AmnioML: Amniotic Fluid Segmentation and Volume Prediction with Uncertainty Quantification

Daniel Csillag, Lucas Monteiro Paes, Thiago Ramos, João Vitor Romano, Rodrigo Schuller, Roberto I. Oliveira, Roberto B. Seixas, Paulo Orenstein
Instituto de Matemática Pura e Aplicada, Rio de Janeiro, Brazil

Overview

- **Amniotic fluid** volume is a key indicator in a pregnancy's health
- **AmnioML** is a deep learning solution for automatic segmentation and volume estimation
- **Deployed** at DASA, AmnioML offers up to **20x** segmentation time reduction
- **Uncertainty quantification** empowers doctors and guides diagnostics
- **Dataset** of 853 fetal MRIs and medical segmentations made publicly available

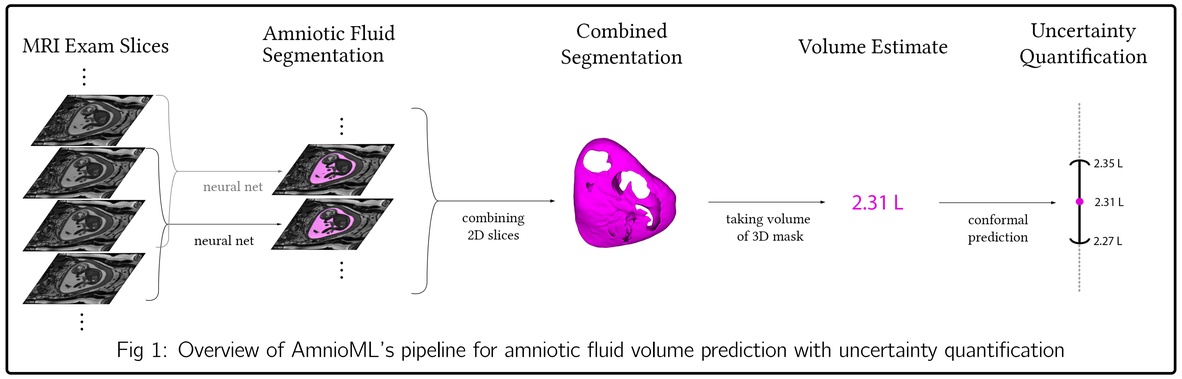

Fig 1: Overview of AmnioML's pipeline for amniotic fluid volume prediction with uncertainty quantification

AmnioML

AmnioML is a tool for automatic **amniotic fluid segmentation** and **volume estimation**, with valid **predictive intervals**.

A **U-Net** is used to predict the amniotic fluid. Hyperparameters were tuned via grid search and selected by the Dice loss on the validation set.

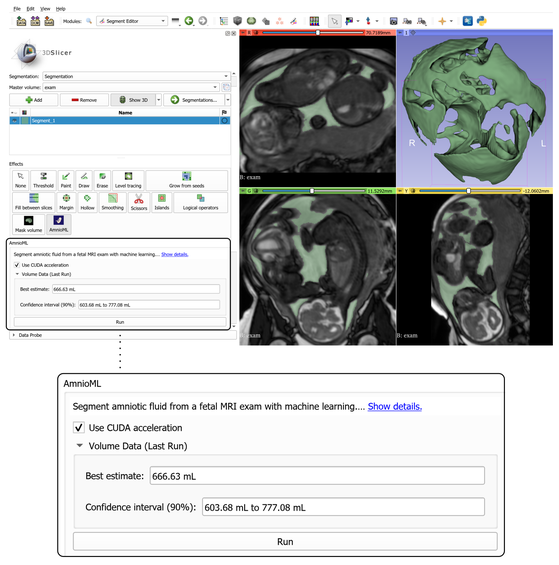

Fig 2: AmnioML's graphical user interface for 3D Slicer

Volume estimates produced by AmnioML have a **mean absolute error of just around 55mL**, displaying wide agreement with medical experts.

