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Fast and low cost acquisition and reconstruction system for human hand-wrist-arm anatomy

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Abstract

3D body scanners are nowadays used in a range of applications spanning from health, fashion and fitness to reverse engineering applications for robotics and computer vision. Nowadays very good performances are achievable when using commercial 3D body scanners; however, focusing on relative complex shape of some body details, the results still lack precision and acceptable accuracy. Such critical issue remains unsolved also when dealing with the instantaneous acquisition of the hand-wrist-arm (HWA) anatomy. In this paper, we present a new approach that leverages the emerging 3D depth cameras technologies to design a compact low cost 3D dedicated HWA scanner system capable of delivering almost instantaneous full 3D measurement.

Keywords: 3D body scanner; hand-wrist-arm anatomy; depth sensors; calibration; 3D surface

1. Introduction

Dedicated 3D body scanners are paramount to deliver the exact measures of a human body to be used in a range of applications dealing with health, fashion and fitness as well as the myriad of reverse engineering applications for robotics or industrial engineering in general [1-5].

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Human oriented 3D scanners pose new challenges in the panorama of existing optical measurement systems; in fact, the agile and deformable human nature, imposes the acquisition to be specifically fast to avoid movement artefacts. Nowadays very good results are possible with the existing body scanners (both professionals and consumer devices) however, focusing on relative complex shape of some body details, the results still lack precision and acceptable accuracy. This is particularly true when the human body (of some of its parts) is acquired by using low-cost devices such as, for instance, the Microsoft® Kinect™ [6] and the Intel® Realsense [7] i.e. camera systems able to provide both color and dense depth image. These sensors have been recently applied in a huge number of industrial and biomedical applications. Compared with traditional 3D scanners, these sensors can capture depth and RGB data at video rate. Despite both the RGB quality and the depth resolution are limited, the major benefit comes from the overall acquisition speed and the near IR pattern that allows the acquisition in poor lighting conditions as well as on dark surfaces. Consequently, the use of such devices rapidly grew especially regarding the human motion analysis [8] but also for creating low-cost body scanners. An early publication dealing with the use of Kinect™ as a 3D body scanner was performed in 2012 demonstrating the effectiveness of approaches based on the use of low-cost device for this kind of application [9-11]. Unfortunately, several drawbacks remain in developing full body scanners based on RGB-D sensors.

First, the depth data captured is of extreme low quality (low X/Y resolution and depth accuracy) especially when dealing with non-static bodies (like living human bodies are) that should be measured instantaneously [12]. Furthermore, RGB-D sensors require relatively long computational time to reconstruct a complete model from the scan data (and the obtained model is often unreliable). Eventually, to increase the resolution of the acquired body/body part requires the contemporary use of multiple devices with several problems related to registration, superimposition of projected IR patterns, data flow management etc. Such critical drawback remains unsolved also when dealing with the instantaneous acquisition of the hand-wrist-arm (HWA) anatomy. Required in a variety of applications related to robotics, medical devices (cast and orthosis), tailor made jewelry as well as sport and fashion apparel, the peculiar geometry of human HWA remains one of the most challenging part to measure.

In this paper, we present a new approach that leverages the emerging 3D depth cameras technologies to design a compact low cost 3D dedicated HWA scanner system capable of delivering, almost instantaneously, a full 3D measurement. Especially suited for medical purposes (i.e. the acquisition of paediatric patients) the dedicated scanner consists of a set of four RGB-D scanners arranged on a circular ring to acquire in a single "shot", the entire geometry of interest under the condition that the patient remains, during the scanning process, as static as possible. The proposed system is provided also with a procedure for the semi-automatic reconstruction of a parametric CAD from the acquired point cloud. This procedure allows to obtain a mesh to be eventually used for several applications (e.g. design of orthosis and ergonomic analysis).

2. Design of a 3D HWA scanner

As mentioned above, obtaining a complete 3D model of the hand-wrist-arm anatomy is a complex task: besides technical issues arising from the need of using more than a single device, other practical problems (mainly due to the agile and deformable human nature and to the variety of dimensions) may arise. This is particularly true, especially when it comes to growing children (see Fig. 1).