BiometryNet: Landmark-based Fetal Biometry Estimation from Standard Ultrasound Planes

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Code

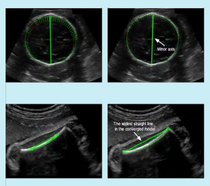
Motivation

- Fetal growth assessment is based on a few biometric measurements that are performed manually and assessed relative to the expected gestational age.
- Biometric measurements includes Occipito-Frontal Diameter (OFD) and Bi-Parietal Diameter (BPD) on head plane and Femur Length (FL) on femur plane.
- Segmentation annotation is time-consuming, thus landmark annotation is preferable.

Previous works

Fetal Ultrasound

Model-based



Khan et al 2017
Van der Heuvel 2018

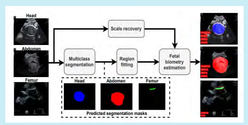
✗ Heuristic

Learning-based

Williams et al 2019

✗ Per-measurement
✓ Performance

Multi-task segmenation

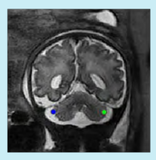


Bano et al 2021

✗ Costly annotations
✗ Bad performance
✓ One solution

Fetal MR

Landmark-based

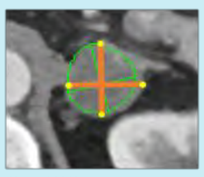


Avisdris et al 2021

✗ Complex pipeline
✓ Universal
✓ Only measurements annotation

Lesions in CT, MRI

Landmark-based segmenation

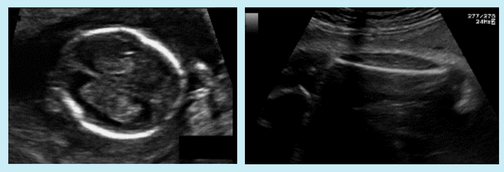


Ke et al 2019

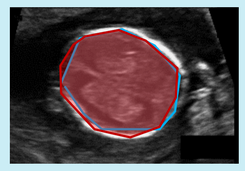
✗ Universal? Geometric assumptions
✓ Only measurements annotation

