Image-Guided Robotic Neurosurgery through Registration of 3D Surface Images with Pre-operative CT/MRI Data

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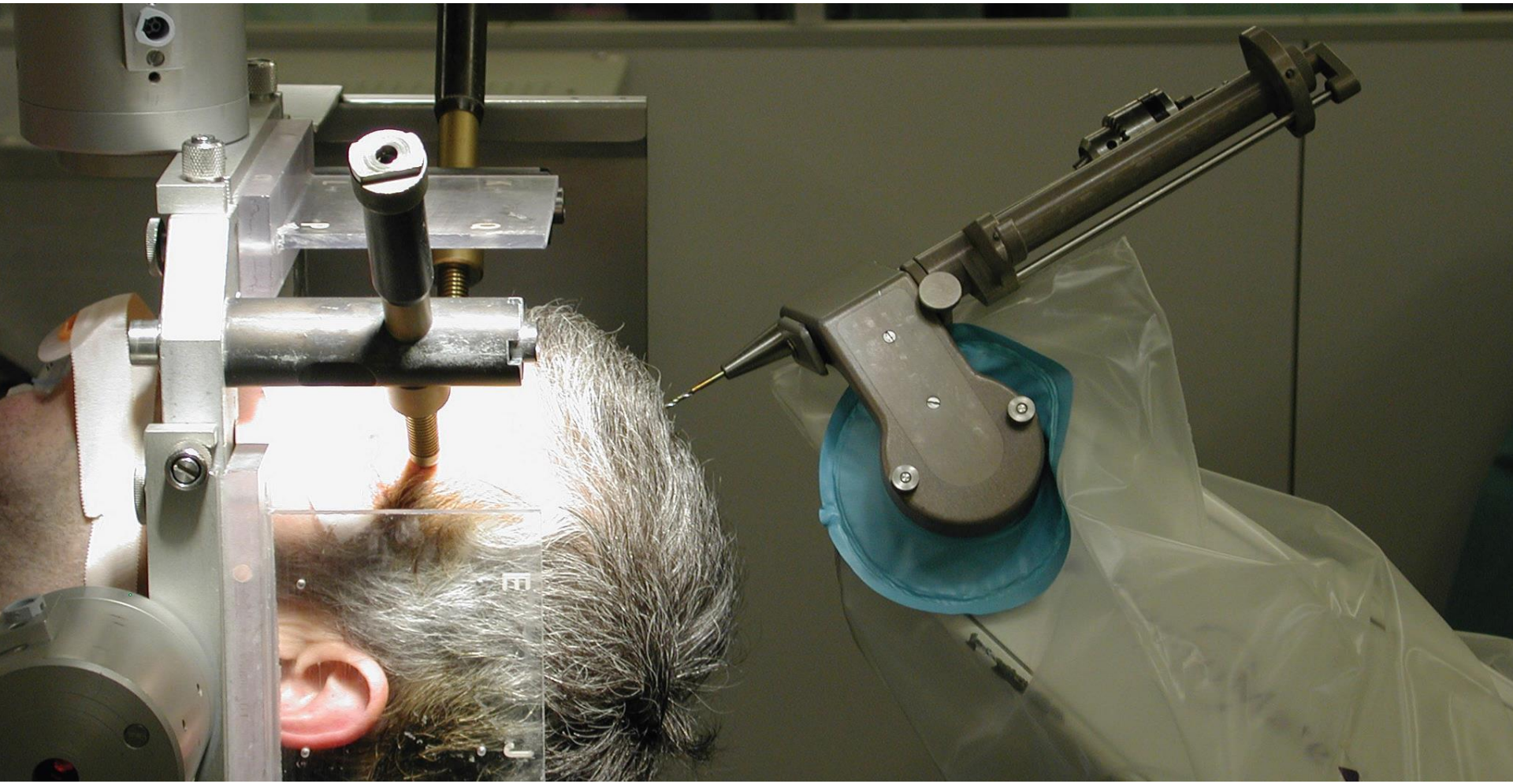
Neuromate® robot

- Stereotactic neurosurgical robot.
- Used for:
  - Electrode implantation
  - Neuroendoscopy
  - Biopsy
- Manufactured by Renishaw plc, our industrial partner in this project.

http://www.renishaw.com/en/neuromate-stereotactic-robot--10712

Registration is currently frame based or uses fiducial markers.

