
TOPOGRAPHY OF SURFACE AND SPINAL DEFORMITY**Dorota ZAWIESKA**Institute of Photogrammetry and Cartography
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Commission V

KEY WORDS: Projection moiré, Fringe pattern analysis, Postural deformity studies, Scoliosis**ABSTRACT**

The Department of Photogrammetry Warsaw University of Technology has been involved in use of in industrial and biomedical applications moiré topography for over ten years. Most of this effort has been inspired by a particular application, namely, the determination of the surface topography of the human back for the detection and diagnosis of spinal deformity.

The moiré technique is recommended for mass screening and early detection of postural deformities among children and young people. It also proved to be invaluable for the assessment of treatment and rehabilitation results, especially in the cases when making X-ray pictures and/or their frequent repeating is contraindicated.

In this paper a few typical examples of an application of the moiré technique in solving different medical problems, will be presented. Determination of the shape of the back of the human body can be readily automated using the phase methods for analysing the fringe patterns. Specialised medical software for studying the deformity of the back and front of the human body illustrated by clinical examples, will be presented.

1 INTRODUCTION

The projection moiré is a powerful tool in displaying and measuring the shape or deformation of objects in three dimensions (Patorski, 1993). Besides industrial applications it is of considerable importance in biomedical studies.

The attractiveness of the method is due to whole-field, non-contact, non-invasive measurements, which can be automated. In this paper the automation aspect of moiré method will be emphasised (Zawieska, at al., 1994).

The object shape information is encoded in moiré fringe, which provides the contour lines on the object. Two main approaches are accepted to obtain the information encoded the intensity tracking method and phase measuring method including temporal and spatial techniques. The phase measuring approaches proved advantages over the intensity tracking such as the reduced sensitivity to the background and contrast variations in the moiré pattern, automatic sing detection and reduced or eliminated operator interaction. From a detailed analysis of various system arrangements used for the shape measurement two basic configurations were selected and implemented as computer aided systems for routine examination of postural deformities.

The special projection moiré arrangement with the horizontal base system was designed and built for the purpose of this study (Zawieska, at al., 1990, Zawieska, at al., 1992, Pirga, at al., 1993). The temporal phase stepping approach has been used for automatic analysis of moiré patterns. On the basis of computer aided moiré fringe analysis it is possible to determine the metric values of the spinal deformities and curvatures in three planes as well as to find postural deformity parameters.

2 PROJECTION MOIRÉ SYSTEM

Figure 1a.b shows schematic representation of the horizontal base projection moiré system.

