Department of Medical Physics and Biomedical Engineering
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Deep Learning

MPHY0041 Machine Learning in Medical Imaging

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Medical Imaging Applications

Medical Imaging Applications

Diagnosis, prognosis and clinical decision prediction
Object detection
Segmentation
Acquisition and reconstruction
Image quality assessment
Denoising and artifact correction
Super-resolution and quality-transfer
Synthesis
Registration
Applications with other types of data, e.g. Digital medical record, longitudinal data, surgical data
…

Tutorials in module repository

Medical Imaging Applications| Classification

- Encoding the output
  - Nominal, One-hot vector, binary
  - Ordinal encoding

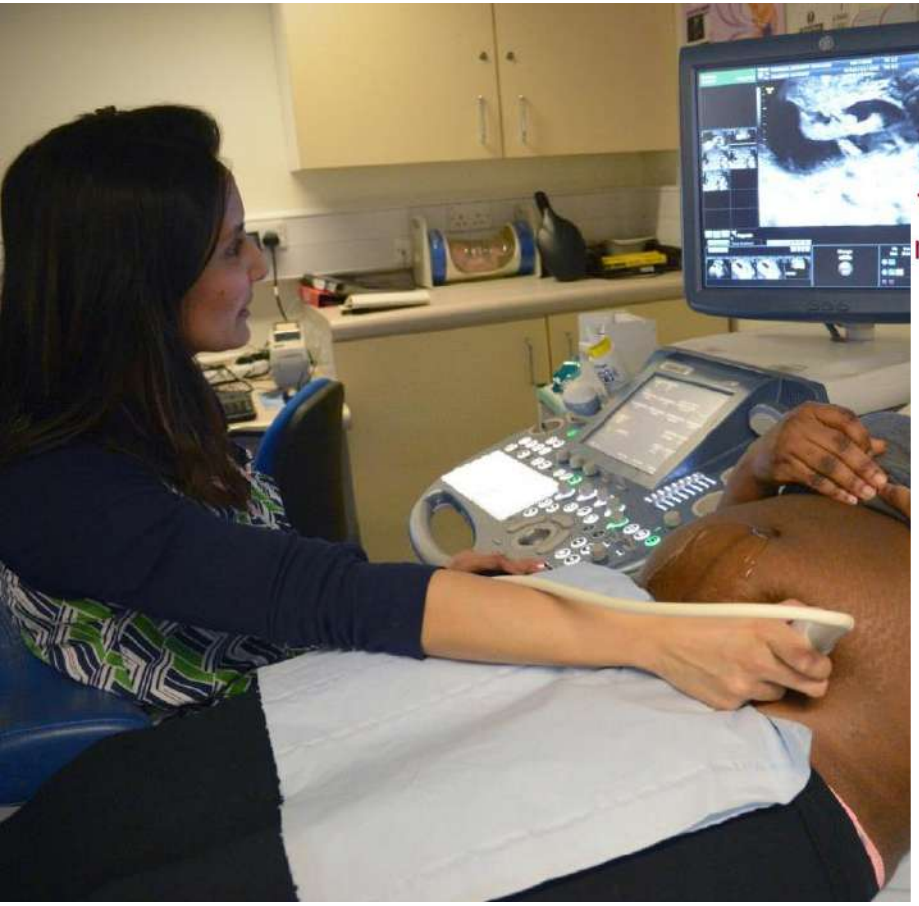
Samples	0 - Ubuntu 1 - Mac 2 - PC 3 - Other	Ubuntu	Mac	PC	Other
1	2	0	0	1	0
2	1	0	1	0	0
3	0	1	0	0	0
4	1	0	1	0	0
5	0	1	0	0	0
6	2	0	0	1	0

Q: how about these classes:
High, medium, low;
Young, middle-age, elderly;
pT2, pT3a, pT3b, pT4

- Which architecture?

Model	Size	Top-1 Accuracy	Top-5 Accuracy	Parameters	Depth
Xception	88 MB	0.790	0.945	22,910,480	126
VGG16	528 MB	0.713	0.901	138,357,544	23
VGG19	549 MB	0.713	0.900	143,667,240	26
ResNet50	98 MB	0.749	0.921	25,636,712	-
ResNet101	171 MB	0.764	0.928	44,707,176	-
ResNet152	232 MB	0.766	0.931	60,419,944	-
ResNet50V2	98 MB	0.760	0.930	25,613,800	-
ResNet101V2	171 MB	0.772	0.938	44,675,560	-
ResNet152V2	232 MB	0.780	0.942	60,380,648	-
InceptionV3	92 MB	0.779	0.937	23,851,784	159
InceptionResNetV2	215 MB	0.803	0.953	55,873,736	572
MobileNet	16 MB	0.704	0.895	4,253,864	88
MobileNetV2	14 MB	0.713	0.901	3,538,984	88
DenseNet121	33 MB	0.750	0.923	8,062,504	121
DenseNet169	57 MB	0.762	0.932	14,307,880	169
DenseNet201	80 MB	0.773	0.936	20,242,984	201
NASNetMobile	23 MB	0.744	0.919	5,326,716	-
NASNetLarge	343 MB	0.825	0.960	88,949,818	-

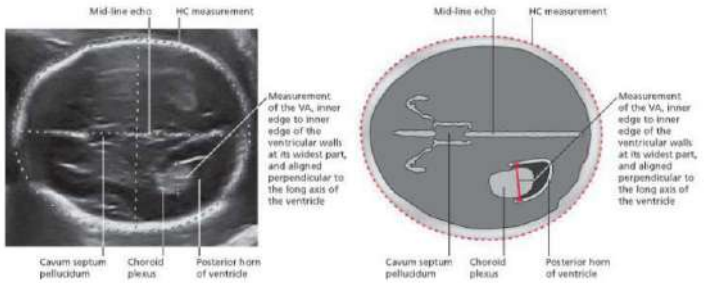
Multiple Anatomical Structure Recognition in Fetal Ultrasound Images



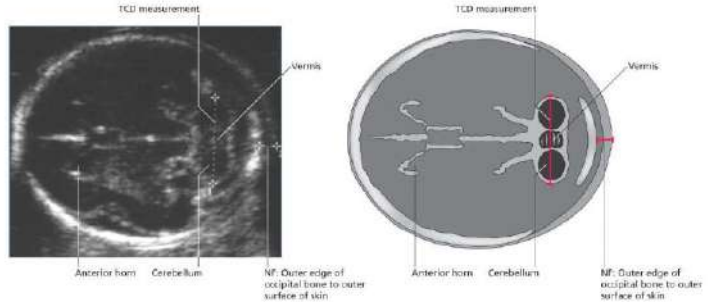
18^{+0} to 20^{+6} FASP ultrasound scan base menu

Structure/Area	Detail	Fetal Measurements*	Images/measurements to capture/archive
Head and neck • **Skull** • **Brain** • **Neck**	Head shape	*Head circumference (HC)	Yes, to include HC measurement, CSP, posterior horn and measurement of the ventricular atrium at the level of the glomus of the choroid plexus
	Cavum septum pellucidum (CSP)	Measurementnot required	
	Ventricular Atrium (VA)	*Atrium of the lateral Ventricle	
	Cerebellum	*Transcerebellar diameter (TCD)	Yes, to include measurement of the TCD in the suboccipitobregmatic view
	Nuchal Fold (NF) Measure if appears large	Distance between the outer border of the occipital bone and the outer skin edge	Yes, if measurement ≥ 6mm
• **Facial Features**	Coronal view of lips & nasal tip	Measurementnot required	Yes
• **Lungs** • **Heart**	Visceral situs/laterality of heart	Measurementnot required	No
	a) Four chamber view (FCV)		
	b) Aorta (Ao) arising from left ventricle		No
	c) Pulmonary artery (PA) arising from right ventricle, or the 3 vessel view (3VV)		No
	d) 3 vessel and trachea view (3VT)		No

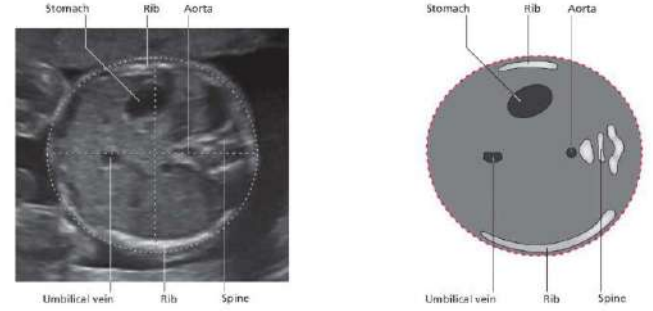
Head circumference (HC) and ventricular atrium (VA)

