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Equipment for 3-D Picturing and Measurement of Atherosclerotic Plaque

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BIOGRAPHICAL NOTES

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KEY WORDS

Atherosclerotic plaque, sonography, measurement, picture recognition, 3-D modelling

ABSTRACT

This contribution presents a management system with the achieved results of a com-

plex grant project focused on the development of equipment for the 3-D picturing of a carotid artery. This problem was solved during years 2006 - 2008 by specialists from the Faculty of Mechanical Engineering VŠB-TUO, Faculty of Electrical Engineering and Computer Science VŠB-TUO and Neurological Clinic FN Ostrava during the solving of research project GA 101/06/0491 supported by the Czech Science Foundation. The main goal is mechanical system for the exact measurement of Atherosclerotic Plaque (AC plaque) in a carotid artery, including the control system and synchronizations with the heart activity. The obtained pictures enable the necessary analysis and acquisition of data for Atherosclerotic Plaque with appropriate accuracy and recurring measurements. These results open the way for medical use.

INTRODUCTION

A ischemic stroke is the third most frequent cause of death and the most frequent reason for disability of our population. Therefore, it is becoming a significant social and economic problem. Ischemic strokes make up 85% of all strokes. The highest risk factors are hypertension, hypercholesterolemia and smoking. The atheromatosis of carotid arteries is the most frequent stroke aetiology factor. This takes part in 30% of developing a stroke. This study aims to develop and follow the testing of equipment for 3-D picturing. To create a 3-D picture we have to make three steps. The first step is acquisition, the second one is reconstruction and the third is rendering. We have to work out a computer system for measuring 2-D sonograph pictures, for the 3-D reconstruction and final creation of all pictures. Then it is necessary to design and construct shoulder bringing ultrasound probe in existence and to deal with the mechanisms of probe movement.

In the last period of the design all the system mentioned above were tested by the repeated measuring on the group of volunteers. The lengths of all the study was three years. The meaning of the project is based on the practical application of the system - the possibility of measuring the progression of atherosclerotic plaque preciously in the area of the carotid artery and to predict the risk of an ischemic stroke [10].

AIMS OF PROJECT AND DESIGN OF SOLUTION

The aim of this project is to develop and test the equipment for measuring 3-D ultrasound for ath-

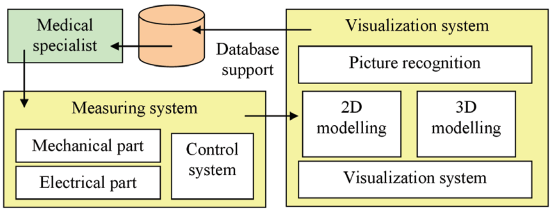

Fig. 1 *Main structure of the developed system*

erosclerotic plaque in carotid artery bifurcation. To create a 3-D picture we have to make four steps [2], see Fig. 1:

- ***To get a set of 2-D sonograph pictures in defined distance taken in the same heart activity phases.***
- ***Reconstruction of these data, object identification.***
- ***To create a final 3-D picture.***
- ***To measure the atherosclerotic plaque size and store all data in the database for comparison with earlier data.***

ULTRASONIC PROBE POSITIONING SYSTEM

To explain the function of the developed mechanical system we will take advantage of the similarity of some parts of a turning lathe. A positioning system is created with the help of ULMER standard parts. It includes the base, which is fixed to the hospital bed. A longitudinal saddle can be manually moved along the base to achieve the needed probe's starting position considering the patient's position. A crosswise position can be adjusted with the help of a cross saddle. To set the appropriate pressure between the probe and a patient's body the cross saddle is equipped by a flexible joint setting mechanism (adjusting spring). The cross saddle movement is car-

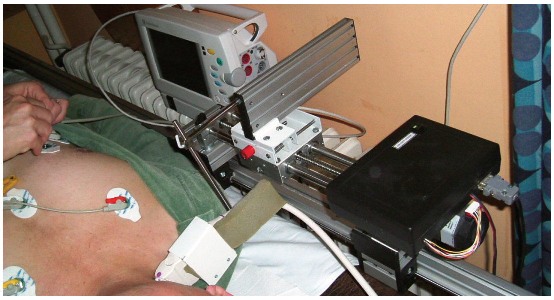

Fig. 2 *Ultrasonic probe linear movement system*

ried out using a MICROCON incremental servo drive, optimized according to [11]. The motion range is between 2 and 3 cm.

