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# Accuracy and Precision of Moiré Fringe Topography System

Moiré fringe topography is a simple, non-contact, noninvasive, nondestructive, photogrammetric technique, which provides 3-dimensional map of a study subject/object (human body, precision instrument), without using X rays or any other ionizing radiation. The technique of moiré fringe topography consists of photographing the study object through a specially constructed screen.



Time Evolution of Moiré Images (obtained by our group)



Accuracy and precision of shadow type moiré system were determined. 99.61% accuracy suggests that moiré technique can be used for fine measurements. 91.21% precision indicates that we need to improve our marking and observing techniques, by viewing still photographs under a microscope.

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## ACCURACY AND PRECISION OF MOIRE FRINGE TOPOGRAPHY SYSTEM

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**Abstract:** Moiré fringe topography is a simple, noncontact, noninvasive, nondestructive, photogrammetric technique which provides three-dimensional map of a study subject/object (human body, precision instrument) without using X rays or any other ionizing radiation. The technique of moiré fringe topography consists of photographing the study object through a specially constructed screen. Dark fringes are produced because of the presence of screen. Accuracy and precision of shadow type, fishing line moiré fringe topography system are determined.


### 1. Introduction

The need to find a convenient three-dimensional measuring system led to the development of photogrammetry in the middle nineteenth century. Medical photogrammetry is the term used to cover all applications of photogrammetry in the broad field of medicine. These include stereophotogrammetry, holography, integrated surface imaging system (ISIS), 3-D video laser scanning system, moiré fringe topography and rasterstereography.

The important advantages of photogrammetry over conventional methods for medical applications are (Lane 1983):

- Photogrammetry is a noninvasive, noncontact and nondisruptive technique. It avoids risks involved in hurting, infecting, or distorting the

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human subject being studied.

- Photogrammetry can make it easy to measure objects otherwise inaccessible or difficult to measure.
- Photogrammetry enables to keep permanent records in the form of photographic images on paper, videotape or diskette.
- Body structures, which could not be seen or illustrated before, may often be studied by photogrammetry.
- Any desired degree of accuracy may be achieved by making a suitable choice of equipment and technique.
- Data obtained from photogrammetric measurements especially if put in coordinate form may be easily utilized by computer systems.

We are, therefore, in need of methods which are inexpensive, easy to implement, simple to be performed by moderately trained personnel and elegant enough to permit handling by various algorithms. Moiré fringe topography (Creath, Wyant 1992) and rasterstereography both have all these characteristics (Kamal 1998). The first one provides height maps and the second curvature maps. If we are able to record and process information from both these techniques we may obtain a complete profile of human trunk during every cycle of gait. Such information may be used in modeling of human gait and understanding of various neurological disorders.

## **2. Moiré Fringe Topography System**

Moiré fringe topography is a photogrammetric technique which gives a three-dimensional profile of the object under study. The technique is simple, noninvasive and noncontact in nature. As such the technique is most suitable to study objects which are difficult to access. Moiré system can be of shadow type, projection type or grating hologram type. In our laboratory we have developed shadow type moiré systems using fishing line and argenza (cloth) as well as a grating hologram type system. A rasterstereography system has also been developed. Construction of the moiré frame has been described elsewhere (Akram 1989; Ahmad, Hashmi 1990; Kamal, Bukhari, Akram 1990a,b). Moiré techniques are known to us since 70's (Takasaki 1970; 1973). These days, moiré fringe topography is being widely applied in the detection (Adair, van Wijk, Armstrong 1977;

Kamal, El-Sayyad 1981; Kamal, Naseeruddin, Waseem 1996; Kamal, Naseeruddin, Waseem, Firdous 1998; Kamal, Yosufzai 1979), documentation (Willner 1979), quantification (El-Sayyad, Kamal 1981; 1982; Kamal 1982a-c; 1983a,b; 1987; 1988; 1996a-c; Kamal, Akram, Bukhari 1988; Kamal, Akram, Siddiqui, Khan 1989; Kamal, Choudhry, Siddiqui 1996; Kamal, El-Sayyad 1981; Kamal, El-Sayyad 1981; Kamal, Lindseth 1980; Siddiqui, Choudhry 1990; Yosufzai, Kamal, Zubairi 1995; Zubairi 1994). Moiré exam must be an integral part of physical examination of every athlete (Akram, Kamal 1991).

