AutoFB: Automating Fetal Biometry Estimation from Standard Ultrasound Planes

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UCL

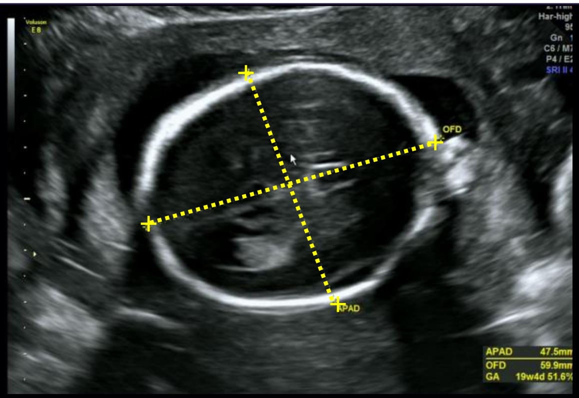
Introduction

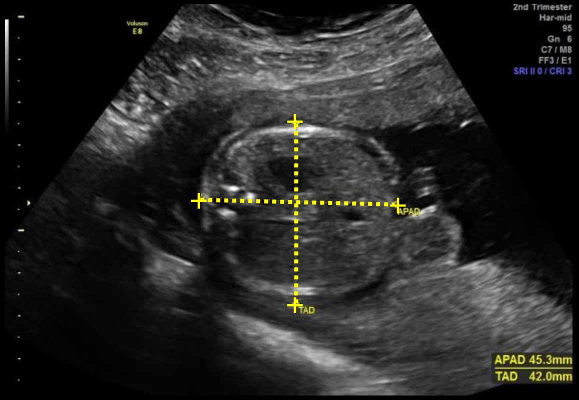
Ultrasound (US) examination during pregnancy can

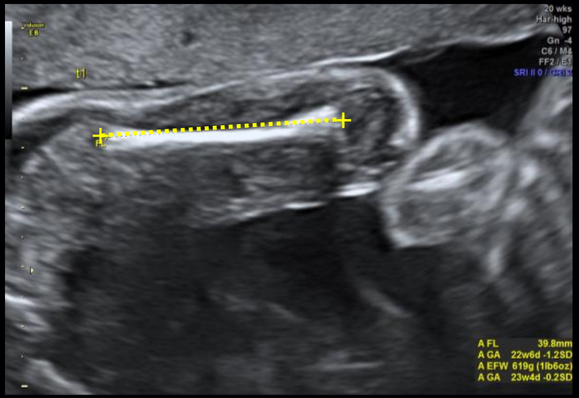
- Assess fetal size according to standardized biometry charts
- Biometry assesses fetal well-being and growth trajectory

Reproducible and accurate fetal biometry requires

- Identification of 3 standard 2D US planes by the sonographer
- Manually marking the key anatomical landmarks to clinically measure biometry







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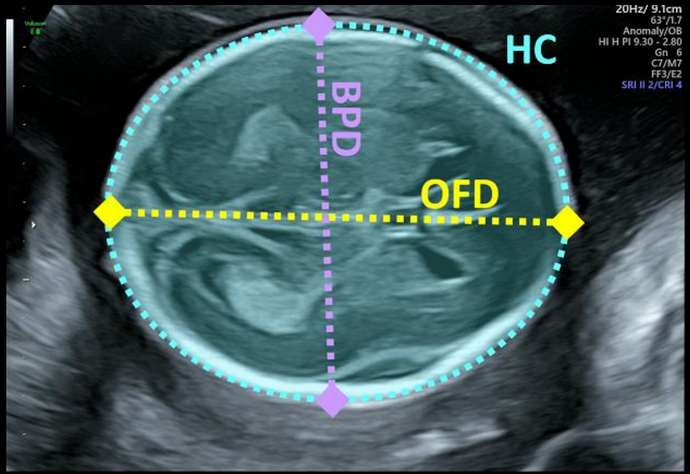
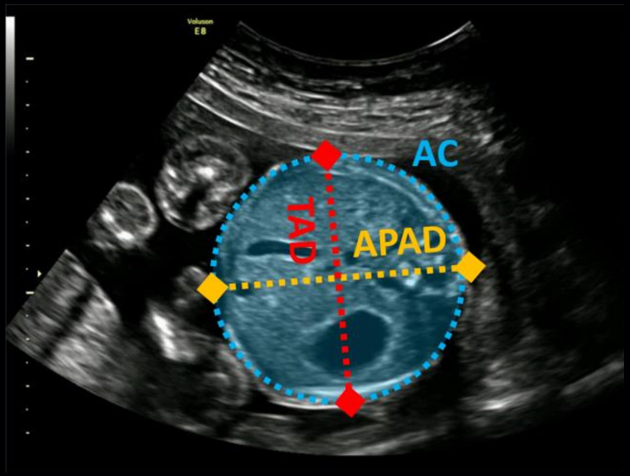
Fetal Biometry

