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Gul N. Khan
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COMPUTER BASED ANALYSIS OF HUMAN GAIT USING MOIRE FRINGE TOPOGRAPHY

M. Ayub Khan Yousuf Zai*, Syed Arif Kamal§ & Junaid Ahmed Zubairi.
Biomechanics Research Laboratory
Sir Syed University of Engineering and Technology,
University Road, Karachi 75300.

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ABSTRACT

Moire' fringe topography is non - invasive 3-D optical imaging technique which provides height and curvature maps of the objects to be studied without ionizing radiation. From the 3-D structures, 2-D records may be photographed or digitized into bitmaps. This technique offer much scope in medical sciences as well as supplement and possibly decrease conventional X - Ray analysis of the human body.

In this communication this technique has been utilized to analyse the human gait in four phases of the steps for healthy school going children of age 3-8 years. The patterns generated indicate the spinal deformities and their relative difference. It also imparts clinically relevant information which may offer diagnostic clues to Orthopedic surgeons without facing difficulty to interpret the results.

1. INTRODUCTION

In the middle of the nineteenth Century development of photogrammetry was needed to find a 3-D system. The medical photogrammetry is the term used to cover all applications of this technique in wide field of medicine. These include (i) Stereogrammetry, (ii) Holography (iii) Integrated Surface Imaging System (ISIS), (iv) 3-D video laser scanning system, (v) Moire' topography and (iv) Rasterstereography.

We are in search of such methods which are supposed to be inexpensive, easy to be implemented, simple enough to be performed by moderately trained personnel and elegant enough to permit handling by various algorithms. Moire' fringe topography (MFT) has all these features. If we are capable of recording and processing information from this technique a complete profile of human trunk could be obtained during every cycle of gait. Such information may be useful in modelling human gait and understanding different neurological disorders and spinal deformities.

Moire' fringe topography is an optical and non - invasive technique used to determine the 3 - D structures of a human body from 2 - D records which may be photographed or digitized.

This technique has a lot of potential in realizing 3-D surface structures of the human trunk & generate the spinal column from the scanned pictures systems.

There are three types of moire' fringe topography (i) Shadow type (ii) Projection type (iii) Grating hologram type. We used in our studies two of the above techniques.

* Department of Applied Physics, University of Karachi, Karachi-75270, Pakistan.

§ *Homepage*: http://www.ngds-ku.org/kamal; *e-mail*: profdrakamal@gmail.com; corresponding author

(1) The shadow type moire' fringe topography apparatus was used in the earlier studies [1,6,7]. A moire' contour recorder was developed earlier to study scoliosis and other bone deformities [6]. In recent studies at Karachi, a wooden frame was used. Nylon thread was wound along the longer side of the frame [5,9]. This method should be chosen if quantitative accuracy is desired.

(2) In the projection type moire' fringe topography human body is supported on a standard holder and a moire' grid is projected on the back forming a deformed image of the grid which is superimposed on the reference grid through a lens so as to generate contour line moire' fringes. Accuracy may be changed by changing the grids [8]. Preliminary studies of posture and gait of normal subjects and polio patients have already been performed [2,3,4].

In this communication we intend to establish the feasibility of using moire' fringe topography in gait analysis and to investigate the means of modelling a fundamental description of children's gait in the age of group 3-8 years old.

2. MATERIALS AND METHODS

Apparatus:

1.	Camera with tripod	NIKKON MODEL EM
2.	Zoom Lens	NIKKON -F
3.	Film rolls	ASA 400, OR ASA 200, B & W
4.	Slide projector	Make Griffin & George (UK) Lamp 24V, 15 W, 1.9 Amps Tungston Halogen, lens 85mm.
5.	Wedge reference device	[Explained below]

Moire' fringes formed on the wedge can be used to calibrate the fringe pattern obtained during the gait cycle, because during normal walking it will not be possible to keep track of the distance of the subject from the camera. It is essential to theoretically calculate the depth by counting the moire' fringes.