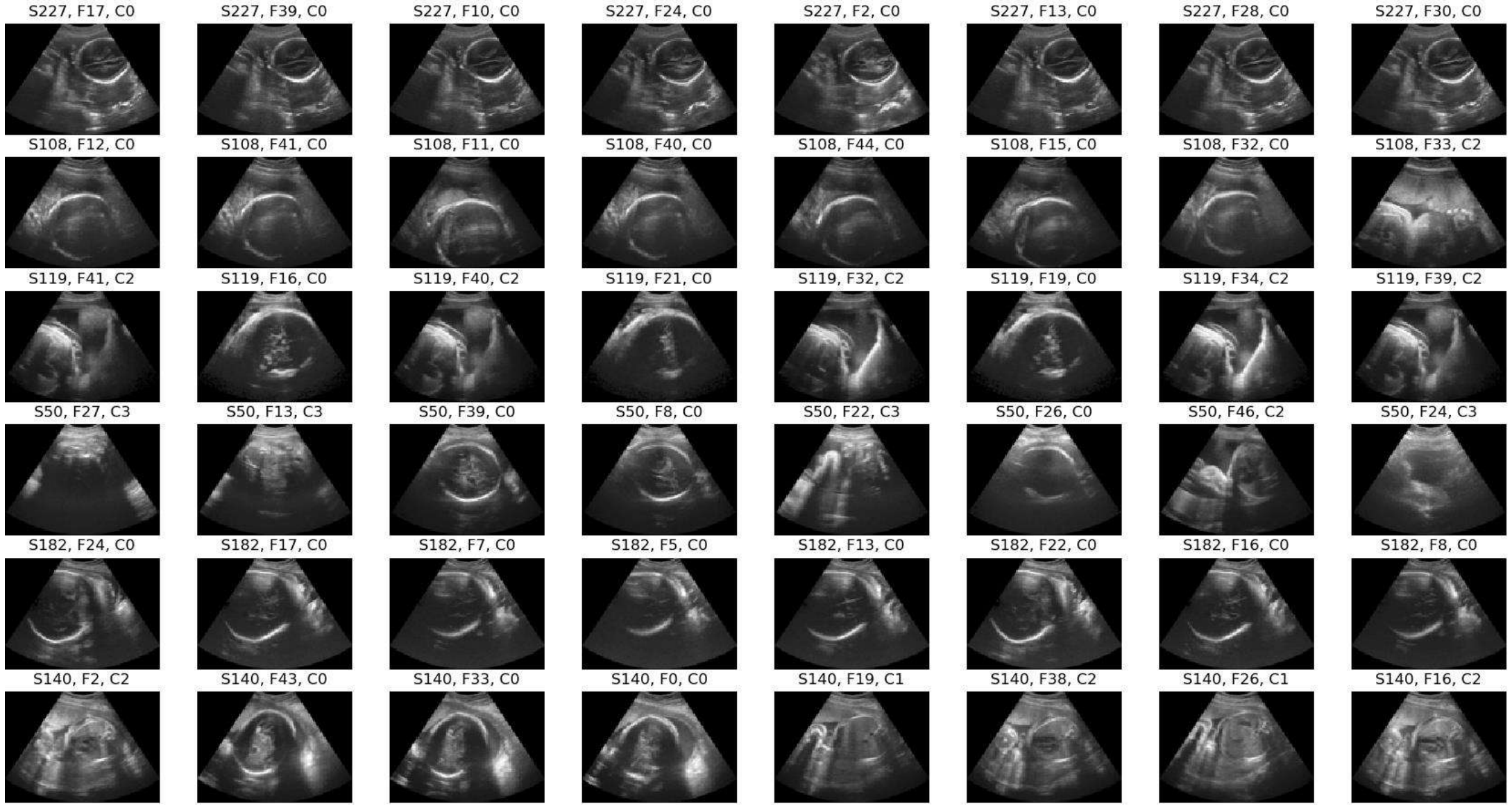


Transcerebella diameter (TCD) and nuchal fold (NF)



Abdominal circumference (AC)

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S227, F39, C0
S227, F10, C0
S227, F24, C0
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S227, F30, C0
S108, F12, C0
S108, F41, C0
S108, F11, C0
S108, F40, C0
S108, F44, C0
S108, F15, C0
S108, F32, C0
S108, F33, C2
S119, F41, C2
S119, F16, C0
S119, F40, C2
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S119, F19, C0
S119, F34, C2
S119, F39, C2
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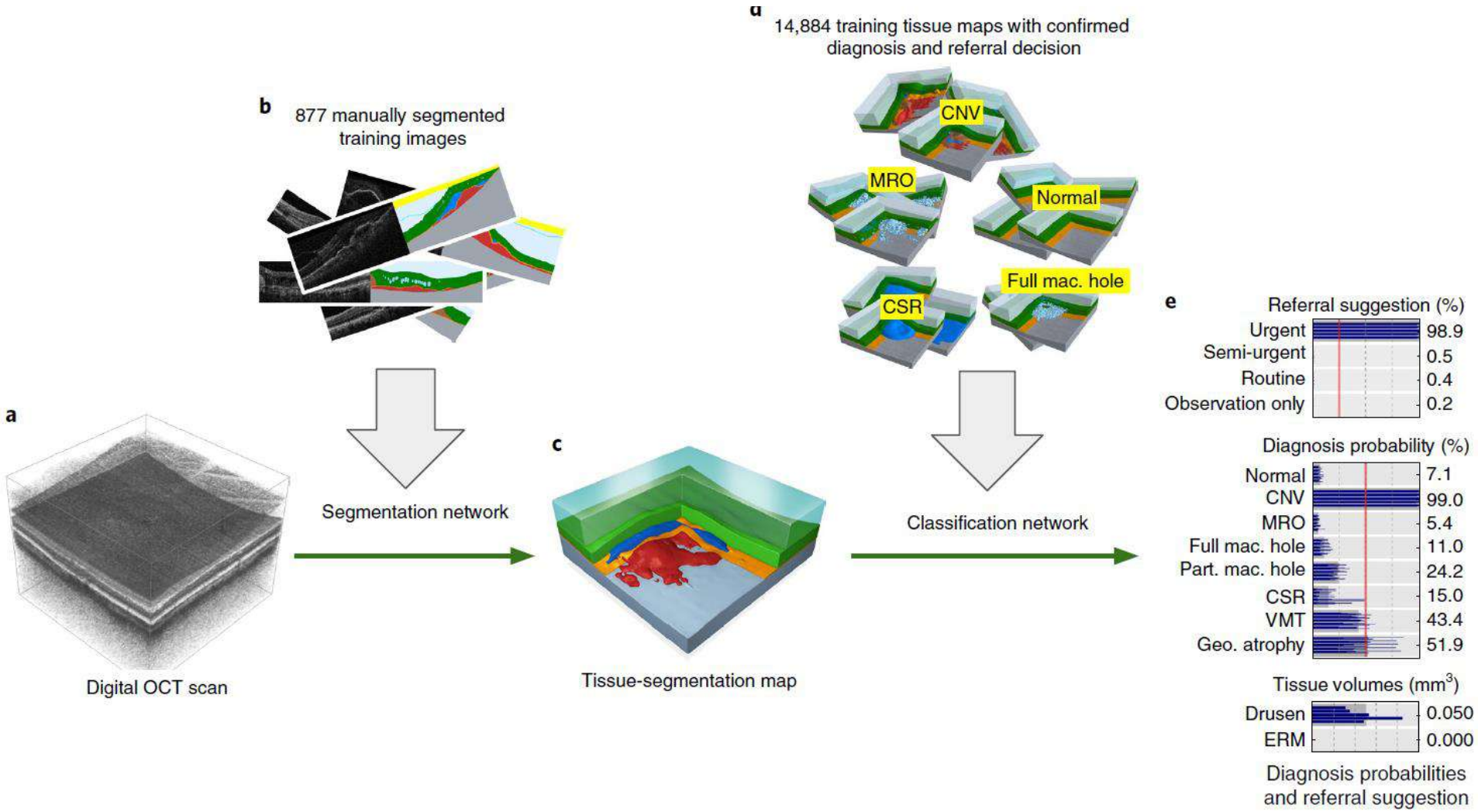
S50, F13, C3
S50, F39, C0
S50, F8, C0
S50, F22, C3
S50, F26, C0
S50, F46, C2
S50, F24, C3
S182, F24, C0
S182, F17, C0
S182, F7, C0
S182, F5, C0
S182, F13, C0
S182, F22, C0
S182, F16, C0
S182, F8, C0
S140, F2, C2
S140, F43, C0
S140, F33, C0
S140, F0, C0
S140, F19, C1
S140, F38, C2
S140, F26, C1
S140, F16, C2

Medical Imaging Applications| Classification

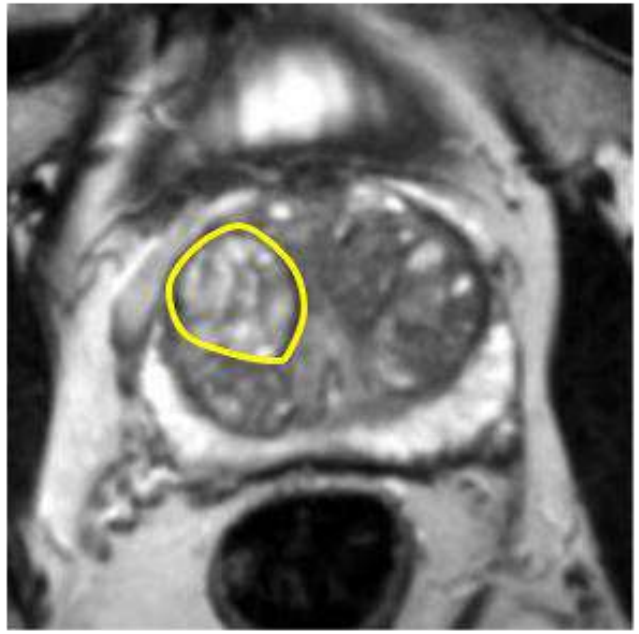


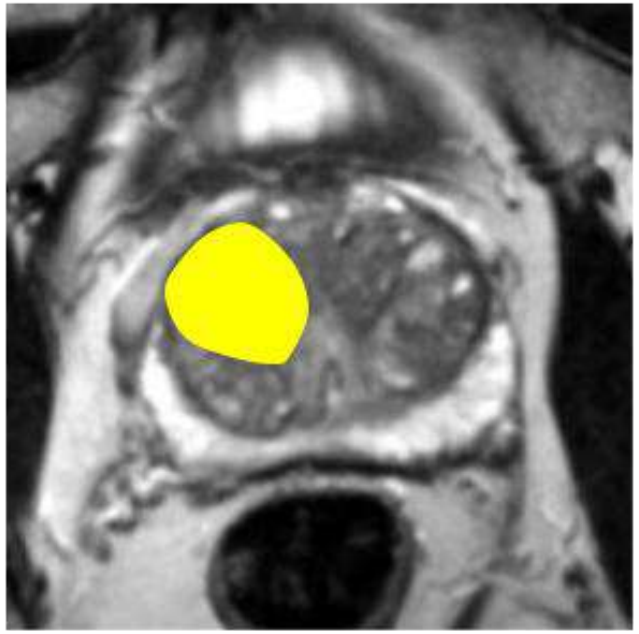
De Fauw, J., Ledsam, J.R., Romera-Paredes, B., Nikolov, S., Tomasev, N., Blackwell, S., Askham, H., Glorot, X., O'Donoghue, B., Visentin, D. and van den Driessche, G., 2018. Clinically applicable deep learning for diagnosis and referral in retinal disease. Nature medicine, 24(9), pp.1342-1350.

