13th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

A NEW APPLICATION OF ROBOTIC DEVICES FOR CORRECTION OF SPINAL DISORDERS

J. Somló, P.Tamás, M. Halász
Budapest University of Technology and Economics
1111 Műegyetem rkp. 3-9
Budapest
Hungary
tamas@inflab.bme.hu

ABSTRACT
The production of corsets for the correction of spinal disorders recently is concerned with painful procedure of getting geometrical models and mostly handwork based manufacturing. The production and the product are not flexible at all. Our recent research and development works are directed to get 3D models by scanners. An 1D motion and 4 cameras and a 6D robotic motion and laser length measurement device systems were developed. Based on the 3D models after medical corrections the corsets are to be manufactured by modern CAD/CAM systems. Rapid prototyping, dieless sheet metal forming (DSF) and other methods are considered and promising. Extended research on materials, the usage of sensors, etc. are planned. The results are important from antropomorphing measurement aspect too.
Keywords: industrial robots, robotic CAD/CAM, 3D antropomorphing model, spinal disorders

1. INTRODUCTION
Spinal disorders (Figure 1.) are dangerous and widespread disease for young girls nowadays. Spinal disorders may be corrected by gymnastic, corsets and operations. Every case is individual. It is very important that the disorder should be detected as early as possible. After computer aided diagnostics (CADM Computer Aided Diagnostic in Medicine) an automatic custom-made corset should be realized to make corrections and avoid operations.

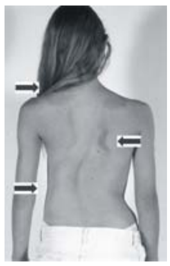

Figure 1. Spinal disorder

2. PRESENT SITUATION

Nowadays corsets are made from thermoplastic polythene (Figure 2.) by unique made gypsum master. Wearing gypsum sampling is very hard physically as well as psychically. Our aim is to mollify distresses of patients. We want to reform the sampling, material and manufacturing of corsets, and the efficiency of treatment.

Figure 2. Corset

3. MEASURING PROCESS

We developed a filtering system based on the well known Moiré method [1]. Corsets are not only negative of the body surface. There are some supports defined by doctors. Measuring [2] and manufacturing the corset we use a special robotized 3D scanner.

3.1. Measuring by cubicle

We use two cooperating computer controlled equipments (a cubicle and a robot) for measuring the surface geometry of the human body. There is a computer controlled moving frame in cubicle. Line lasers installed on the frame scan along the body while cameras rigged on the frame store pictures of the illuminated body surface. The stored pictures are sent to the controlling computer. The machine processes pictures and defines the points of the body surface. There is a 6D robot equipped by a camera and a laser distance-meter measuring the hidden places for the frame (Figure 3). As we want to achieve necessary accuracy for garment trade, we had to calibrate photos of parallel cameras, in order to develop measuring methods as well as to analyze errors.

Figure 3. The Measuring Equipment.

The task of the frame is the definition of the points on a two-dimensional curve based on photos. Points of the curve are defined by picture processing methods. The question is only how to define the 3D position of points upon the photo. In order to find the non-linear bijection between the photo and the 3D plane, we used calibration process [2]. There is an automated corner based calibration process integrated. Determination of corner coordinates starts at the corner closest to the actual camera. If we define the point of the edge image in the coordinate system connected to the left-bottom corner of the photo, then regression lines can be defined for every x_s on section $x<x_s$ and $x>x_s$. Let the error of the regression H is a function of x_s! In other words $H(x_s)$ is the sum of the differences of y_i point coordinates and the $a*x_i+b$ lines with unknown parameters (x_i are point coordinates) in front of the corner and behind the corner Eq. (1).

Figure 4. Calibration

$$H(x_s) = \sum_{x_i<x_s} (y_i - (a_{x<x_s} x_i + b_{x<x_s}))^2 + \sum_{x_i>x_s} (y_i - (a_{x>x_s} x_i + b_{x>x_s} x_i))^2 \quad (1)$$

After calibration surface points of body should be defined by picture processing methods, but the result will be better, if regressed curves are searched. Surface curves on body parts are approached by Fourier series [3]. The angles as the independent variable of the curves are determined from the centre of gravity of point set and the position of points on actual level. Approximating function (R) is the distance from centre of gravity as the function of the angle from x-axis (φ). Only the first 2*n+1 members of Fourier series are considered where the n is defined differently on different body parts. Unknown Fourier coefficients are determined by least square method. If there are N points on the actual level where the distance and the angle of k-the point is (Rk,φk), then ai, bi coefficients are defined by the minimum of (2).

$$\sum_{k=1}^{N} \left\{ R_k - \left[\frac{1}{2} a_0 + \sum_{i=1}^{n} a_i \cos(i\varphi_k) + \sum_{i=1}^{n} b_i \sin(i\varphi_k) \right] \right\}^2 = \min \quad (2)$$

Figure 5. shows the results of the cubicle measuring.

3.2. Measuring by robot

There are hidden parts of the body from cubicle for example armpits, groin. Kuka robot is equipped by a Stabila (TOF – Time Of Flight) equipment [4, 5] and controlled to measure coordinates of points. Precision of Stabila is 1 mm satisfies every demand of needs.