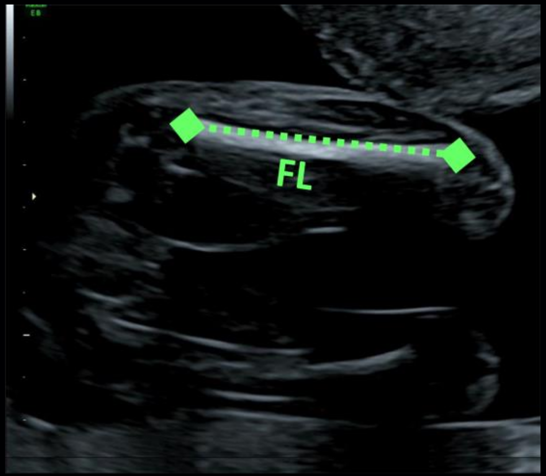
Three Standard Ultrasound Planes



Transventricular plane in the head



Transabdominal plane in the abdomen



Femur plane

HC – Head Circumference

BPD - BiParietal Diameter

OFD - Occipito-Frontal Diameter

AC - Abdominal Circumference

TAD - Transverse Abdominal Diameter

APAD - Anterior-Posterior Abdominal Diameter

FL - Femur length

Motivation

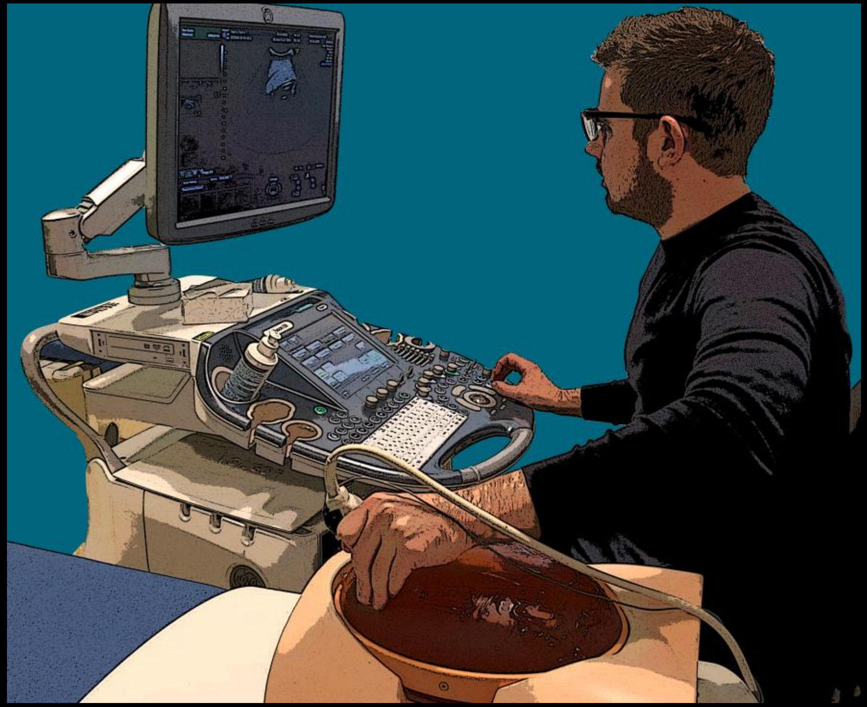
- Time-consuming task especially for less experienced sonographers
- Subject to intraoperator and interoperator variabilities

Automating fetal biometry

- Help in minimizing variabilities
- Serve as expert for trainee sonographers

Existing methods

- Rely on prior knowledge of which measurement to perform on a given image [1, 2, 3]



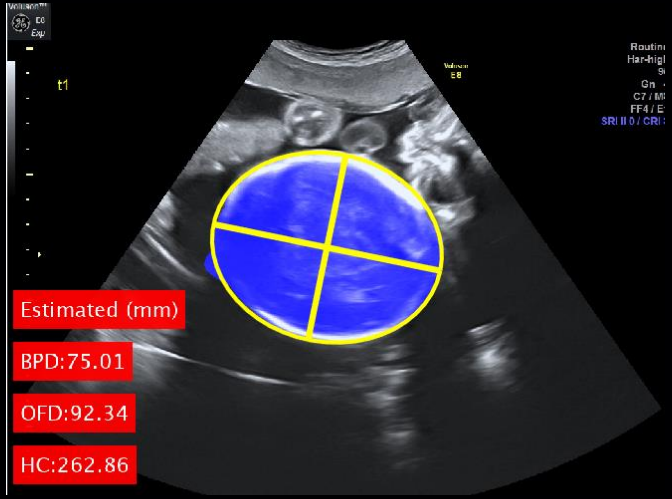
[Dromey, Prenat. Diagn. 2020]

[1] Sobhaninia, et al. “Fetal ultrasound image segmentation for measuring biometric parameters using multi-task deep learning." EMBC 2019.
[2] Khan, et al. “ Automatic measurement of the fetal abdominal section on a portable ultrasound machine for use in low and middle income countries.” IUS 2016.
[3] Hermawati, et al. “Automatic femur length measurement for fetal ultrasound image using localizing region-based active contour method.” Journal of Physics, 2019.