Patient multipurpose monitoring systems serve in ECG (electrocardiograph) monitoring, pulse frequency, temperature and other measurements [6]. These monitors are equipped by output signals from the ECG ranging in the order of Volts. This signal is used to synchronize probe movement with a patient's pulse. Some of these systems are equipped also by wireless communication, which can be used to obtain appropriate signals [3], see Fig. 2.

CONTROL SYSTEM

A single-chip microcomputer from the PIC family PIC16F84A was used to carry out the technical part of the developed control system as a triggering pulse generator. This processor can communicate with the RS 232 bus with the configuring PC (Personal Computer) and also with the power unit for the MICROCON (CD30M) incremental servo drive. This power unit executes commands sent from the triggering unit. These command strings are also transmitted via RS 232 serial bus to the PC to start the power unit configuration programme.

The self-chip microcomputer used does not include A/D input; therefore an ADC0831 CC A/D converter must be included in the triggering (starting) unit. This converter is necessary for trigger signal scanning. The triggering unit generates movement commands for the incremental servo drive power unit when the triggering signal level is achieved.

The developed control system software can be divided into a few levels [12]. The first level includes the program support for the triggering unit, which is developed in a single-chip PIC family programming environment. The triggering algorithms for the ultrasonic probe stepping movement is included in this program level. The second program level includes the software support developed in the Visual Basic 6 environment. It allows monitoring of the triggering signals and the configuration.

MEASURED SONOGRAPH DATA VISUALIZATION

The main problem to visualize measured sonograph data is the difference between standard data charts or tables and graphical object metrics found in a sonograph picture. It is possible to show the results of the picture analysis in numerical form, but the graphical form could be more declarative [1].

CREATING MEASUREMENT PICTURES

The recording process is processed by an ultrasonic probe and special moving equipment, developed also during completing this project. All taken pictures are stored in the AVI file. Special software like VirtualDub converts this file to a set of BMP pictures

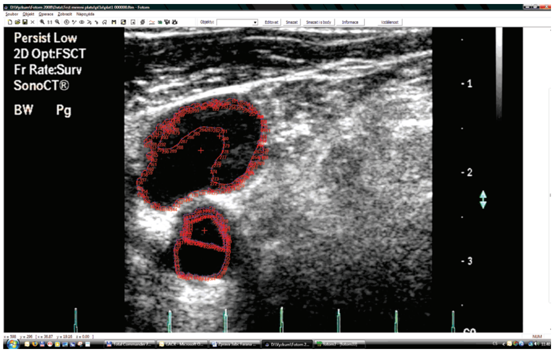

Fig. 3 *Carotid artery picture analysis and object recognition*

for the following analysis. The main goal of this analysis is object recognition and its dimension measurement, see Fig. 3.

An object manager, included in the FOTOM software system [7] allows working comfortably with the picture scenery, especially by the interactive point changes, polygon point movement, direct object point setting and deletion. The special tool "Sketch" was developed to make picture processing easier.

2-D MODELLING AND OBJECT DISTANCE MEASUREMENT

Six object classes were defined to describe the picture scene: separate point, edge, vertex, circle, ellipse and polygon. Objects from these classes are defined in the editing mode by selecting some objects and setting a concrete class [7, 8]. A common parameter of all objects is their centre position in the picture. The object classes with an inner area such as a circle will be mostly used for describing a 2-D picture. These objects have some area and could be used for 3-D modelling of a carotid artery [9]. For example, see Fig. 3. The object profiles need to be a circle, but in case of their bending it seems to be an ellipse. A special tool for relative rolling helps to see an object from a correct view.

Object centre distances are very important measurements, especially to determine their deformations. This data can give additional information about the general state. FOTOM module 2 solves this problem, see Fig. 4.