Challenges

Requires expertise

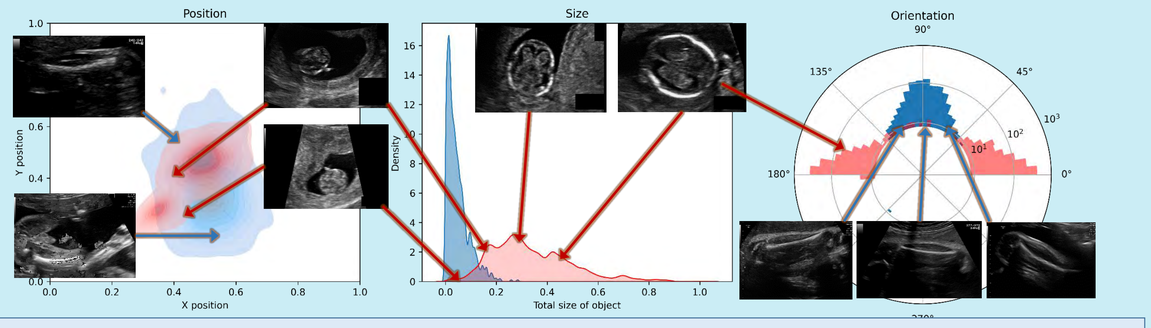


Each biometric measurement requires different geometric characteristic



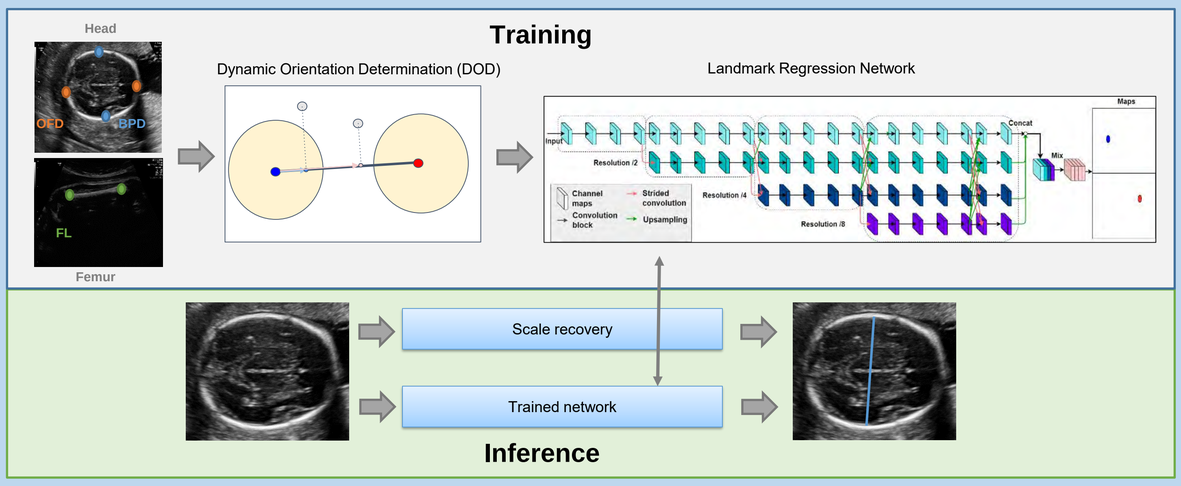
Observer variability and segmentation accuracy

US Variability



Proposing end-to-end framework automating fetal biometry for multiple fetal structures using direct landmark detection

BiometryNet framework

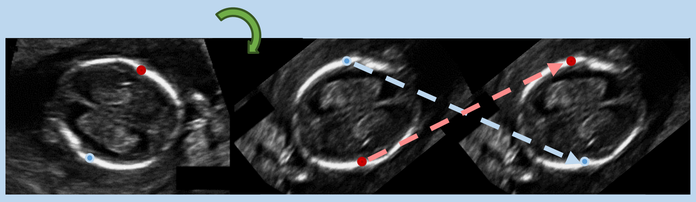


During training, annotated head and femur planes are fed into the Dynamic Orientation Determination (DOD) module and to the landmark regression network (a variant of HRNet) to predict two landmarks per biometric measurement. During Inference, the trained model predicts the landmarks followed by scale recovery (px→mm) for biometric measurements estimation.

Dynamic Orientation Determination

Motivation

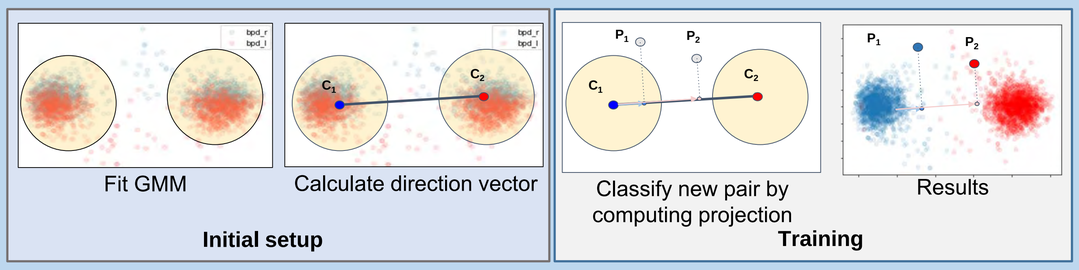
- How can we handle orientation variability? Augmentations.
- Augmentation may cause train inconsistencies in landmark class.



Original SP | After rotation augmentation | After Dynamic Orientation Determination

Solution: Dynamic Orientation Determination

- learn "normal" measurement direction vector at initial setup.
- Enforce standard landmark class by projecting and ordering using direction vector.