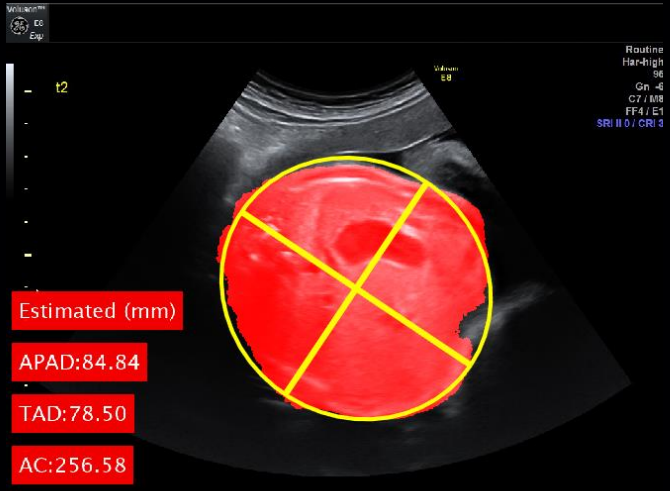
AutoFB - Contributions

- A unified automated framework that estimates all relevant measurements for fetal biometry assessment from all three standard ultrasound planes

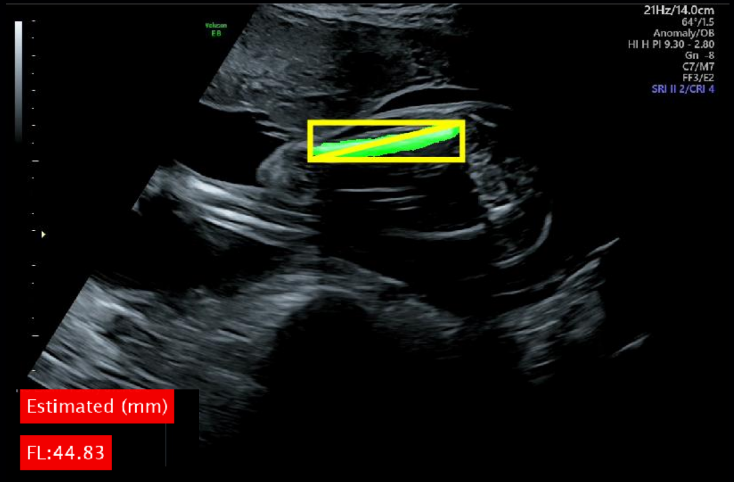
Head



