHz Dual-Pentium III PC. Measurement of the vessel diameters is objective and reproducible with a precision of 6.7 percent.

Why LabVIEW?

LabVIEW is ideally suited to any application that needs to combine conventional image analysis with other types of I/O (in this case, serial control of the video recorder). The IMAQ Vision Toolkit offers access to very sophisticated image processing tools from within the easy-to-use, consistent “look-and-feel” of LabVIEW. The entire analysis of the ECG R-wave and the blood vessel diameter is in each case accomplished via a sequence of three sub-VIs from the IMAQ Vision Toolkit (Extract Region of Interest, Auto-Threshold, and Convert Image to LabVIEW Array), together with one custom analysis VI.