2.1 Moire' fringe topography:

Moire' fringes are a series of interference fringes arising from the super-position of sets of parallel lines or threads. The width of the lines of the grid should be equal to the space between them. The fringes are contour lines of constant height. They are produced on the body of a subject which is illuminated by a point source of light through a plane grating of equally spaced lines. The height step between successive fringe increases with the numerical order. The height of the n_{th} fringe from the grating is given as:

$$q_n = \frac{n \times l}{d/s - n}$$

Where,

s = pitch of the grating or screen interval (line thickness + spacing = 1.7 mm.)

l = distance of light source and observation point from the grating plane. (255 cm.)

d = vertical distance between light source and observation point (115 cm.)

In the shadow apparatus a frame of horizontal or vertical grating is placed in front of the child. A light source is used to produce shadow of the grating on the child's back and front. When the lines of the actual grating interfere with its shadow, moire' fringes are produced.

Moire' fringe topography of the projection type is selected if open space around the subject is required. In such situations we don't want to use a frame. In projection type apparatus grating is made on a slide or transparency and is focused on the subject using a slide projector. The imaging system uses another grating in the viewing plane to interfere with the first grating to produce moire' fringes.

If the subject's back is free from any problem, the moire' fringes produced on the back are symmetrical about the midline of the back as shown in Figure 1. This figure shows the moire' patterns generated on the back of a healthy subject. If the subject is suffering from any spinal problem, the patterns produced on the back will be asymmetrical.

3. EXPERIMENTAL SET UP FOR GAIT ANALYSIS

The entire setup of the experiments carried out in this communication can be illustrated as in Figure (2). This setup is used in shadow type and projection type moire' fringe topography. Figure (3) depicts the grid for moire' fringe topography.

The procedural steps involved in the experimental work are as follows:

1. Each child was made to stand erect with feet together. Light from slide projector was used so that the line joining camera lens and the light source of the projector was parallel to the frontal plane.

Distance from the camera to back of the child was 255 cm. as shown in Figure 2. To obtain sharper fringes we used parallel light from a slide projector and applied talcum powder on the back of the child. The light source and camera were placed 255 cm from the screen. Separation of the camera and the light source was 115 cm. Fringe heights used for the analysis can be calculated and listed in Table (1).

2. The children were asked to stand in the anatomical position & picture of the back was taken after projecting a moire' grid onto it. Another photograph was taken during the 1st phase of single step.

4. DISCUSSION:

The moire' photographs were obtained by projecting a grid onto a curved surface. Analysis of the distortion produced by the curvature bestows information about the degree of curvature as well as depth of the object. Topography of the surface can also be studied in the form of a contour map. This contour map is made up of curves or lines of constant distances from a fixed plane. This technique also provides us height and curvature maps of 3-D objects Moire' fringe topography has been developed to study human gait at different circumstances.

In gait and other body locomotion the patterns generated in the lower extremities consist of 35% swing phase and 65% stance phase. Both phases can not be coincided during walking posture, therefore the same position can not be reproduced.[11] It is necessary to record heights and curvatures of child's trunk i.e. selected positions on the child's back at the same time. The simplicity is due to the fact that the legs are activated out of phase with one another in each step. The complexity arises from the relatively unstable equilibrium that occurs even when standing on two legs as shown in Figure 4 which exhibits the four phases of the steps. Normal gait is always in the sagittal plane. Flexing and extending of the arms and legs which causes the body to move also occurs in the same plane. Normal gait is thus a combination of flextion and extension. Steps of normal gait are depicted in table 2. Moire' topographs taken in 4 phases of a single step would exhibit the position of spinal column in each phase which may be compared and related to the spinal column in anatomical position through edge-based algorithm.

The moire' image will digitized using either a scanner or a digital still camera with RS-232C port. The digitized picture is then processed with thresholding to remove unwanted noise and to reduce the image to a bitmap. Then the moire' fringes will be identified and labelled distinctly. For this purpose we use 8-neighbourhood testing approach. In this technique, the 8 -neighbours of the seed pixel are examined and those with the same value are labelled accordingly. The labelled image is now ready to be converted into a depth map. Each moire' fringe is at a certain distance from the screen as shown in Figure 5 and this distnace is to be carefully tagged onto the pixel belonging to this particular fringe. The gait analysis algorithm processes the results in graphical and tabular forms.

