MASTER'S THESIS KICKOFF PRESENTATION

Hybrid Specimen Imager for Intra-operative **A**ssistance in Radical prostatectomy

- Kathiresan Chandrasekaran

Supervisor 1: Dr. Thomas Wendler (TUM)

Supervisor 2: Berkay Cakal (SurgicEye GmbH)

Supervisor 3: Dr. Matthias N. van Oosterom (Leiden University Medical Center)

Director: Prof. Dr. Nassir Navab (TUM)

Technische Universität München + Johns Hopkins Whiting School of Engineering

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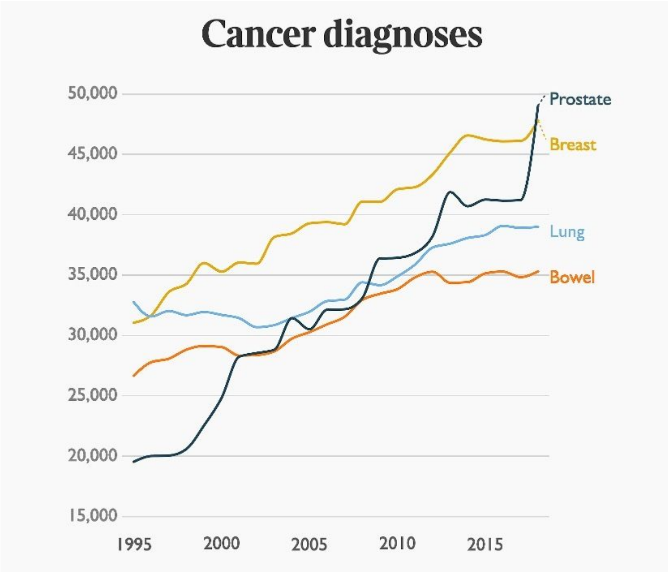
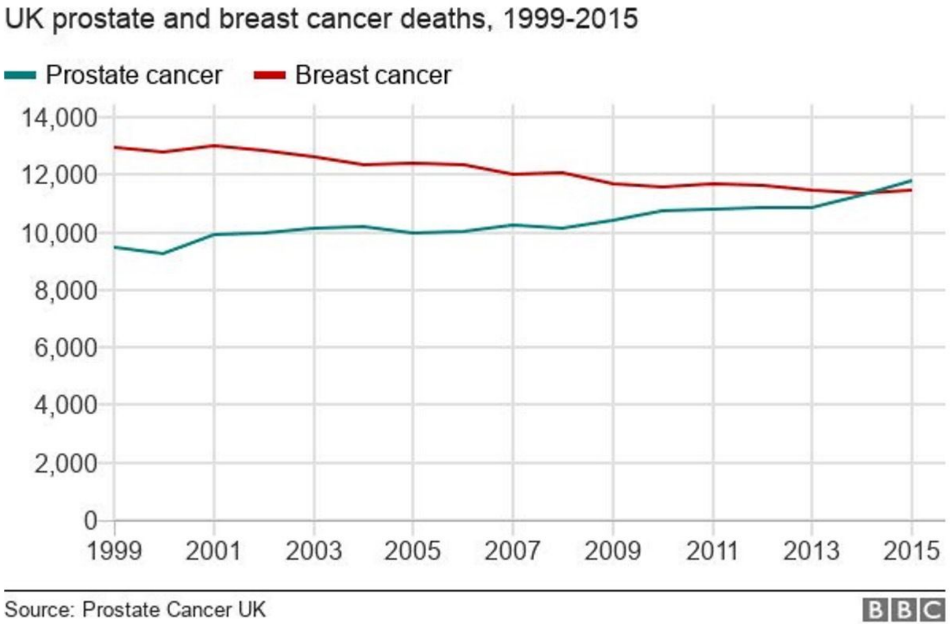
Introduction

- **Prostate cancer** is the 4th most common cancer overall and the 2nd most commonly occurring cancer in men. [1]
- The count of prostate cancer patients surpasses other deadliest cancer types since 2014. [2]



Source: Prof. Christopher Eden, Refer [x]



[1] Prostate cancer statistics 2020, *World Cancer Research Fund International*, accessed 19 February 2023, <https://www.wcrf.org/cancer-trends/prostate-cancer-statistics> .
[2] SANTIS Clinic Website > Prostate Cancer Information Centre.Testing & Diagnosis> The importance of celebrities in increasing the awareness of prostate cancer, accessed 27.02.2023, <https://www.santishealth.org/prostate-cancer-information-centre/the-importance-of-celebrities-in-increasing-the-awareness-of-prostate-cancer/>.

