

## ORTHOPAEDIC INVESTIGATION SYSTEM FOR MEDICAL NON-INVASIVE DIAGNOSTICS

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**Abstract:** The qualitatively new measuring and evaluating system for orthopaedic purposes has been derived from the Matrix Areal Pressure Transducer, and from the special 3D – SW for PC evaluation. Digitising the transducer’s outputs (up to 7500 sensors – semiconductive elastomer) insures the comfortable complete orthopaedic non-invasive diagnostics, and beside that the extraordinary high processing dynamics (up to 60 snaps/200 ms, i.e. – 300 Hz for full snaps).

**Key words:** orthopaedic investigation, pressure transducer, 3D – evaluation, semiconductive elastomer, visualisation.

### 1. INTRODUCTION

The task for modern medicine is not only to realize the treatment but to predict, to prevent and to insure to be caught the starting diseases in the same beginning - being weak, in this time only. “The early-bird” treatment is then more effective and economy, too. To analyse – the data in orthopaedics, several years ago – it meant usually – to be used the “one-way” measurement techniques or the recognition means, only as – e.g.: water pattern, coal paper, gyps pattern and “shoes”. Moiré’s methods, mirror’s systems, various pressures films, etc. The main disadvantages: no flexibility, time duration and delay, the special technical stuff, the storage-obstacles – to be followed the diseases or treatment development.

To be left these disadvantages, the Orthopaedic Investigation System has been realized. This one allows to get the instantaneous results not only typical for common PC – evaluation, besides that for the more comfortable, and more precise data analysing – the special 3D – SW has been developed, and the others HW + SW improvements oriented for the orthopaedics problems have been done, too.

### 2. PRINCIPLE – ORTHOPAEDIC INVESTIGATION SYSTEM PERFORMANCE

As the measuring sensitive layer is being used the high quality semiconductive elastomer thick 0,5 mm (Yokohama Rubber [3]), by means of which is transformed the acting superficial force or the areal pressure to the electric signals. Having been digitising the step area with grid-resolution usually (from 2 to 4 mm) is given 2D – sensitivity with high density levels (up to 256 greyness levels, which to 256

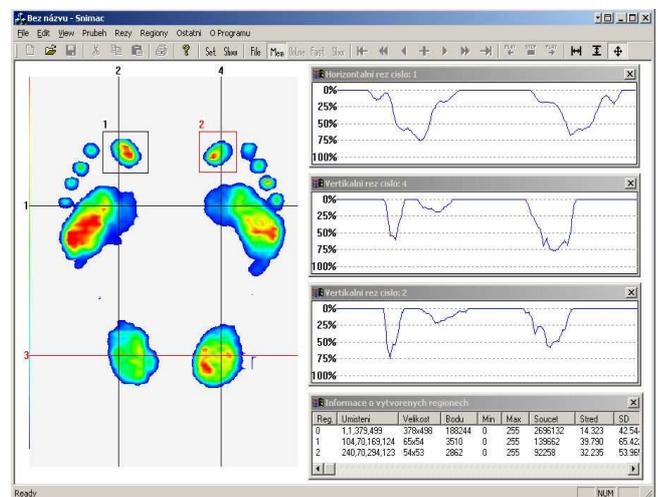
colours has been assigned)– what can be seen in Fig. 1 – The PC evaluation. This one – 2D pattern represented the top for the 1-st Generation of Orthopaedic Investigation System. Of course, the 2-nd Generation held all former merits, and beside that – the special 3D– SW has been added, see Fig. 2. This one enables - to be followed the recognition details – for what the clockwise and anticlockwise rotation of the MM “mountain model” can be observed. The other improvement is the base plane panning – for the more comfortable problems – studying. For the more details in any place of MM can be realised the several Cuts of Interest – to be compare among themselves, at once, or later, too.

By the System Development, the SW demand was - to be created an interactive environment for medical doctors and technicians (who are – no programming experts), who need:

- to quickly analyse the measured data;
- to easily configure and manage the tests;
- to simply view real-time and historical data – results.