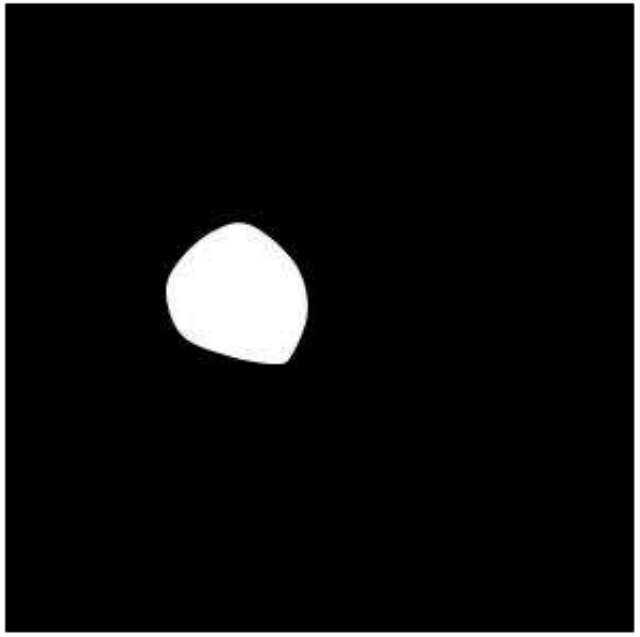
Medical Imaging Applications| Segmentation

Medical Imaging Applications| Segmentation

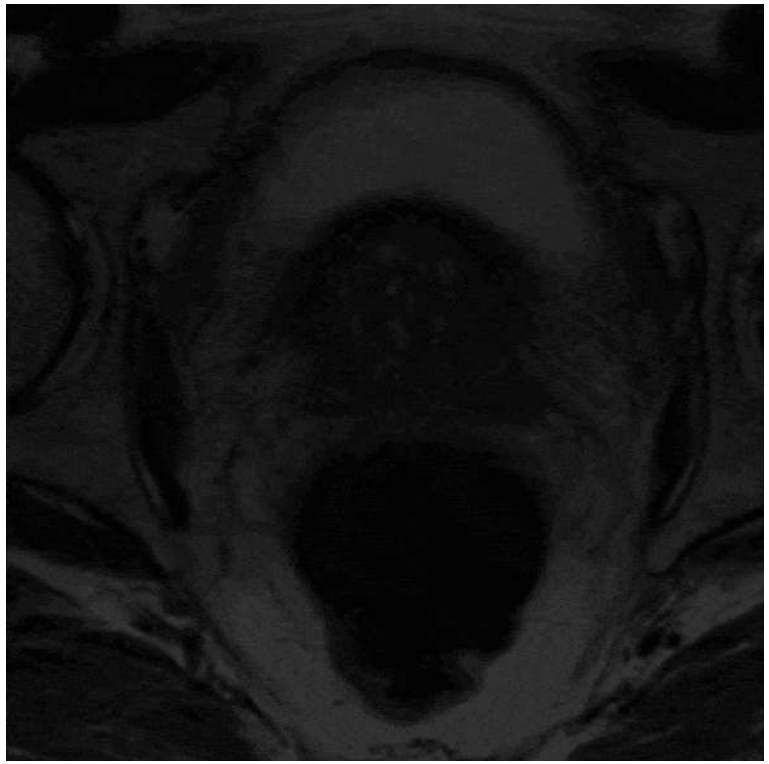
- What is medical image segmentation
- Why is this useful

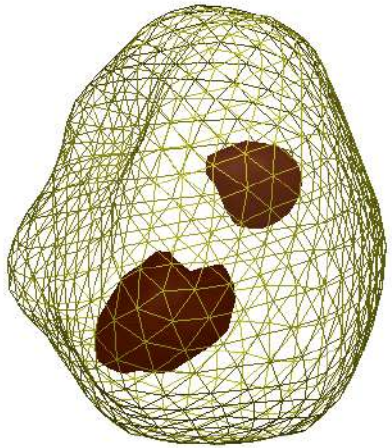






Representation of segmentation





1	0	0	0	0
1	1	0	0	0
1	1	1	1	0
1	1	1	1	0
1	1	1	0	0

- Loss for segmentation
  - Cross-entropy at each voxel

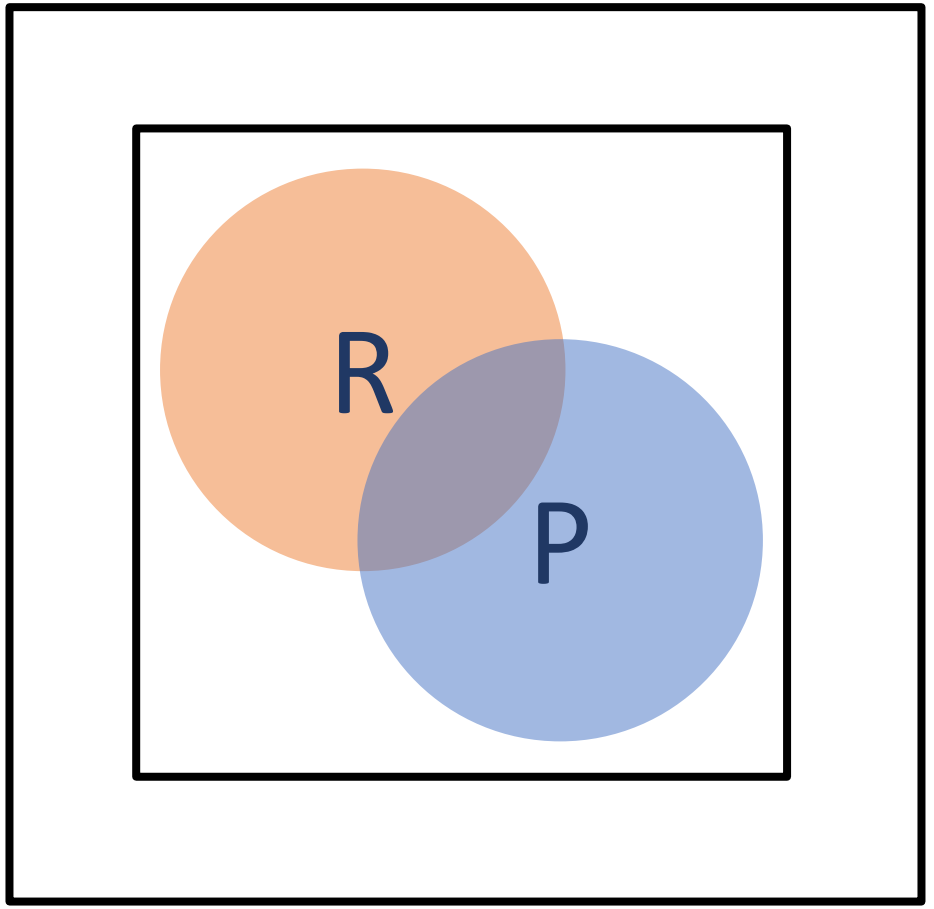
$$CE_{voxel} = R\ log(P) + (1-R)\ log\ (1-P)$$

$$\mathrm{WCE} = -\frac{1}{N}\sum_{n=1}^{N} w r_n \log(p_n) + (1 - r_n)\log(1 - p_n)$$