5. CONCLUSION

Moire' fringe topography has been applied to gait analysis of the children of school going age. This technique claims to provide useful information to detect spinal deformities as well as neurological disorders. It may find applications in the study of gait and motion especially analysing the gymnastic performance. The moire' fringe examination of spine may be useful in screening potential gymnasts and athletes. There is a need to bring clinically relevant information which may provide diagnostic clues to the orthopedic surgeons without taking the trouble to interpret the patterns or results.

We are working in the Biomechanics Research Laboratory of Sir Syed University of Engineering and Technology to offer a computer based analysis of human gait and to detect spinal deformities and neurological disorders. We have planned to computerise the processing of moire image data so that the computer based system can become fully automated and the chances of human error can be eliminated. In this study we applied this technique to gait analysis of normal children. Further work in this area will include accuracy analysis of moire' technique and study of gait of scoliosis patients.

Some difficulties were faced in the photographic process which can be rectified latter using suitable expertise in photography.

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[$]Full text: http://www.ngds-ku.org/Papers/C33.pdf

[#]Full text: http://www.ngds-ku.org/Papers/C04.pdf

[@]Full text: http://www.ngds-ku.org/Papers/C08.pdf

Table 1: Distance of finges from screen or body for test case shown in Figure 5
Distance of Camera from the screen = 2250 mm
Distance of Light Source from Camera = 1150 mm .
Screen Pitch = 1.7 mm

Fringe No.	Distance of fringe from Screen (mm)	Consecutive Difference
1	3.6	3.6
2	7.4	3.8
3	11.3	3.9
4	15.1	3.8
5	18.9	3.8
6	22.8	3.9
7	26.6	3.8
8	30.5	3.9

TABLE-2-

RIGHT LEG	LEFT LEG
Step-1: *Right leg forward, left toe & right heel touching the ground. Center of gravity lying between the two feet.*	
Hip : Extension *Knee : Extension* *Ankle : Dorsiflexion*	*Hip : Extension* *Knee : Extension* *Ankle : Plantar Flexion*
Step-2: *Right leg forward. Right toe & right heel (i.e., the right foot) & the left toe on the ground.*	
Hip : Extension *Knee : Flexion* *Ankle : Neutral*	*Hip : Extension* *Knee : Flexion* *Ankle : Neutral*
Step-3: *Left foot in the air (moving forward), body supported by right foot only. Centre of gravity lying on top of right foot.*	
Hip : Flexion *Knee : Flexion* *Ankle : Neutral*	*Hip : Flexion* *Knee : Flexion* *Ankle : Neutral*
Step-4: *Left leg forward, right toe & left heel touching the ground. Centre of gravity lying between the two feet.*	
Hip : Extension *Knee : Extension* *Ankle : Plantar Flexion*	*Hip : Extension* *Knee : Extension* *Ankle : Dorsiflexion*