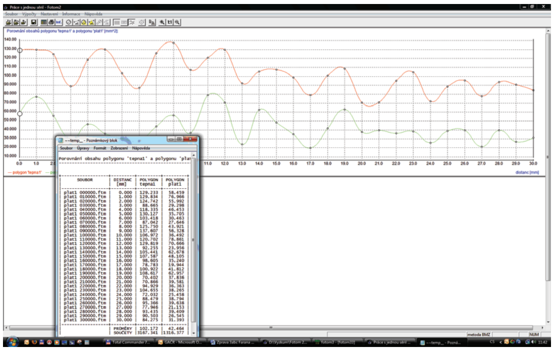

Fig. 4 *Carotid artery and atherosclerotic plaque recognition*

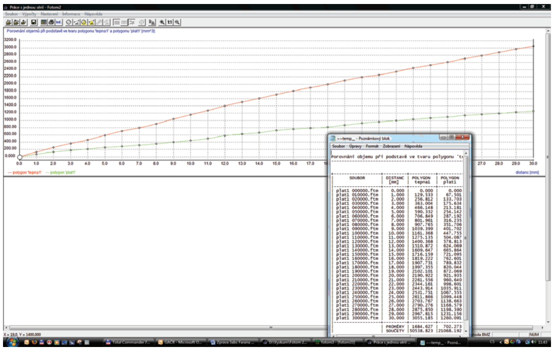

Fig. 5 *Carotid artery and atherosclerotic plaque volume computation*

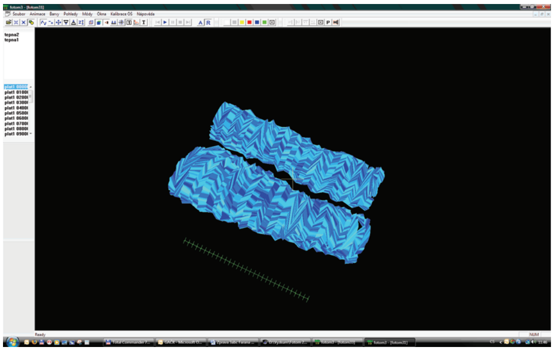

Fig. 6 *Carotid artery 3-D model*

Analysed carotid artery and atherosclerotic plaque dimensions allow their volume computation, see Fig. 5.

3D MODELLING AND ANIMATION

We need to use some transformation to show a 3D picture on a computer monitor, which can show 2D pictures only [1]. The FOTOM System uses standard axonometric projection based on a wire frame model, created on the set of analysed sonograph pictures [5], see Fig. 6.

SONOGRAPH PICTURING INFORMATION SYSTEM

The analysed 2D and modelled 3D pictures of a carotid artery need to be organized for their next use. The best way seems to be some web-oriented database application, which allows storing all appropriate data [4], like:

- Blood speed in extracranital arteries.
- Blood speed in intracranital arteries.

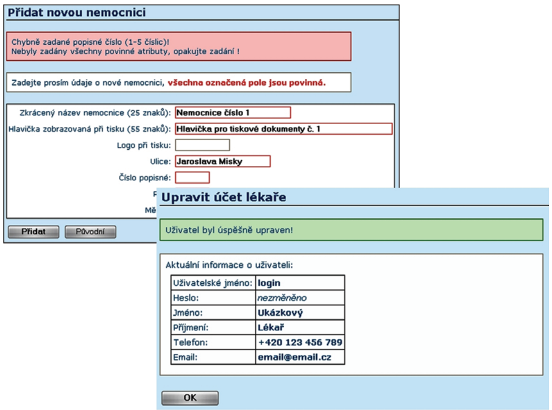

Fig. 7 *Information system GUI examples*

- Atherosclerotic plaques.
- Carotid arteries stenosis.
- Carotid and intracranital artery drawings.
- Other special attributes, like:
  - echogenity of brain strain,
  - patient anamnesis,
  - LDL-cholesterol level and other areas.

The client application was developed in the PHP version 5.2.1 environment to enable all needed data operations, picture search, presentation and processing with the help of the FOTOM System as a modern way to share medical data, see Fig. 7.

CONCLUSIONS

This contribution presents the final results obtained during completing the grant project "The Development of Equipment for 3-D Picturing and Measurement of Atherosclerotic Plaque". Triggering unit synchronising the ultrasonic probe movement according to a patient's pulse was developed and tested to obtain a set of 2D ultrasonic pictures of an artery bank at requested distances in the same pulse cycle moment. The 3D modelling of the artery carotid was processed with the use of this picture set. The developed control system allows both manual movement control and an automatic picture set processing. All the needed parameters can be configured from a PC based control software environment.

The developed database information system allows all needed operations with sonograph pictures to analyse the carotid artery and atherosclerotic plaque trend analysis with the help of specialised FOTOM software system, developed at VSB - Technical University of Ostrava.

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