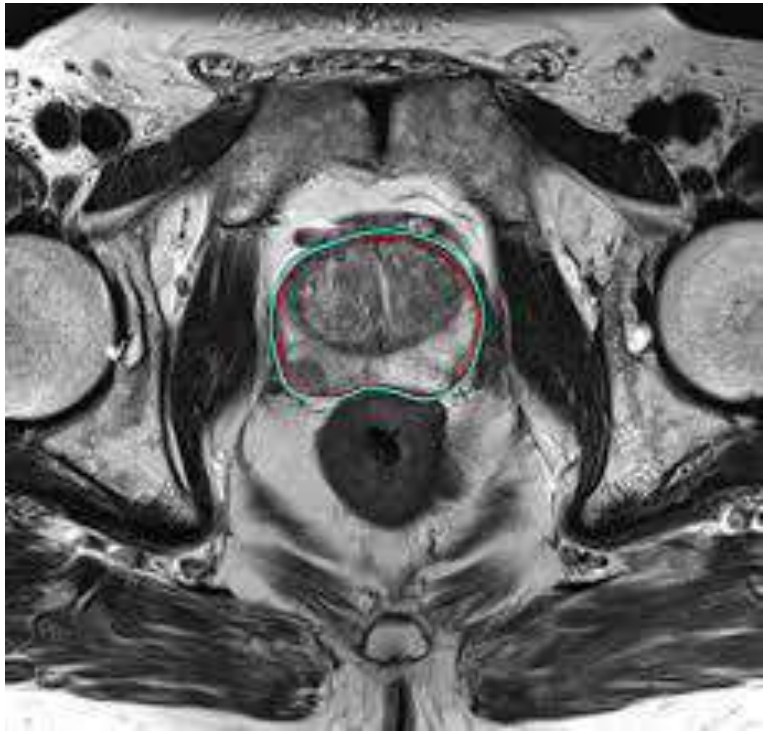
  - Overlap measures, e.g. Dice

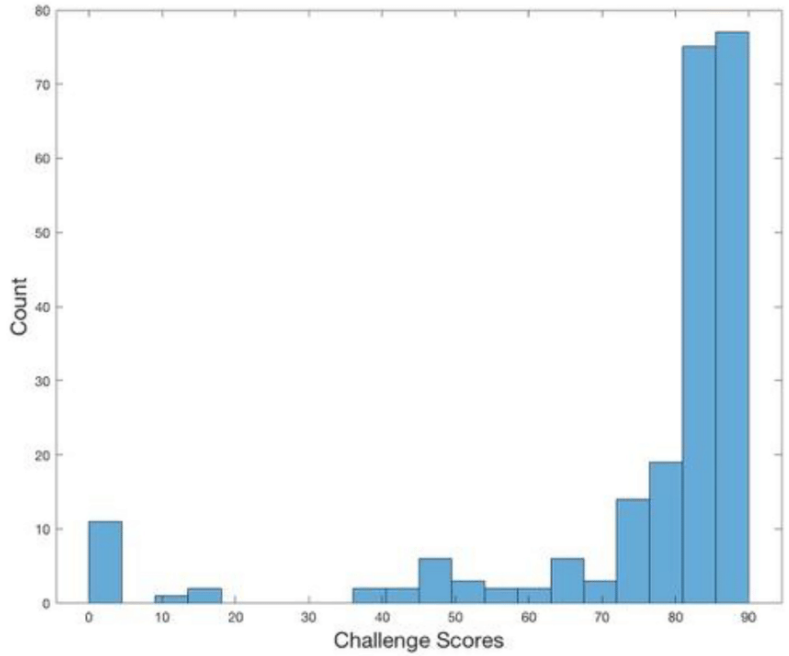
$$Dice = 2(P\ \&\ R)\ /\ (P + R)$$

$$\mathrm{DL}_2 = 1 - \frac{\sum_{n=1}^{N} p_n r_n + \epsilon}{\sum_{n=1}^{N} p_n + r_n + \epsilon} - \frac{\sum_{n=1}^{N} (1 - p_n)(1 - r_n) + \epsilon}{\sum_{n=1}^{N} 2 - p_n - r_n + \epsilon}$$

