



*3D shape measurement, fringe and Gray code projection,  
cloud of points, 3D calibration, posture evaluation, spinal deformities,  
screening, telediagnosics*

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## **SCREENING TELEDIAGNOSTICS OF SPINAL DEFORMITIES BASED ON OPTICAL 3D SHAPE MEASUREMENT SYSTEM AND AUTOMATED DATA ANALYSIS – PRELIMINARY REPORT**

The developed concept of telediagnosics system based on 3D shape measurement system is designed for posture evaluation that may be applicable to children, adults and elderly. Structured light measurement method is exploited. Proposed system can work in two states: stable laboratory installation with direct connection to database system or remote measurement unit with slow and limited connection to database by GPRS/EDGE/UMTS protocol. It is based on sinusoidal fringes and Gray codes projection. As a result of measurement cloud of (x,y,z) points is received. On the base of automatic analysis of these clouds positions of characteristic areas are calculated. Next, relative features of measured shape are calculated basing on characteristic areas positions. These features give direct hint about patient posture status. We present some selected cases as examples of measurement of human back shape.

### **1. INTRODUCTION**

The widespread occurrence of scoliosis, or curvature of the spine often becomes apparent in teenage years and elderly, with both cosmetic and functional consequences. Measurements are needed to detect the condition and for monitoring the progress of treatment. Screening tests are recommended for evaluation of the problem scale in the entire population. Spinal deformations may appear also later in older population due to osteoporosis. The forward bending

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test, widely used in scoliosis screening, is associated with high false-positive rates. Instrumentation is indicated for the qualitative and/or quantitative assessment of the human posture. Direct surface measurement of the human posture by digitization could increase the predictive value of detecting scoliosis without sacrificing sensitivity. [4,5] The 100% sensitivity and 85.38% specificity was found for previously developed Moiré topography cohort study by Karachalios et al. [6,7] The concept of proposed system covers screening testing in all areas of Poland. The results would be stored in central database at Medical University of Warsaw. Scheme of proposed system is shown in figure 1. Stationary system with four calibrated directional measurement modules would capture whole 3D-shape of patient's body. The measurement is based on determination of parameters of visible anatomical landmarks and calculation of clinically useful indexes and curves. All measured and calculated data are stored in database as a patient's record. Diagnostic stands connected to database give possibility to review patient's records for better posture diagnosis. On the other hand, there are many mobile systems manufactured with one or two directional modules which can be operated by technical staff only. These modules are connected to database by slow GPRS/EDGE/UMTS protocol. The concept is to put on-line smaller patient's image and calculate final features from whole measurement data. Accurate measurement data in the form of cloud of points will be updated in database when measurement system will be connected to Internet by broadband connection.

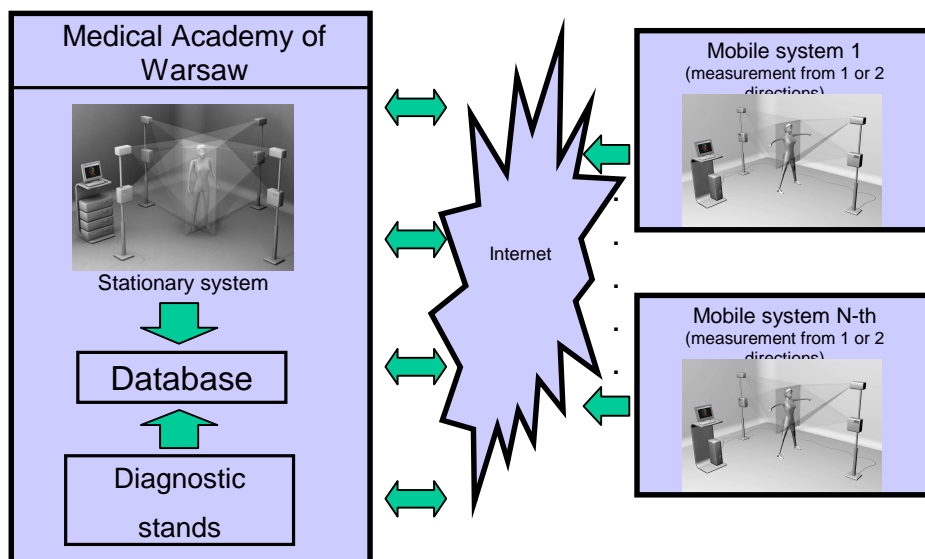


Fig.1 Scheme of proposed system structure.

