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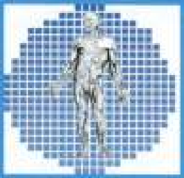

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points and lines. The deformation and positioning of the model was done iteratively until the model corresponded, by visual inspection, to the images for all abduction angles. Bony landmarks of the scapula were then identified in the same way as for the humeral head for at least one position. Last, the displacement of the COR of the humeral head relative to the scapula was determined from simple matrix transformations.

Results

Precision analysis: the manual analysis process took less than 1 min for each pair of images of the radiographic phantom. The method allowed us to determine the displacement which had been applied to the humeral head with an average precision greater than 0.5 mm in all directions and for all humerus orientations. The standard deviation was smaller than 0.2 mm in all cases. Repeated analysis of the images four times by the same observer lead to average variations of 0.48 mm (max 0.75 mm; SD 0.19 mm).

Preliminary study on in vivo images: early tests were run on a series of radiographs of one healthy subject. The analysis process was applied three times to the series of images and took between 10 and 20 min for each trial. The method allowed us to detect displacements of the humeral head of small amplitude (up to 3 mm) in all directions. Standard deviations across all trials were smaller than 1 mm in every direction.

Conclusion

The main advantage of this technique over other radiographic techniques is that it allows to track displacements of the humeral head relative to the scapula in 3D without the use of a CT scan, which greatly reduces exposure to radiations. It could also be adapted to more conventional X-ray machines and would then be easily accessible to almost every hospital to assist doctors in the assessment of the impact of shoulder disorders on ROM limitations.

The results obtained in the precision analysis suggest that the COR of the humeral head can be precisely determined from biplane X-rays. The preliminary results obtained from the analysis of in vivo images show the feasibility of the method for the detection of displacements of the amplitude reported in the literature for patients with RC disorders. Further improvement of the method and its automatisation (or semi-automatisation) could very likely lead to a precise tool for the study of shoulder pseudo-kinematics.

Automated human body 3D measurement system supporting screening for posture and body shape evaluation

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Keywords 3D measurement · Posture evaluation · Chest deformation · Fringe and Gray code Projection · screening

Purpose

The predictions and assessments of body deformities namely scoliosis or chest deformations (i.e. funnel chest) are typically performed utilizing standard imaging modalities that include X-ray and computed tomography (CT). In order to reduce X-ray exposures non-contact, optical-based 3D data acquisition techniques are developed to image human surfaces, e.g. the back surface, full trunk, whole body, human face, foot, etc.

Early detection of progression in adolescent idiopathic scoliosis and other chest deformations is anticipated. Clinically validated attempts of measurement of changes in back or thorax shape with 3D optical imaging have been developed and presented [1–4].

Methods

Presented shape measurement system is able to capture 3D surface of full human body in the form of set of (x, y, z) co-ordinates (cloud of points). It consists of four directional measurement heads that simultaneously capture visible 3D shape of the human body (Fig. 1). Measurement method is based on white light illumination and it exploits combined fringe and Gray code projection [5]. During simultaneous measurement from four heads multispectral separation of its spectrum is used. Each of directional heads captures 3D shape of visible part of human surface. By combining four directional clouds of points a full 3D human surface representation is created.

Single measurement head consists of the projector, the detector and the fixing frame. The Digital Light Projector is based on the Digital Mirror Device (DMD) technology developed by Texas Instruments. The gray scale CCD camera is used. DLP projector and CCD camera are equipped with spectral filters that separates projected and observed patterns from other heads. The fixing frame is constructed on the base of aluminium profiles. Knowledge of the parameters of the objectives in the DLP and CCD is not important and does not influence the measurement accuracy. Analysis is carried out on an ordinary PC based computer with several controllers: camera controller (acquisition of camera image), DLP pattern generator (projecting patterns on DLP).

The size of the measurement volume depends on actually used calibration model, efficiency of the projector light source and camera-projector objectives. In this configuration the volumes used ranging from $0.5 \times 0.5 \times 0.5\ \mathrm{m}^3$ up to $2 \times 2 \times 2\ \mathrm{m}^3$.

Results

Below, the measurement process will be illustrated by the sequential results obtained from the measurement of human chest. At the first stage, the unwrapped phase Φ is calculated for each pixel (i, j) from a set of measurement images including:

- Phase shifted deformed grid patterns with sinusoidal profiles, each pattern includes fringes within the field of view. These images are used for determination of $\Phi(i, j)\mathrm{mod}(2\pi)$ by the temporal phase shifting method [6].

