SOFTWARE FOR ANALYSIS OF PRESSURE DISTRIBUTION DATA

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Abstract: Evaluation of pressure distribution over the contact surfaces is commonly used in many fields like industry, biomechanics, dyscomfort studies, medicine, footwear design, etc. In sport, biomechanics, orthopedics there is a common task to measure the pressure distribution under the foot during gait or during standing by electronic force platforms, electronic foot insoles or other more or less sophisticated devices. Distribution of pressure under the sole of the foot is a typical interaction problematic. From mechanical point of view the human foot contact with the rigid solid (ground, force platform respectively). Mechanical loading of the foot structures is a factor which can be in direct relation with some pathological conditions of the foot like ulceration and tissue damage under the excessively overloaded structures or the bone prominences, flat feet, heel pain and other. It can also be used to record the progression of the disorder or recovery from orthopaedic operation, etc. The common method to detect he pressure under the foot during gait or standing is by force platform, electronic pressure platform respectively. The aim of the project was to develop the analytical program module and design routines for evaluation of pressure data from formerly developed pressure platform.

Introduction

Pressure distribution under areas of contact plays important role in many fields of industry like pressure under the tires, brakes, gaskets, etc.

Analysis of distribution of pressure over the contact surfaces (e.g. interaction of human structures with other solids) is also common task in fields like biomechanics [1, 2], forensic application, footwear design, medicine [3, 4, 5], podiatry, military, sport [6], sitting discomfort studies [7], biofeedback applications, development of antidecubital mats and materials, prosthetics, dentistry, etc. There are many studies that deal about the pressure distribution on interaction of the sole of the foot and ground during gait and upright standing under physiological and pathological conditions, eyes open, eyes closed conditions, after pharmacologic interventions, corrective operations, gait research studies. The pedobarography is called one of these detection methods of pressure distribution, which detect the pressure under the feet during quite upright standing or walking. Detection of pressure distribution could be valuable in consideration of mechanical overloading of foot structures like metatarsals rays and heads, toes, heel pad and ligaments, inverse calculation of forces acting along the foot. It is in direct relation to medical care for example about diabetic patients where overloading can cause soft tissue damage and ulcers, it is important in detection of flat feet, evaluation of pre and postoperative states and successfulness of corrective operations, influence of neurological disorders and other. It is valuable in foot insoles design and shoe industry.

Because the changes of pressure on interaction surfaces (feet) during gait and even during standing are dynamic processes it is necessary to capture pressure data under the sole of the foot during the course of time. The methods of estimation of pressure distribution under the feet from footprint in special matter or from optical footprint are obsolete and appropriate for clinical assessment only. The modern electronic devices like pressure platforms are able to record the data in digital format with sufficient sampling rate. The advantages of digital format are clear. The more sophisticated data processing is allowed.

We are used to work with the pedobarography platform that was developed with tight coordination with Czech Technical University in Prague [8] and we have possibility to work with commercial pedobarography platform also.

Our aim was to design and develop the analytical software module for offline analysis of contact pressure distribution data from these devices. The software should allow evaluation of parameters of foot contact during gait and during standing.

Materials and Methods

Description of the developed device: The system consist of three main parts: sensing platform, interface unit and basic control software [9, 10].

The platform consists of elementary sensors arranged in matrix (100 rows by 75 columns). The dimension of one elementary sensor is 3 by 3 mm. Spaces between sensors are 1 mm, so the discriminative ability is 4 by 4 mm, that is quite enough for medical purposes. The active area (400 mm by 300 mm) of the pressure platform consists of 7500 sensing elements. Pressure sensitive element is Yokohama rubber which changes its ohmical resistance due to external load. Electrical signal is digitized by 8bit A/D convertor. Range is 0-200 kPa. Temperature range is -40- +100 °C.

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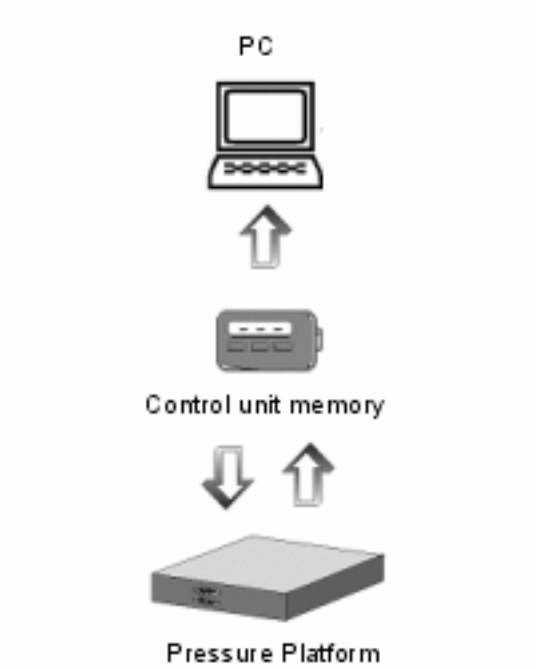