System under development shall be used in a wide range of medical applications including, posture analysis, spinal deformation assessment and anatomical morphology. The static evaluation is performed for steady, habitual and standardized position of the body. The wide application of the method is even wider due to its great safety. No ionizing radiation is used, so monitoring examination may be repeated very often if necessary. The age group of the qualified patients is also wide range from childhood to elderly. Children and adolescents require the posture analysis and screening for at least spinal deformity detection, the spine in the elderly group also require evaluation due to osteoporotic kyphotic deformity. Follow up of those patients may reveal the general trend of the posture with diminished x-ray exposure.

## 2. MEASUREMENT SYSTEM

To achieve complete functionality connected with the requirements mentioned in Section 1 (3D) Measurement with Algorithms of Directional Merging And Conversion (3DMADMAC) system [1,2] developed at Institute of Micromechanics and Photonics (IMiF) of Warsaw University of Technology is used (Fig. 2). The method of measurement is based on structured light technique with digital sine patterns and Gray codes projection [3]. This system consists of Digital Light Projector (DLP) and matrix detector (industrial CCD camera). The offered system can be customized depending on an end user requirements connected with measurement volume size, amount of measurement points and maximum time of a single measurement. Set-up used for measurements presented in this paper includes: DLP projector with resolution 1280x720 pixels and color digital camera with resolution 1600x1200 pixels.

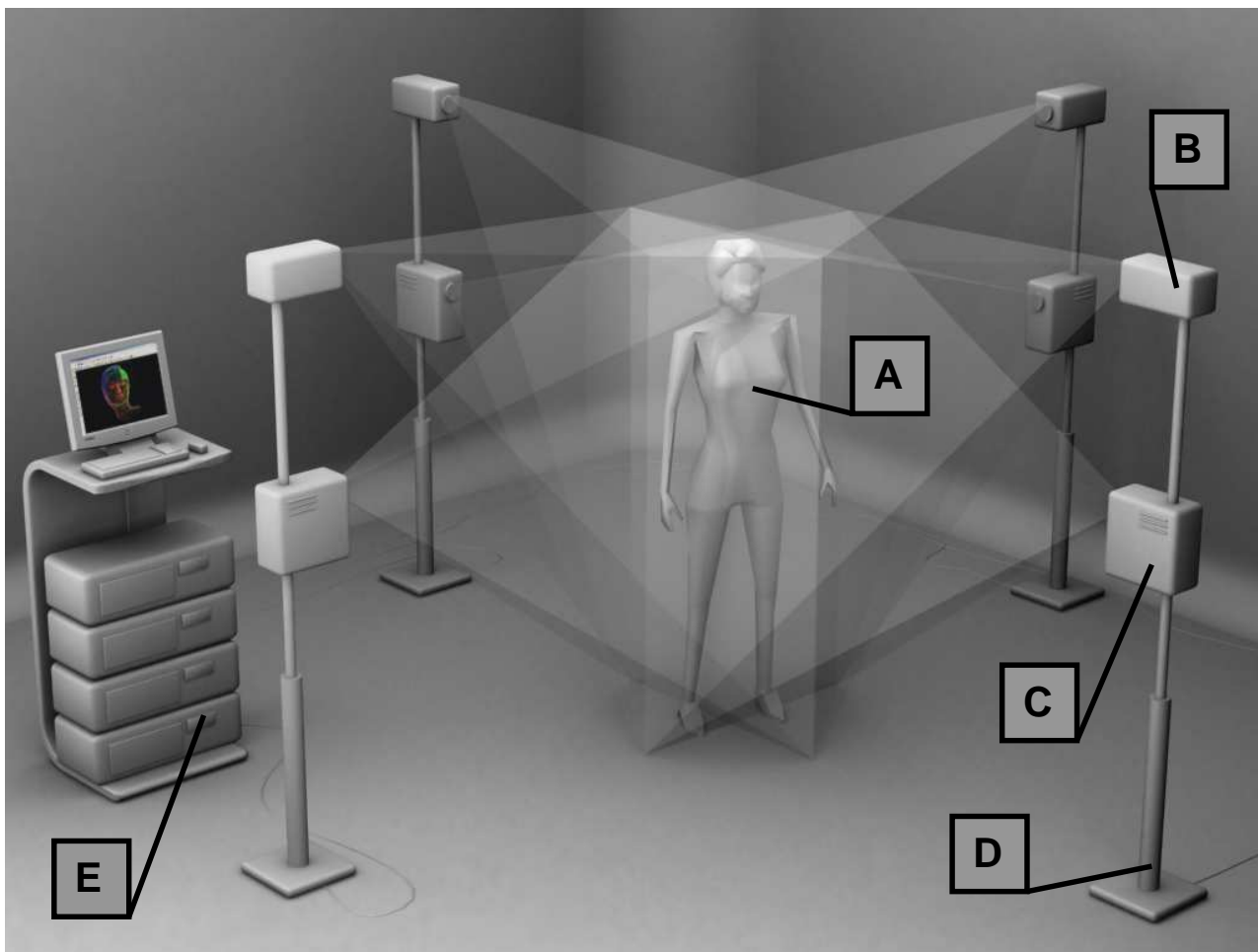


Fig.2 3DMADMAC measurement system: A – subject, B – matrix detector CCD, C – DLP projector, D – fixing frame, E – control/calculation/measurement workstations.