Therefore, this Orthopaedic Investigation System features – with the intuitive wizard and dialog boxes - to help them, as simply as possible – to realise:

- the Data Acquisition;
- the Datalogging;
- the Data Visualisation;
- the Data Processing.



**Fig. 1. 2D presentation**

- Of course, the others standard's evaluation and the statistical functions typical for an orthopaedic investigation could be used by processing, too – as e.g.: (ROI – region of interest, SROIs – several ROIs, COP – centre of pressure, SCOPs – several COPs, histograms, vertical (horizontal) cuts, isobars etc. The Orthopaedic Investigation System enables the transducer's 7500 sensing points, to be caught in one snap, as the output data processing signals, which can be PC-evaluated, either in the real-time, or either in the future. The reason for it – being the other demand – to realize the “terrain” measurement possibility, too - with as low as the minimal System configuration (NO – PC!); what enables the special set (The Transducer + The HDD Unit), only (so called – “travel storage arrangement”. What is worth seeing for this Tactile System is one of the top-world dynamics (up to 60 snaps/200 ms, i.e. 300 Hz for full snaps).

### 3. EXPERIMENTS – METHODS

Being used the semiconductive elastomer as the areal pressure /el. signal converter; and being known only little for this purpose, about – the experiments number was realized. These ones have been focused – to be received the background results and experiences for an intended matrix transducer arrangement with the active sensing area, as large as 0,3 x 0,4 m; 7500 sensors – having been concentrated, there (each 3 x 3 mm). The first experiments have had the basic investigation character – being followed: sensitivity, reproducibility, hysteresis, supply and temperature influence etc. - for the single sensors – see Fig 3. To be caught the behaviour experiences, the later experiments have been focused – on the small sensing area (sensors group) –what is

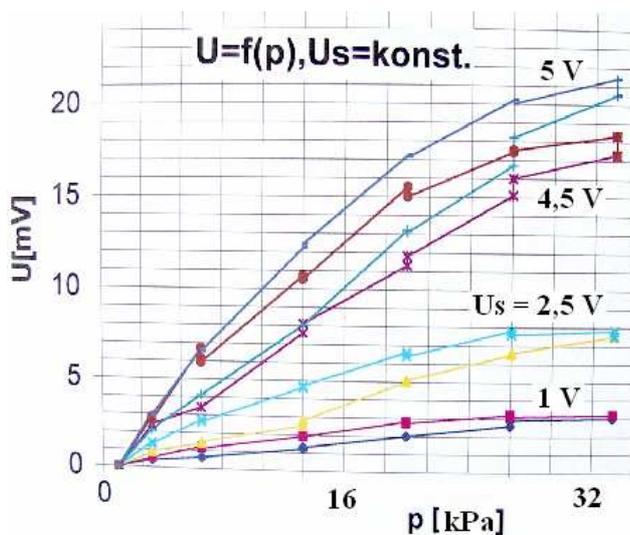


Fig. 3. Single-point transducer – The supply voltage  $U_s = \text{const}$  influence on the hysteresis of the Output voltage vs Pressure dependence  $U = f(p)$

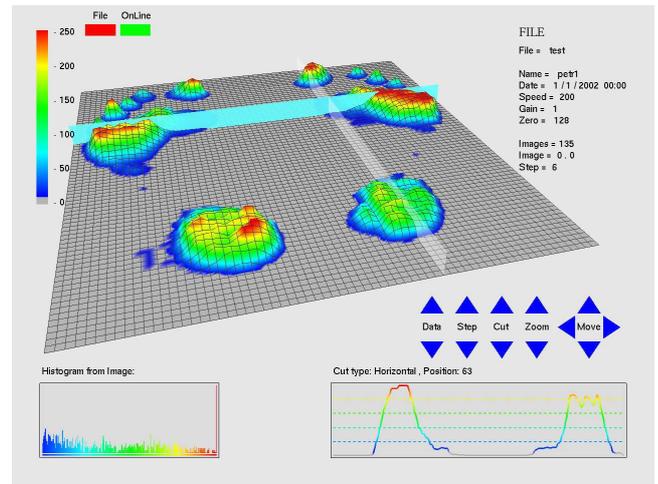


Fig. 2. 3D presentation

the inter-sensors sensitivity; the shape – (size-) loaded area influence; the various covers materials influence, too.