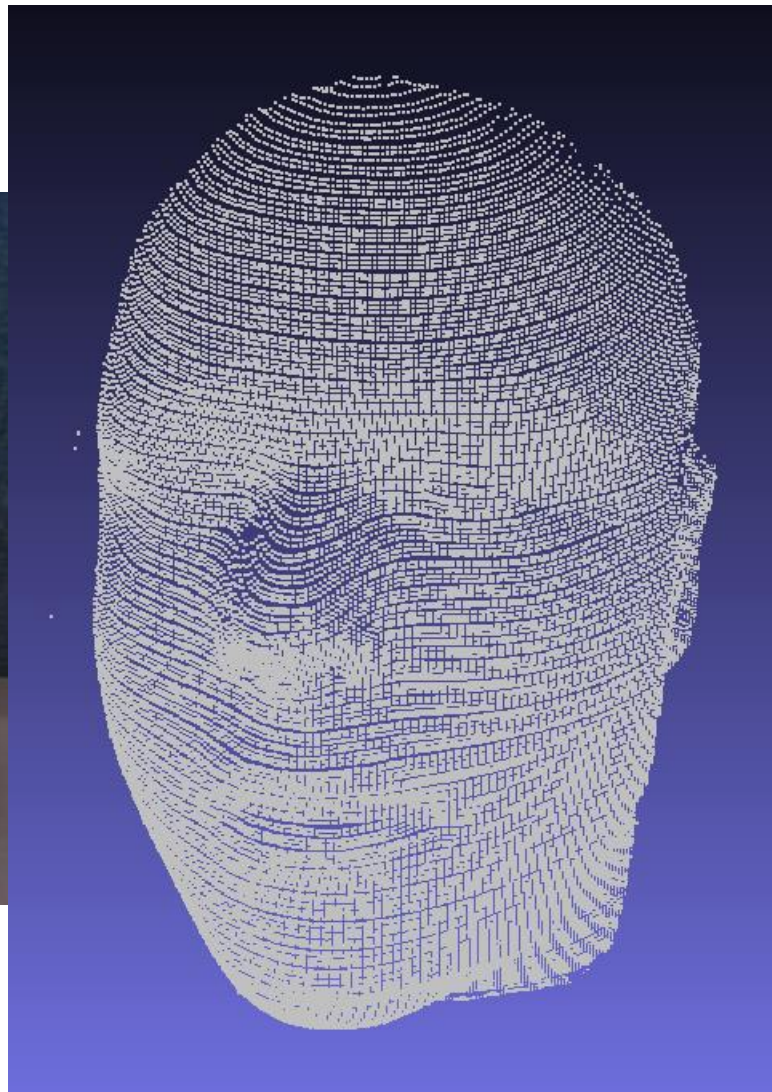


We wish to develop an accurate and non-invasive image-based technique, to allow the head to be repositioned.

