A Novel Framework for an In-room Collision Monitoring System

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INTRODUCTION

Collisions between the LINAC (gantry) and patient (including, patient support devices and couch) or with other objects inside the room represent a major safety concern for radiotherapy treatment **[1,2]**. Such collisions often result in treatment delays and/or disruption of clinical workflow, equipment damage, and potentially patient injury. Current safety mechanisms provided by vendors can only mitigate collisions with the patient and don't consider collisions outside treatment zone.

AIM

In this study, we present a novel method to predict in-room collisions by constructing an accurate 3D map of the entire treatment room. Our methodology employs a novel and low-cost solution to avoid collisions by creating an accurate 3D map using a light detection and ranging technique (LiDAR) technique for 3D mapping.

METHOD

2D mapping was achieved using a laser range scanner (RPLIDAR A2, SLAMTEC) shown in **Figure 1**. The device has a range of 12 meters and runs at frequency of 5Hz with angular resolution of 0.45 and distance resolution of 0.2cm. The device performs a 360 degree scan at a sampling rate of 8000/sec.

Multiple 2D scans were performed at various locations inside the room (**Figure 2**) using Python script and merged using simultaneous localization and mapping algorithm (SLAM) available in MATLAB to generate high resolution 2D maps **[3]**. The 2D maps were then combined to construct a 3D point cloud representing the entire room.

RESULTS

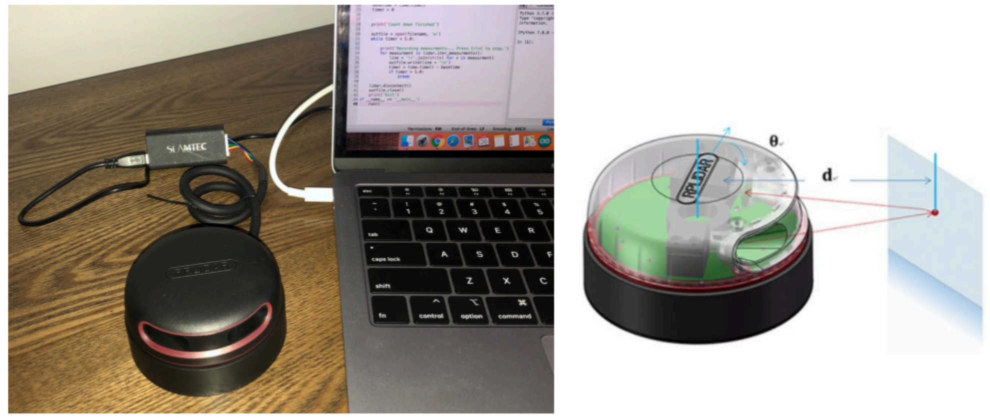

Figure 1. *(**Top left panel**) shows a Laser range scanner RPLIDAR-A2 connected to a laptop via USB port type-C which provide power and data communication. The RPLIDAR is controlled using a Python script running on MacOS. The LIDAR estimates the distance based on triangulation principle as shown by the schematic in the **top right panel**. A low power (~3 mW) modulated laser pulse in the infrared light band (785nm) is emitted which gets reflected by the object in its path. The reflected signal is then sampled by vision acquisition system and analyzed using the embedded digital signal processing (DSP) unit to measure the distance **[4]**. The range scanner is mounted on a rotating platform which allows a 360-degree scan of the surrounding environment.*

Figure 2*. A 2D map of a treatment room shows the floorplan of the room and the outline of the gantry rotated at 90 degrees. The dimensions from the scan matched the physical dimensions of the room. The blue line shows the different locations where the 10 LiDAR scans were taken.*

Figure 3. *An actual image of treatment vault showing the True Beam linear accelerator and other accessories including BrainLab x-ray imaging system.*

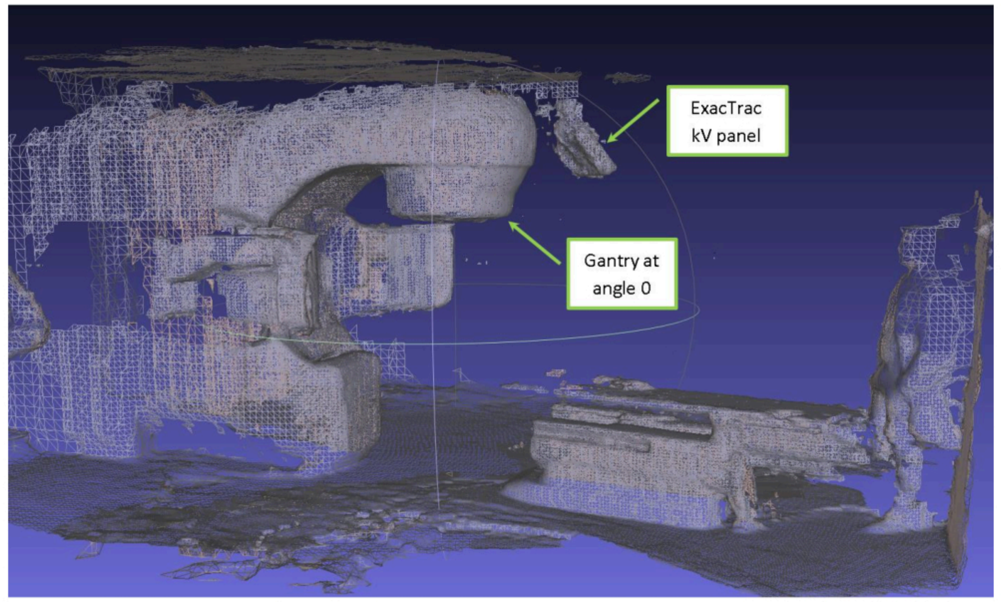

Figure 4*. A mesh representation of a partial 3D scan of the treatment vault. All the different components are clearly visible including the gantry at 0, couch, ExacTrac kV panel in the ceiling, and a person standing near the wall on the right.*

RESULTS

The 2D scans showed an accurate representation of the room floorplan. The room dimensions extracted from the 2D scan agreed with the physical dimensions (L=6.73m, W=6.77m). The accuracy was ±0.2cm for short range (15cm < distance <500cm) and ±1 cm for long range scans (distance>500cm). The accuracy was improved by combining multiple 2D scans taken at different locations using the SLAM algorithm. The mesh representation of a partial 3D scan showed an accurate depiction of all the components inside the treatment room as shown in **Figure 3& 4**.

DISCUSSION

A highly detailed and accurate 3D map of the treatment room was achieved using a low-cost LiDAR. This information is then used to verify the trajectory clearance of the gantry and couch to avoid collisions. Successful implementation of this technique will lead to automatic detection of potential collisions between the treatment machine and patient, as well as unexpected collisions between the machine and other objects inside the treatment room. Furthermore, these devices can operate under any light conditions to provide improved visibility.

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