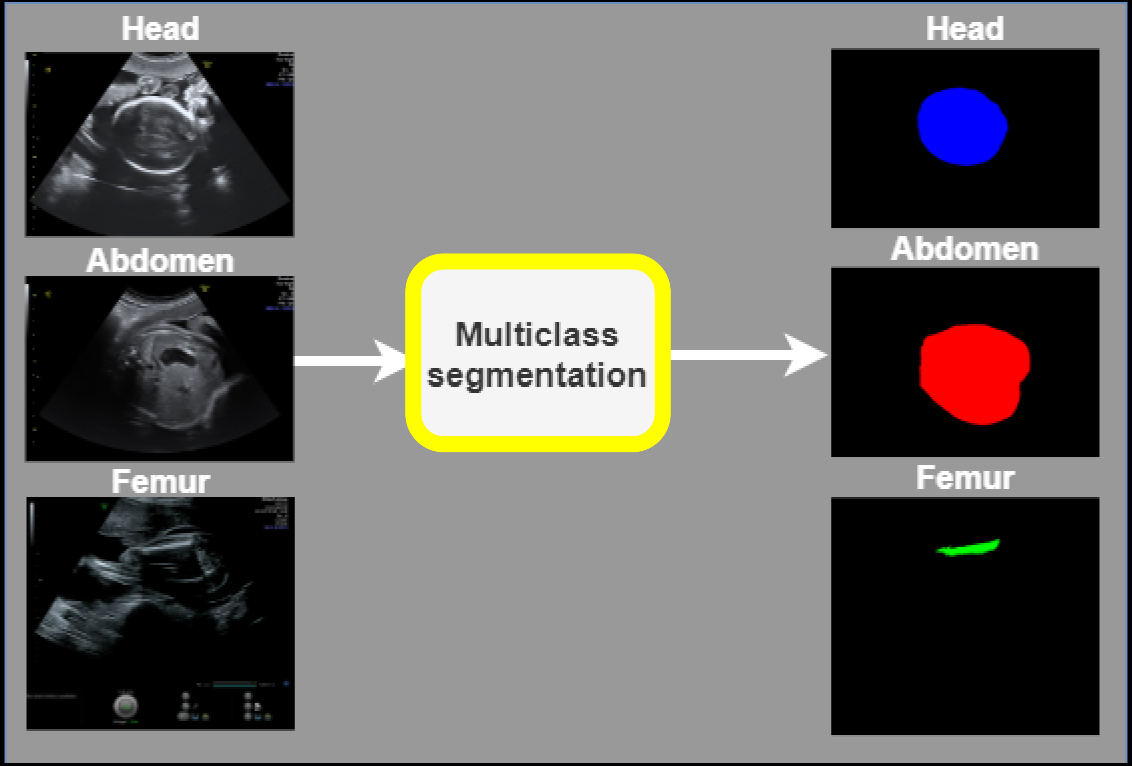
Abdomen



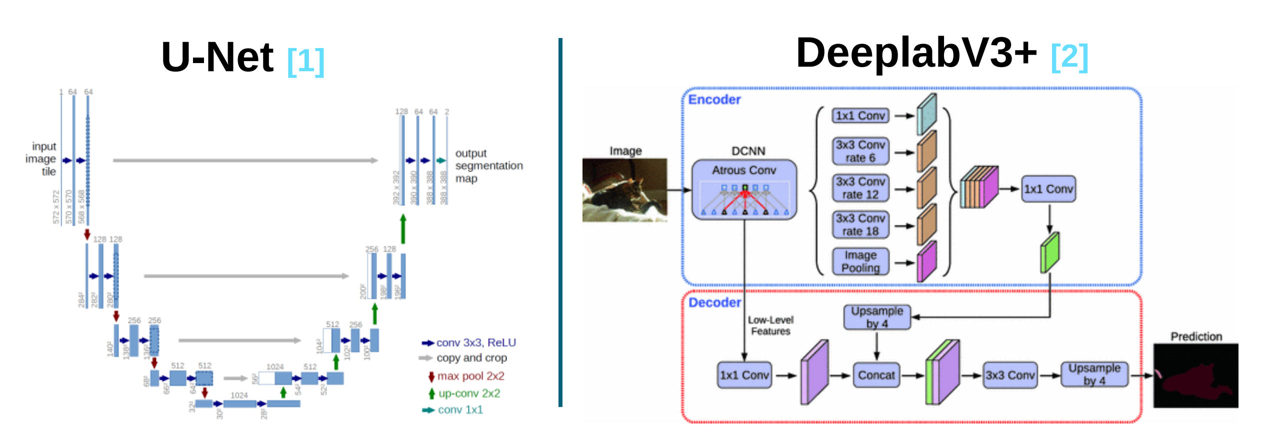
Femur



Proposed Method

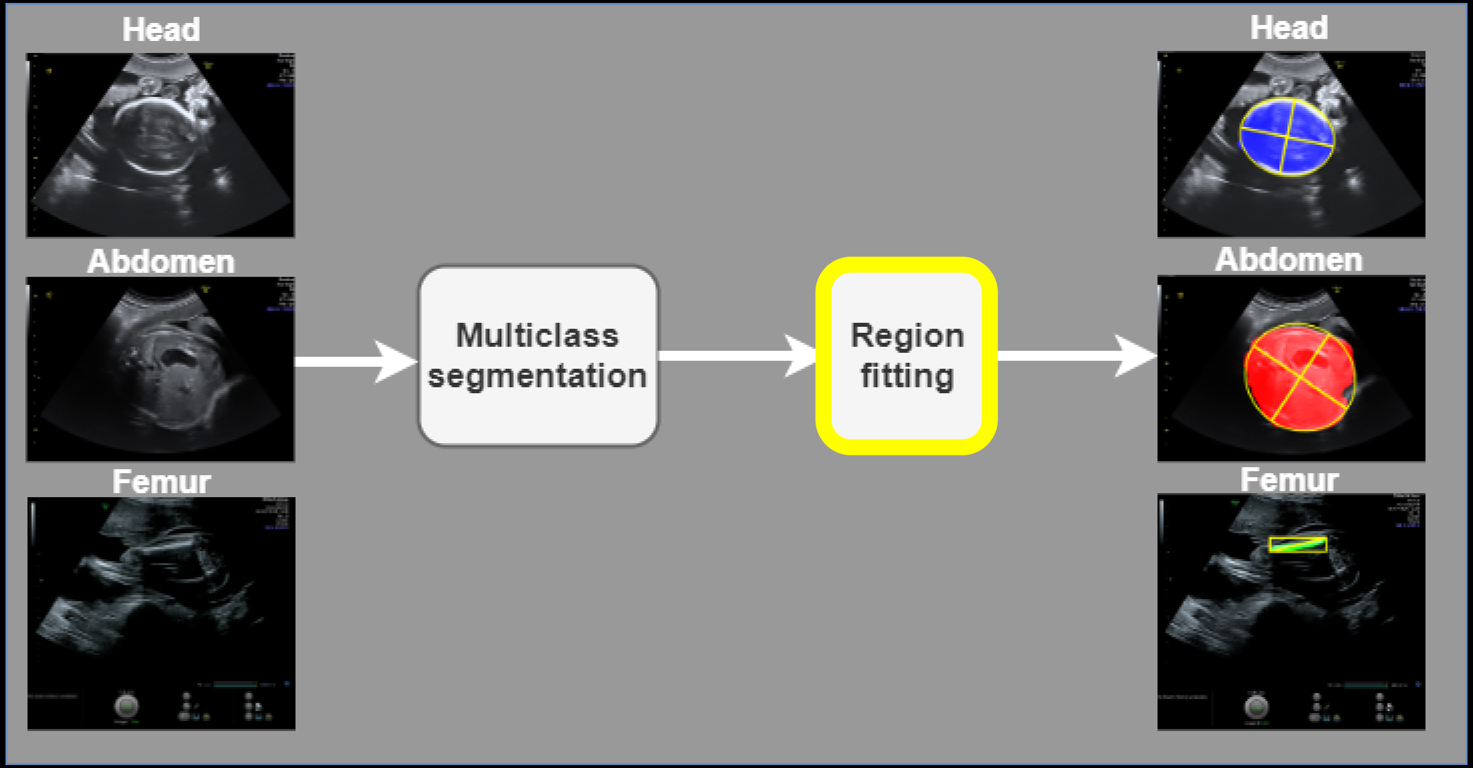


- Identifies and segments head, abdomen and femur
- Ablation study of UNet [1] and Deeplabv3+ [2] with different backbones