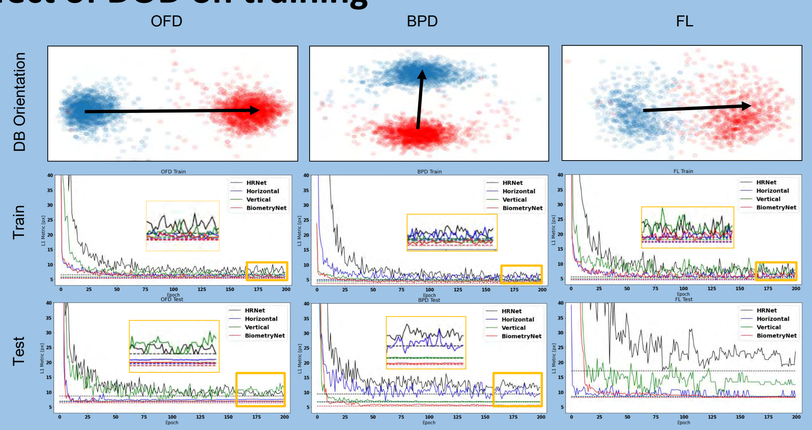


Data

- Two public datasets: HC18 and Fetal Planes (FP), 3 medical centers, 6 different US devices
- HC18: HC annotated → OFD,BPD extract with least-squares.
- Train set of 737 Head (600 subj.) images
- FP: published for US fetal planes automatic detection → FL, BPD,OFD manual annotation (took 20 sec per image).
- Train set of 757 (Head, 449 subj.) and 437 (Femur, 368 subj.) images

DB	HC18	FP		Total
	Head	Head	Femur	
Subjects	806	909	630	1829
Planes	999	1638	761	3398

Effect of DOD on training



Learned direction vector is similar to data orientation

BiometryNet converged faster, achieving better results

Performance

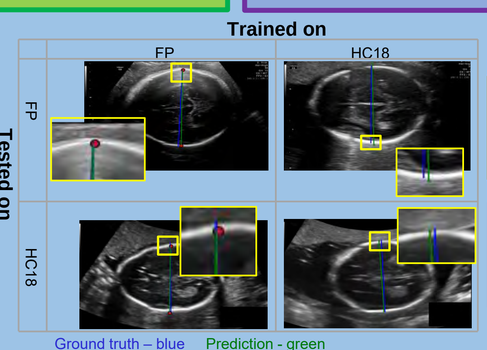
Train DB	Test DB	Method	Head - OFD				Head - BPD				Femur - FL			
			Bias [mm]	CI_{95} *[mm]*	L_1 *[mm]*	$\widetilde{L_1}$ *[mm]*	*Bias [mm]*	CI_{95} *[mm]*	L_1 *[mm]*	$\widetilde{L_1}$ *[mm]*	*Bias [mm]*	CI_{95} *[mm]*	L_1 *[mm]*	$\widetilde{L_1}$ *[mm]*
FP	**FP**	*HRNet*	6.23	26.40	6.30	3.30	2.84	22.57	3.20	0.80	1.80	18.40	2.70	0.62
		Horizontal	2.65	10.23	2.87	1.90	2.36	21.60	2.78	0.76	0.17	3.27	0.99	**0.59**
		Vertical	4.73	23.51	4.86	2.46	0.77	8.28	1.28	0.65	0.33	10.27	1.47	0.65
		*FMLNet**	1.96	7.80	2.16	1.43	1.30	14.56	1.71	0.65	**0.14**	**3.00**	1.02	0.68
		BiometryNet	**0.21**	**2.75**	**1.01**	**0.71**	**0.04**	**2.50**	**0.77**	**0.58**	0.18	3.03	**0.97**	0.62
	HC18	*BiometryNet*	2.31	5.21	2.46	1.85	0.84	2.70	1.06	0.91				
HC18	**HC18**	*HRNet*	0.64	6.01	1.51	0.92	2.64	21.48	3.10	0.71				
		Horizontal	2.82	23.9	3.69	0.93	1.35	12.86	1.75	**0.59**				
		Vertical	4.02	29.15	4.92	0.97	0.50	5.13	0.98	0.65				
		*FMLNet**	2.23	17.48	2.61	1.02	0.73	4.00	0.93	0.64				
		BiometryNet	**0.56**	**4.43**	**1.39**	**0.84**	**0.16**	**3.54**	**0.88**	0.61				
	FP	*BiometryNet*	-3.24	6.01	3.54	2.72	-1.11	3.35	1.40	1.08				

BiometryNet outperforms all other methods, in all biometric measurements

Using preferred fixed orientation (Horiz/Vert) of measurement improves over HRNet

Impact of training dataset

- We trained the OFD and BPD models on FP dataset and tested each on HC18, and vice versa.
- Bias can be explained by differences in annotation protocols between datasets.



Complementary biases between datasets

BiometryNet variance below interobserver in both datasets

Conclusions

BiometryNet requires only landmark annotation, achieving better results compared to other methods

DOD enforces measurement-wise orientation consistency, reducing inherent US plane variability effects, resulting in improved landmark localization

BiometryNet can learn different annotation protocols and measurements

References

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