Figure 1: Schema of the system

The system is designed to allow detection of distribution of pressure respectively loading of each elementary sensor over the area of contact during the course of time. Maximal sampling frequency is 2.25 MHz, it means 300 snaps (all sensors of platform) per second. Data can be stored on RAM for fast measurement or on the external harddisk for long time measurement. In this case the time of measurement is limited by disc capacity only, so the time of data capturing can be few hours. The maximal snap frequency in the case of harddisk data capturing is limited to 80 snaps per second. Data are stored in binary form and is possible to export data to ASCII file afterwards.

In the control software is possible to set several parameters like time of measurement, amplification, threshold level, sampling rate, write name and notes about measurement. The control software allows capture one single snap, consecutive sequences or snap the pressure data manually in time. Viewing the stored sequences, playing sequences forward or backward, pause the sequence, skip snaps one by one is allowed. The online viewing of loading pressure platform is also possible (figure 2). The control software allows also the basic manipulation with data like selecting regions of interest (ROI) or selecting sections and some basic calculation with data like sum of all pressures over the platform or center of pressure. All data and all information about regions or sections is possible to export. There are several possibilities to export stored data. The first possibility is to export data in ASCII file, the second possibility is to export pressure images like bitmap file. The user can select one or several samples or whole data sequence for both type of export (TXT file, BMP file). Analysis of exported data can be done in external software.

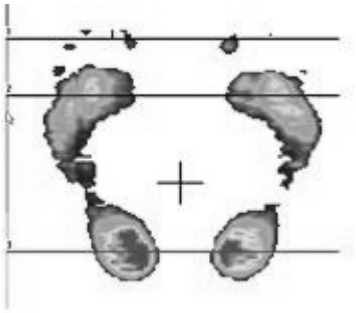

Figure 2: Visualization of pressures under the sole of the feet with 3 horizontal sections

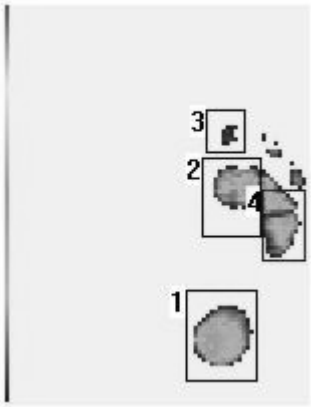

Figure 3: Basic selection of regions of interest in the control software

The analytical software is assign for offline analysis of pressure data. The software module was developed in Matlab programming environment. Our aim was to design the modular program with possibility to add simply new potential modules for pressure data analysis with maximal flexibility and accessibility of source data or just calculated data. The software read the source data directly in binary format. The structure of this application consists of three main logical parts - main screen, analysis of center of pressure (COP), analysis of regions of interest (ROI) (figure 3).

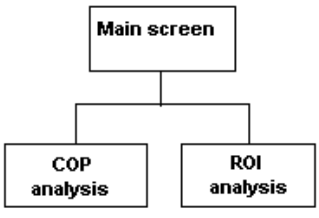

Figure 4: Schema of the analytical software

Main screen contain all common function to work with data. The software is able to read data from a few basic file formats like binary file format and ASCII

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format. It is possible to display actual frame (data matrix) in different ways – image, contour, mesh, surface graph (figure 5).

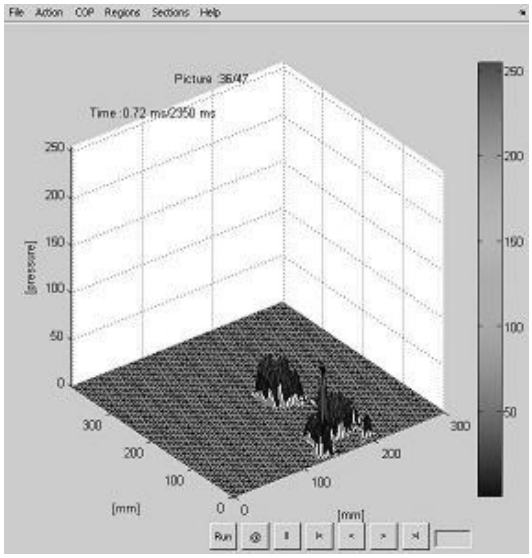

Figure 5: Surface plot of pressures under the sole of the feet

Also it is possible to skip frames forward and backward through the record (collection of frames in time), play and pause the record forward and backward, measure the distances on the image. Each graph can be saved separately like picture. On the image could be selected regions of interest. For example regions of interest can correspond to anatomical areas on the image (figure 6).

