IMAGE MATCHING AND SURFACE REGISTRATION FOR 3D RECONSTRUCTION OF A SCOLIOTIC TORSO

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The focus of this research is a hierarchical image matching strategy and a multiple surface registration technique for 3D reconstruction of a scoliotic torso. Scoliosis is a deformity of the human spine most commonly occurring in children. After being detected, periodic examinations via x-rays are traditionally used to measure its progression. However, due to the increased risk of cancer, non-invasive and radiation-free scoliosis detection and progression monitoring methodologies are being researched. For example, quantifying the scoliotic deformity through the torso surface is a valid alternative because of its high correlation with the internal spine curvature. This work proposes a low-cost, multi-camera photogrammetric system for semi-automated 3D reconstruction of a torso surface with a sub-millimetre level accuracy. The paper first describes the system design and calibration for optimal accuracy. It then covers the reconstruction and registration procedures giving insights into the hierarchical image matching strategy and the multiple surface registration technique. Final accuracy is evaluated through the goodness of fit between the reconstructed surface and a more accurate set of points measured by a coordinate measuring machine.

Cette recherche met l'accent sur une stratégie d'appariement hiérarchique d'images et d'une technique de mise en correspondance à surfaces multiples pour la reconstruction en 3D d'un torse scoliotique. La scoliose est une déformation de la colonne vertébrale humaine qui se retrouve le plus souvent chez les enfants. Une fois détectée, des examens périodiques par rayons X sont traditionnellement utilisés pour mesurer sa progression. Toutefois, en raison de l'augmentation des risques de cancer, la recherche vise à trouver des méthodes, non invasives et sans radiation, de détection et de surveillance de la progression de la scoliose. Par exemple, la quantification de la difformité scoliotique au moyen de la surface du torse constitue une alternative valable en raison de sa corrélation élevée avec la courbe interne de la colonne vertébrale. Ce travail propose un système photogrammétrique multicaméra peu coûteux pour la reconstruction semi-automatisée en 3D de la surface d'un torse avec une précision submillimétrique. Cet article décrit d'abord la conception et l'étalonnage du système pour une précision optimale. Il couvre ensuite les procédures de reconstruction et de mise en correspondance qui permettent de comprendre la stratégie d'appariement hiérarchique d'images et la technique de mise en correspondance à surfaces multiples. La précision finale est évaluée par l'adéquation entre la surface reconstruite et un ensemble plus précis de points mesurés par un appareil de mesure de coordonnées.

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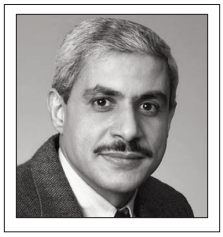

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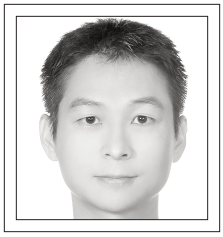

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Introduction

Scoliosis is a lateral curvature of the spine. A normal spine viewed from behind appears straight, while a scoliotic spine appears "S" or "C" shaped. A person is diagnosed with scoliosis once the spinal curvature exceeds 10° [*Kane* 1977]. The disease generally begins at the onset of puberty and progresses during the period of rapid growth. If left untreated, it can negatively impact the patient's quality of life (e.g. causing respiratory problems and/or heart malfunction), so it is imperative to detect abnormal spinal curvature as early as possible. Scoliosis is usually first detected, or at least suspected, during a school screening session. The method most widely practiced during such a session is the Adam's bend forward test, where a scoliometer is used to initially estimate any visible trunk asymmetry. If scoliosis is detected, a full-length standing x-ray is taken in order to better quantify the spinal curvature. This is done by measuring what is known as the Cobb angle [*Cobb* 1948].

The magnitude of the Cobb angle and the speed of the curvature progression are essential for assigning optimal scoliosis treatment. A curvature of 45° or less can be treated conservatively with exercises or bracing, however, rapidly changing curvature or curvature exceeding 45° requires surgery [*Roach* 1999]. This is why the disease progression must be monitored by periodic examinations;