Proceedings of the Society of Photo-Optical Instrumentation Engineers

Volume 240

Periodic Structures, Gratings, Moiré Patterns, and Diffraction Phenomena

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C. L. O'Bryan III
Editors

July 29–August 1, 1980
San Diego, California

Published by
The Society of Photo-Optical Instrumentation Engineers
P.O. Box 10, Bellingham, Washington U.S.A. 98227
206/676-3290

Moiré topography for the detection of orthopaedic defects

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Abstract

Moiré topography is applied for the follow-up of scoliosis patients. The results are then compared with the X-rays. A special lamp and scale arrangement is utilized for patient alignment. It is suggested that this technique will be used for the detection of all orthopaedic defects.

During recent years there has been much activity in the field of moiré topography[1,2]. Moiré is a French word which means watered[3]. Moiré fringes are a series of interference fringes arising from the superposition of line grids, the lines of which are slightly inclined to each other, or are otherwise in register[4]. The width of the lines of the grid should be equal, to the space between them. The moiré effect also arises where there is an interference between a screen and its shadow which falls upon an object behind. In this case the various shadow lines - the contour lines - appear on the surface of the object at regular distances from the grid[5]. Takasaki[6,7] introduced contour moiré pictures of a full size living body. Adair et al.[8] applied this technique for the early diagnosis of scoliosis through a school screening program. Willner[5] has studied the correllation of the moiré fringe interval and the lateral deviation of the spine. Boyer and Goitein[9] have developed a new moiré camera. A method has been developed for the measurement of the angle of spinal curvature by moiré topographs[10]. In taking the moiré topographs there has been a problem of patient alignment[8]. This difficulty has now been resolved by introducing a new process for patient alignment[11,12].

With a little modification,this procedure is now being used at J.W. Riley Hospital for Children at Indianapolis for the follow-up of scoliosis patients. The screen is made up of fishing line of nylon, 0.5 mm thick, stretched vertically across a rectangular opening in a steel frame. The distance between the two threads is 0.5 mm. The frame has the horizontal support to make the screen standing. To align the patient parallel to the screen,two laser beams are used. A special scale is constructed with horizontal and vertical lines. One of the laser equipments is fixed right below the vertical scale. It is slightly tilted in the upward direction so that if a plane mirror is held parallel to the scale (which is in turn parallel to the screen) the light will be reflected back on the vertical scale. If the mirror is rotated along the horizontal axis, the light will move along the vertical scale. But if the mirror is rotated along the vertical axis, the light will no longer fall on the vertical scale. Therefore,this arrangement will show that the vertical plane in which the incident and reflected laser beams lie is perpendicular to the plane of the mirror as well as the plane of the scale (on which the light falls back) if the beam is reflected back on the vertical scale. Care should be taken in drawing the vertical scale. It would be preferable if a plumb line is used to draw the vertical scale. To insure that the mirror is not rotated along the horizontal axis also, a second laser beam is used. The incident and reflected beams from this second laser equipment lie in the horizontal plane. If the laser equipment is kept on the right side of the scale, the laser should be slightly tilted towards the left and vice versa. In this way the light reflected from the mirror will fall on the horizontal scale. If the mirror is rotated along the horizontal axis, the light will not fall on the horizontal scale, but above or below it.

To obtain the moiré topograph of the back, the patient stands behind the screen with his back close to the screen. The patient is asked to stand in a relaxed and normal mode, looking straight ahead. The mirror is held touching the stomach of the patient and adjusted in such a way that the light from the first laser falls on the vertical scale and from the second on the horizontal scale. If the patient twists in the horizontal direction, light from the first laser will not fall on the vertical scale and if the child twists in the vertical direction, light from the second lamp will not fall on the horizontal scale. Now the patient is ready to be photographed.

