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Detection, reconstruction and segmentation of chronic wounds using Kinect v2 sensor

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Abstract

The advent of inexpensive RGB-D sensors pioneered by the original Kinect sensor, has paved the way for a lot of innovations in computer and robot vision applications. In this article, we propose a system which uses the new Kinect v2 sensor in a medical application for the purpose of detection, 3D reconstruction and segmentation of chronic wounds. Wound detection is based on a per block classification of wound tissue using colour histograms and nearest neighbour approach. The 3D reconstruction is similar to KinectFusion where ICP is used for determining rigid body transformation. Colour enhanced TSDF is applied for scene fusion, while the Marching cubes algorithm is used for creating the surface mesh. The wound contour is extracted by a segmentation procedure which is driven by geometrical and visual properties of the surface. Apart from the segmentation procedure, the entire system is implemented in CUDA which enables real-time operation. The end result of the developed system is a precise 3D coloured model of the segmented wound, and its measurable properties including perimeter, area and volume, which can be used for determining a correct therapy and treatment of chronic wounds. All experiments were conducted on a medical wound care model.

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Keywords: chronic wound; detection; reconstruction; segmentation; measurement; kinect v2

1. Introduction

Chronic wounds heal very slowly and the healing process may further be prolonged if an ineffective treatment is used. Clinicians need an objective wound characterization method to decide if the current treatment is adequate or

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requires adjustments. Accurate wound measurement is an important task in chronic wound treatment because changes in the physical parameters of the wound are indicators of the healing progress.

Wound measurement methods currently in use are mostly based on simple approaches for area measurement, using rulers and transparency tracing, or photography based non-contact systems. Such methods give a rough estimate of the total wound area and the evaluation depends on human experience; it is not objective and not eligible for validation of the wound healing process. The first step in creating a precise non-contact measurement system is having the ability to reconstruct the wound as a 3D model. This would facilitate complex analysis or measurement of wounds which is otherwise awkward and painful for the patient or inconvenient for clinicians. Furthermore, the reconstructed 3D model could be used for collaboration between clinicians and telemedicine.

Wound measurement is typically divided into two main approaches: contact and non-contact. Contact based methods require measurements to be taken directly with wound contact[1, 2]. Non-contact methods require a recording device, whereby a standard camera is typically used. It is generally accepted that image based methods are a viable alternative to contact based methods, and have a maximum error of area measurement of about 10% depending on the wound location and the camera angle[3]. Other non-contact wound assessment systems use 3D reconstruction to enhance image based methods and gain more precise measurements. For example, two wound images taken from different angles can be used to generate a 3D mesh model[4]. Eykona, a system similar in principle and commercially available, generates more dense 3D representation[5]. Besides being very expensive, costing about $18000, Eykona has limitations with respect to the size and position of the wound it can reconstruct since the whole wound needs to be visible in a single frame. Lasers are also commonly used for 3D reconstruction in medical research[6, 7, 8]. Even though they have proven to be very precise, they are not easy to use and are very expensive. Furthermore, they also share the limitation as stereo vision systems: the whole wound must be visible in one frame. InSight by eKare uses a technology similar to the original Microsoft Kinect and is used in the study[9] for comparison in measurement performance with SilhouetteStar. The new InSight system has the limitation regarding the visibility of the whole wound in a single frame.

As can be seen, most of the systems have limitations regarding precision, ease of use and price, the latter of which limits the widespread use of most systems. However, the biggest limitation of all presented systems is that the whole wound must be visible from a single view. This constraint limits the wound's size and location. The 3D wound reconstruction system proposed in this paper does not have such a constraint. Since it is based on scene fusion, the wound can be located on a larger area and on curved surfaces. Furthermore, an inexpensive Microsoft Kinect v2 sensor is used which costs about $150, making the system available to a much wider user base.

In this paper, we propose a system for the detection, 3D reconstruction and segmentation of chronic wounds using a Kinect v2 sensor. The Kinect v2 sensor consists of a 1920 x 1080 resolution RGB camera and a 512 x 424 resolution depth camera, both at 30FPS. The developed system automatically detects wounds by analysing image blocks and utilizing colour histogram similarity and nearest neighbour approach. The 3D reconstruction is similar to the KinectFusion approach[10] where Iterative Closest Point (ICP) algorithm is used for determining rigid body transformation. Colour enhanced Truncated Signed Distance Function (TSDF) is applied for scene fusion and the Marching cubes algorithm is used for creating a surface mesh. The wound segmentation algorithm is driven by changes in surface geometry and colour with the main goal of separating the wound tissue from the surrounding healthy tissue (skin). Furthermore, except for segmentation, the entire system is implemented in CUDA, which enables real-time operation. The proposed system provides a high resolution 3D coloured model of the wound and its surrounding tissue suitable for further analysis. Analysis implemented in the system includes measurement of wound perimeter, area and volume, which clinicians could use to develop more responsive therapy and treatment for chronic wounds.

The system proposed herein was fully developed in C++ and CUDA v7.0. Furthermore, all experiments were run on a laptop computer with Intel Core i7 4710HQ CPU, Nvidia 860M GPU and Windows 8.1 Pro x64 operating system. In addition to the Kinect v2 sensor and the PC computer, the materials used also included Saymour II wound care model by VATA Inc. which was used for experimental evaluation of the developed system.

The rest of the paper is structured as follows. In Section 2 an overview of the wound detection and 3D reconstruction subsystems is provided, while Section 3 elaborates on the segmentation subsystem. Section 4 explains the methods used for measurement of wound perimeter, area and volume. Finally, this paper is concluded with Section 5, which comments on the results.