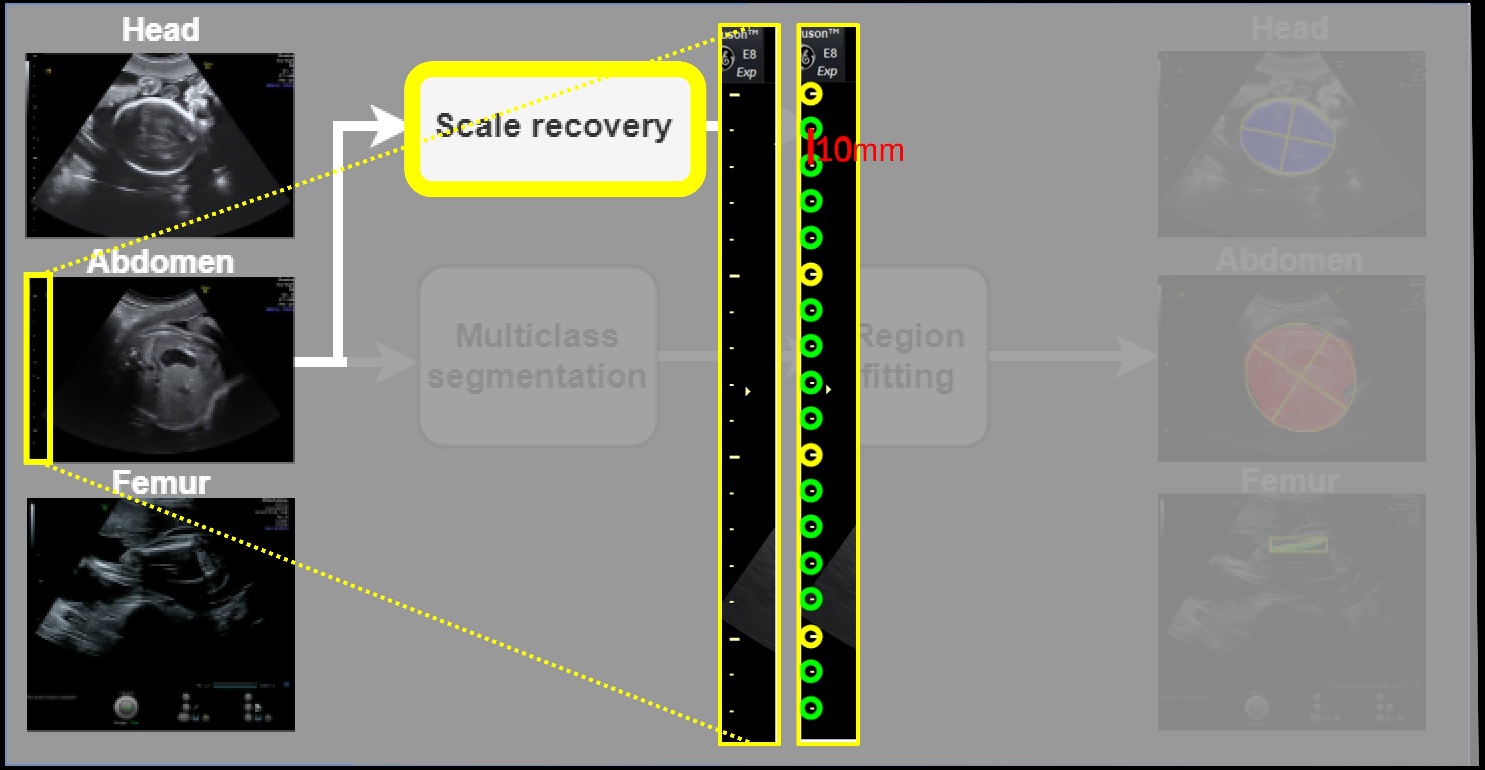
[1] Ronneberger, et al. "UNet: Convolutional networks for biomedical image segmentation." MICCAI, 2015.
[2] Chen, et al. "Encoder-decoder with atrous separable convolution for semantic image segmentation." ECCV, 2018.