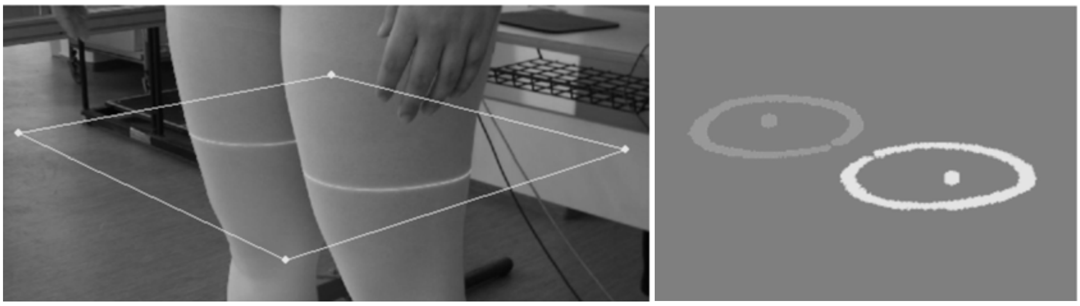

Figure 5. Cubicle Measuring

4. MODELLING BODIES

Measured 3D points are used to define the body model. Similarly to the parameterised model [6] body surface sectioned measuring features (Leg, trunk arm, shoulder, neck, head Figure 6). Surface of features interpolated NURBS. Vertexes of surfaces are defined by the measured points.

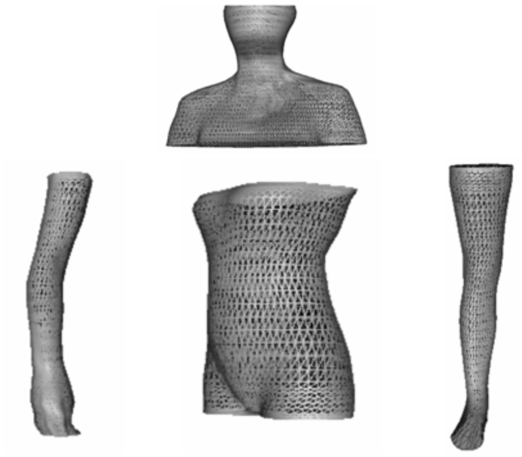

Figure 6. Body part features

Positions of vertexes of features and surfaces (Figure 7. b.) are determined from curves approximating point cloud (Figure 7. a.).

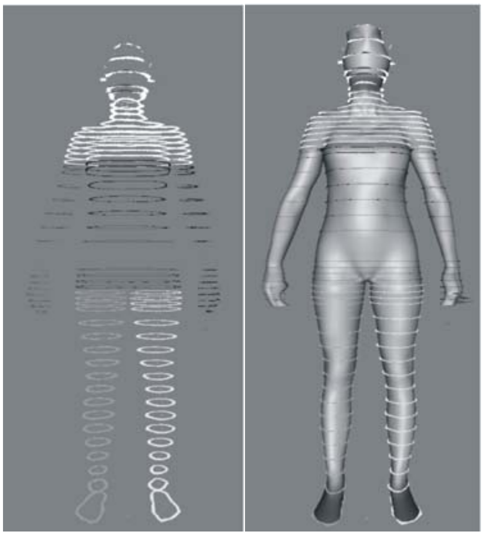

Figure 7 – Measured body model

5. MANUFACTURING OF CORSETS

Nowadays the corsets are manufactured by creating torsos from artificial wood based on gypsum models. Torsos are made using a specialized CNC machine tool. Then vacuum forming is applied. The recent research work make possible to realize CAD/CAM principles using CNC machine tools on robots for manufacturing omitting the stage of gypsum models. Even a rather modern approach has chances to be applied, when the torso-making is also omitted. 3D model information is useable for dieless forming 3D freeform sheets. Recently promising research results were published [7] from the field of DSF of polymers. Our goal is to realize corsets by robots using this technology.

6. REFERENCES

[1] K.Wenzel, Gy.Ábrahám: Measurement of Distortion Using the Moire Method. Experimentelle Technik der Physik 36. 1988.6p.429-434.

[2] P. Tamas – M. Halasz – J. Somló: 3D Measuring of the Human Body by Robots 5th International Conference Innovation and Modelling of Clothing Engineering Processes – IMCEP 2007, University of Maribor, Faculty of Mechanical Engineering, October 10-12, 2007, Moravske Toplice, Slovenia P 109-115 ISBN 978-961-248-047-9,

[3] Stoyan Gisbert, Takó Galina (2002), "Numerical Methods" Typotex publisher, Budapest

[4] KUKA Robotics, www.kukarobotics.com

[5] STABILA www.stabila.com

[6] P. Tamás, M. Halász, J. Gräff, (2005), "3D Dress Design", 5th World Textile Conference AUTEX 2005, Slovenia, pp 436-441

[7] P.A.F. Martinns, L. Kwiatkowski, V. Franzen, A.E. Tekkaya, M.Kleiner: Single Point Incremental Forming of Polymers, CIRP Annals – Manufacturing Technology. CIRP 396 2009 Articles in Press