For photographing SX-70 (Sonar Focussing - One Step) Land Camera and SX-70 Land Film is used. The source of light used is 1000 watt lamp. The shadows of the fishing lines of nylon fall on the body and a pattern is formed depending on the depth and elevation of the surface. The distance h_n between the n^{th} fringe, as projected on the body, and the screen is

$$h_n = nL(s_o^{-1}d - n)^{-1} \qquad (1)$$

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where L is the horizontal distance from the light and the camera to the screen, d is the vertical distance between the camera and the light and s_o is the screen interval[13]. In our experiment

$$L = 100 \text{ cm}; \quad d = 50 \text{ cm}; \quad s_o = 1.00 \text{ mm}$$

Therefore

$$h_n = (100\, n)\,(500 - n)^{-1} \tag{2}$$

The difference between n^{th} and $(n + 1)^{th}$ fringe is

$$D = h_{n+1} - h_n = (n+1)L(s_o^{-1}d-n-1)^{-1} - nL(s_o^{-1}d-n) \tag{3}$$

This can be written as

$$D = Ls_o^{-1}d(n-s_o^{-1}d)^{-1}(n+1-s_o^{-1}d)^{-1} \tag{4}$$

Therefore

$$D = (100)\,(500)\,(n - 500)^{-1}(n + 1 - 500)^{-1} \tag{5}$$

If n = 1, the difference between the 1^{st} and the 2^{nd} fringe is 0.20 cm, whereas for n = 50, the difference is 0.24 cm.

The purpose of the experiment is to obtain moiré topographs of children having scoliosis at regular intervals and compare them with the previous moiré topographs. If there is a change observed in the moiré pattern, a radiographic examination may be taken. In this case the repeated taking of X-rays can be avoided. Only in the case of a change should X-rays be taken. This change will be noted from the change in the moiré pattern. It is also planned to find the angle of spinal curvature and compare it with the angle found by the X-rays. From moiré topographs the angle can be measured at regular intervals[10].

The method as described in ref.[10] consists of selecting a reference line on the moiré topograph. The line is drawn by joining the midpoint of the neck to the midpoint of the waist. From this line, the distances to the first visible moiré fringe on both sides are measured at different points. We adopt the convention that the distances on the right of the reference line are positive and those on the left are negative. Let d_1 be the position of the spine with respect to the reference line at the point of maximum asymmetry and d_2 be at the point of minimum asymmetry. D_1 is the distance between the points of maximum and minimum asymmetry on the reference line, then the angle of spinal curvature is given by[10]

$$\theta = 2 \tan^{-1}(D_1^{-1}|d_1 - d_2|) \tag{6}$$

If the spine is not curved at the midpoint, the above formula is modified as[10]

$$\theta = \tan^{-1}(D_1^{-1}d) + \tan^{-1}(D_2^{-1}d) \tag{7}$$

where D_1 is the distance between the point of maximum asymmetry and that of minimum asymmetry above it on the reference line and D_2 is the distance between the point of maximum asymmetry and that of minimum asymmetry below it. d is given by

$$d = \tfrac{1}{2}\,(|d_1 - d_2| + |d_1 - d_3|) \tag{8}$$

where d_1 is the position of spine with respect to the reference line at the point of maximum asymmetry and d_2 is at the point of minimum asymmetry above it, whereas d_3 is the position of the spine with respect to the reference line at the point of minimum asymmetry below it. At the time of initial examination, the points of maximum and minimum asymmetry can be judged with the help of comparison of initial X-rays and the moiré topograph, and in the following moiré topographs the same points may be used for measurements.

It is hoped that the set up will enable the medical personnel to reduce the number of X-rays taken, to keep a photographic record of the prognosis of scoliosis, and to record and measure the possible changes in the curve due to result of treatments (braces, exercises, surgery etc.). It is further hoped that the method will also be used for the follow-up of lordosis (topograph of front) and kyphosis (topograph of side with hand excluded) and many other orthopaedic defects. If the topographs of the full body of very young children are taken at regular intervals, it is unlikely that any orthopaedic disorder may remain undiagnosed at the very early stage[14].

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