Proposed Method

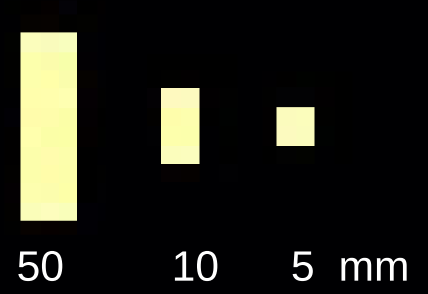


- Fitting an ellipse on the head or abdomen masks
- Fitting a bounding box on the femur mask

Proposed Method

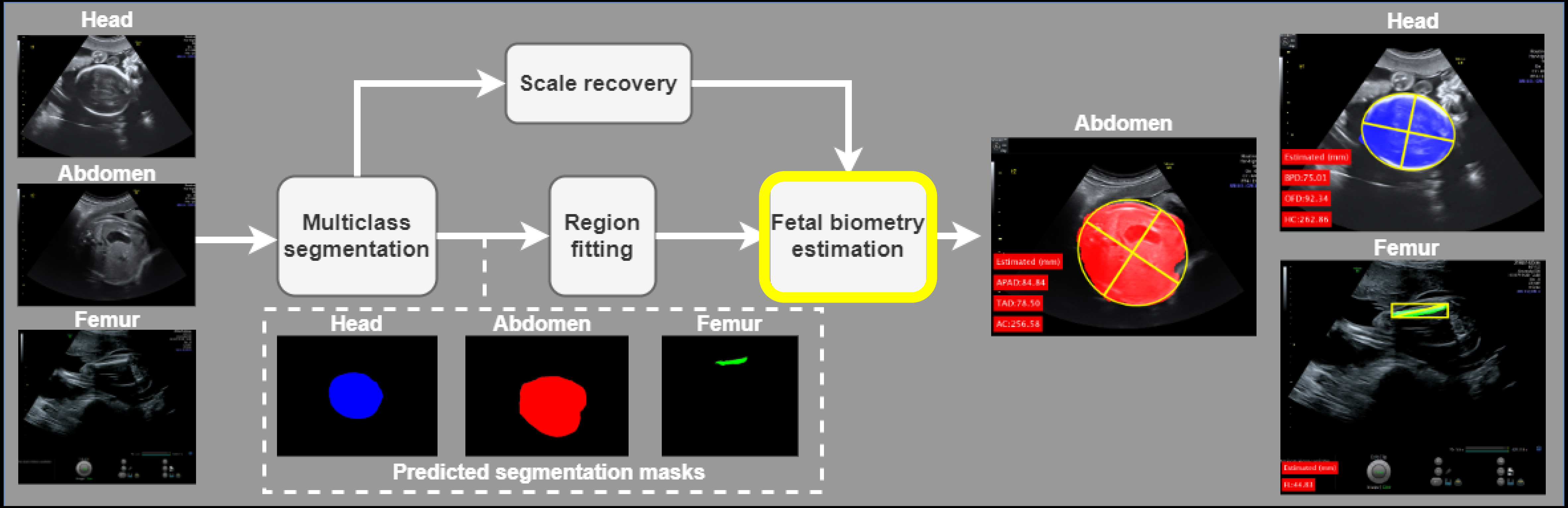


- Template matching detects the ruler markers on the caliper visible on the US images
- Templates of ruler markers:



- Ratio of millimetre (mm) to pixel gives the scaling factor

Proposed Method

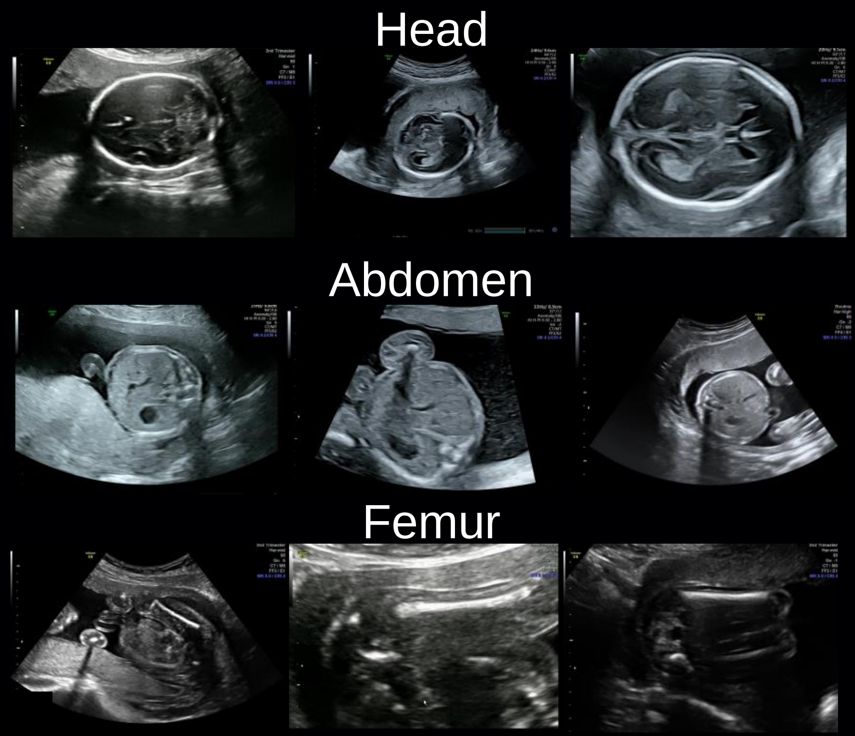


- Fitted ellipse circumference gives HC (AC) estimates
  - Major and minor axes gives BPD and OFD (TAD and APAD) estimates
- Bounding box diagonal gives FL estimates