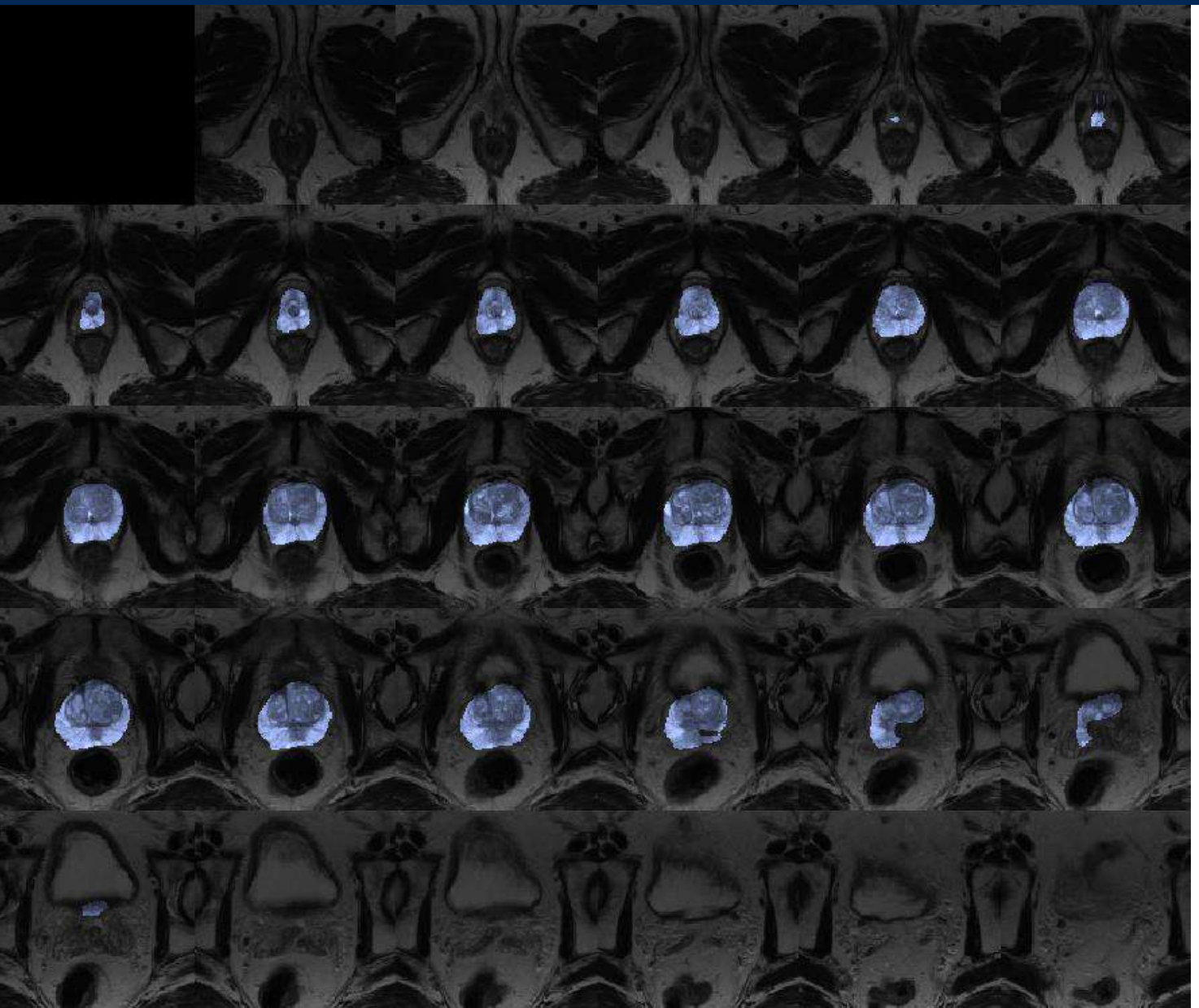


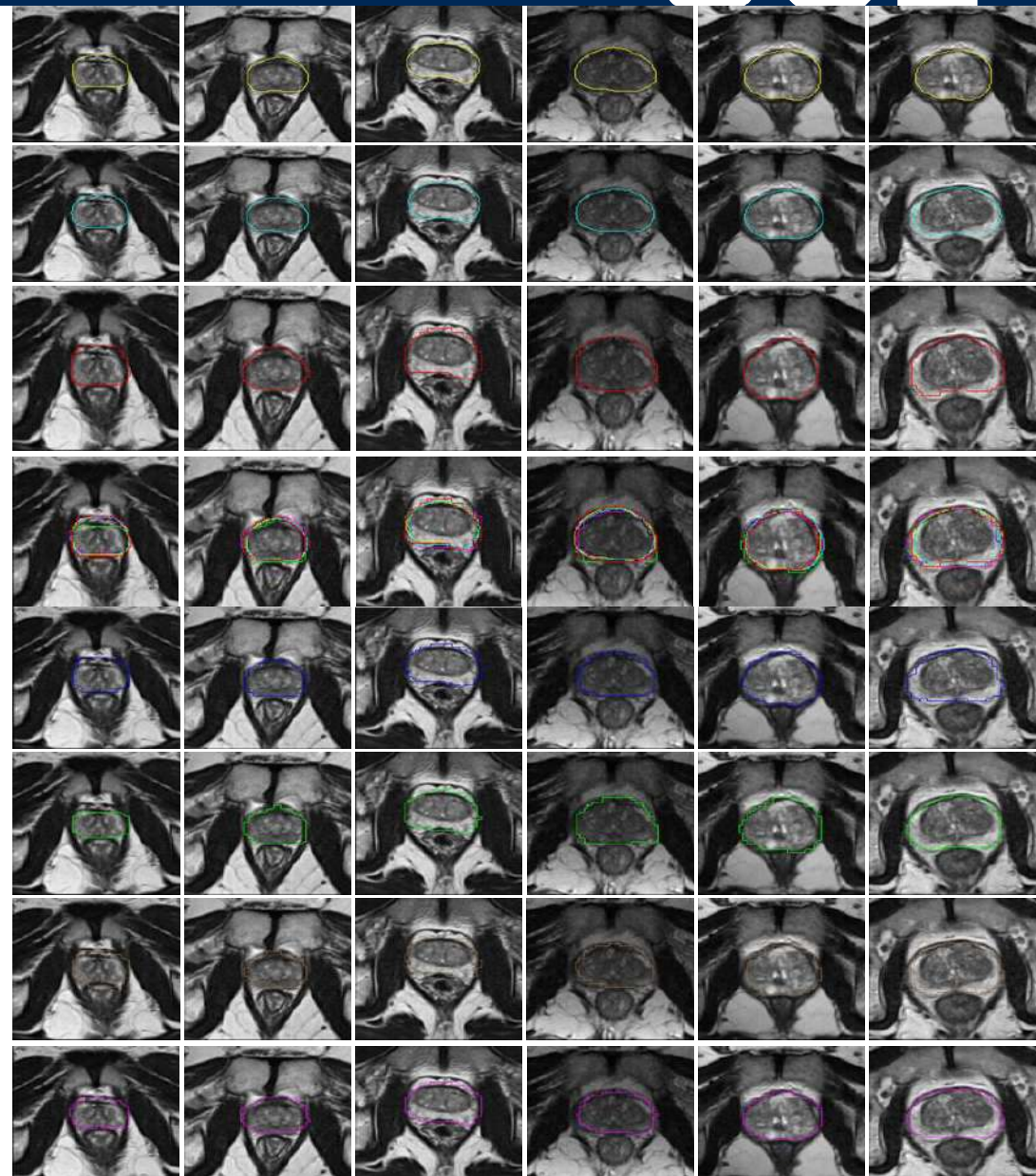

PROMISE12




Count
Challenge Scores
0
10
20
30
40
50
60
70
80
90

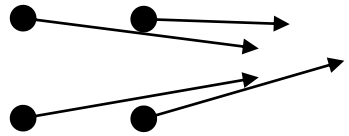
UCL



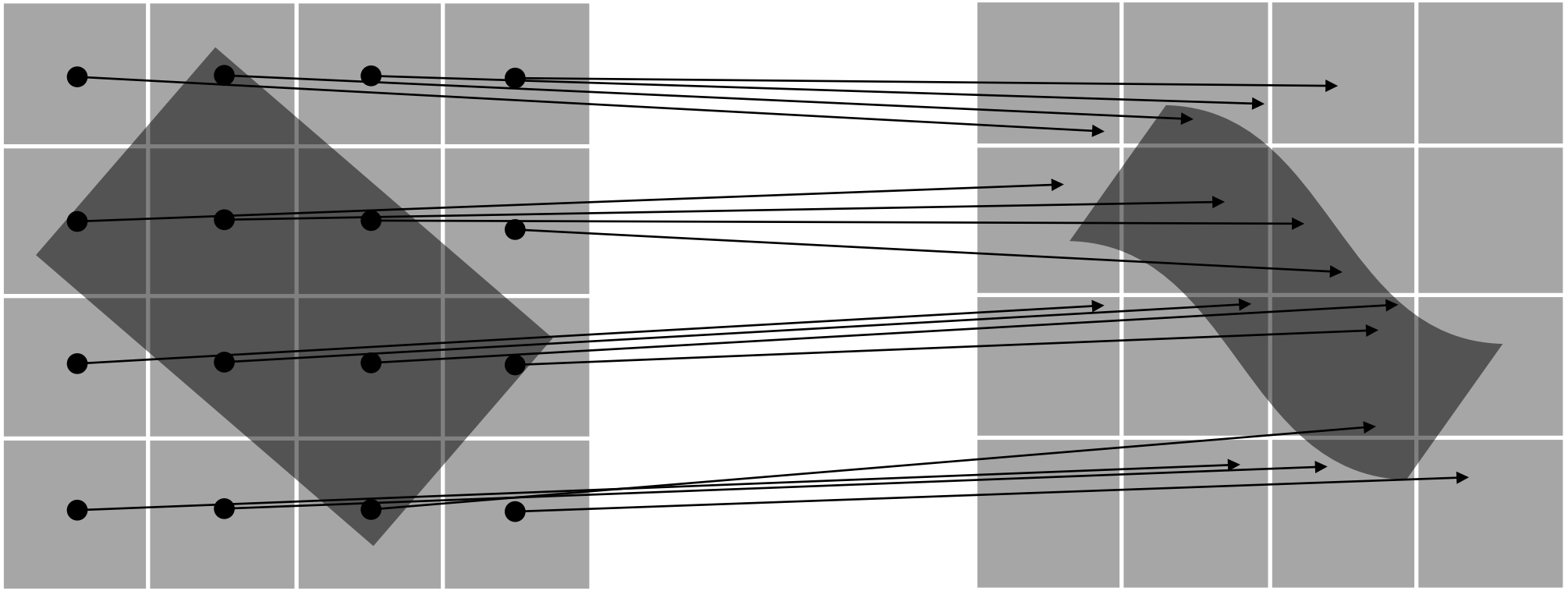


Medical Imaging Applications| Registration

Dense Correspondence

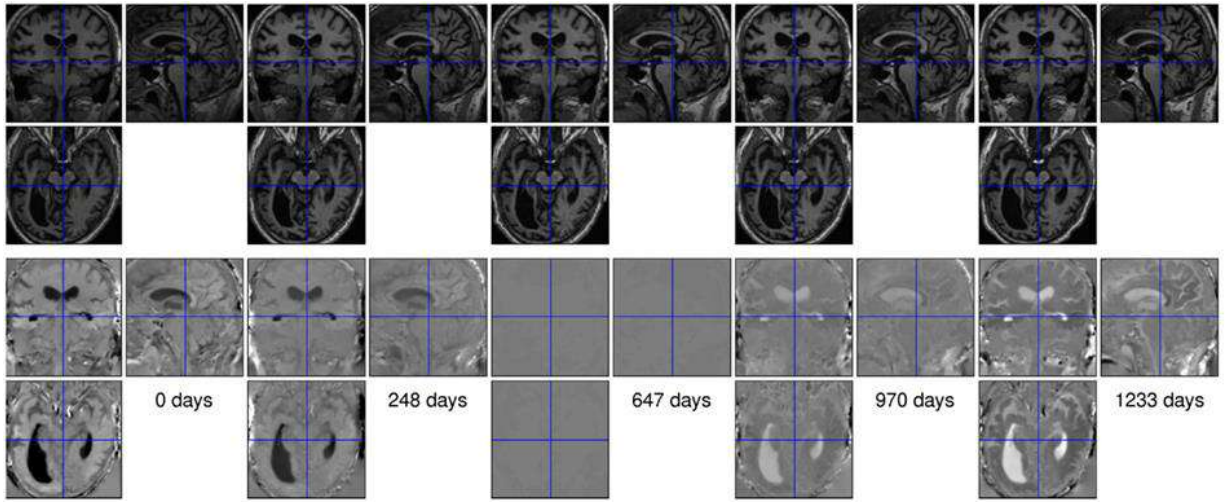


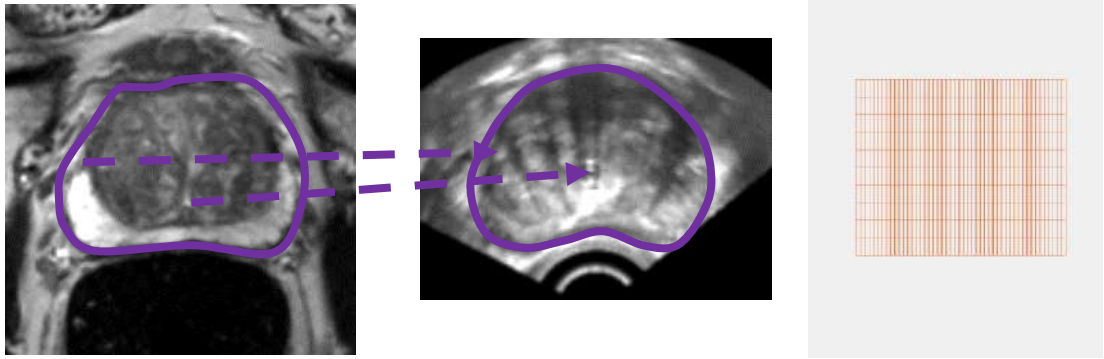
- Dense Displacement Field
- Transformation Model