Obstacle Avoidance

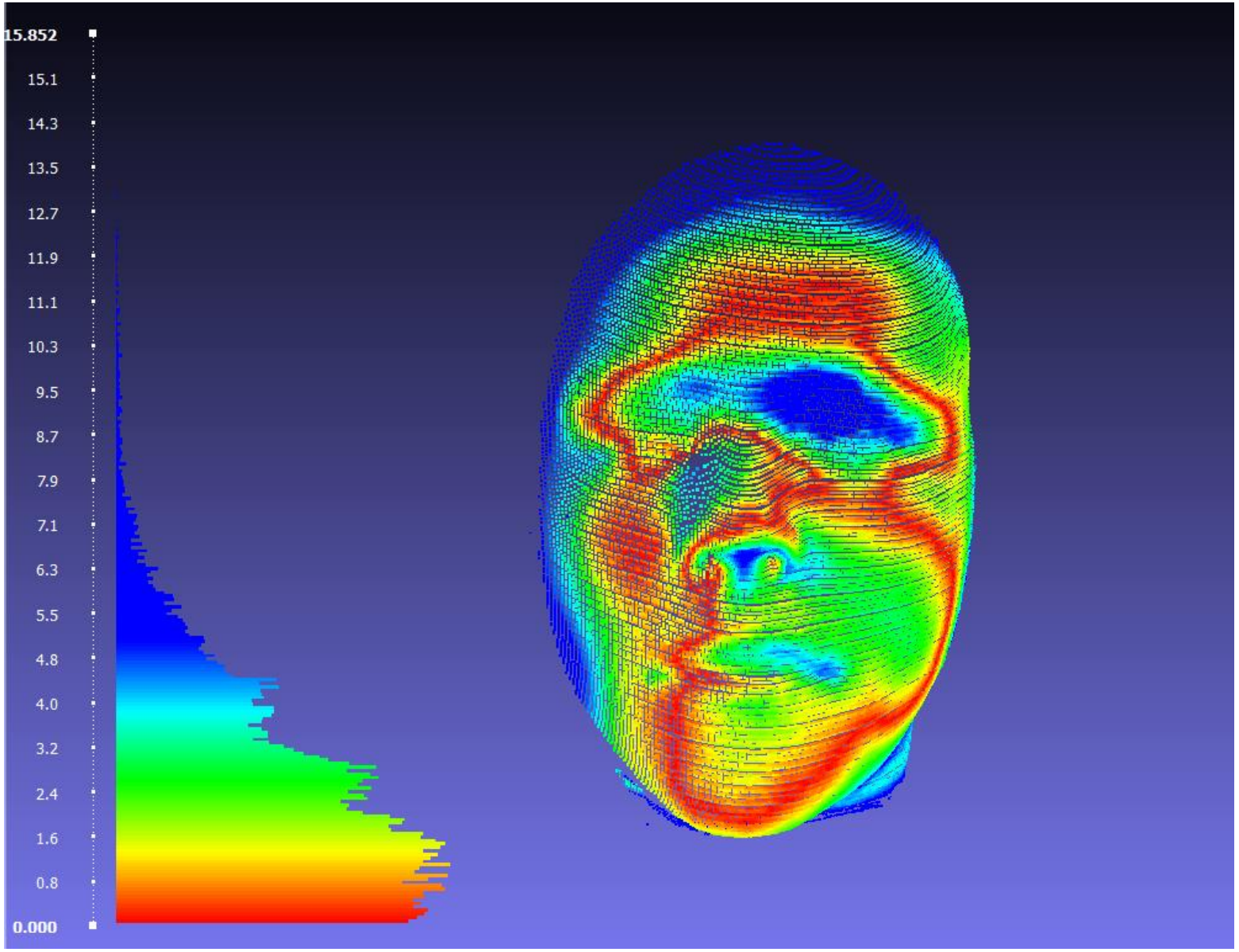
- Static obstacles: breathing apparatus, sterile drapes, etc.
- Dynamic obstacles: theatre staff & equipment.