Introduction

- General treatment: **Radical Prostatectomy** (removal of entire prostate cancer tissue). [3]

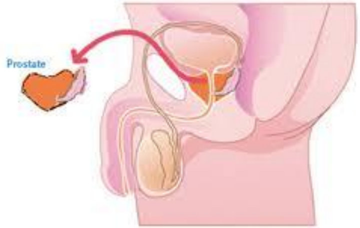


Figure 1: Prostate tissue

- Confirmation of **“resection margin”** is required during surgery. [3]

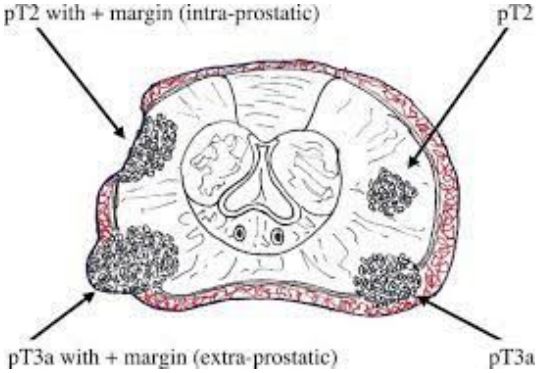


Figure 2: Resection Margin

[3] Montironi R, van der Kwast T, Boccon-Gibod L, Bono AV, Boccon-Gibod L. Handling and pathology reporting of radical prostatectomy specimens. Eur Urol. 2003 Dec;44(6):626-36. doi: 10.1016/s0302-2838(03)00381-6. PMID: 14644113.

Motivation / Problem statement

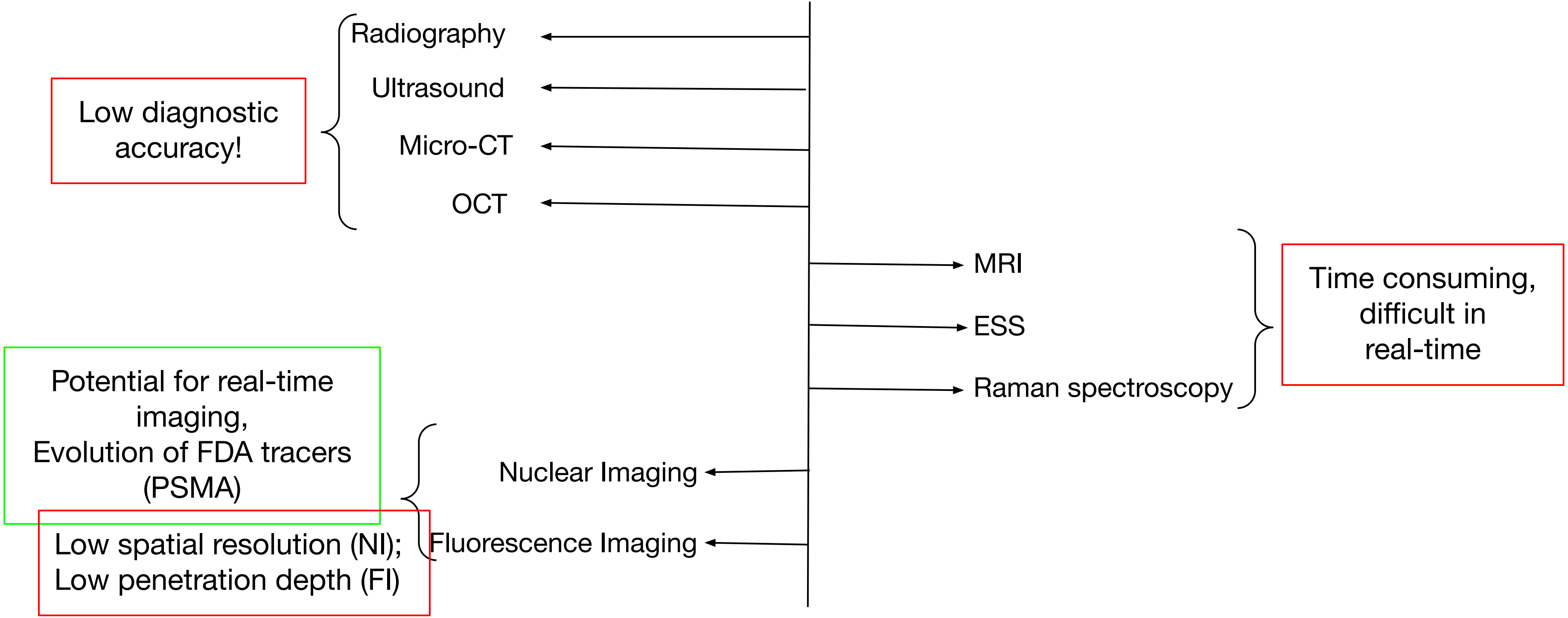
- Problem 1: Requirement of a Pathologist in the OR. [3]
- Problem 2: Time consuming for sample preparation. [4]
- Problem 3: Prostate tissue undergoes faster autolysis than most of the other organs. [5]