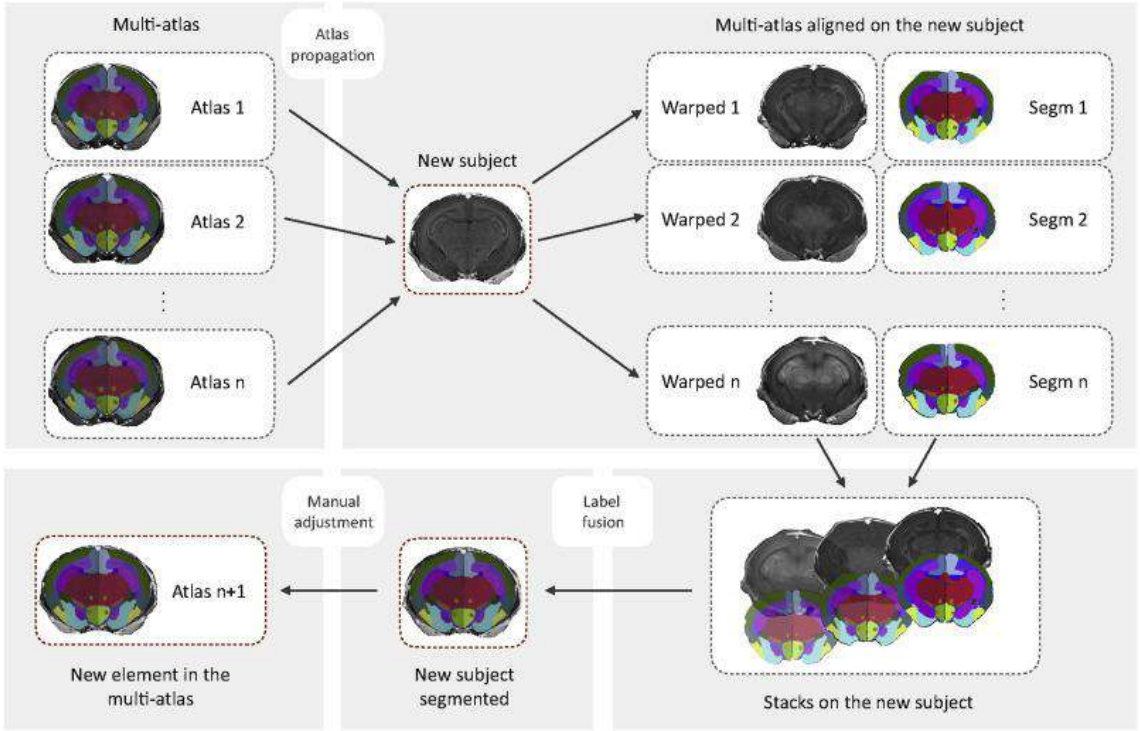


Registration applications

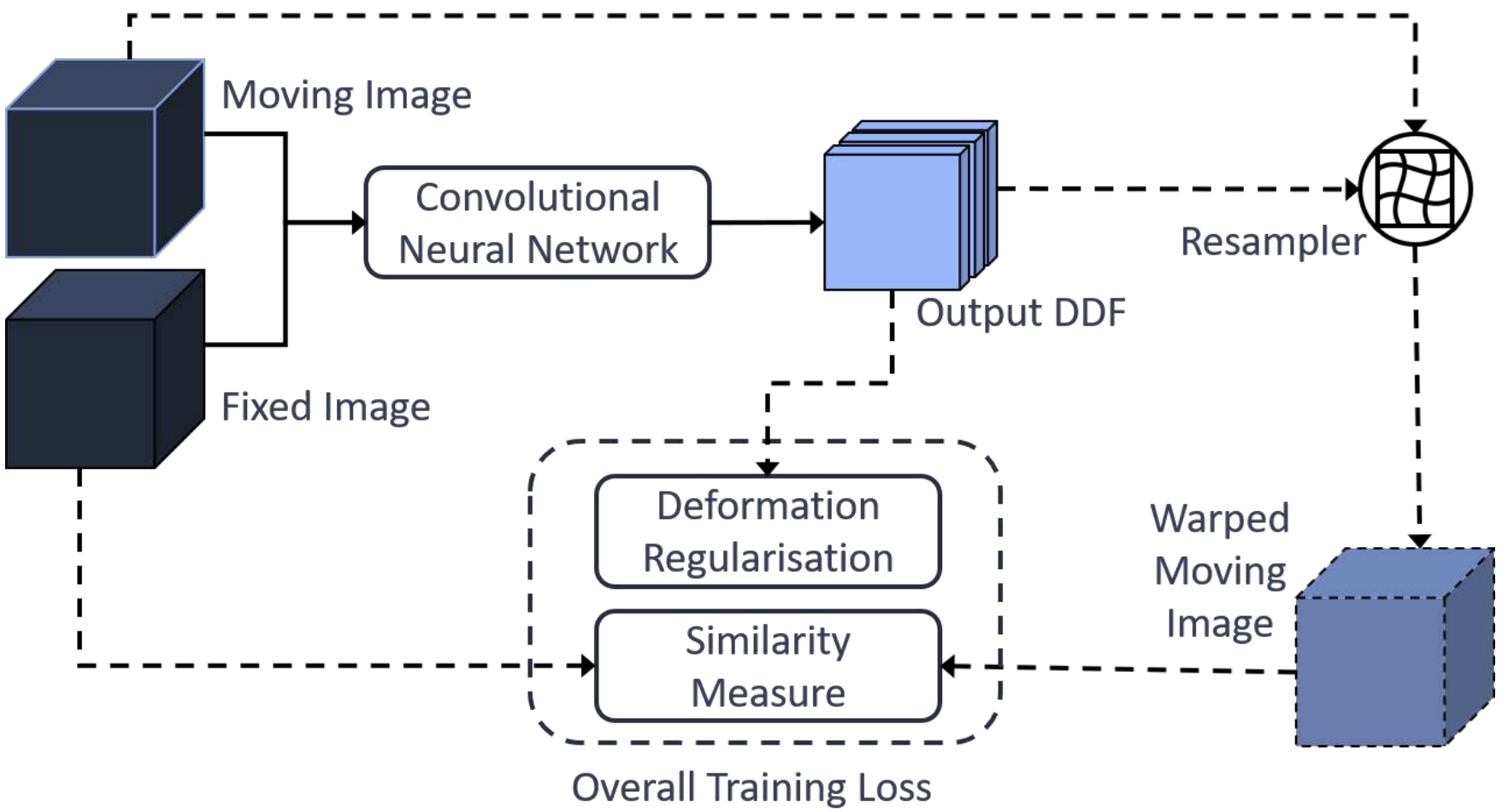
- **Multi-modal, e.g. image-guided interventions**
- **Inter-subject, e.g. atlas-based segmentation**
- **Intra-subject, e.g. longitudinal analysis**



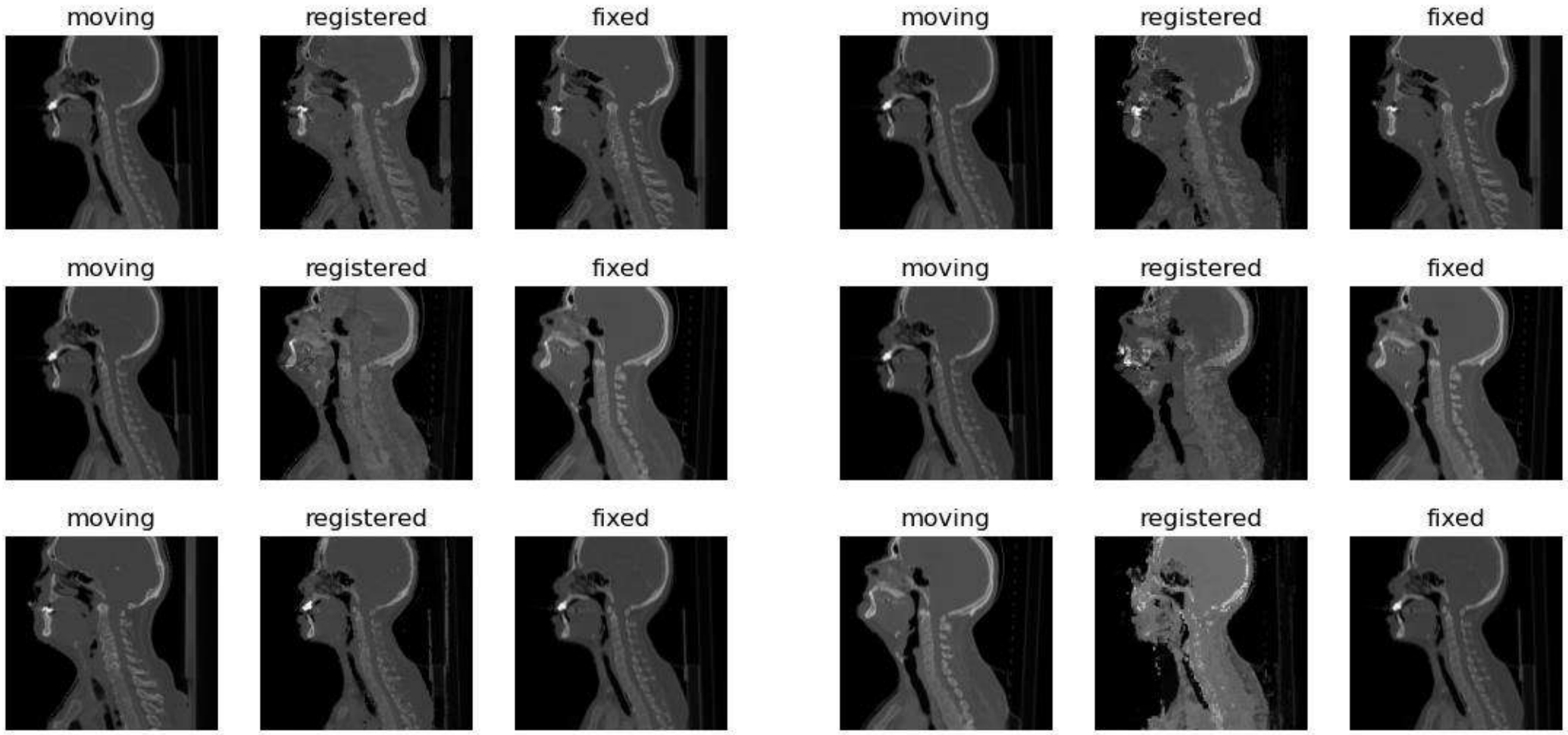




Unsupervised image registration



Inter-subject head-and-neck CT images



DeepReg.net

GitHub

Read the Docs

JOSS
The Journal of Open Source Software

deepr

DeepReg: a deep learning toolkit for medical image registration

Yunguan Fu[1, 2, 3], **Nina Montaña Brown**[1, 2], **Shaheer U. Saeed**[1, 2], **Adrià Casamitjana**[2], **Zachary M. C. Baum**[1, 2], **Rémi Delaunay**[1, 4], **Qianye Yang**[1, 2], **Alexander Grimwood**[1, 2], **Zhe Min**[1], **Stefano B. Blumberg**[2], **Juan Eugenio Iglesias**[2, 5, 6], **Dean C. Barratt**[1, 2], **Ester Bonmati**[1, 2], **Daniel C. Alexander**[2], **Matthew J. Clarkson**[1, 2], **Tom Vercauteren**[4], and **Yipeng Hu**[1, 2]

1 Wellcome/EPSRC Centre for Surgical and Interventional Sciences, University College London, London, UK 2 Centre for Medical Image Computing, University College London, London, UK 3 InstaDeep, London, UK 4 Department of Surgical & Interventional Engineering, King's College London, London, UK 5 Martinos Center for Biomedical Imaging, Massachusetts General Hospital and Harvard Medical School, Boston, USA 6 Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Boston, USA

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Software

- Review
- Repository
- Archive

Summary

Image fusion is a fundamental task in medical image analysis and computer-assisted inter-