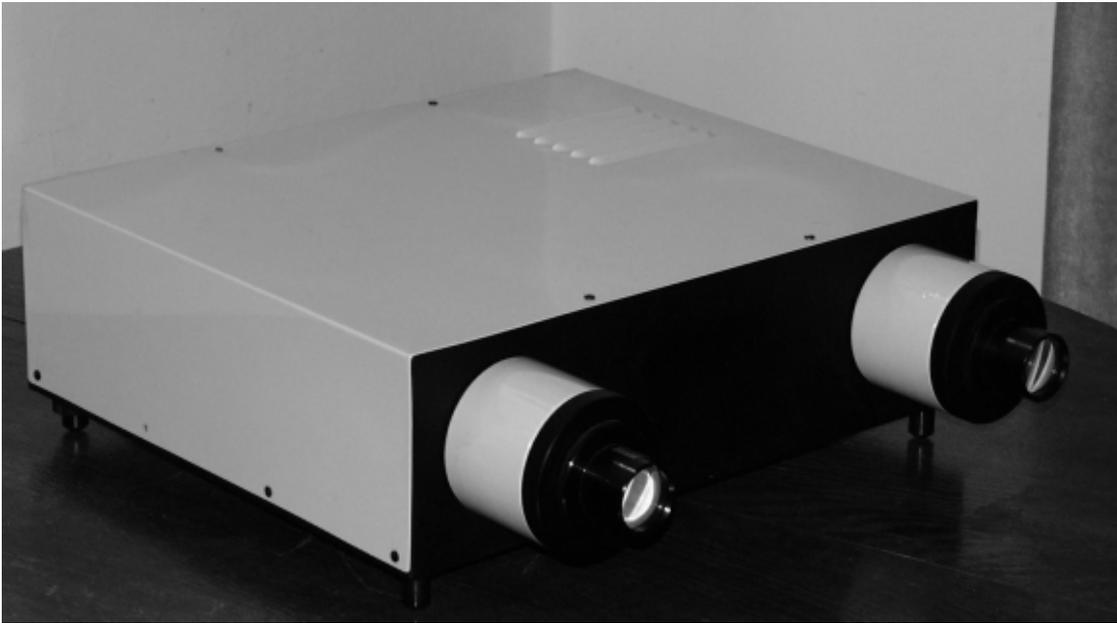


Fig.1.a. Optical arrangement

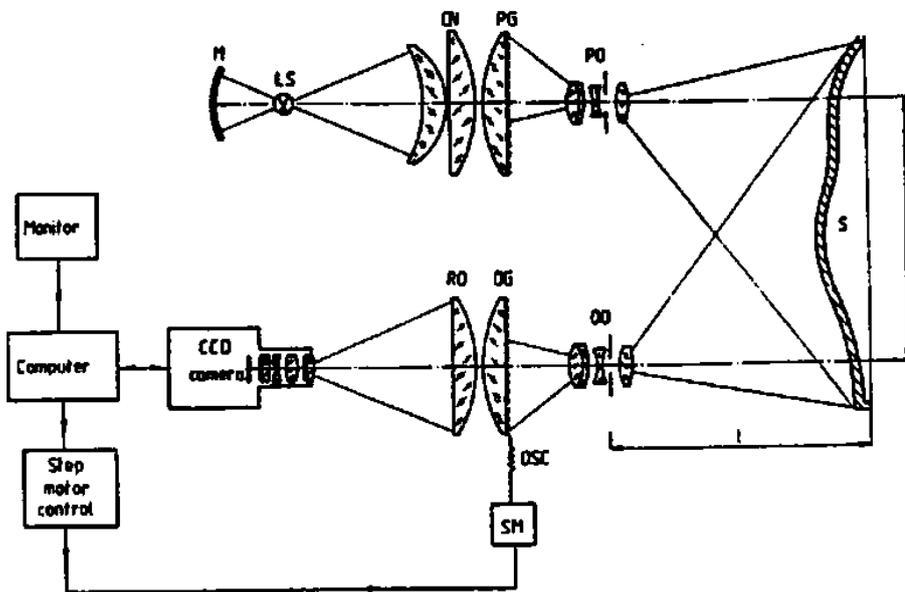


Fig1.b. Schematic of the horizontal base projection moiré system. LS – light source; CN – condenser; PG – projection grating; PO – projection objective; OB – object under test; OO – observation objective; DG – detection grating; RO – relay optics; SM –step motor; DSC – driving screw

The projection distance range can be from 1.5 m to 4.5 m. The maximum object size is ranged from 1200 mm to 800 mm. The projection/ observation objectives are two identical three-lens systems F2 10/5.6. The image is registered by CCD TV camera with zoom type objective F6-12 mm. With gratings of spatial frequency of 10 lines/mm, the distance of 350 mm between the axes of optical system - PO and -OO, and the projection distance of 4.4 m, the basic

fringe contour interval is 25 mm. After applying the phase stepping algorithm the accuracy of the human back shape determination is ± 1.25 mm (Zawieska, at al., 1994)

The temporal phase stepping technique using the four-frame algorithm is mainly used (Patorski, 1993). This algorithm assumes that $\pi/2$ phase shift between subsequent images is implemented by programmed displacement of the detecting grating. The algorithm optimises the compromise between the accuracy (numerous frames required) and the image acquisition time (it should be minimised due to possible object movement). Four frames taken with resolution of 256×256 or 128×128 to receive the proper intensity of information within the frame grabber memory and to shorten the calculation time. Four sequential images are read into the computer memory so that four intensities are stored at each pixel location. The phase, which is calculated from the arctan function is then unwrapped to obtain continuous phase function. The phase function is subsequently used to determine the object height.

3 POSTURAL DEFORMITY STUDIES

Medical software developed in (Zawieska, at al., 1995) enables routine image analysis in three body planes for free standing position: sagittal, frontal and transverse plane.