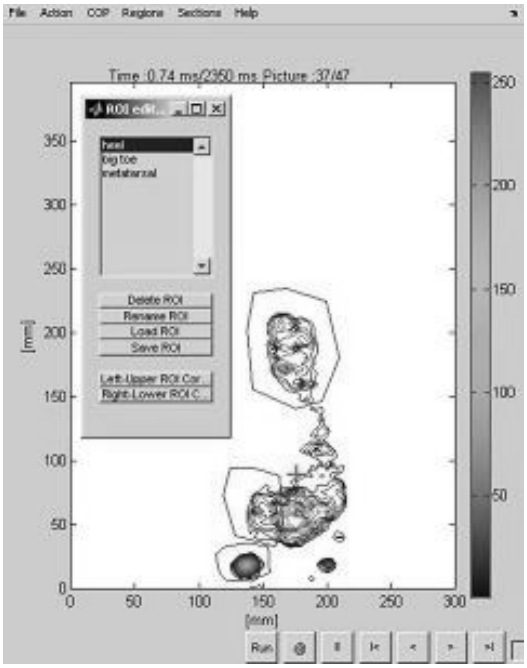

Figure 6: Contour plot of pressures and ROIs

Analysis of center of pressure (COP) is screen that allows analysis and visualization of center of pressure trajectory in different directions, COP velocity and acceleration of COP in different directions like anteroposterior and madiolateral direction, calculation of power spectral density, cross spectral density, coherence, phase. Center of pressure is point location of the vertical ground reaction force vector and represent a weighted average of all the pressures over the surface of the area in contact with ground respectively with detection platform.

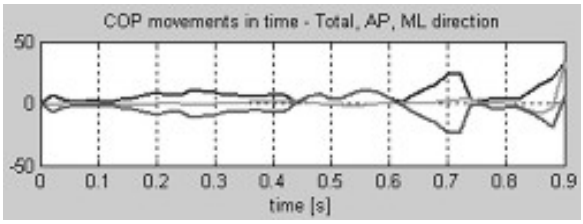

Figure 7: Magnitude of COP excursions in time

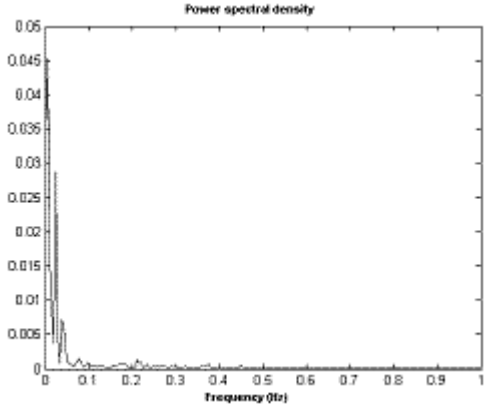

Figure 8: Power spectral density of COP excursions

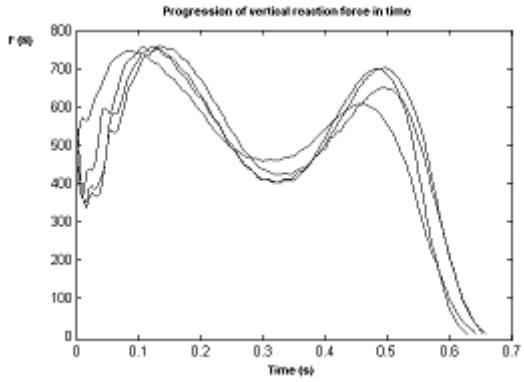

Figure 9: Progression of vertical reaction force of four consecutive steps in time

Calculated parameters can be stored in ASCII format for potential statistical analysis. Analysis of regions of interest is screen that allows analysis of selected areas of the image. It means progression of loading in the regions of interest during the time, total loading, maximum pressure value in area of interest, number of active sensors in the region, histogram of pressure values, time of contact, area under the curve (impulse of force). It is possible to count separate center of

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pressures in different regions. All parameters and graphs can be saved and exported.

Results

The software for distribution of pressure analysis and visualization was developed. The system offers convenient way of data processing and calculation of parameters of contact features during standing or walking. We calculate also parameters like crosscorrelation, coherence, phase, but according to our experience this parameters seems to be unclear in interpretation of pedobarographic measurement.

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