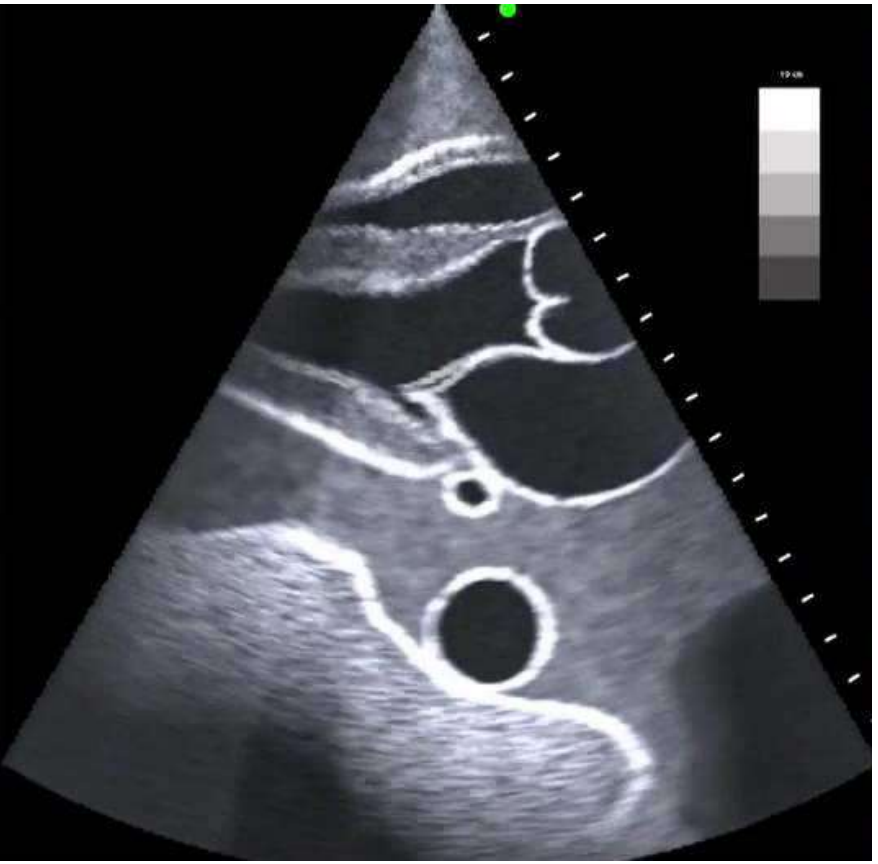
Medical Imaging Applications| Synthesis

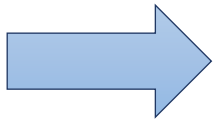
Medical image simulation

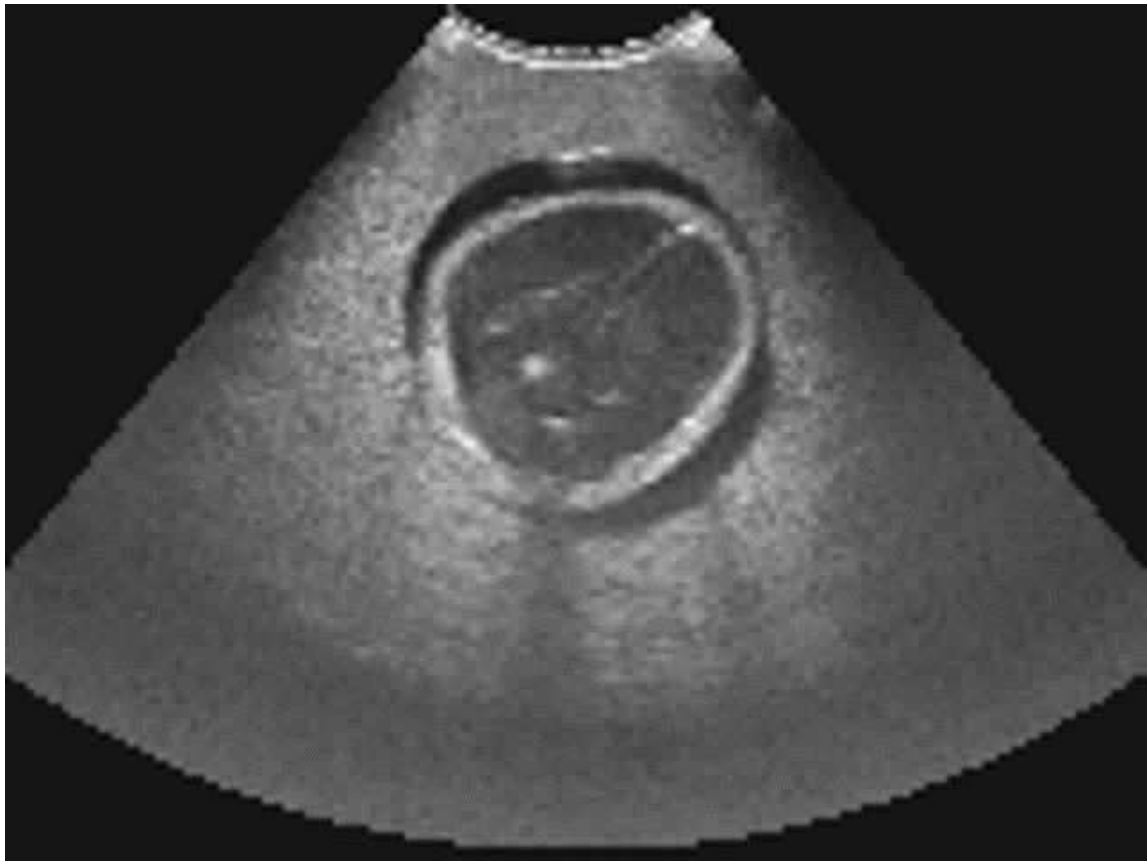
- Training models
- Training clinicians
- Provide “extra” information, e.g. super-res./IQT
- Providing prior knowledge for training other ML models
  - Domain adaptation
  - Transfer learning
- Registration
- Generative modelling for unsupervised learning