Clinical Ultrasound Data Collection

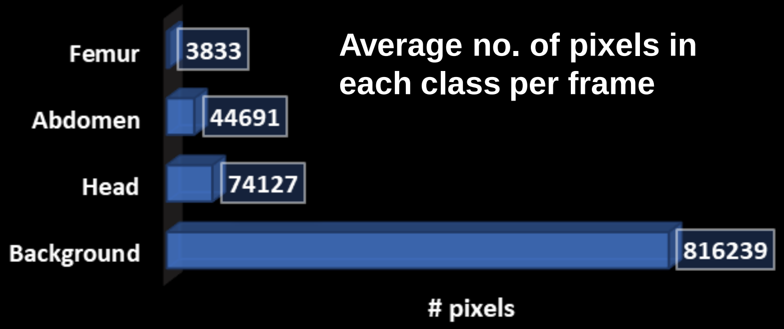
- Patients attending University College London Hospital for US examination enrolled and pseudo-anonymized after written consent and ethics approval
- Segmentation ground-truth obtained using the VIA tool [1]
- Clinically obtained measurements provided by the clinicians

# Subjects	# US Images	# Head	# Abdomen	# Femur
42	346	135	103	108



Observations

- Large intra-class variability
- Class imbalance



[1] Dutta and Zisserman, “The VIA Annotation Software for Images, Audio and Video.” MM, 2019.

Results – Multiclass Segmentation

- 4-fold cross-validation applied on Deeplabv3+ [1] and UNet [2] models
- Models trained with MobileNetv2 (MNv2) and ResNet50 backbones
- Either cross-entropy (CE) or weighted cross entropy (wCE) loss was used

Overall and per-class mean Intersection over Union (mIOU) for methods under comparison

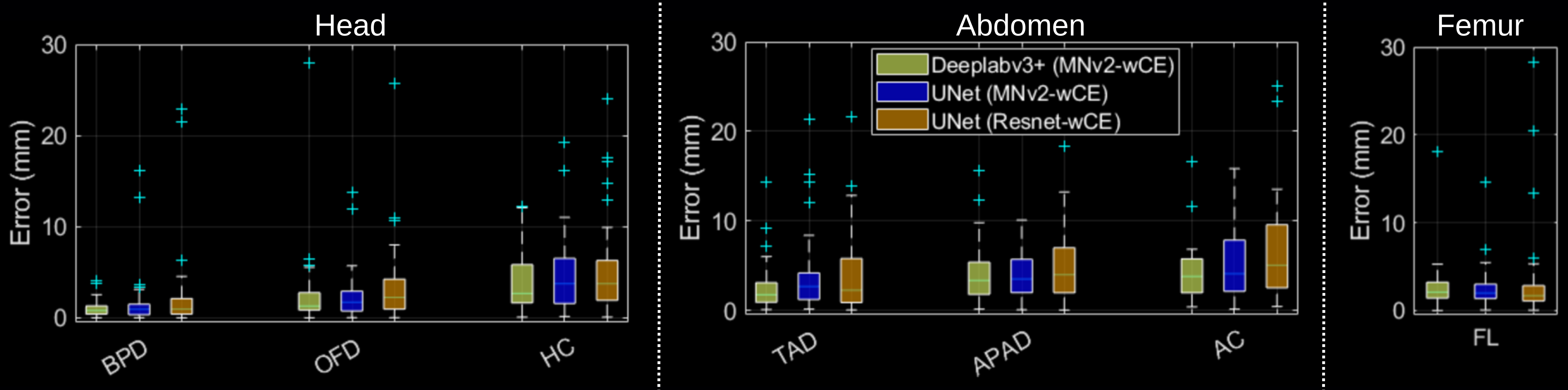
Method	mIoU	mIoU-BG	mIoU-H	mIoU-A	mIoU-F
Deeplabv3+ (MNv2-CE)	0.87 ± 0.02	0.95 ± 0.02	0.93 ± 0.02	0.89 ± 0.03	0.61 ± 0.03
Deeplabv3+ (MNv2-wCE)	$\mathbf{0.88 \pm 0.01}$	$\mathbf{0.95 \pm 0.01}$	$\mathbf{0.93 \pm 0.02}$	$\mathbf{0.89 \pm 0.02}$	$\mathbf{0.61 \pm 0.02}$
UNet (MNv2-CE)	0.82 ± 0.05	0.93 ± 0.03	0.89 ± 0.05	0.85 ± 0.05	0.56 ± 0.03
UNet (MNv2-wCE)	0.86 ± 0.01	0.94 ± 0.01	0.91 ± 0.02	0.86 ± 0.02	0.58 ± 0.01
UNet (Resnet-CE)	0.75 ± 0.06	0.88 ± 0.05	0.84 ± 0.07	0.77 ± 0.05	0.53 ± 0.03
UNet (Resnet-wCE)	0.78 ± 0.04	0.87 ± 0.03	0.83 ± 0.04	0.75 ± 0.06	0.53 ± 0.02

BG – background
H – Head
A – Abdomen
F – Femur

[1] Chen, et al. “Encoder-decoder with atrous separable convolution for semantic image segmentation.” ECCV, 2018.
[2] Ronneberger, et al. “UNet: Convolutional networks for biomedical image segmentation.” MICCAI, 2015.