In sagittal plane, first some general parameters are calculated and analysed such as the length of the vertebral column, body and trunk inclination angles, global value of curvatures and the angular balance factor in this plane. Next, the system makes an analysis of the individual curvatures from the point of view of the length, depth, angular values and mutual interrelationships.

Also in the frontal plane the general data are presented first. For example, they concern body and trunk inclination angles in this plane and localisation of shoulders, shoulder blades and waist angles including their directions and possible asymmetry values. Subsequent analysis is concerned with the vertebral column itself. If the lateral spine curvature is found its localisation and direction(s) of deflection(s) would be determined, and detailed linear and angular parameters of the spinal curvature would be calculated. On base of the above the subsequent curvatures can be also determined as a consequence the linear and angular curvature compensation, can be introduced.

In the transverse plane the posture analysis can be conducted at predetermined levels (e.g. peaks of particular curvatures in the sagittal plane or the peak of the lateral curvature). The cross section in this plane are analysed from the symmetry point of view. This permits for precise determination of the rotation component of possible postural deformity and its localisation and value of the trunk deformation.

All determined parameters for the particular patients are registered in a computer data base. The data stored enable detailed analysis of abnormalities accompanying different postural deformations, in particular lateral spine deformations.

As an exemplary results of postural deformity studies, obtained using the projection moiré system and medical software described above, are shown.

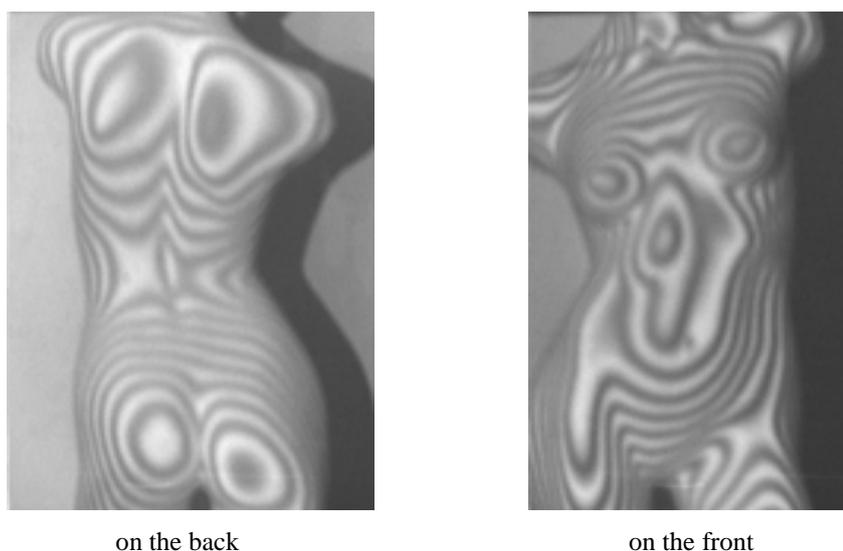


Fig.2. Moiré topogram of a model human body surface.