U-Net-like encoder-decoder supervised learning, Autoencoder, GANs and variants

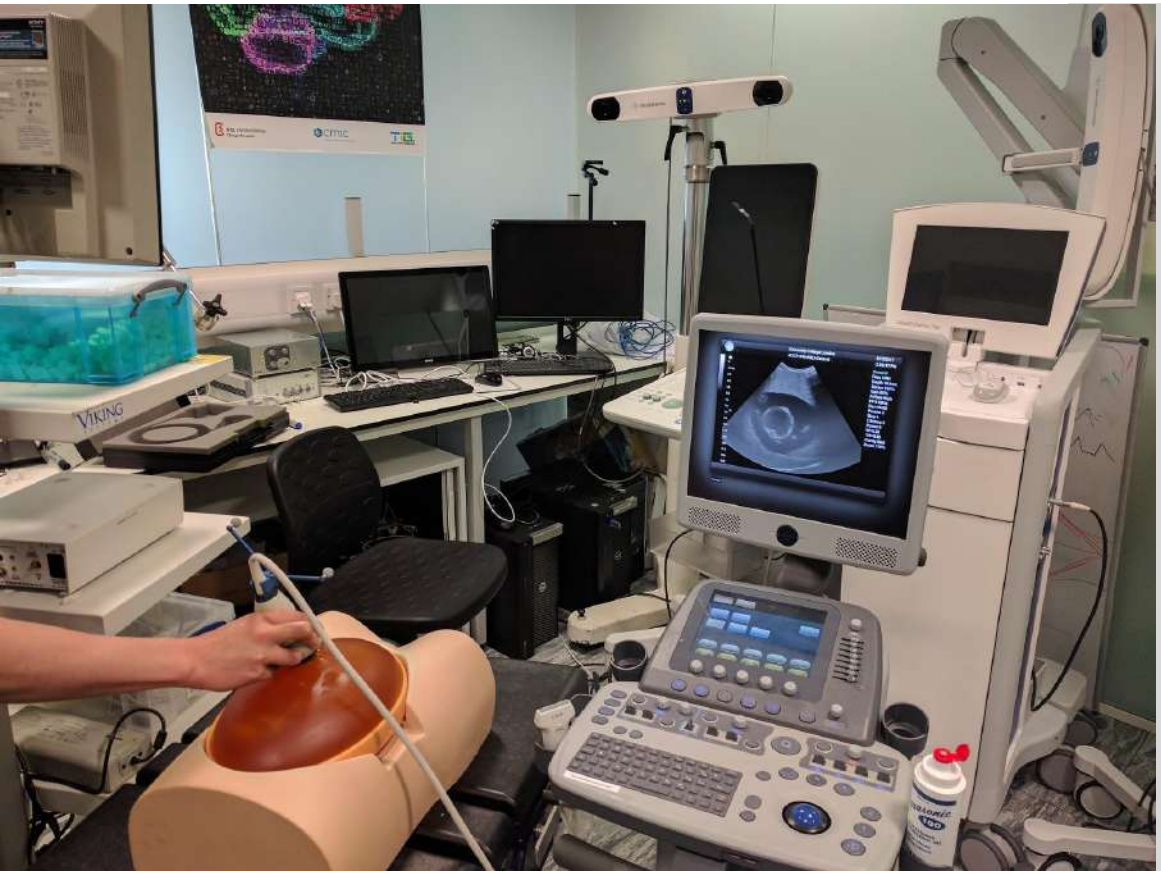
Ultrasound simulation

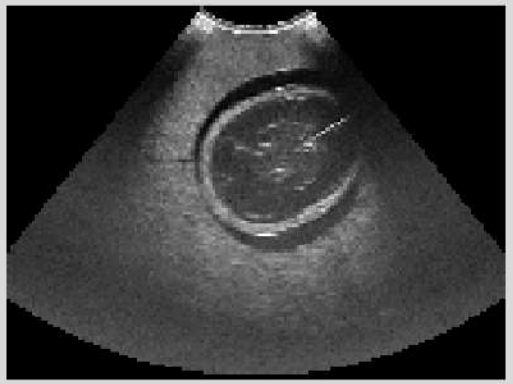


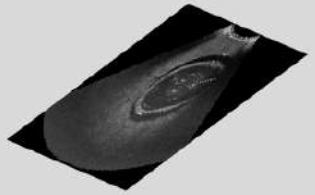




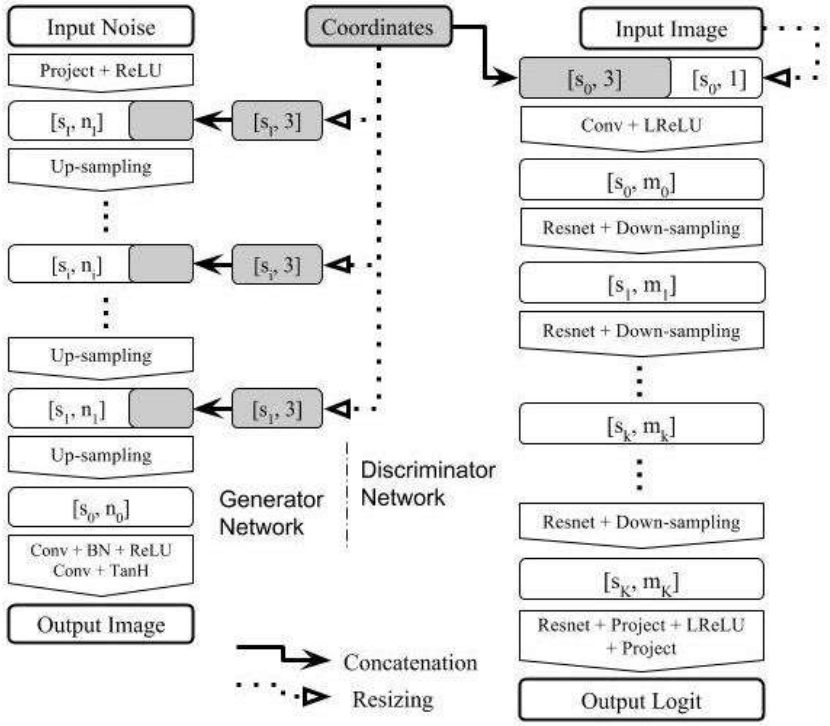
Freehand hand-held ultrasound imaging with spatial tracking

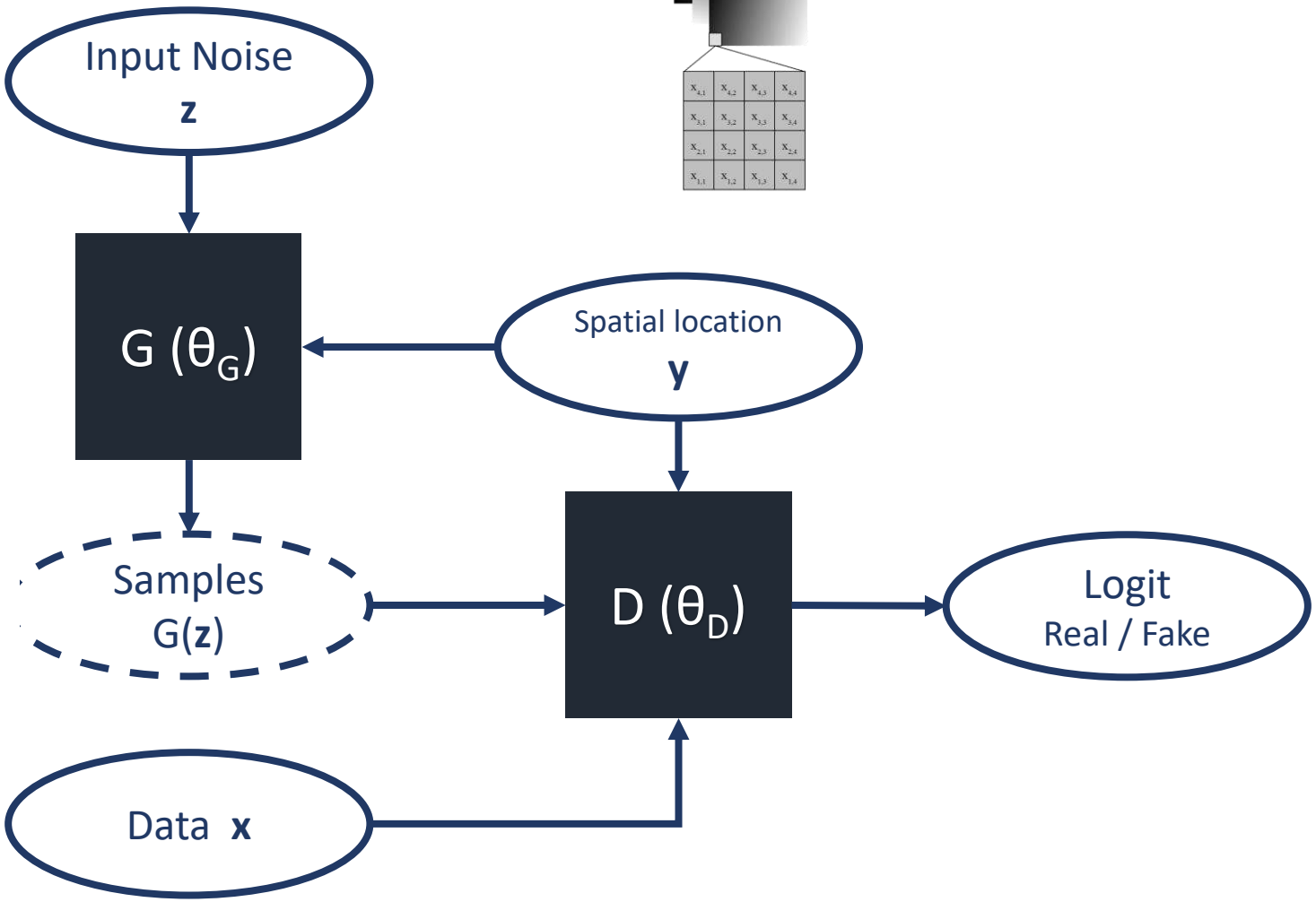


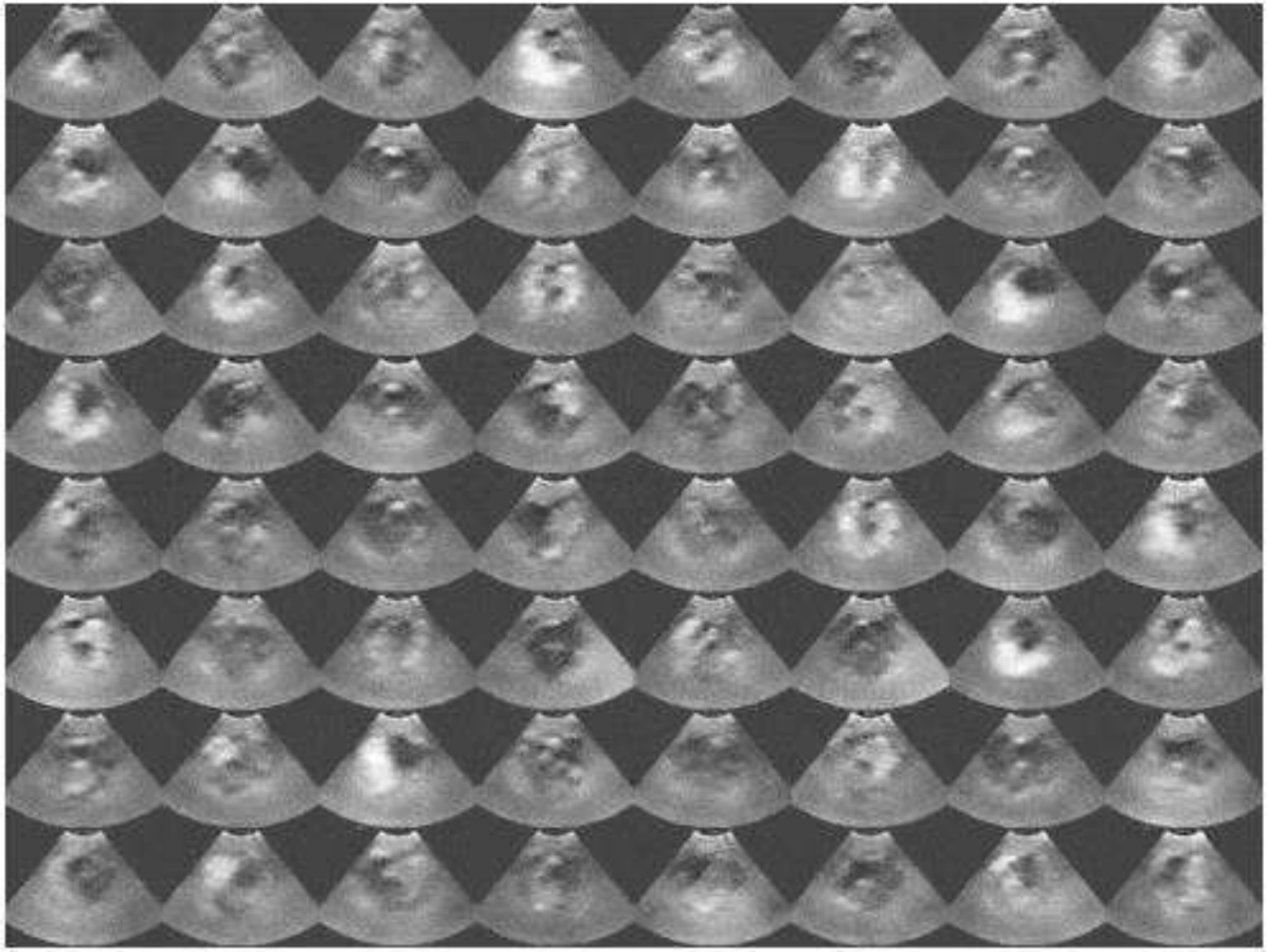




Conditional generative adversarial models







Where are we now?