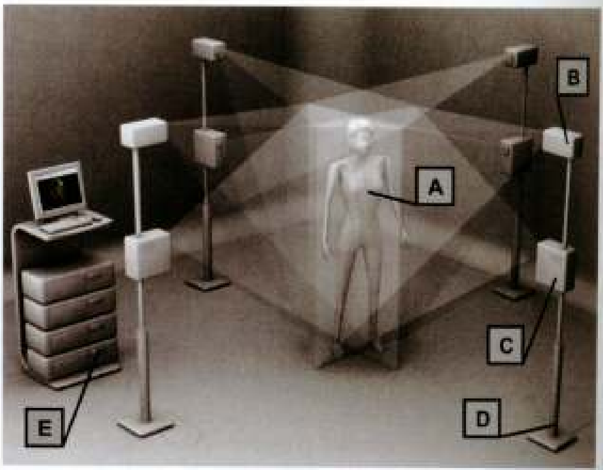

Fig. 1 OGX|3DMADMAC measurement system: **a** subject, **b** matrix detector CCD, **c** DLP projector, **d** fixing frame, **e** control/calculation/measurement workstations

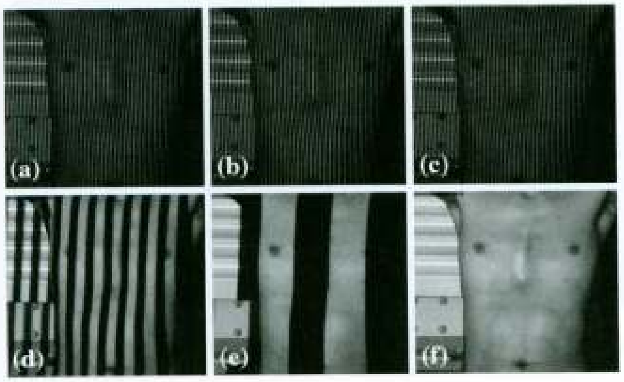

Fig. 2 Measurement sequence: **a–c** sine pattern images, **d–e** gray code images, **f** texture image

- gray code images (Fig. 2d, e); these images provide data for hierarchical phase unwrapping procedure, i.e. $N(i, j)2\pi$, where N is an integer value [7, 8],
- one full, natural image, white light illumination; this image is used for gathering the (R, G, B) or intensity (I) information attached to each (x, y, z) point.

Current measurement is relatively fast. Single measurement takes about 0.25 s. Number of measurement points vary and depends on object size in detector space but it is limited by detector resolution (up to two millions of points from single measurement head and up to eight millions of points from whole system). Measurement uncertainty for human surface measurement (including skin semi-transparent properties) is less than 0.2 mm for the whole body measurement and it is less than 0.05 mm for small part of the body measurements.

Conclusions

Calibration and measurement process together with comparison to existing competitive systems for human full body 3D surface measurement influence on presented system development and quality. The measure of uncertainty evaluation and calibration remains the most important issue and makes the whole method most reliable. Large scale approach to cohort patients study covers almost all age groups of patients beginning in childhood (scoliosis screening) and ending in elderly (osteoporotic kyphosis screening). Implemented method for automatic segmentation of the final cloud of points allows to assess and store all human body segments separately, namely hands, legs, head, chest, or whole body.

Acknowledgment

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Visual report: a concept to support the workflow in oncological software applications

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Keywords Visualization · Reporting · Application · Oncology

Purpose

With regards to the diagnosis of oncological patients modern software assistants offer sophisticated methods for tumor measurement, statistical evaluation and visualization to enhance workflow and diagnostic quality for radiologists. Nevertheless, the report of the diagnosis which is forwarded to the oncologist is usually a plain text. In discussions with clinical partners we found that oncologists would appreciate a brief look at the actual images. Unfortunately, this is not easily done. First they would have to obtain the data itself by the information they have in the textual report (which in the worst case means searching the PACS for the correct image acquisition). Second they would have to search the image for the findings described in the radiologist's report, which might even be ambiguous. As this is not compatible with tight clinical time restrictions, nowadays oncologists rarely view radiological images of most of the patients. Similar issues are faced by the radiologist who, when reading a follow-up study, first has to recover the initial findings in the baseline scan often described by another reader in not well standardized terms.

For these reasons we propose an approach called "Visual report", where we aim to create a high quality 3D visualization of the measured lesions including also the most important structures of their surrounding organ—especially major vasculature and the organ's border. This visualization allows a fast overview of the state of the disease and in addition provides easy access to detailed measurements per lesion (like RECIST or WHO diameter, volume and density). Furthermore, interaction with the Visual report can be used to navigate through the data, e. g. to immediately jump to a finding in the axial view.

In the following, we describe the methods that are implemented so far within a prototypical application. Our goal is to include the Visual report into radiological workstations and to provide a light version that serves as a viewer for intuitive and fast access to images for oncologists and surgeons. This should enhance the workflow and interconnection of different clinical disciplines.

Methods

As basis for our implementation we used an oncological software that provides sophisticated measurement tools such as tumor segmentation for volumetry. The tumor masks resultant from the segmentation are