[3] Montironi R, van der Kwast T, Boccon-Gibod L, Bono AV, Boccon-Gibod L. Handling and pathology reporting of radical prostatectomy specimens. Eur Urol. 2003 Dec;44(6):626-36. doi: 10.1016/s0302-2838(03)00381-6. PMID: 14644113.

[4] Jorns JM, Visscher D, Sabel M, Breslin T, Healy P, Daignaut S, Myers JL, Wu AJ. Intraoperative frozen section analysis of margins in breast conserving surgery significantly decreases reoperative rates: one-year experience at an ambulatory surgical center. Am J Clin Pathol. 2012 Nov;138(5):657-69. doi: 10.1309/AJCP4IEMXCJ1GDTS. PMID: 23086766; PMCID: PMC3988579.

[5] Montironi R, Lopez Beltran A, Mazzucchelli R, Cheng L, Scarpelli M. Handling of radical prostatectomy specimens: total embedding with large-format histology. Int J Breast Cancer. 2012;2012:932784. doi: 10.1155/2012/932784. Epub 2012 Jul 10. PMID: 22844601; PMCID: PMC3400332.

Relevant research works on resection margin imaging



[CT: Computed Tomography; OCT: Optical Coherence Tomography; MRI: Magnetic Resonance Imaging; ESS: Elastic Scattering Spectroscopy]

