Keynote Lecture delivered during *the First Undergraduate National Computing Conference*, Usman Institute of Technology, Karachi, Pakistan, Thursday, May 30, 2013

3-D-Spinal-Column-Surface Analysis (Height and Curvature Maps) by Combining Moiré Fringe Topography and Rasterstereography with Backscatter-X-Ray-Scanning Technology

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Human stereophotogrammtry has its roots in *anthrogeometry* (http://www.ngds-ku.org/Presentations/AMTM.pdf), which is the mathematics of interpretation of distances and curvatures on the human skin or surfaces of bones and organs. Moiré fringe topography and rasterstereography are non-contact, non-distorting, non-destructive, non-invasive, stereophoto-grammetric techniques, which provide 3-D information of the surface under study (height and curvature maps). They have been, traditionally, used for surface studies in engineering sciences and human-skin-anatomical studies in medical sciences. One particular application is in the detection, the documentation, the quantification and the follow-up of spinal deformities. These techniques have, also, been applied to the dynamic studies of spinal-column motion during gait analysis. However, their scope is limited to surface studies, as these techniques, although *active scanning* in nature, use only ordinary light, which does not penetrate to the bones http://www.ngds-ku.org/Presentations/Security.pdf — the backscatter-body-scanning system, introduced for security screening at airports, offers the possibility of using these stereophotogrammetric techniques for the study of structure of spinal column. In the backscatter-X-ray scan, radiation penetrates through clothes and is Compton scattered to produce image of the body, thus detecting any concealed weapons through shape detection. For medical applications, it was suggested to adjust the intensity enough so that the X rays were scattered off the bone generating its picture instead of skin. For 3-D-spinal-column-surface analysis (height map), the radiation was filtered through a moiré frame (located next to skin; X rays are blocked by threads of moiré frame) to produce a 3-D-moiré pattern of the spinal column. Such moiré patterns of human back are being, routinely, used since the last century in scoliosis studies. How-ever, both X-ray- and moiré-scanning mechanisms are giving gross information of spinal column. These techniques are not capable of going to the next level of analysis (suggested by our group), in which crystal-structure concepts — form factor and structure factor — http://www.ngds-ku.org/Presentations/BZU1.pdf were applied to static and dynamic modeling of the human-spinal column. With 3-D-height map of spinal column at the disposal of orthopedic surgeon, diagnosis and treat-ment of scoliosis might be improved. The above set up (shadow-type-backscatter moiré) could not be corrected-for-mis-alignment or rotated, after an image was recorded and shored. Only *active-image correction* was possible (asking the patient to change position) by the operator. However, if the X rays were passed through a moiré grid, in which these rays were blocked by grid-strips (grating-hologram-type-backscatter moiré), a *passive-image correction* (post-recording correction of image itself) was possible, a distinguishing feature of grating-hologram moiré. A projected-raster grid (X rays blocking ras-ter patterns) generated 3-D-curvature map of the spinal column. With the technique of simultaneous moiré and raster record-ing, proposed by our group in 1990 http://www.ngds-ku.org/Papers/J16.pdf spinal-column-3-D-surface structure could be studied during gait analysis. Holographic images could be generated by recording and processing multiple images in the angular range $-\pi/2$ to $+\pi/2$ (like sliced images in CT scan). Being *active-scanning processes*, holographic-backscatter-moiré and -raster seemed to offer the potential to generate real-life images of bones or vessels. From the point of view of radiation damage to humans, one may note that the backscatter-X-ray intensity is low as compared to regular X-ray intensity. Further, these rays reflect off the bone surface and are not absorbed in the bone material. Hence, it might be, reasonably, assumed that there would not be so much damage as from regular X rays. The speaker, still, suggested discretion in the use of these techniques in the high-risk groups, *i. e.*, infants, children, elderly people, cancer patients, and pregnant women. Eyes and gonads must be, properly, shielded, when any such procedure is performed and the safety protocols recommended by PNRA (Pakistan Nuclear Regulatory Authority) followed to letter and spirit. With the help of techniques from physics (image pro-jection/recording), computer science (edge-based and intensity-based algorithms) and information technology (image pro-cessing), human sreophotogrammtery has the capability to, not only, record heights and curvatures of bone and organ sur-faces, but also, their infinitesimal movements as well as sectional-semicircular views through edge-based-holographic-backscatter-moiré and -raster (simultaneous recording). For example, when used to study heart, such views would quantify infinitesimal movement by giving time-evolution of configuration space — change of height (curvature) function over the heart surface and during a certain time period. The proposed techniques could find applications in bone anatomy, organ anatomy and physiology as well as skeletal-maturity determination through determination of bone age.

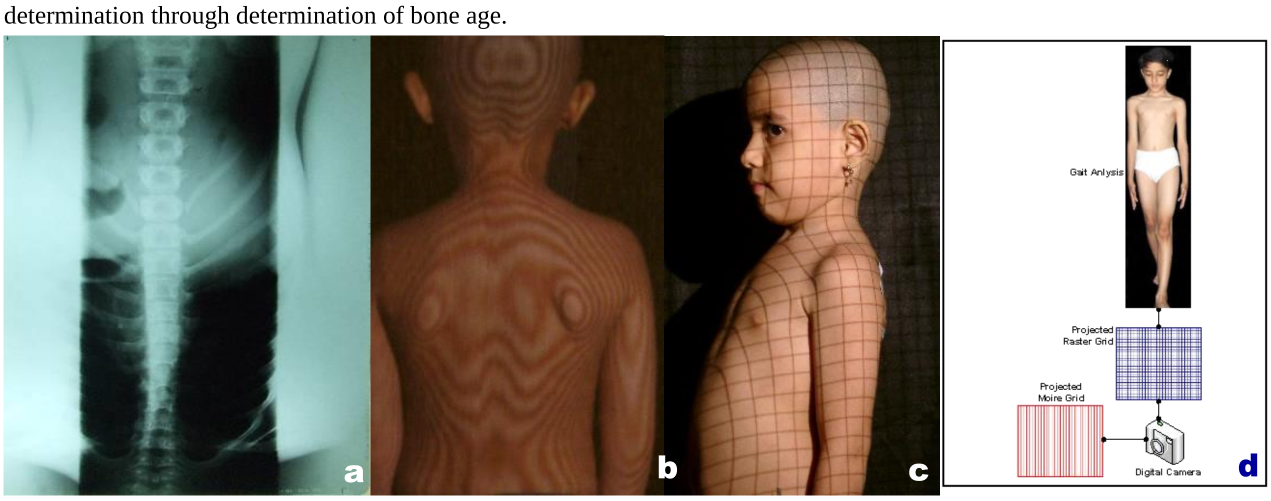

Fig. 1*a*-*d*. AP-X ray showing (*a*) the spinal column, (*b*) moiré grid projected on back, (*c*) raster grid projected on shoulder and (*d*) simultaneous moiré and raster recording

*Keywords***:** Backscatter-X-ray scanning, moiré fringe topography, rasterstreography, spinal column, edge-based algorithm, holography
*Conflict of Interest Statement***:** No potential conflict of interest is identified for this work
*Grant Sponsor***:** Dean's (Science) Research Grant, University of Karachi, number DFSR/2009
*Research Ethics***:** Project initiated after *Institution Review Process* and is conducted in compliance with ethical and human-right standards in our region.

*Web address of this document***:** http://www.ngds-ku.org/Presentations/Backscatter.pdf
*HTML version***:** http://www.ngds-ku.org/pub/confabstA.htm#C96:

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