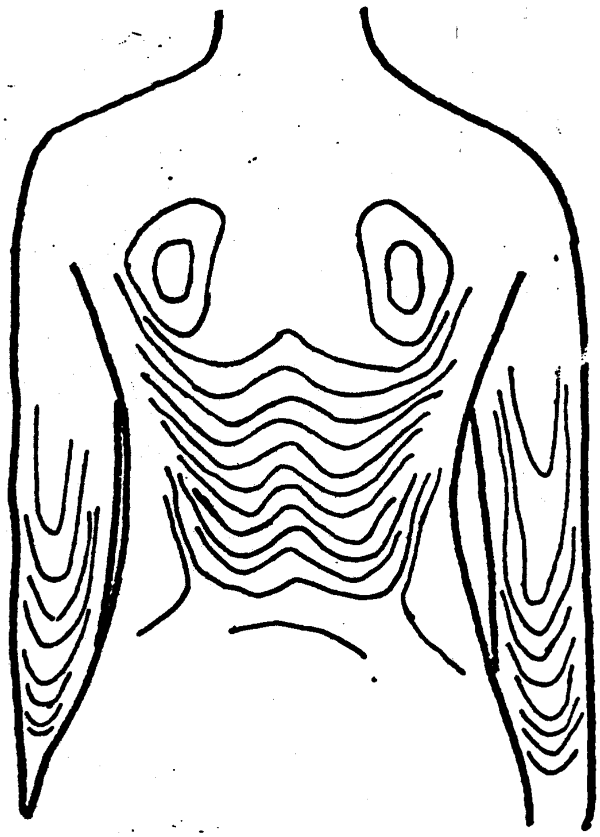

Figure 1: Moiré Patterns on the Back of a Healthy Subject

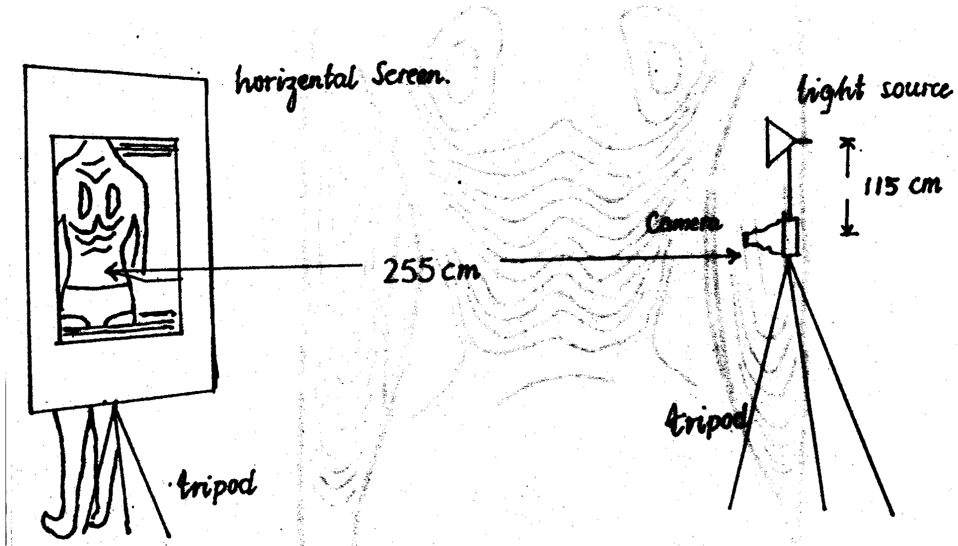

FIGURE 2 EXPERIMENTAL SETUP FOR MOIRÉ TOPOGRAPHY.