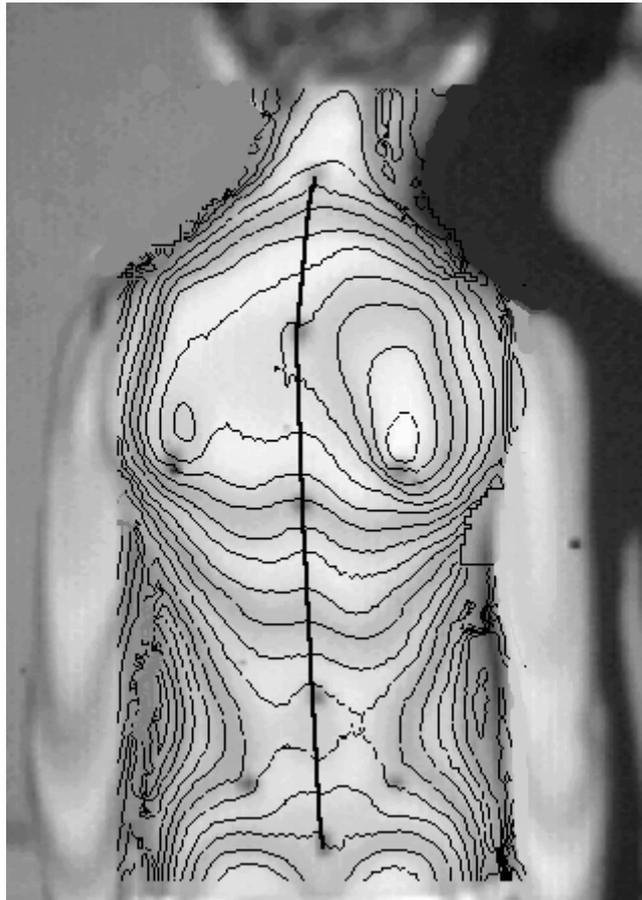


Fig.3. Patient with lateral curvature

At this stage it possible to determine primary and secondary curvature values and degree of deformation (lateral spine curvature). The results are recorded according to the scoliosis formula for the orthopaedists.

Postural deformity studies

Patient No	Name			
Date of birth	Height	Weight	Right-handed	
Date of examination		Examination type 1 (max.exhalation-before)		
Sagittal plane				
Global parameters:				
Spine length DCK (C7 - sacral bone)				
Inclination angles [deg]		Alpha deg	Beta deg	Gamma deg
	Trunk inclination angle KPT			
Total value of curvatures [deg]		Compensation factor		[deg]
Lordosis				
Length DDL	[mm], [%]	Angle KLL		[deg]
Length RLL	[mm], [%]	Depth GLL		[mm], [%]
Kyphosis				
Length DKP	[mm], [%]	Angle KKP		[deg]
Length RKP	[mm], [%]	Depth GKP		[mm]
Frontal plane				
Trunk inclination angle KNT				[deg]
Left shoulder blade higher by				[mm]
Left shoulder blade further by				[mm]
Left waist triangle lager than right one by				[mm]
Pelvis: inclination angle KNM L4 [deg]		Twist angle KSM		[deg]
Primary deflection angle is aprox.				[deg]

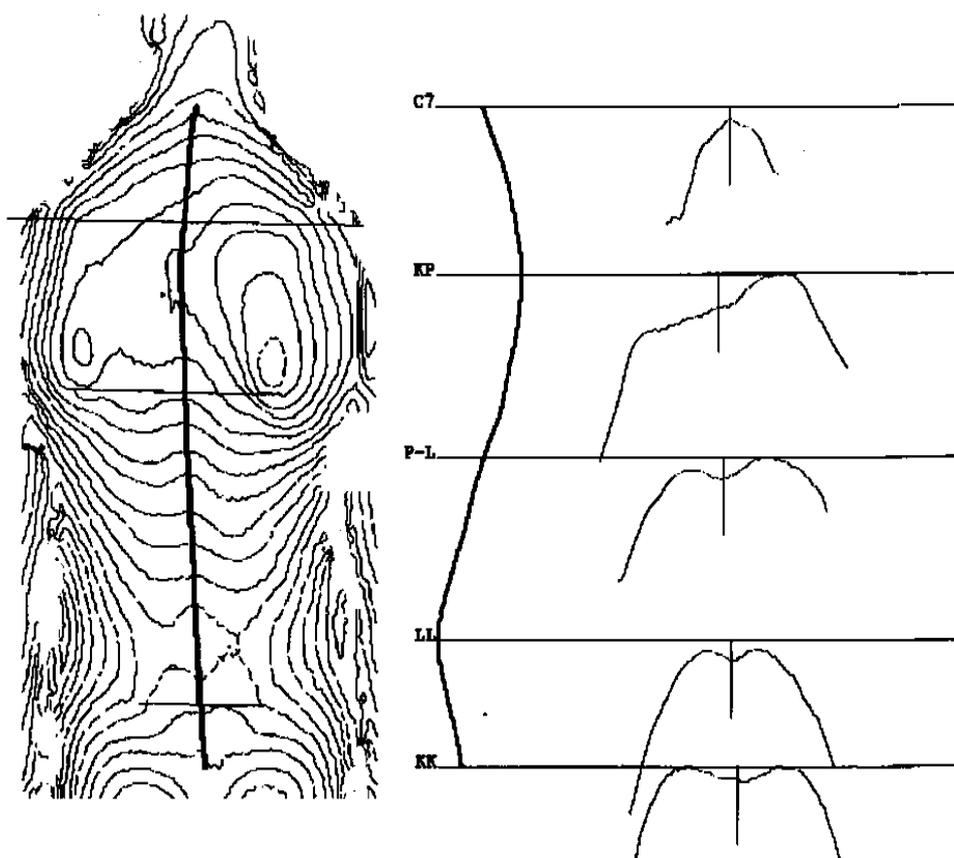


Fig.4. Graphic presentation of the experimental results: back in frontal, sagittal and cross surface.

