Radiotherapy Positioning with Augmented Reality

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Acknowledgments

Varian Medical Systems
Sevelin Stanchev
Dr. John van Heteren
UC Davis Medical Center
Dr. Robin Stern
Dr. Sonja Dieterich
Dr. Daniel Hernandez
Dr. David Campos
UC Davis Biomedical Engineering Department
Dr. Jennifer Choi
Robert Gresham
Alireza Tafazzol
UC Davis Computer Science Department
Michael Sun

RADAR

BACKGROUND

Radiation therapy is a cancer treatment that uses high doses of radiation emitted from a linear accelerator (LINAC) to kill cancer cells and shrink tumors. A typical patient treatment plan requires patients to come in to the clinic 5 days a week for 2-10 weeks. During the patient setup process, patient positioning is one of the most crucial aspects of radiotherapy.

OBJECTIVE

We decided to focus mainly on the Initial Positioning phase of the patient setup process in order to complete our project within the Senior Design time-frame.
Our long-term goal is to develop a device that will verify patient identity, accessory usage, and increase patient positioning accuracy during Final Positioning. The device will allow radiation oncology therapists to safely treat cancer patients more efficiently and to position them within smaller margins.

CURRENT TREATMENT WORKFLOW

Step 1: CT Simulation

BB Markers

Step 2: CT Dosimetry

Step 3: Daily Patient Positioning

Initial Positioning: Laser alignment system

Disadvantage: Difficult to see and objections

Final Positioning: Cone Beam CT Scan (CBCT)

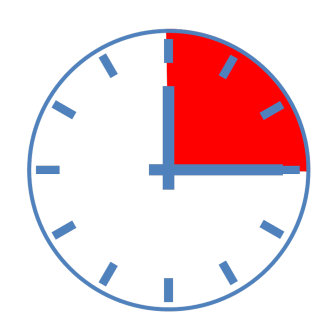
Disadvantage: Excess radiation exposure

Step 4: Administer Radiation Treatment

TREATMENT CHALLENGES

There is a need for a more efficient way for radiation therapists to optimize patient setup in the radiation oncology clinic.

- Verify patient identity
- Verify accessory usage
- Verify patient positioning
- 15-minute appointments



Misalignment of the patient will result in radiating the incorrect target site and damaging healthy tissue. Therefore, it is essential for patients to be positioned exactly like the Sim setup every time.

DESIGN CRITERIA

Based on survey results, we developed a list of quantifiable metrics. They represent the target values RadAR should satisfy in order to meet the clinical user needs.

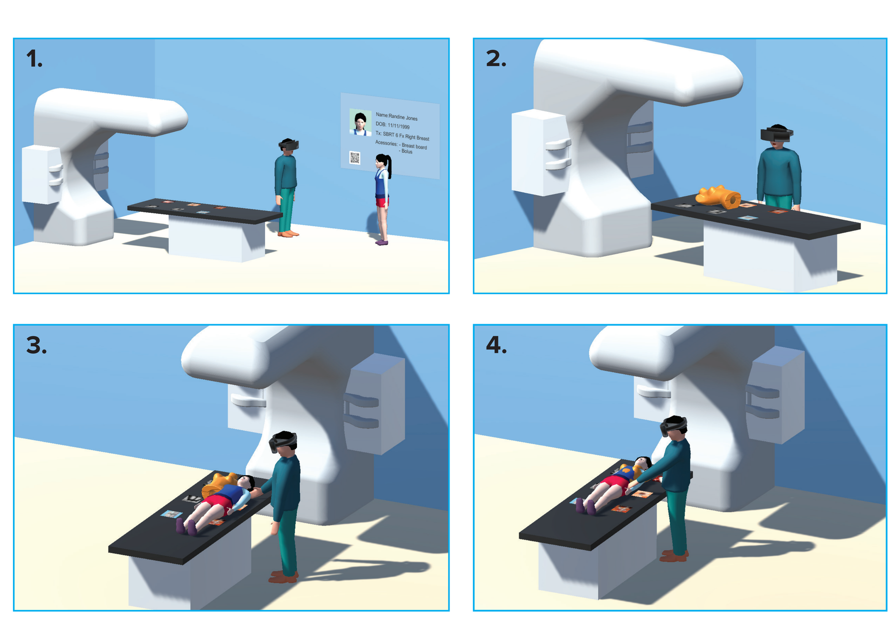
Engineering Design Specifications

Metric	Value Range	Ideal Value
Weight	1.2 - 35 lb	< 3 lb
Cost	$500 - 10,000	< $5,000
Frames per Second	10 - 120 frames/sec	60 frames/ sec
Reference Position Accuracy	0.5 - 2 cm	< 2 cm
Range of QR Code Registration	100 - 5000 mm	<500mm & >2000mm
Warm-up time	1 - 45 mins	< 30 mins
Battery Life	2 - 8 hrs	> 2.5 hrs

