Placental Flattening via Volumetric Parameterization

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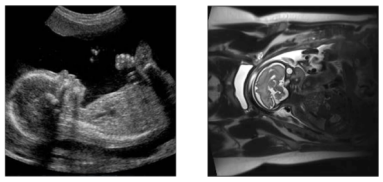
Goal: Improve visualization of placenta function and anatomy.

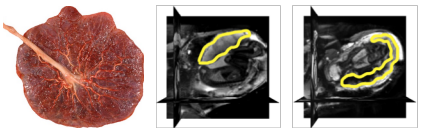
Clinical Motivations:

- Prevent pregnancy complications: assess placental function by fetal MRI

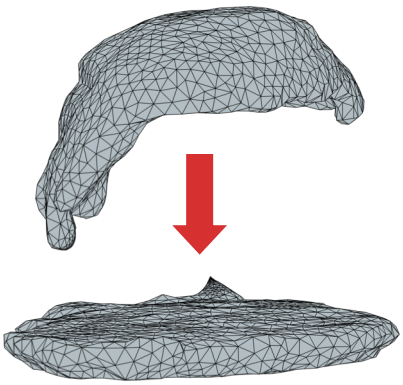


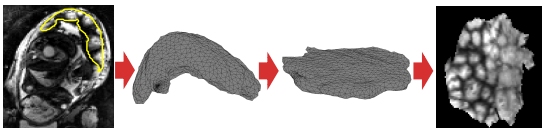
Ultrasound MRI

- Difficult to visualize and study function: variable placental shape and curved geometry



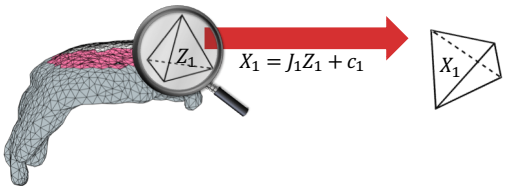
Approach: Map the placenta volume to a flattened template to resemble the well-studied post-birth shape.





Fetal MRI | Tetrahedral mesh | Flattened mesh | Flattened image

Map: Piecewise affine to a template



Mapping Objective Function:

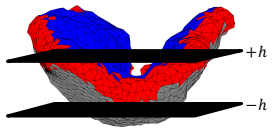
$$\phi(X,h) = \sum_{m:\, x_m \in \partial Z} \underbrace{A_m T(x_m,h)}_{\text{Template Match } (T)} + \lambda \underbrace{\sum_{k=1}^{K} V_k \mathcal{D}(J(X_k))}_{\text{Volumetric Distortion } (\mathcal{D})}$$

- Distortion: Symmetric Dirichlet Energy

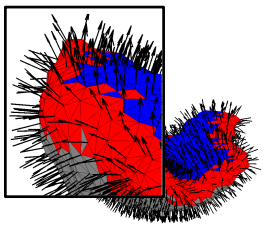
$$\mathcal{D}(J) = \|J\|_F^2 + \|J^{-1}\|_F^2 = \sum_{i=1}^{3} (\sigma_i^2 + \sigma_i^{-2})$$

- Template: Uniform thickness

$$T(x,h) = \begin{cases} (x^{(3)} - h)^2, & \text{if } x \in \mathcal{F}(\partial Z) \\ (x^{(3)} + h)^2, & \text{if } x \in \mathcal{M}(\partial Z) \\ 0 & \text{otherwise} \end{cases}$$



- Boundary parcellation: spectral clustering



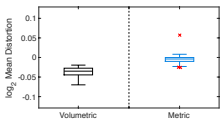
- Invertible map: no tetrahedron can "flip"

Dataset:

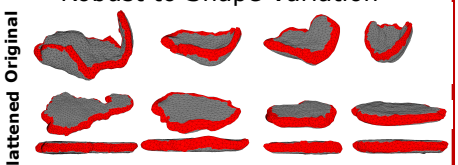
- X subjects, GA: X-Y weeks
- 105 segmentations
- BOLD MRI, Parameters:

Results:

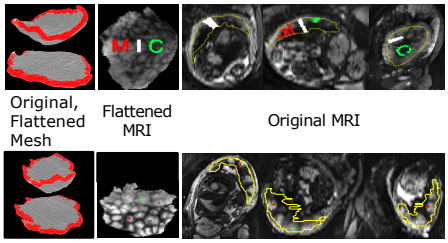
- Shape distortion: 4.1±1.9%
- Average template mismatch 0.07±0.03 voxels



- Robust to Shape Variation

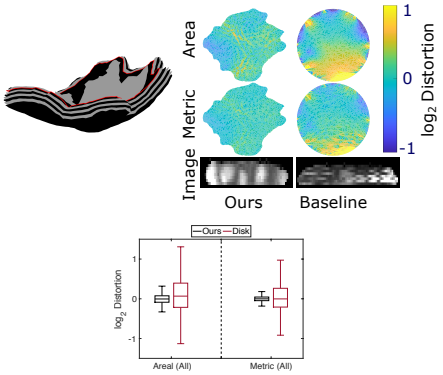


- Enables Contextual Visualization



Original, Flattened Mesh | Flattened MRI | Original MRI

- Improved distortion, visualization over 2D baseline[1]



1. Miao et al., "Placenta Maps…", IEEE TVCG: 23(6), 2017

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