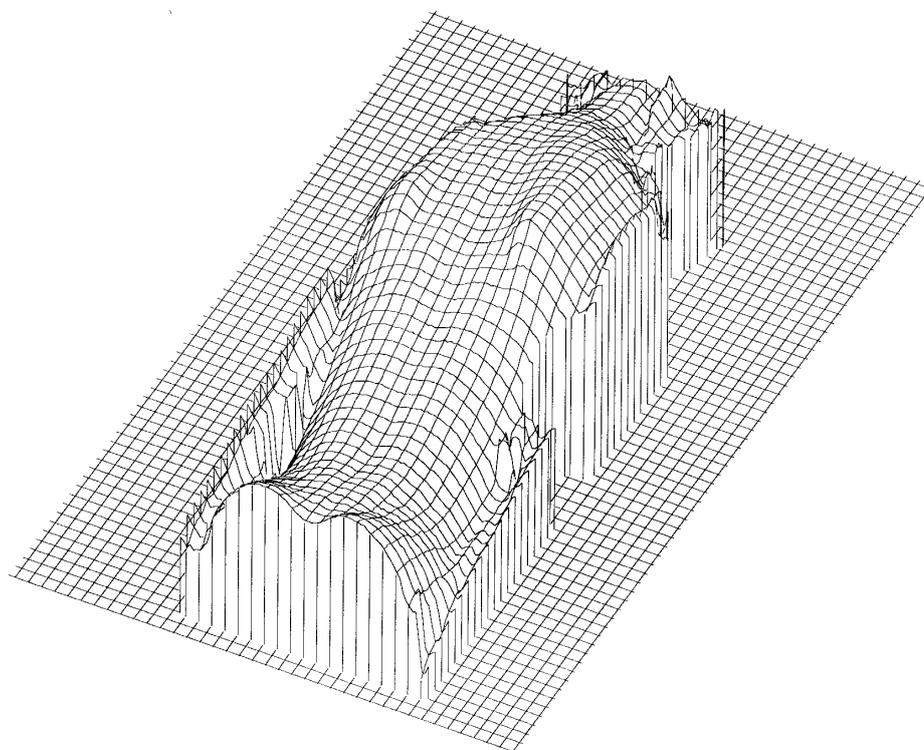


Fig.5. Perspective view of the back of muscle – osseous system.

4 CONCLUSIONS

This system, have been used for the routine analysis of the human posture. Depending on the requests of the specialists of the hardware and software is continuously updated.

Solution, proposed creates possibility of automatic, fast and accurate analysis of back and spine shape. The system, which had been tested, since, ten years in eleven medical clinics has proved:

- correctness of its action at scope of moiré fringes with high contrast generation,
- realisation of phase stepping method
- high usefulness of system for needs of rehabilitative and orthopaedic diagnostics.

Research concern with use of the moiré technique for control on the effects of physiotherapy, on gymnastic or musical education, will certainly help understand to better human postural control, and to enhance consequently therapeutical efforts.

The advantages of moiré technique in comparison with other methods are:

- Short time of image acquisition,
- Captured image can be analysed many times
- Possibility of static and dynamic measurement,
- Easy automatization of the fringe pattern analysis using on-line phase stepping method
- The system is mobile and easy maintain
- Provides metric parameters,
- Enables multiple examinations to be performed,
- The system is portable and easy to operate.

5 ACKNOWLEDGEMENTS

This research has been carried in part under KBN (State Committee for Scientific Research) Grant No 04.10.22 SPR-1. I thank Prof. Krzysztof Patorski and Prof. Janusz Nowotny together with team for co-operation and valuable comments by realisation of that subject.

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