The experiments results have been the base for the transducer project. Unless we consider, the others optional layers – the principle transducer arrangement can be seen in Fig. 4.

Beside that, the development of our own HW-Electronics and Interface, has been started as so as SW, too - to be realized: - an extraordinary high demand for the dynamics snaps processing (300Hz); - the several operation mode, and the various connectivity possibilities;. From The 1-st Generation of the Orthopaedic Investigation System (main features : 2D; 250 Hz snaps frequency; NO – transversability) has been derived The 2-nd Generation (main features : 3D – rotation; panning; 300 Hz snaps fr.; real time and buffered signal processing). The other details and using possibilities (see later the SW- Overview).

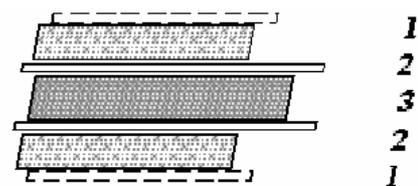


Fig. 4. Transducer Arrangement 1 – Cover layers, 2 – Cufflex Electrode, 3 – Semiconductive Elastomer

### 4. RESULTS

#### Technical parameters:

Patient Mass	to 120 kg
Rated Pressure Range	5 - 80 kPa
Permissible Overload	1.4 MPa
Transducer Activated Area	400 x 300 mm
Transducer Dimensions	750 x 650 mm
Sensing Elements Number	7500 pcs
Dimension of Sensor	3x3 mm
Transducer Supply Voltages	+ 5V; + 12 V
Transducer Analogue Output	to 1V

Digital Output                      256 levels  
 Snap Frequency                      300 Hz  
 Sampling Frequency                  2.5 MHz

System Requirements - for PC (minimum):

- PENTIUM 1,6GHz or high version
- 512 MB – RAM
- HDD space – 130 MB
- GRAPHIC CARD – 3D acceleration

Operating System – Windows 98/2000/XP

## SW – Software Overview

The System is determined for the pressure data -acquisition, -logging, -evaluation, as the points results from the tactile pressure transducer. Anytime, all recorded data can be read to SW again, so that it is possible to operate as the actual results, with.

Data Acquisition - three base mode – using:

- Continues Visualization - to display the actual pressure distribution on the transducer in real time. The speed acquisition data is 10 snaps/second, about - what is given the computer speed. Beside that, the speed is possible to be set from the 10 snaps/second to the 1snap/10 seconds. This mode is mainly used, either for the parameters setting for the later precise measurement; and either for the single-shot snaps acquisition. Then, these ones can be stored.
- Long Time Measurement with Low Speed Data Acquisition. No display - the data measurement. These ones being recorded on the internal hard disk (HDD) – for the later PC-transfer. The speed is from 50 to 100 snaps/second, about. The optional disk capacity (e.g. common HDD – 1 GB enables to be caught the more over one hour record). The standard device equipment is 3 GB disk, what is for the 4 hours recording, approximately. The several records can be stored on the disk at once, for the later PC- datalogging. This mode is used for the record of the low speed, long-time processes.
- Short Time Measurement with High Speed Data Acquisition. No display - the data measurement. These ones are stored in buffer for the latter PC-transfer. The speed range can be set from 50 to 300 snaps/second and the recording time is from 1,6 to 10 seconds (what depends from the recording speed). This mode is used for the fast single-shot processes.

## Control and Supervisory Tools

The System can be PC-controlled. The several various parameters can be set for each measurement (any parameters can be used for the typical mode only):

- Speed Measurement/Data Acquisition (depends through the Measurement Mode);
- Transducer Signal Gain (1/2x, 1x, 1.5x, 2x, 3x, 4x, 5x). User-matched, to be used the total

visualisation range, or to be set an alarm conditions limits;

- Input Signal Zero Setting - for e.g.: to limit signal interference/noise; or vice versa – to shift the acquisition threshold voltage on the interference/noise level – to be caught the extra-low loading.
- Record Trigger Mode:
  - o instantaneous by means of PC;
  - o external;
  - o by transducer activation (e.g.: by the step on).