Reproducibility of moiré technique has been investigated (Kamal 1990; Kamal, Benoni, Willner 1994). Some authors have performed error analysis and determined accuracy of their systems (Karras 1990; Klein, Rooze 1990; van Wijk 1980; 1981). There is a need to establish a protocol for checking the accuracy and the precision of our moiré systems.

For a shadow type moiré system (Terada 1974) the depth of a bright fringe may be expressed as

$$\Delta_n = nL[n - d/s]^{-1} \quad (1)$$

and a dark fringe as

$$\Delta_n = (n - \frac{1}{2})L[d/s - (n - \frac{1}{2})]^{-1} \quad (2a)$$

where 's' is the pitch of moiré grid, 'L' the distance from the moiré screen to the observer/ recording instrument lens center and d the distance from observer/recording instrument lens center to light source lens center. The light source used is a slide projector. Focus of the lens is so adjusted that a slide will project sharply on the moiré grid.

We have to use dark fringe formula in our calculations. The dark fringe formula may be rearranged as

$$(\Delta_n)^{-1} = (d/sL)(n - \frac{1}{2})^{-1} - L^{-1} \quad (2b)$$

A graph between  $(n - \frac{1}{2})^{-1}$  and  $(\Delta_n)^{-1}$  shall, therefore, be a straight line with slope  $d/sL$ . Therefore, pitch of the moiré grid may be computed from

$$s = d/L(\text{slope}) \quad (3)$$

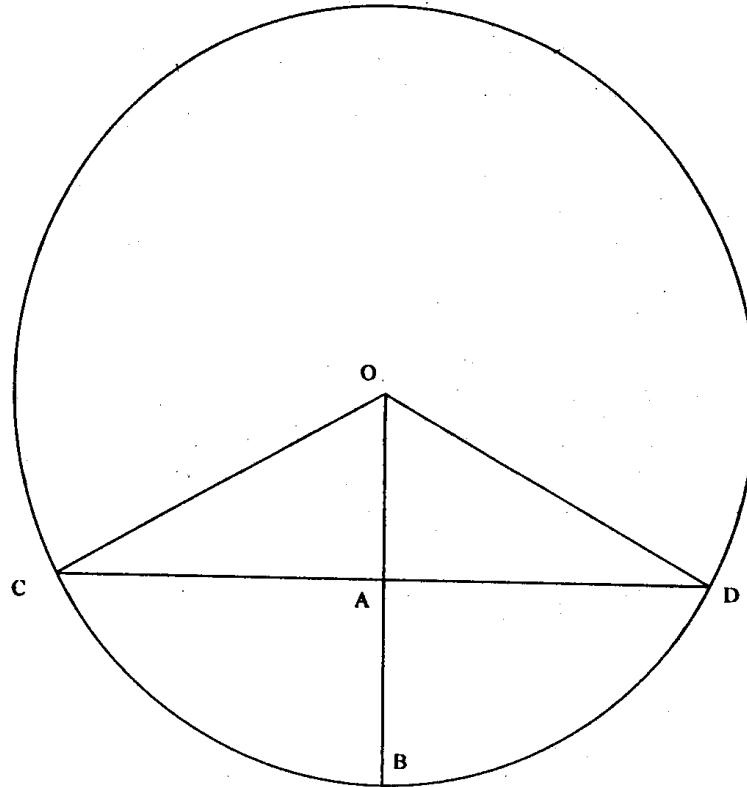


Fig.1. Geometry of the reference object (right-circular cylinder)

Depth of the  $n^{\text{th}}$ -order fringe may be computed considering Fig. 1 which shows the cross section of a right circular cylinder (our standard measuring object). The zeroth-order fringe falls at B. Let the  $n^{\text{th}}$ -order fringe be observed at D on the left and C on the right. The depth  $\Delta_n = AB$  may be computed from geometrical considerations. It can be easily verified that

$$\Delta_n = r[1 - (1 - \delta_n^2/4r^2)^{1/2}] \quad (4)$$

where ' $r$ ' is the radius of cross section of the cylinder,  $\delta_n = DC$ , length of the line segment joining  $n^{\text{th}}$ -order fringe on the left to the corresponding  $n^{\text{th}}$ -order fringe on the right.