3D surface capture imaging of phantom head[1]

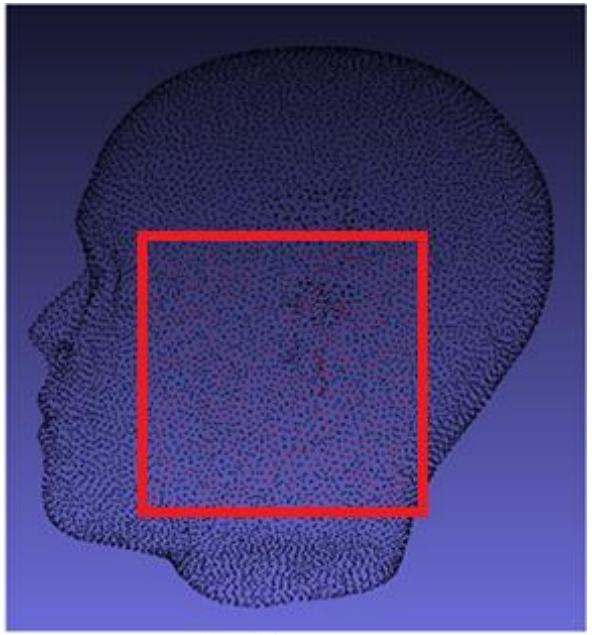


[1]Basevi et al. Simultaneous multiple view high resolution surface geometry acquisition using structured light and mirrors. Optics express, 21(6):7222{7239, 2013.

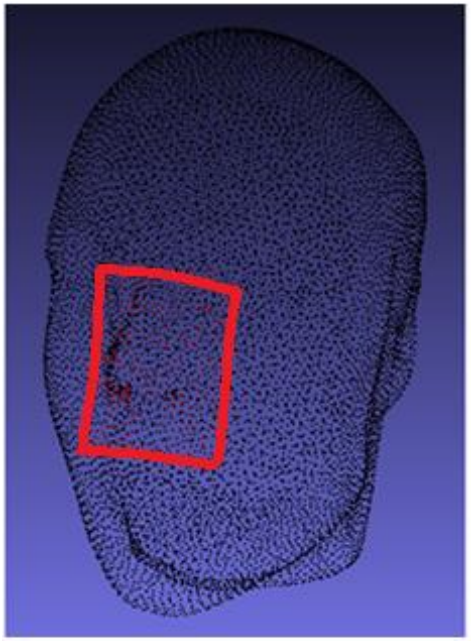
Registration using ICP algorithm



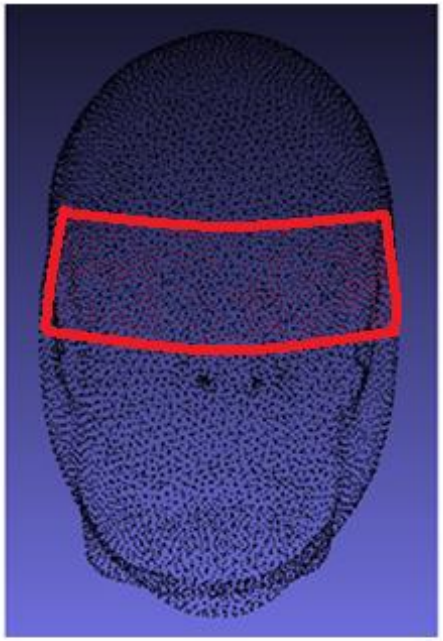
Registration based on particular facial features



