Target Definition with 3D Surface Scanning for Orthovoltage Radiation Therapy Planning

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Introduction

Orthovoltage radiation therapy (ORT) is a non-invasive cancer treatment technique commonly used to treat superficial tumours, such as non-melanoma skin cancer. This treatment can be preferred to surgical excision in cases where surgery could cause poor cosmetic outcomes [1]. Currently, there is no commercially available treatment planning system for ORT. Non-melanoma skin cancers treated with ORT present on the surface of the skin, typically in the head and neck region. As part of treatment planning process, the extent of the skin cancer must be localized in a CT scan [2]. As the skin cancer does not show in CT, prior to scanning the radiation oncologist marks the tumor contour on the skin with a cut-out fiducial, which then is visible in the CT image. This process is suboptimal for a several reasons: it is prone to human error, and it is expensive for requiring the radiation oncologist to be present during an otherwise routine CT scanning. We propose to use non-contact optical three-dimensional surface scanning to acquire colored and textured image of the patient at the time of CT scanning, segment the tumour and overlay its contour on the CT images for subsequent dosimetry planning.

Methods

A red sticker representing a skin lesion was placed on a male plastic mannequin phantom. The head and neck phantom was segmented from a CT image using thresholding based on image intensity. The resulting segment was cropped to remove the shoulders and traces of the bed table and pillow, keeping only the head of the phantom. The surface of the phantom's face was scanned using the Artec Eva 3D Surface Scanner (Artec 3D, Luxembourg), to obtain a full-coloured textured 3D mesh. The Artec Eva is a handheld 3D scanner that can be used to make fast high-quality scans of medium sized objects, such as the head and neck phantom. The segmented head model and surface scan model were pre-registered using five fiducials manually placed on the nose tip, inner corners of eyes, and front of ears. After pre-registration, the Iterative Closest Points (ICP) algorithm was used to align the two models more precisely (Figure 1). The pre-registration step is needed to ensure the two models are sufficiently close to each other before running the ICP algorithm; if the pre-registration step is skipped, an incorrect registration may be found by the ICP algorithm.

The tumour was manually segmented by following the outline of the lesion from the surface scan model. The tumour was segmented to a depth of approximately 1cm, to mimic depth of superficial NMSCs. The defined tumour was saved with the CT scan to DICOM-RT, for use in treatment planning (Figure 2). The software platform 3D Slicer, an open-source application for medical image visualization and analysis, was used for segmentation and registration [3].

Results

The Artec Eva was chosen for 3D surface scanning because is can provide 3D resolution of up to 0.5mm and has colour capture capability. The red sticker placed on the mannequin to mimic a skin legion was clearly visible on the textured mesh created using the scanner's software, and could be easily segmented by following the outline of the lesion. After pre-registration using five fiducials placed on the segmented head model and the surface scan model, the two models were roughly aligned. Performing registration using the ICP algorithm on the two pre-registered models yielded the final registration, with a mean distance after registration of 0.25mm. The mean distance was computed between the points which constitute the surface scan model and the nearest corresponding points on the triangulated cells of the model segmented from CT. The workflow of 3D surface scanning, segmenting the head from CT, registering the 3D surface scan model to the segmented phantom model, and segmenting the tumour was completed in about 7 minutes.

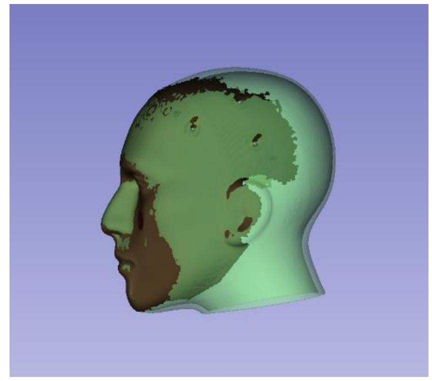

Figure 1: Following pre-registration using fiducials, the ICP algorithm is used to register the surface scan model of the head to the model of the head segmented from CT.

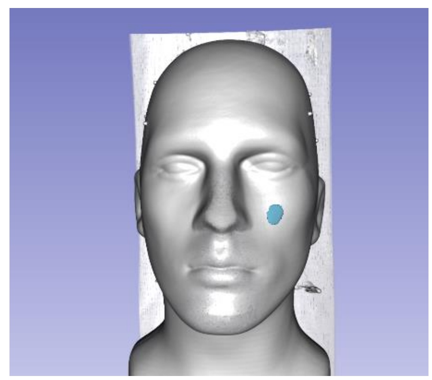

Figure 2: The tumour (blue) was segmented from a 3D surface scan. The segmented tumour is shown with the CT image of the mannequin head; both of these are needed for treatment planning.

Conclusion

Tumour location for lesions visible at the surface of the skin can be defined with the help of 3D surface scanning, leading to a quick workflow and eliminating the need for more complex methods of localizing the tumour. This project presents the first step toward developing a free open-source treatment planning system for orthovoltage radiation therapy.

Finally, this method of using 3D surface scanning to define target location can be extended beyond non-melanoma skin cancer, to define the location of any superficial or shallow tumours and lesions which are visible at the skin's surface.

References

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