### 3. Accuracy and Precision

Accuracy is a measure of how close the observations are to the accepted value. Precision is a measure of how close the observations are

to the arithmetic mean. The pitch of shadow type, fishing line system may be computed using fringe formula and by direct measurement of the width and spacing of the grid (fishing lines in our case). Direct measurement of the pitch,  $s_0$ , is considered as the reference value which is to be used to determine accuracy. The other values computed from the depth of the 1<sup>st</sup>-, 2<sup>nd</sup>- and 3<sup>rd</sup>-order fringes on a standard object (right circular cylinder) may be  $s_1, s_2, s_3, \dots, s_N$  for different sets of observations. Accuracy and precision are, therefore, given by

$$\text{Accuracy} = 100 [1 - \sigma(s_0)/s_0]; \quad \text{Precision} = 100 [1 - \sigma(\langle s \rangle)/\langle s \rangle] \quad (5a,b)$$

where  $\langle s \rangle = (\sum s_i)/N, \sigma(x) = [(1/N)\sum(s_i - x)^2]^{1/2}$ ; the summation runs over  $i = 1, 2, \dots, N$ .

**Table 1: Fringe Depths for a Standard Object**

Observation set no. N	Fringe no. n	Length of line segment CD $\delta_n$ (cm)	Depth of n <sup>th</sup> fringe $\Delta_n$ (cm)	$(n - 1/2)^{-1}$	$\Delta_n$ (cm) <sup>-1</sup>
1	1	1.9	0.180	2.00	5.55
	2	2.85	0.427	0.67	2.34
	3	3.5	0.680	0.40	1.47
2	1	1.9	0.180	2.00	5.55
	2	3.0	0.478	0.67	2.09
	3	3.9	0.884	0.40	1.13
	1	1.9	0.180	2.00	5.55
3	2	3.2	0.553	0.67	1.81
	1	2.05	0.211	2.00	4.73
4	1	2.05	0.211	2.00	4.73
	2	3.25	0.573	0.67	1.75

#### 4. Experimental

Experiment was constructed in the Optics Laboratory. A paper was pasted on the top and the bottom surfaces of the cylinder and positions of the zeroth-order, the first-order, the second-order and the third-order fringes were marked using a fine marker. The experiment was repeated for different positions of the cylinder and a total of 4 sets of observations were taken. Fringes beyond the third-order were not visible. In two of the cases fringes beyond the second order were not visible. For this experiment 'L' was taken as 170 cm and 'd' as 70 cm, diameter of cylinder was 5.185 cm. Data collected were classified and least square lines were fitted to compute the slope. From the slope pitch of the moiré grid was estimated. Accuracy and precision of these estimates were obtained taking  $s = 0.15$  cm as the reference value (Akram 1989). Tables 1 and 2 show the data analysis and the results. Accuracy of our fishing-line moiré system came out to be 99.61% and precision 91.21%. These values were reasonable under the present experimental conditions.

**Table 2: Fitting of Least Square Line and Computation of Pitch**

$$\text{Equation of the least square line: } (\Delta n)^{-1} = (d/sL)(n - \frac{1}{2})^{-1} - L^{-1}$$

Reference value of the pitch,  $s_0 = 0.15$  cm

Distance from the moiré grid to the observer,  $L = 170$  cm

Distance from the observer to the slide projector,  $d = 70$  cm

Observation set N	Slope of the least square line (cm)	Pitch of the moiré system $s_N = d/L(\text{slope})$ (cm)	Accuracy (%)	Precision (%)
1	2.50	0.164	99.61	91.21
2	2.71	0.152		
3	2.90	0.142		
4	2.29	0.179		