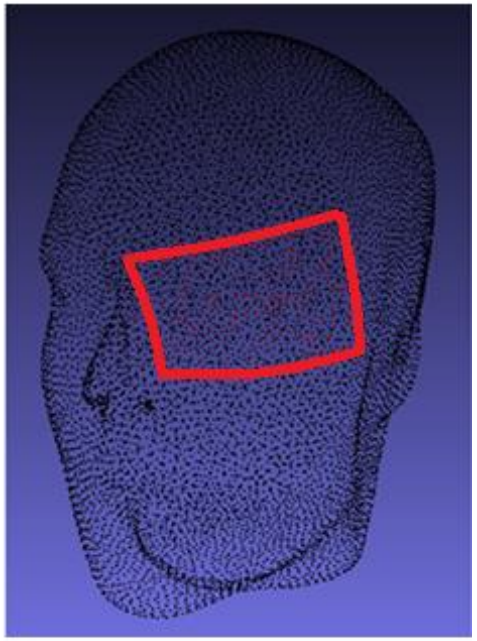
Left ear



Nose

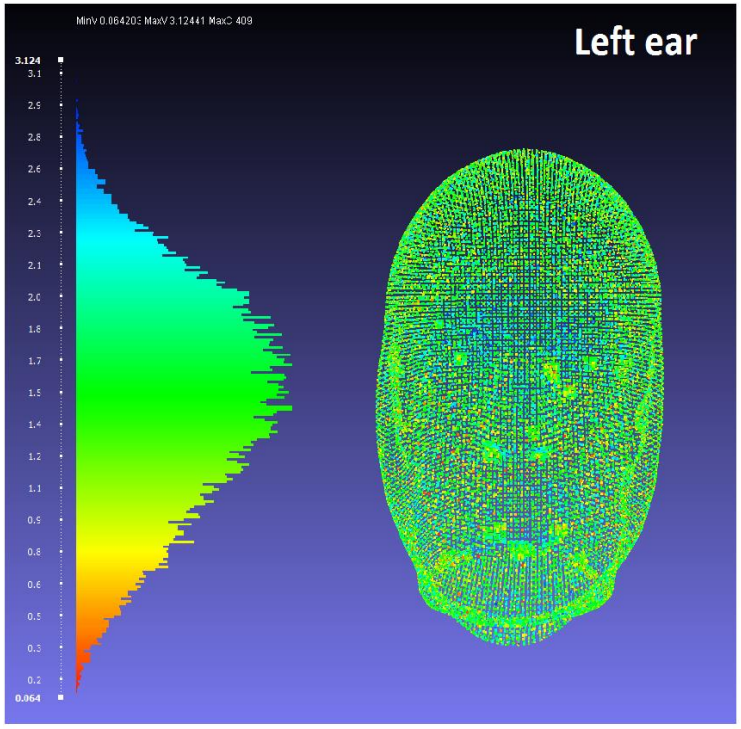


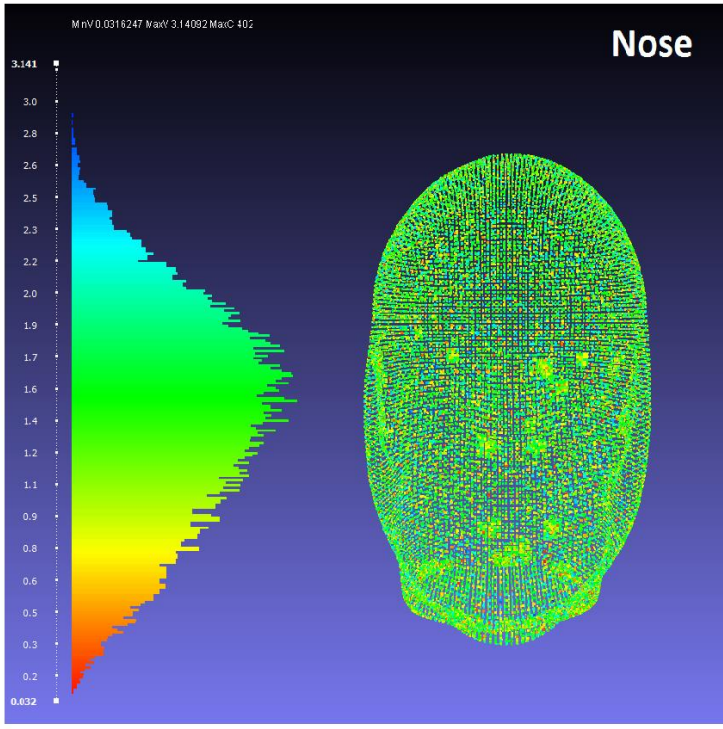
Both eyes

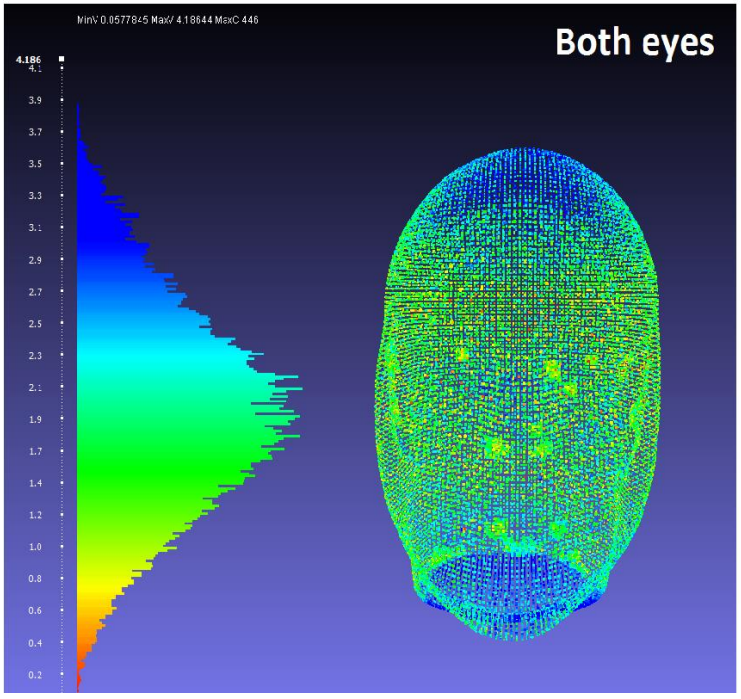


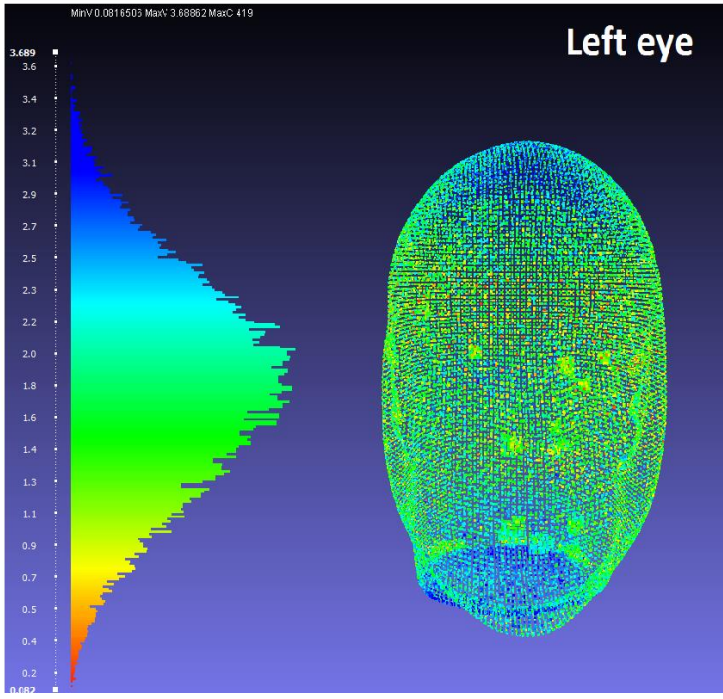
Left eye

Hausdorff distances after aligning point clouds based on facial features









Normal Distribution Transform (NDT)

- Maps a point cloud to a smooth surface representation, made up of a set of local probability density functions (PDFs)[2].
- First we have to split the point cloud into cells/clusters – can use an octree method, fixed size cells, k-means etc.
- Each cell is then represented as a PDF – these can overlap.
- Can be used for point cloud registration, by maximising the likelihood.