DESIGN SOLUTION

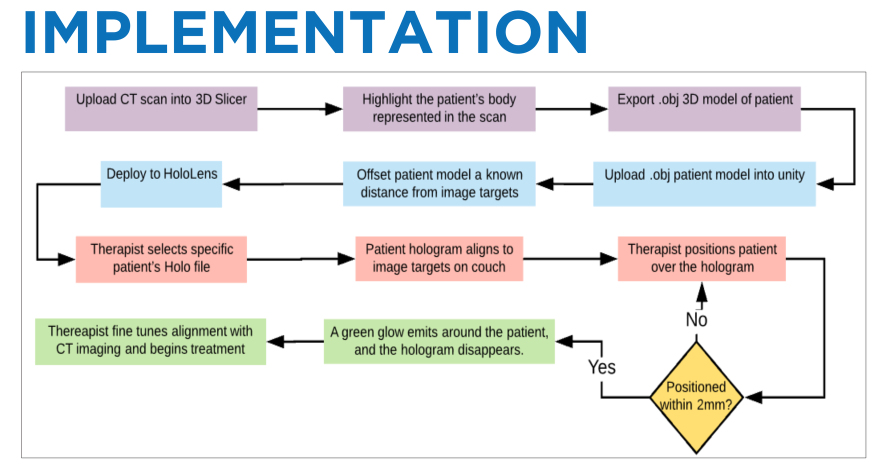
RadAR is an Augmented Reality (AR) software program that enables radiation therapists to accurately position cancer patients during radiation treatment. Using Microsoft HoloLens, a 3D holographic model of the patient's correct position and location is displayed onto the treatment couch. By superimposing the patient with the holographic image, a therapist can accurately align the patient during the treatment setup process. RadAR enables radiation therapists to efficiently position cancer patients each time.

RadAR in action



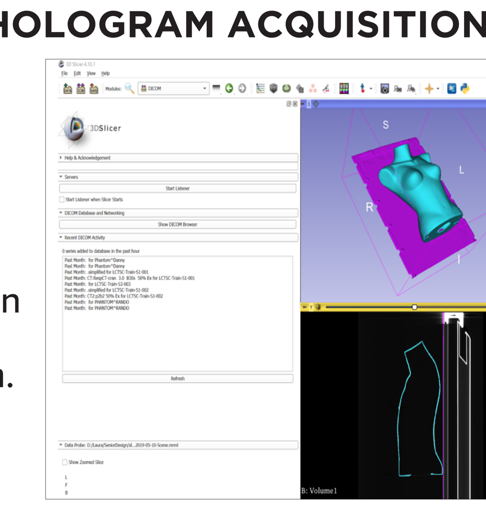
Workflow

IMPLEMENTATION



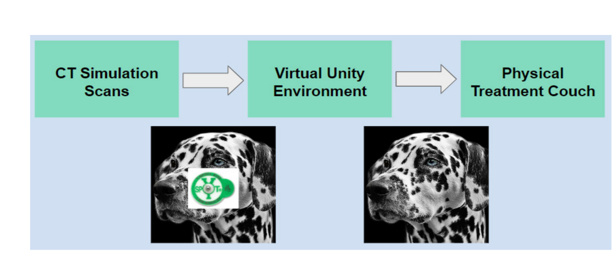
BODY-CONTOUR HOLOGRAM ACQUISITION

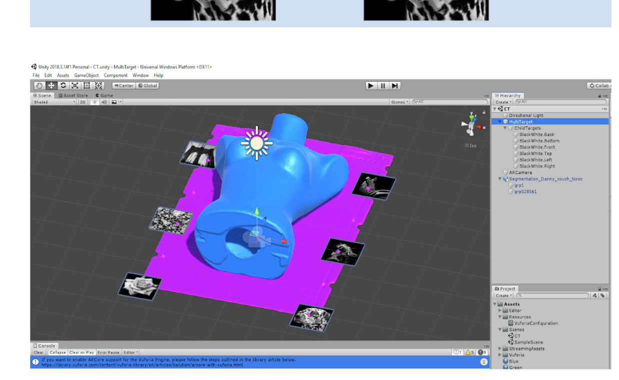
The patient's CT Sim slices are converted to a 3D model using a software program called 3D Slicer. This model is made into a hologram positioned in space using the Unity development platform.