## 5. Discussion and Conclusion

Accuracy and precision of shadow type moiré system have been determined. A value of accuracy of 99.61% suggests that moiré technique can be used for fine measurements. However, a precision of 91.21% indicates that we need to improve our marking and observing techniques. This may be improved if still photographs are taken and viewed under the microscope to improve measurements. We also need to determine the accuracy and the precision of argenza (cloth) shadow type moiré system as well as grating hologram type moiré system. We are also in the process of developing an inexpensive, lightweight, portable projection-type moiré system which could be used for mass screening in schools. Projection-type systems developed in Japan are heavy and expensive. Photogrammetric techniques like moiré fringe topography, stereophotography, holography and rasterstereography shall play an increasing role in industry, health care and education in the third millennium we are going to enter within the next two years.

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## References

1. Adair IV, van Wijk M, Armstrong GWD (1977) Moiré topography in scoliosis screening, *Clin Orthop* **129** 165-171
2. B. Ahmad, UF Hashmi, (1990) To develop different techniques to study spinal deformity, *MSc Project*, Univ Karachi, (unpublished) supervised by Dr SA Kamal.
3. M. Akram,(1989) Construction of a shadow type moiré apparatus, *MSc Project*, Univ Karachi, (unpublished) - supervised by Dr SA Kamal
4. M. Akram and S.A. Kamal, (1991) Role of moiré fringe topography in the skeletal examination of school athlete, *International Congress & Exposition on Sports Medicine and Human Performance*, Vancouver, Canada, (poster presentation)<sup>€</sup>
5. K. Creath and JC Wyant, (1992) Moiré and fringe projection techniques, In: *Optical Shop Testing* (ed Malacara D), 2<sup>nd</sup> ed, John Wiley, New York, pp 653-683
6. MM El-Sayyad and S.A. Kamal, (1981) Cobb's angle measurement by

<sup>€</sup>Abstract: <https://www.ngds-ku.org/Presentations/Skeletal.pdf>

- moiré topographs, *Proc 34th Ann Conf Eng Med Biol* 23 311<sup>v</sup>
7. MM El-Sayyad and S.A. Kamal, (1982) The use of holographic techniques to obtain moiré topographic fringes of the human body, *Bull Amer Phys Soc* 27 502 (poster presentation)<sup>£</sup>
  8. S.A. Kamal, (1982a) A new process for patient alignment, *Bull Amer Phys Soc* 27 502 (poster presentation)<sup>¥</sup>
  9. S.A. Kamal, (1982b) Measurement of the angle of spinal curvature by moiré topographs, *J Islamic Med Assoc (USA)* 14 146-148<sup>€</sup>
  10. S.A. Kama, (1982c) Moiré topography for the measurement of angle of spinal curvature in three dimensions, *Bull Amer Phys Soc* 27 301 (poster presentation)<sup>∇</sup>
  11. S.A. Kamal, (1983a) Determination of degree of correction of spinal deformity by moiré topographs, In: *Moiré Fringe Topography and Spinal Deformity*, Proceedings of the 2<sup>nd</sup> International Symposium, 1982, (ed Drerup B, Frobin W, Hierholzer E), Gustav Fischer, Stuttgart & New York, pp 117-126<sup>θ</sup>
  12. S.A. Kamal, (1983b) Moiré fringe topography and spinal deformity, *National Guard 8<sup>th</sup> Saudi Medical Conference*, Riyadh, Saudi Arabia<sup>ξ</sup>
  13. S.A. Kamal SA, (1987) Moiré topography for the study of multiple curves of spine, In: *Surface Topography and Spinal Deformity*, Proceedings of the 4<sup>th</sup> International Symposium, 1986, (ed Stokes IAF, Pekelsky JR, Moreland MS), Gustav Fischer, Stuttgart & New York, pp 43-50<sup>§</sup>
  14. S.A. Kamal, (1988) Moiré topography. *Physics Dialogue (Karachi)* 1 16-17<sup>#</sup>
  15. S.A. Kamal SA (1990) Reproducibility of moiré topographs, In: *Surface Topography and Body Deformity*, Proceedings of the 5<sup>th</sup> International Symposium, 1988, (ed Neugebauer, Windischbauer G), Gustav Fischer, Stuttgart & New York, pp 151-153<sup>@</sup>
  16. Kamal SA (1996a) A 3-D static model of the human spinal column, *Kar U J Sc* 24(1) 29-34<sup>&</sup>
  17. Kamal SA (1996b) 3-D dynamic modeling of the human spinal column, *21<sup>st</sup> International Nathiagali Summer College on Physics and Contemporary Needs*, Nathiagali, Pakistan, June-July 1996 (poster presentation)<sup>∩</sup>
  18. Kamal SA (1996c) Combination of moiré contours and edge-based algorithm to study motion in the sagittal plane, *Kar U J Sc* 24(2)53-60<sup>©</sup>
  19. Kamal SA (1998) 3-D optical imaging and image processing --- iomedical