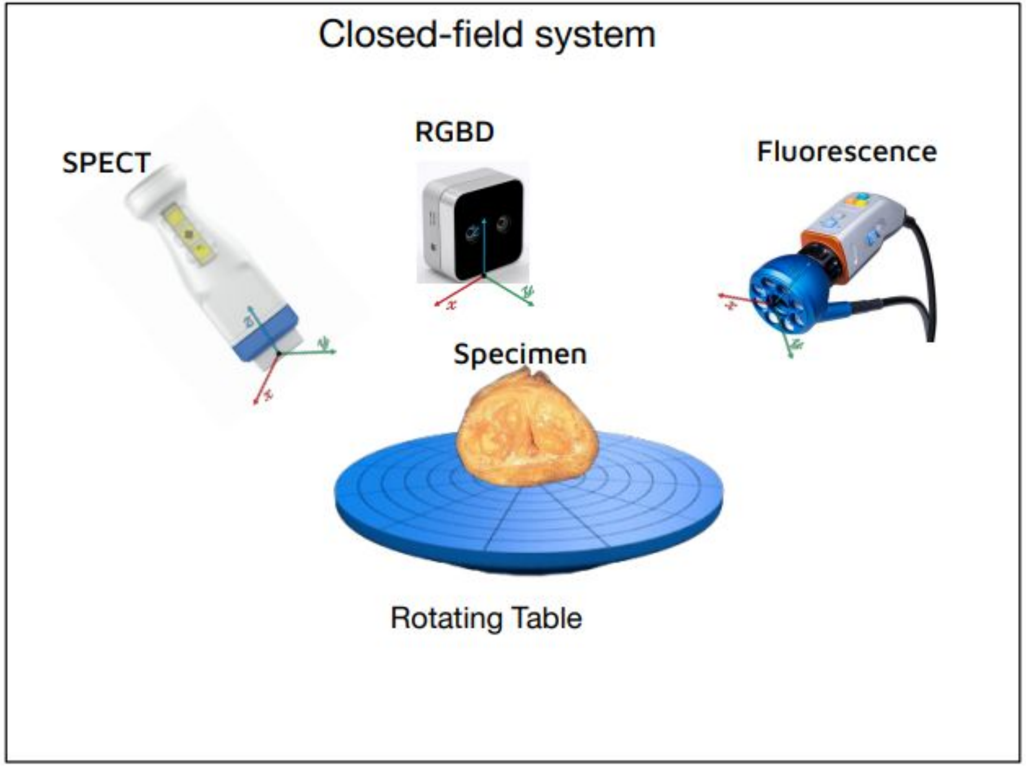
[6] Heidkamp J, Scholte M, Rosman C, Manohar S, Fütterer JJ, Rovers MM. Novel imaging techniques for intraoperative margin assessment in surgical oncology: A systematic review. Int J Cancer. 2021 Aug 1;149(3):635-645. doi: 10.1002/ijc.33570. Epub 2021 May 4. PMID: 33739453; PMCID: PMC8252509.

Overview of the proposed approach:

- Step 0: Inject the tracer (99mTc-EuK-(SO3)Cy5-mas3) and proceed with radical prostatectomy.
- Step 1: Excise the prostate tissue.
- Step 2: Prepare the tissue (chemical treatment).
- Step 3: Place it inside the specimen imager and close the shutter.
- Step 4: Turn on the RGB-D camera and reconstruct the volume and turn it off. Measure fluorescence data too during this RGB-D data acquisition and turn it off. Register the fluorescence data within the point cloud of RGB-D data.
- Step 5: Bring the SPECT camera close to the tissue and turn on the SPECT camera and register the data on top of reconstructed volume. Turn off the camera and add the SPECT data into the point cloud (registration).
- Step 6: Open the shutter and take the tissue out of imager.
- Step 7: Properly dispose the tissue.

Methodology: Design

- Voxelized surface reconstruction of tumor
- RGBD camera for surface points
- Fluorescence imaging for positive surgical margins
- Nuclear imaging for localization of tumor



RGB-D task overview

Depth maps → 3D point cloud $\xrightarrow{\text{ICP}}$ 3D model of the prostate tissue

Open3D

Methodology: RGB Depth Camera

- Activate grids with depth camera

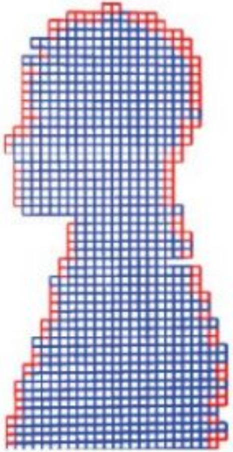


Figure. Solid voxelization[1].

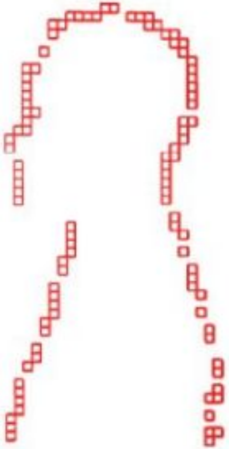


Figure. Surface voxelization[1].