Datalogging - all Measured Data can be saved in several formats:

- Working File DAT - the format change is possible, later. The stored data hold all the parameters setting and the information presented by measurement.
- Text File TXT. - useful for the measured data processing by using the other program (EXCEL, MATLAB, ...).
- Figures BMP – for the later print, modification and the creation of customized reports.

Data Evaluation - SW-enables not only the measured data – logging and visualization, but the fundamental processing, too. Vision Tools Possibilities:

- display any snap from the recorded waveform; 2D – visualization;
- X- and Y axis snaps rotation; zooming;
- the motion control running - both direction;
- display the main pressure centre (the balancing point – COP);
- the local/separate regions with the own local pressure centres;
- horizontal and vertical cuts - each one can have the own interactive motion profile – to be seen the waveforms in the extracted cuts;
- colour scale/palette (pressure/colour); The customized creating - to be caught any interesting pressure levels - by means of any special colour; for histogram, too;
- rotation 3D – MM (mountain model); panning;
- 3D motion trajectory (movie, permanent e.g. of the balance centre);
- base (space) grid resolution; isobars; contours.

Mathematical Processing – the standard Statistics is included – for common orthopaedic evaluation, too:

- ROI (region of interest) – 2D, area, perimeter; several ROIs – each one with specific local evaluation as:
- COP (centre of pressure), several COPs;
- min.; max.; mean; median; modus; sum; standard deviation; variance;

- extracted cut (region) can be generated as the waveform cut (region) file - with the optional mentioned parameters.

### Customize Arbitrary Processing

Delivered SW is created through the WIN 32 by means Microsoft Visual C++. Despite the fact, to be no – source program, a full series of C/C++ class libraries can be included to this one, very simply (e.g.. mathematics). Program is able – e.g.: by the visualisation or the processing of any snap – to send this one before, into an external library for its preprocessing or its complete processing. For an external library, the snap pointer is given, so that the extracted snap can be adapted to changing needs; or to be completely converted, too. E.g. – the various filters designing can be created by this way to be deleted, or to be modified the meaning of the whole snap or its part, only. So that, the library is used for the mathematical processing, only - and all the others (data visualisation, datalogging, reading) is done the original SW, by means.

Above mentioned SW- possibilities are only fundamental. The SW can be configured with regards to the customize needs. At present, the second generation (HW and SW) deals about, which has the improvements number – there is mainly allowed the multifunctional HW- and SW- extensibility. The arbitrary external triggering can be added to the HW; or vice versa the triggering signal can be generated for the arbitrary external device as camera, printer etc. The extended SW provides the number of the others creative possibilities by means of the customize libraries, too.

## 5. DISCUSSION

Having been get the quite well results, and the satisfied attendance, almost too - the development cannot be said to be finish, at this time. Being used the qualitatively new measuring way – the others problems are being generated, too. Here, we appoint only any ones. The last not least – is the calibration problem, especially for the large Areal Pressures Transducers, the EMC (elmg. compatibility) problems, the other using new materials and technologies etc. This Orthopaedic Investigation System – has a great benefits number (mentioned above), but the restriction is in the fact – to be no-absolute transducer, what means that this one cannot be used as the absolute weighting system, to this time. The calibration question of the large areal transducer - is what we are trying to solve at present. This transducer can be used as the relative one only, what is quite enough for an orthopaedic investigation, where is more important to be caught the over all relation of the pressure distribution among the single points of the followed area (e.g. the foot-sole).

## 6. CONCLUSION

To make an effort – to improve the non-invasive orthopaedic methods – the new one Orthopaedic Investigation System has been developed. The first results

show, to be the qualitatively new effective way for the orthopaedic investigation. More than, the painless way for the patient investigation, the preventative way determination of the starting troubles and following diseases is appreciated – for the life quality and health care improvements.

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