<sup>v</sup> Full text: <https://www.ngds-ku.org/Papers/C12.pdf>

<sup>£</sup> Full text: <https://www.ngds-ku.org/Papers/C18.pdf>

<sup>¥</sup> Full Text: <https://www.ngds-ku.org/Papers/C17.pdf>

<sup>€</sup> Full text: <https://www.ngds-ku.org/Papers/J04.pdf>

<sup>∇</sup> Full text: <https://www.ngds-ku.org/Papers/C16.pdf>

<sup>θ</sup> Full text: <https://www.ngds-ku.org/Papers/C23.pdf>

<sup>ξ</sup> Full text: <https://www.ngds-ku.org/Papers/C22.pdf>

<sup>§</sup> Full text: <https://www.ngds-ku.org/Papers/C26.pdf>

<sup>#</sup> Full text: <https://www.ngds-ku.org/Articles/A13.pdf>

<sup>@</sup> Full Text: <https://www.ngds-ku.org/Papers/C34.pdf>

<sup>&</sup> Full text: <https://www.ngds-ku.org/Papers/J18.pdf>

<sup>∩</sup> Abstract: <https://www.ngds-ku.org/Presentations/Dynamical.pdf>

<sup>©</sup> Full text: <https://www.ngds-ku.org/Papers/J17.pdf>

- applications, *Proceedings of the International Workshop on Recent Advances in Computer Vision*, January 1998, (ed Laghari JR, Naqvi AA, Rajput AQ, Sangi NA, Shah MA), SZABIST, Karachi, pp 86-95<sup>Σ</sup>
20. Kamal SA, Akram M, Bukhari N (1988) Moiré topography for the study of neurological disorders, *2<sup>nd</sup> National Symposium on Frontiers in Physics*, Quaid-é-Azam Univ, Islamabad, Pakistan<sup>Ξ</sup>
21. Kamal SA, Akram M, Siddiqui KA, Khan NU (1989) Moiré, raster & EEG studies of epileptics during washable memory period, *7<sup>th</sup> International Conference on Biomagnetism*, New York Univ, New York<sup>⊖</sup>
22. Kamal SA, Benoni G, Willner S (1994) A study to check the reproducibility of moiré topographs, *Kar U J Sc* **22**(1 & 2) 67-74<sup>⊖</sup>
23. Kamal SA, Bukhari N, Akram M (1990a) A comparison of back moiré topographs of children in the sitting and in the standing positions, In: *Surface Topography and Body Deformity* (Proc 5th Int Symp), loc cit pp 77-78<sup>⊗</sup>
24. Kamal SA, Bukhari N, Akram M (1990b) A comparison of side moiré topographs of children in the standing, in the sitting and in the forward bending positions, In: *Surface Topography and Body Deformity* (Proc 5th Int Symp), loc cit pp 79-80<sup>⊕</sup>
25. Kamal SA, Choudhry AS, Siddiqui YA (1996) Gait analysis using moiré fringe topography and rasterstereography (simultaneous recording), *Kar U J Sc* **24**(2) 7-18<sup>⊖</sup>
26. Kamal SA, El-Sayyad MM (1981) The use of moiré topographs for the detection of orthopedic defects in children of age group four to seven years, *23<sup>rd</sup> Annual Meeting of the American Association of Physicists in Medicine*, Boston, Ma, USA, (presented by title); *Med Phys* **8** 549<sup>⊖</sup>
27. Kamal SA, Lindseth RE (1980) Moiré topography for the detection of orthopedic defects, *Periodic Structures, Moiré Patterns and Diffraction Phenomena* (Proc Soc Photo-Opt Instr Eng), **240** 293-295<sup>⊖</sup>
28. Kamal SA, Naseeruddin, Waseem M (1996) Physics of the screening procedures to detect trunk deformities, *3<sup>rd</sup> Annual National Symposium of the Aga Khan University*, Karachi (poster presentation)<sup>⊖</sup>
29. Kamal SA, Naseeruddin, Waseem M, Firdous S (1998) Physics of scoliosis screening in school-going children, *Kar U J Sc* (in press)<sup>⊖</sup>  
Kamal SA, Yosufzai MAK (1979) Moiré contour recorder, *19<sup>th</sup> Annual Science Conf*, Quaid-é- Azam Univ Islamabad, Pakistan<sup>⊗</sup>