[1] Garcia F, Ottersten B. CPU-based real-time surface and solid voxelization for incomplete point cloud. In2014 22nd International Conference on Pattern Recognition 2014 Aug 24 (pp. 2757-2762). IEEE.

Methodology: Near-Infrared Fluorescence (NIF) Camera

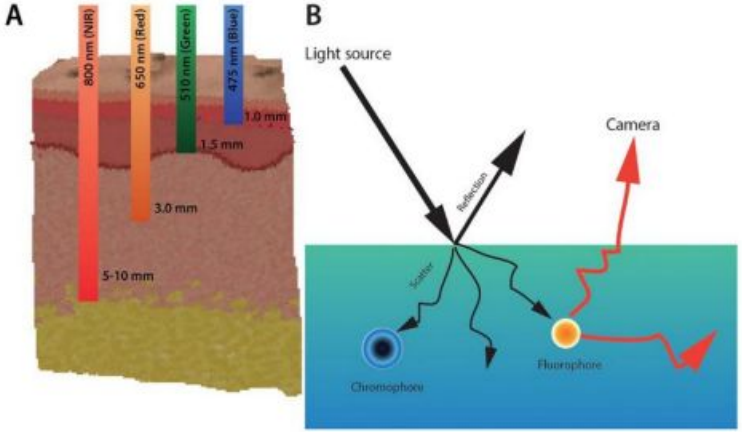


Figure. Penetration depth comparison of fluorescences through tissue [1].

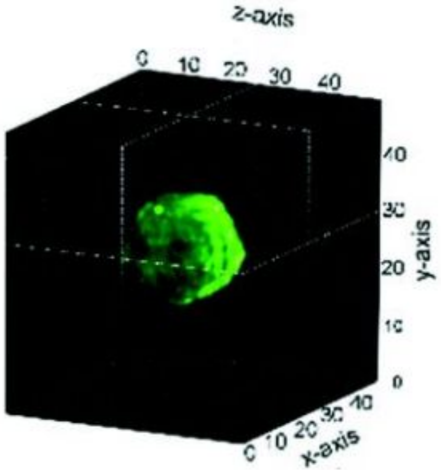


Figure. Surface mapping of fluorescence

[1] Teraphongphom N, Kong CS, Warram JM, Rosenthal EL. Specimen mapping in head and neck cancer using fluorescence imaging. Laryngoscope investigative otolaryngology. 2017 Dec;2(6):447-52.

SPECT task overview

Step 1: Data (Gamma ray) acquisition using CrystalCam

[Source/Courtesy: Crystal Photonics GmbH]

Step 2: Formation of linear set of equations

$$\boxed{y = Ax}$$

Where, y = Physical measurements

A = System matrix (Each row corresponds to one measurement in our system; Each column represents the different contributions of a particular voxel to the results on each measurement)

x = Quantity we want to reconstruct

SPECT task overview

Step 3: Solving the linear system of equations using MLEM (Maximum Likelihood Expectation Maximization)

$$x_i^{k+1} = x_i^k \cdot \frac{1}{\sum_{j=0}^{J} a_{ij}} \cdot \sum_{j=0}^{J} \frac{y_j \cdot a_{ij}}{q_j}$$

$$q_j = \sum_{i=0}^{I} x_i^k \cdot a_{ij}$$

Values from the previous iteration (*k*)

coverage factor of the voxel, i.e. how well the measurements included that particular voxel.

Backward projection, and it is the correction factor applied to the voxel

[9] Y. Vardi, L. A. Shepp, and L. Kaufman, “A statistical model for positron emission tomography,” Journal of the American Statistical Association, vol. 80, no. 389, pp. 8– 20, 1985

Timeline & Conclusion

Literature Research

Components acquisition

Phantom creation

Prototype assembly

RGB-D reconstruction

SPECT reconstruction

Fluorescence reconstruction

Registration of SPECT and fluorescence data with RGB-D

Prototype demo

Testing / Validation

System adaptation according to the test results

Finalization

Thesis writing and submission

[TIMELINE SUMMARY (April 2023 - February 2024)]


Thank you for your attention!
Any questions?