Novel Dataset

To train and test AmnioML, we collected **853 fetal MRI exams**, annotated by medical professionals, and make the resulting **dataset publicly available**. Annotations include: amniotic fluid segmentation masks, gestational week and pathologies exhibited throughout the pregnancy.

We gathered exams from multiple patients, with gestational age between 19 to 38 weeks. Over 65% of exams display some degree of pathology. Whenever one of the doctors disagreed with the segmentation, it was either refined or discarded.

Exams displaying significant motion artifacts were included for both training and testing purposes.

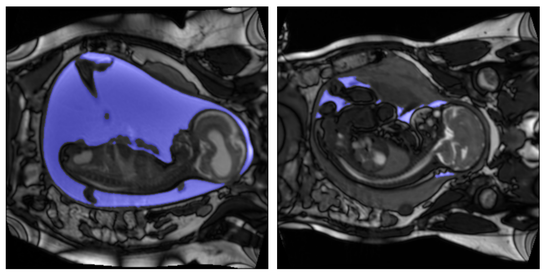

Fig 3: A polyhydramnios case (excessive volume, left) and an oligohydramnios case (reduced volume, right). Fluid in blue.

We believe this **dataset can be used for other important fetal tasks**, such as brain and lung segmentation and fetus' weight estimation.

Uncertainty Quantification

We developed novel uncertainty quantification techniques based on **conformal prediction** tailored to the medical segmentation task. The stakes are high in the field of medicine and point predictions are generally not enough; AmnioML's conformal tool builds **prediction intervals** with **statistical guarantees** around the initial point estimate.

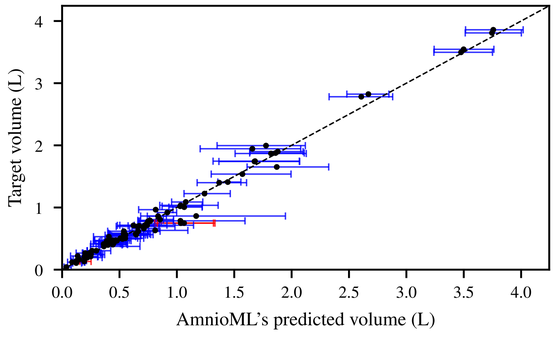

Fig 4: Comparison of AmnioML's volume prediction with target. Predictive intervals containing the target are in blue.

For any new MRI exam, AmnioML is able to quickly produce intervals at any coverage level picked by the user. There is a trade-off between nominal coverage and interval size. In collaboration with doctors, a coverage of 90% was found to strike a good balance and yield useful, narrow intervals for most previously unseen exams.

Deployment

AmnioML was deployed as a plugin for *3D Slicer*, and has been publicly released under an open-source license.

We perform **offline inference**, enabling a private and secure application. Analysis of a whole exam takes under **6 seconds** with a standard consumer-grade GPU, and takes at most 35 seconds on a CPU.

To evaluate our solution, new predictions were performed by a specialist employing AmnioML, and each was rated from 1 (worst) to 5 (best).

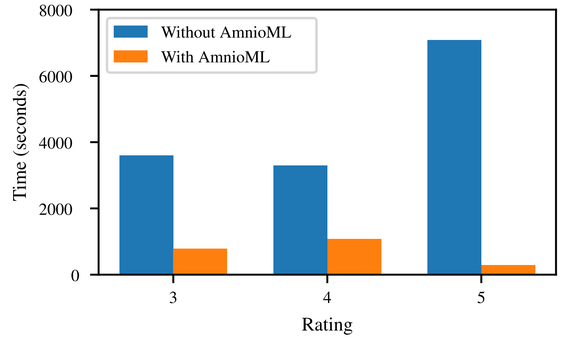

Fig 5: Segmentation times with and without the aid of AmnioML, grouped by the rating of the predictions.

Our ratings indicate that manual adjustments might still be needed in some cases (3 and 4), but over 60% of the time AmnioML is able to produce near-perfect segmentations (5). Ratings 1 and 2 were negligible. Our plugin enabled a clear improvement on segmentation time, being **20.7 times faster** than manual segmentations performed by trained professionals.

AmnioML code

Dataset download