Results – Fetal Biometry Estimation

Comparison between the best performing models and absolute error between the clinically measured and predicted fetal biometry



For the best performing segmentation network (Deeplabv3+):

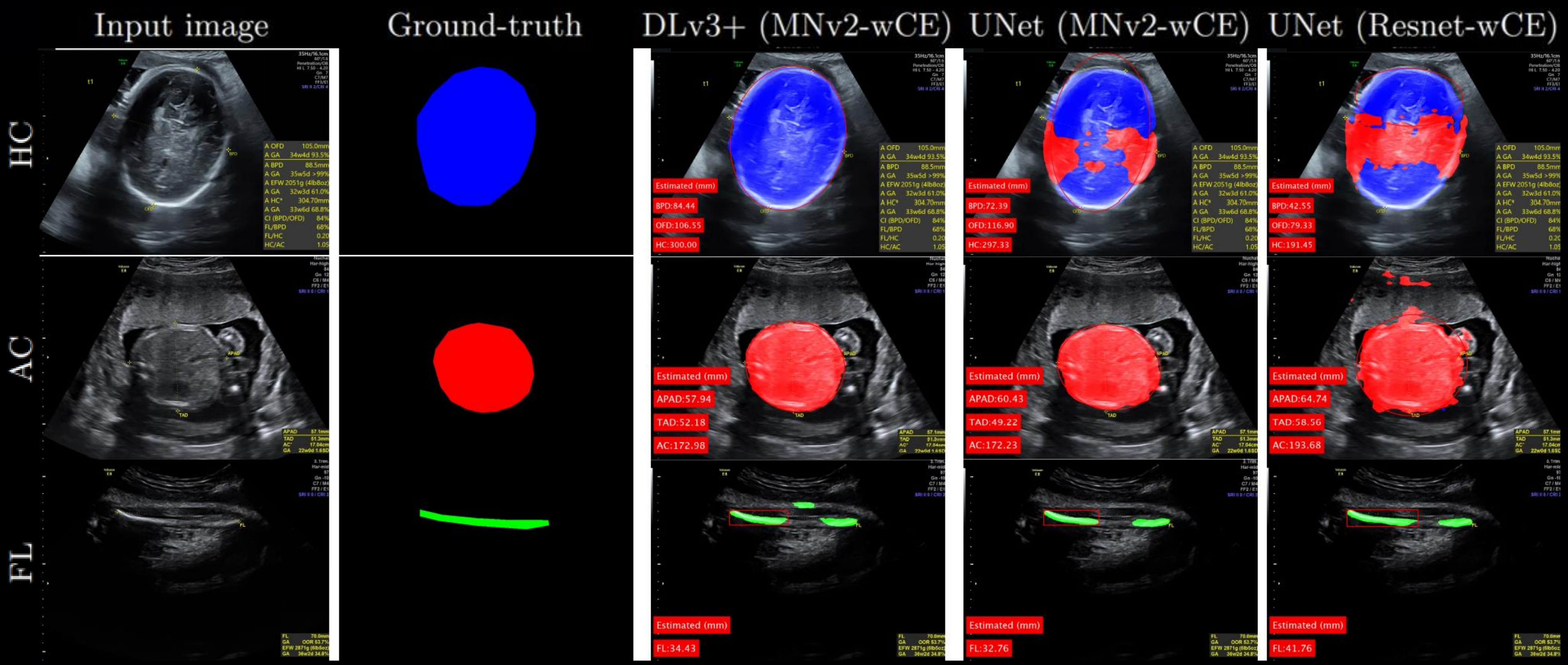
Error is lowest with a median of
- 0.80*mm* for BPD
- 1.30*mm* for OFD
- 2.67*mm* for HC

Error is lowest with a median of
- 2.39*mm* for TAD
- 3.82*mm* for APAD
- 3.77*mm* for AC

FL Error is comparable
- median of 2.1*mm*
- but with fewer outliers

Results – Qualitative Comparison

- Inaccurate segmentation resulted in fetal biometry estimation failure



Conclusion

- AutoFB framework with Deeplabv3+ outperformed other models despite large intra-class variability
- Obtained errors are lower than the ±15% error permissible during routine clinical assessment

Future work

- Online detection of standard planes and biometry estimation in ultrasound videos
- Experts and novices comparison with the AutoFB can provide evidence supporting clinical translation

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Thank you

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sophiabano
https://sophiabano.github.io

Oral & poster presentation: 29th September, 2021

Sessions: We-Oral-PM-A | We-S1

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