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MR Surgery: Mixed reality prostate surgery from patient derived MRI scans

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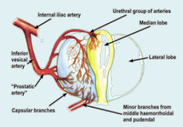
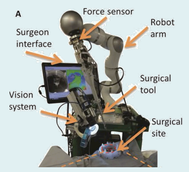
Background & Motivation

PROBLEM: Prostate cancer currently affects millions of Americans and often requires radical prostatectomy as treatment. Residents in urology as well as robots used in surgery require guidance in what tissue requires resection without harming surrounding organs.





OUR SOLUTION: Our aim is to develop a digital 3D model of prostate anatomy be used to generate a simulations in augmented reality (AR) and virtual reality (VR) that can train and guide both surgeons and the STAR robotic arm that is currently being developed to perform automated surgery.

Objectives

1. Generate an augmented reality overlay for video feeds of prostate resection that allow user interaction with display of the prostate and surrounding anatomy
2. Generate a virtual reality simulation which can model the tissue deformation of the prostate and surrounding tissue for pre-surgical planning purposes.
3. Integrate the two simulations to provide training data and real-time surgical guidance for prostate resection.

Approach

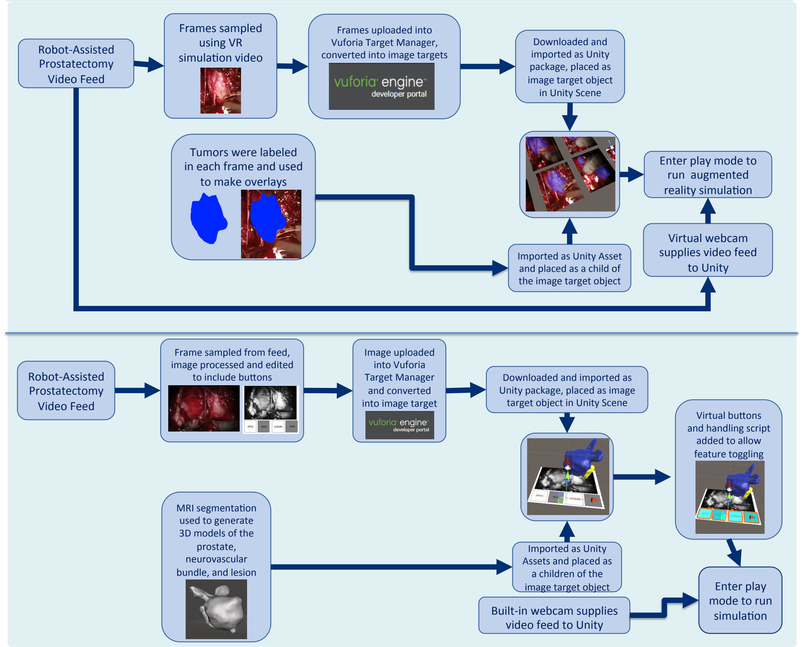
To implement our objectives in both augmented and virtual reality, we used **freely available software and toolkits:**

- **Unity:** A cross-platform engine originally developed for game development, but also now the main platform for mixed reality
  - The coding language for this software is **C#**, written in **Visual Studio**
- **Vuforia:** A software development toolkit used to easily implement augmented reality using automated detection of feature points
- **Blender:** An open-source 3D computer graphics software used to develop 3D textured models in games, animation, art, and more.

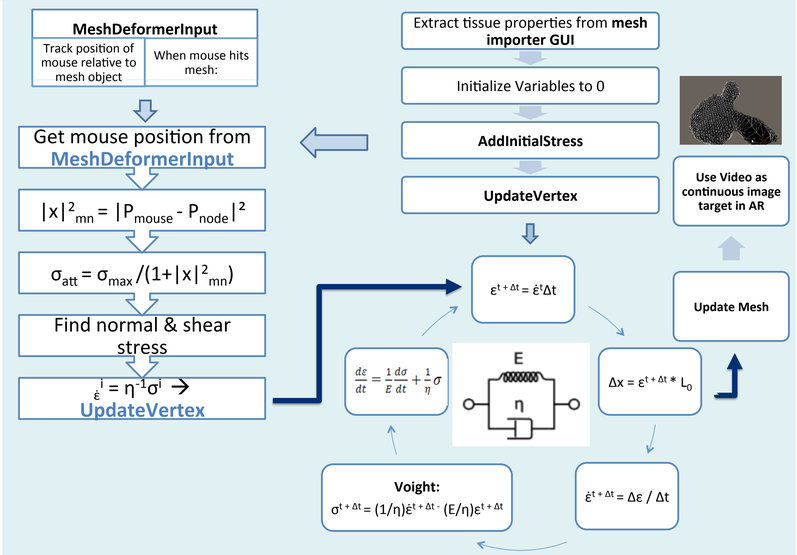
To complete simulations and verify our results, we used **licensed software**

- **MATLAB:** A numerical computing environment that allows for matrix manipulations and finite element analysis
- **Creo**: A computer aided design (CAD) software that allows the prediction of physical behavior using finite element analysis

Methodology: AR Simulation

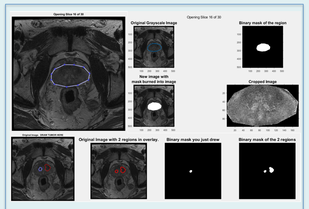


Methodology: VR Simulation

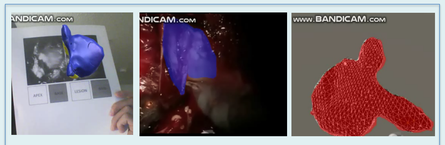


Results

AUGMENTED REALITY RESULTS

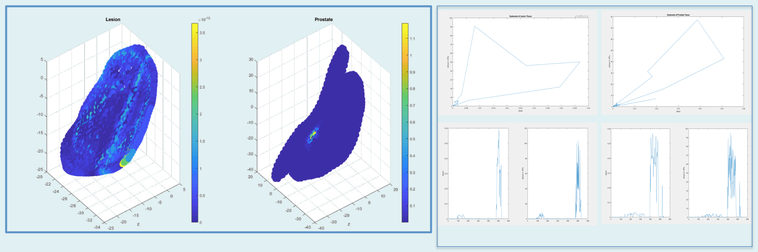


Above: MATLAB program for hand-labeling prostate anatomy in MRI scans



Left: 3D models of the prostate, neurovascular bundle, and lesion overlaid onto an image target with virtual buttons.
Middle: Automated blue overlay over the prostate in a video feed of a robot-assisted prostatectomy
Right: Automated red overlay of the VR prostate deformation

VIRTUAL REALITY RESULTS



Left: Modulus displacement map plotted on the mesh of lesion(Top) and Prostate (Bottom)
Middle: Stress (kPa) strain hysteresis loops obtained from simulation
Right: Stress (kPa) and strain graphs over time for lesion and prostate

Future Directions

NEXT STEPS

- Evaluate the practicality and usability with Likert survey
- Integrate the AR and VR simulations into a single platform
- Use patient specific video feed

ETHICAL IMPLICATIONS

- Obtaining medical files for calibration must be done with the proper approval
- By improving the pre operative planning, the rate and cost associated with correctional procedures will decrease

CONCLUSIONS

- Here we demonstrate a proof of concept for soft tissue modeling with native properties using Unity, a traditional game engine, for medical applications.

References

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4. Shademan, A., Decker, R. S., Opfermann, J. D., Leonard, S., Krieger, A., & Kim, P. C. (2016). Supervised autonomous robotic soft tissue surgery. Science translational medicine, 8(337), 337ra64-337ra64.