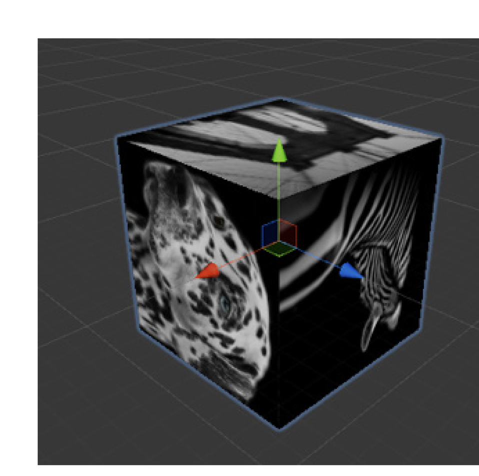


PLACING HOLOGRAMS IN THE CORRECT POSITION

A coordinate system referenced to the physical environment was created using image targets generated by a toolkit called Vuforia. These images match with BB markers placed on the treatment couch during CT Sim.

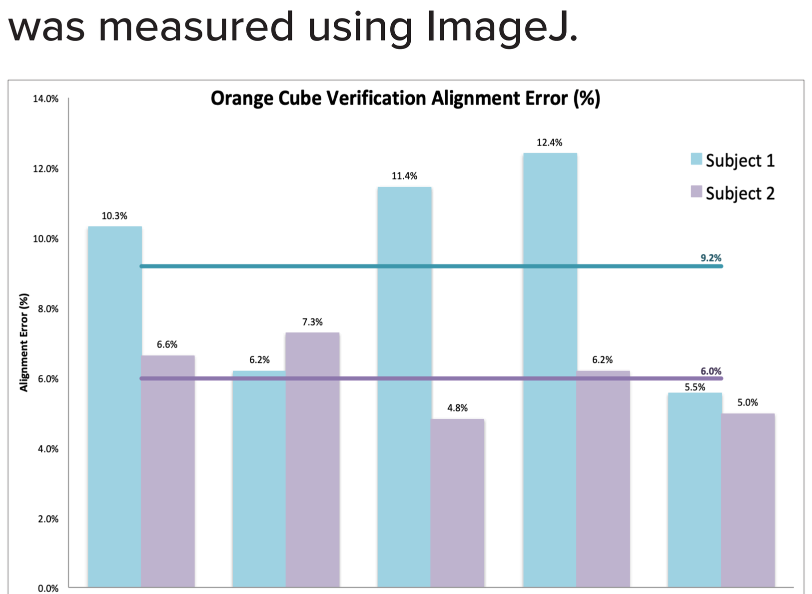






VERIFICATION TESTING

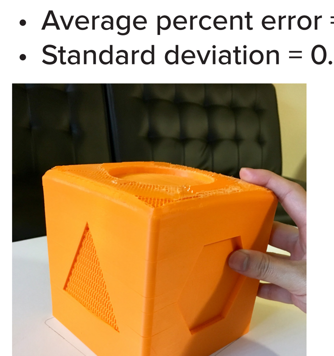
Users positioned an orange cube using an image target and RadAR. The surface area displacement between the user-positioned orange cube and the expected location was measured using ImageJ.