Σ Full text: <https://www.ngds-ku.org/Papers/C46.pdf>

Ξ Abstract: <https://www.ngds-ku.org/Presentations/Neurological.pdf>

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⊖ Full text: <https://www.ngds-ku.org/Papers/J15.pdf>

⊗ Full text: <https://www.ngds-ku.org/Papers/C33.pdf>

⊕ Full text: <https://www.ngds-ku.org/Papers/C32.pdf>

⊖ Full text: <https://www.ngds-ku.org/Papers/J16.pdf>

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⊖ Full text: <https://www.ngds-ku.org/Papers/C08.pdf>

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⊖ Full text: <https://www.ngds-ku.org/Papers/J22.pdf>

⊗ Full text: <https://www.ngds-ku.org/Papers/C04.pdf>

30. Karras GE (1990) Calibration and accuracy of shadow moiré topography, In: *Surface Topography and Body Deformity* (Proc 5<sup>th</sup> Int Symp), loc cit pp 143-145
31. Klein P, Rooze M (1990) Close range moiré topography: an error analysis, In: *Surface Topography and Body Deformity* (Proc 5<sup>th</sup> Int Symp), loc cit pp 147-149
32. Lane HR (1983) Photogrammetry in medicine, *Photogramm Eng* 49 1453-1456
33. Siddiqui YA, Choudhry AS (1990) Gait analysis using moiré fringe topography and rasterstereo-graphy, *MSc Project*, Univ Karachi, (unpublished) --- supervised by Dr SA Kamal
35. Takasaki H (1970) Moiré topography, *Appl Optics* 4 845-850
36. Takasaki H (1973) Moiré topography, *Appl Optics* 9 1457-1462
37. Terada (1974) A new apparatus for stereometry: Moiré contourograph, In: *Advances in Eperimental Medicine and Biology - Nutrition and Malnutrition*, ed Roche AF, Falkner F, Plenum Press, London, pp 27-46
38. Van Wijk (1980) Moiré contourograph --- an accuracy analysis, *J Biomech* 13 605-613
39. Van Wijk M (1981) Accuracy of moiré topography, In: *Moiré Fringe Topography and Spinal Deformity*, Proceedings of the 1<sup>st</sup> International Symposium, 1979, (ed Moreland MS, Pope MH, Armstrong GWD), Pergamonn, New York, pp 47-57
40. Willner S (1979) Moiré topography for the diagnosis and documentation of scoliosis, *Acta Orthop Scand* 50 295-302
41. Yosufzai MAK, Kamal SA, Zubairi JA (1995) Computer-based analysis of human gait using moiré fringe topography, *Proc 2<sup>nd</sup> Int Workshop on Computer Vision & Parallel Processing*, (ed Khan GN, Naqvi AA, Shah M), Quaid-é-Azam Univ, January 1995, pp 60-71<sup>o</sup>
42. Zubairi JA (1994) Image processing algorithms to detect trunk deformities, *New IT Order*, Proc of XIII Conf of South East Asia Regional Computer Confederation, November 1994, pp 270-279 – supervised by Dr SA Kamal.

<sup>o</sup> Full text: <https://www.ngds-ku.org/Papers/C41.pdf>

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