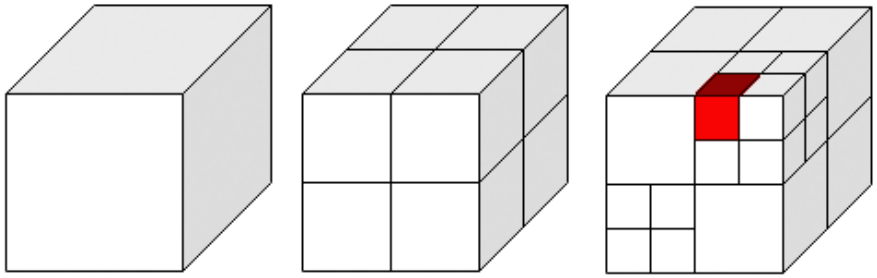
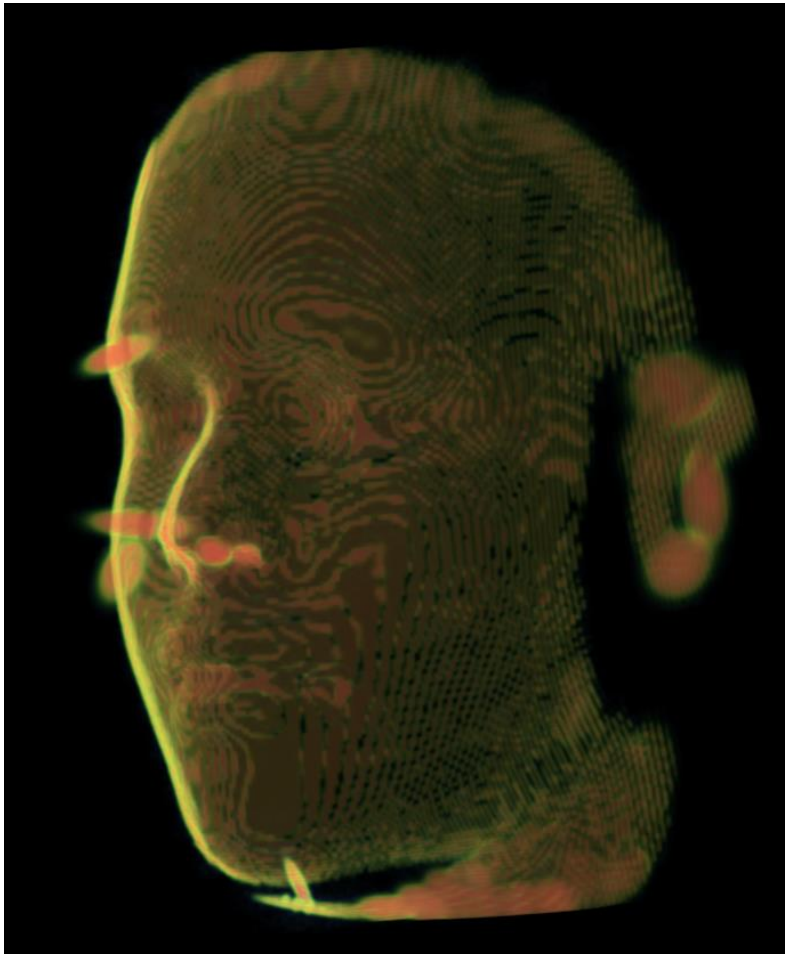


Image from:
http://2.bp.blogspot.com/_kvCpVC7wn5s/TOr_DsGqO0I/AAAAAAAAAe4/zYF4UssOk0o/s1600/octree.png

[2]Martin Magnusson. *The three-dimensional normal-distributions transform: an efficient representation for registration, surface analysis, and loop detection.* PhD thesis, Örebro universitet, 2009.

Choice of distribution

- We can use a normal distribution for each cell, however this can be overly affected by outliers.
- Statistical tests show that it is not a good representation of the points.
- We can combine normal and uniform distributions.



Future Work

- Registration using NDTs.
- Comparing NDT registration with ICP.
- Surface capture imaging of the subject used to create the phantom; registering these images with the phantom ground truth.
- Working out which features are most useful for registration and whether we will be able to see them during surgery.

Acknowledgments

- Supervisors:
  - Ales Leonardis
  - Hamid Dehghani
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  - Hector Basevi
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