Measurement system is characterized by the following parameters:

- measurement volume equal to  $2 \times 1.5 \times 1.5 \text{ m}^3$ ,
- time of measurement from single direction: 0.25 second,
- measurement uncertainty corresponding with Root Mean Square (RMS) error for normal distribution (99% coverage) is less than 0.4 mm,
- number of points with (x,y,z,R,G,B) co-ordinates from single measurement with assumption that object fulfils whole field of view: about 1 million.

The figure 3 presents a back shape. The subject fills approximately 40% of detector field of view.

## 2. MATERIAL AND METHODS

Thirty ten years old, otherwise healthy children were selected for the study. Their average height was 146,36 cm. They were rather slim what was represented by the average Body Mass Index = 17,8. Additionally, a few cases of spinal and thoracic deformations were evaluated. Data acquisition delivered 3D digital points cloud that was chosen for posture evaluation. Angles and distances between established points were determined for quantitative posture assessment. As an example shoulder position was found as a factor determining posture impairment.

## 3. RESULTS

Count	30
Average	-0,0607823
Median	-0,11405
Variance	84,2974
Standard deviation	9,18136
Standard error	1, 67628
Minimum	-24,268
Maximum	12,997
Range	37,265
Lower quartile	-4,316
Upper quartile	8,092

Tab 1. Summary statistics of shoulder position

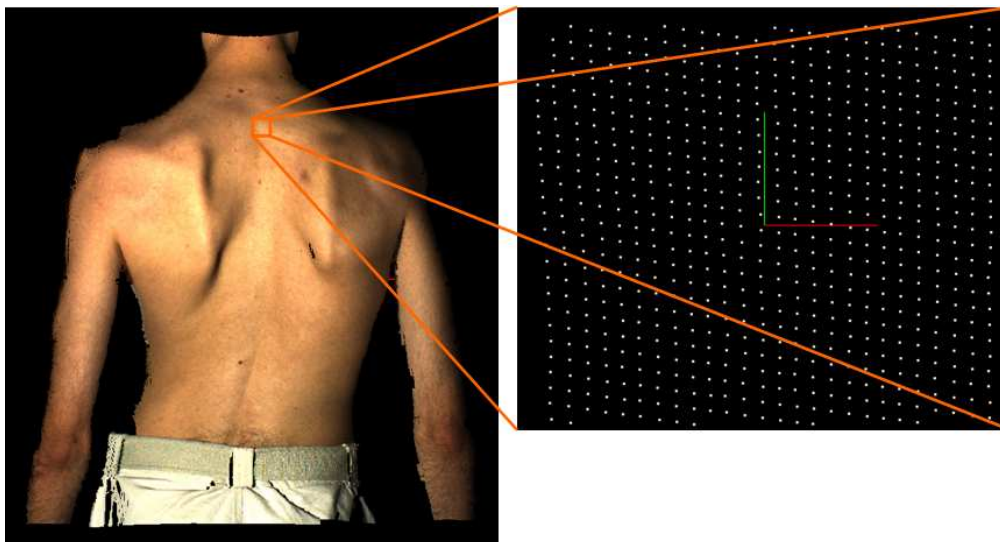


Fig.3 A case of scoliotic posture - example result of the measurement: 417 261 measurement (x,y,z) points.

With 3D MADMAC procedure shoulder position difference was detected. The positive measure represented higher position of the left shoulder versus right one. Higher position of the right shoulder obtained negative values. Average values of the examined group did not show significant differences. Negative median value demonstrates that more than a half of the children have had right shoulder higher positioned.

### 3. CONCLUSIONS

Optometric system (3D MADMAC) was utilized to measure and evaluate the human back shape three dimensionally. Presented system combines new concept and methods of telemedical quantitative posture assessment and becomes concurrent to other systems mostly based on moiré method. Fringes projection by 3DMAD/MAC system is significantly accurate that allows to measure whole examined surface as well as small eminences located on the body of examined patient. Preliminary assessment of the shoulder position presents only the example of measurement technique, its applicability and highest accuracy. The static posture deformations require early detection that makes early corrective treatment and its non-invasive monitoring.

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