10 trials were performed in total
Subject 1:
- Average percent error = 9.3%
- Standard deviation = 0.031

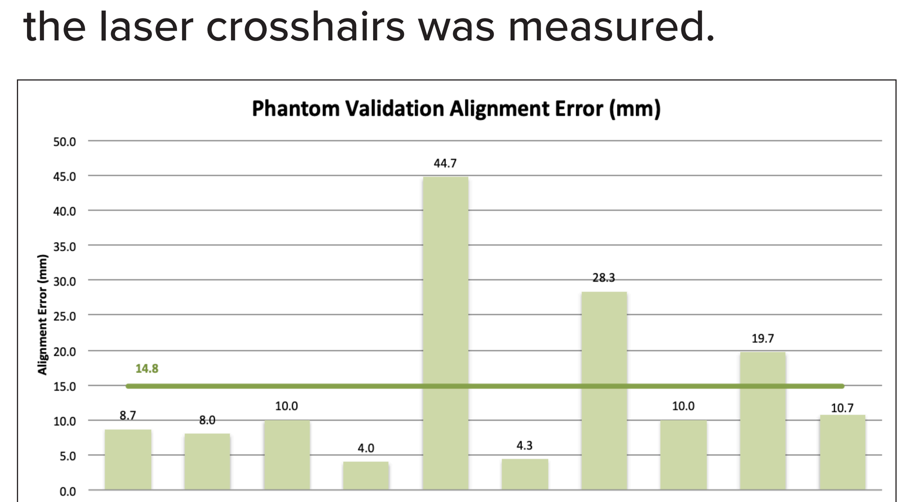
Subject 2:
- Average percent error = 6.0%
- Standard deviation = 0.011

Total Trials:
- Average percent error = 7.6%
- Standard deviation = 0.023

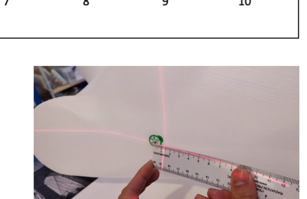


VALIDATION TESTING

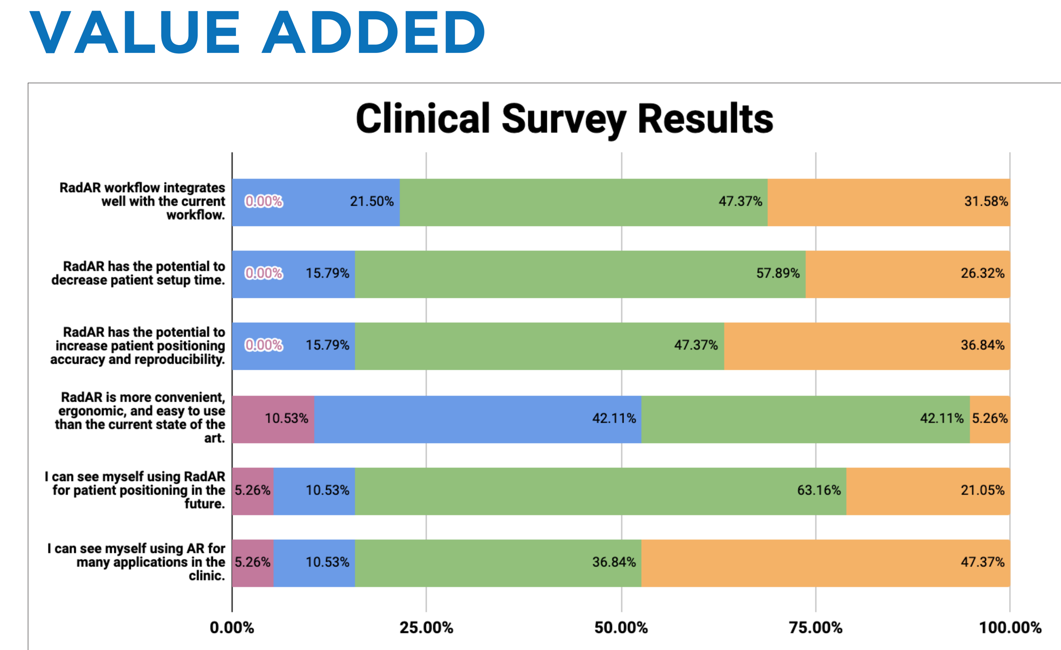
Users positioned a phantom on the treatment couch using RadAR. Distance between the phantom's BB markers and expected location at the laser crosshairs was measured.



10 trials were performed in total
- Average alignment error = 14.83 mm
- Standard deviation = 12.91 mm



VALUE ADDED



Our device improves upon the existing initial positional and final positioning solutions:
- Solves laser blockage issues in the initial positioning
- Eliminates excess radiation exposure in the final positioning
- Ergonomic use allowing the therapist to see the patient and reference position in the same field of view
- AR has broad potential for different clinical applications (collision detection, adaptive therapy, treatment planning visualization, reduce patient anxiety)