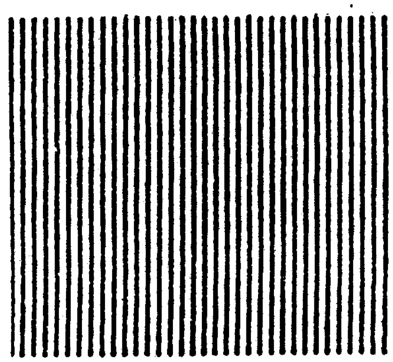

Fig. 3 GRID FOR MOIRE FRINGE TOPOGRAPHY

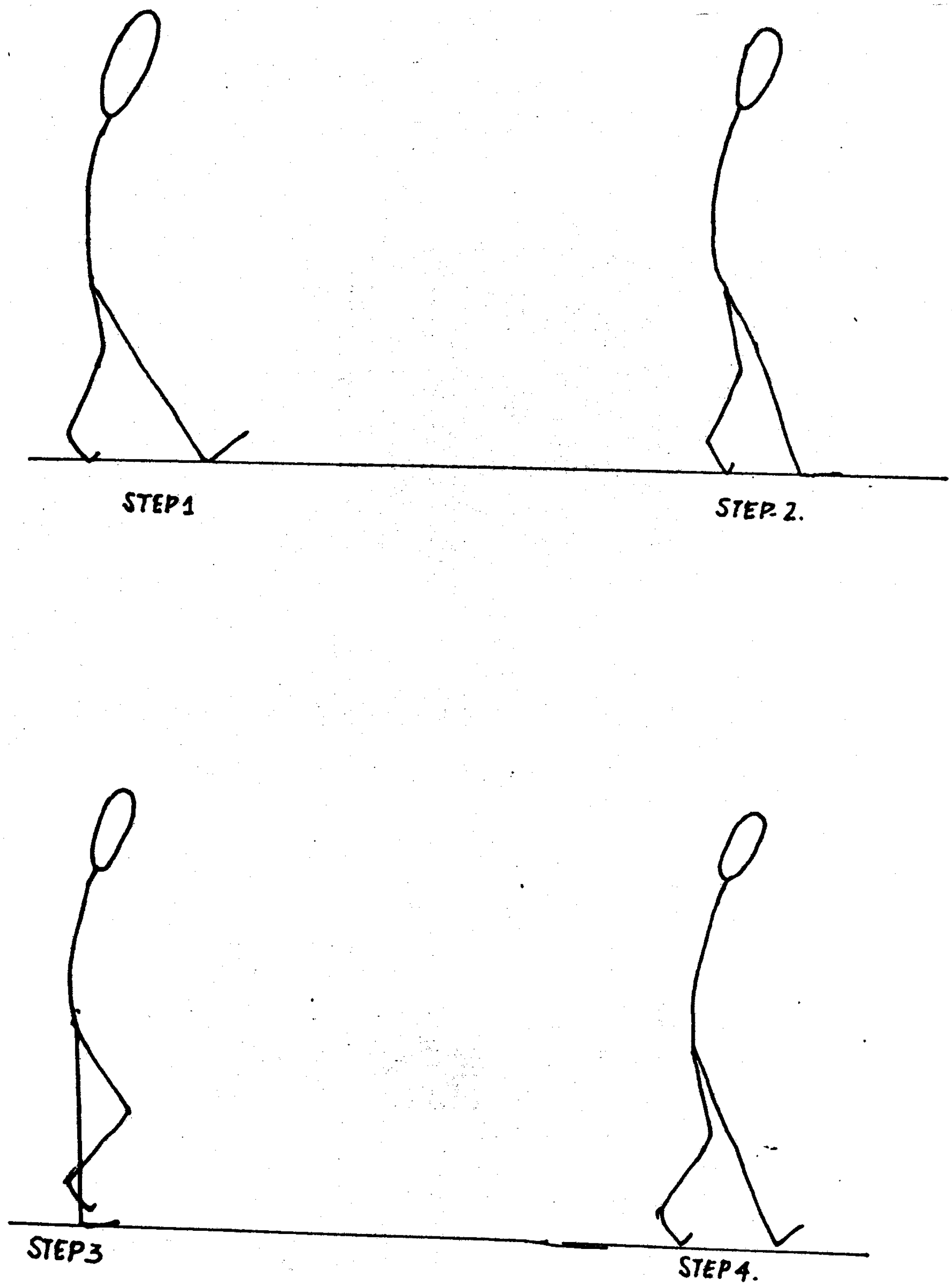

Fig. 4. FOUR PHASES OF A SINGLE STEP.

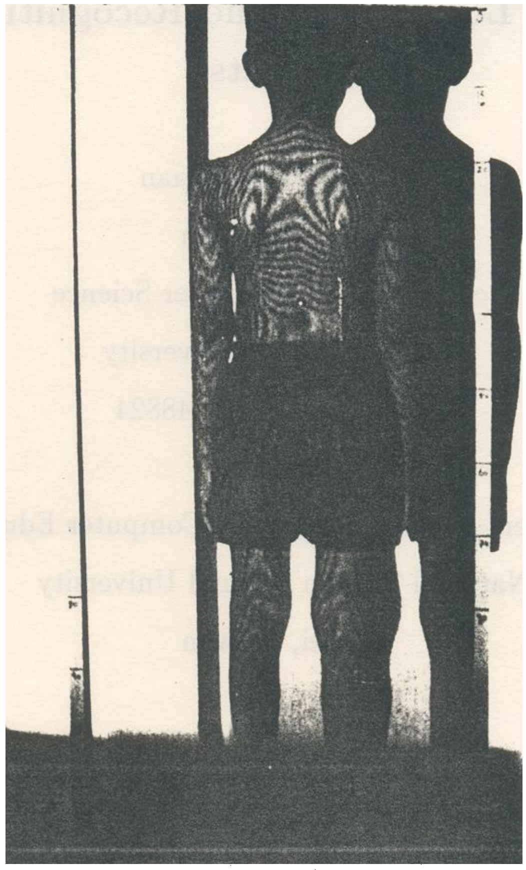

Fig. 5 ACTUAL MOIRE PHOTOGRAPH