

¹ Fetpipe: An Open-Source Pipeline for Reproducible ² Fetal Brain MRI Analysis

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¹⁰ Summary

¹¹ Fetal brain Magnetic Resonance Imaging (MRI) is crucial for assessing neurodevelopment
¹² *in utero*. However, analyzing this data presents significant challenges due to fetal motion,
¹³ low signal-to-noise ratio, and the need for complex multi-step processing, including motion
¹⁴ correction, super-resolution reconstruction, segmentation, and surface extraction. While various
¹⁵ specialized tools exist for individual steps, integrating them into robust, reproducible, and
¹⁶ user-friendly workflows that go from raw images to processed volumes is not straightforward.
¹⁷ This lack of standardization hinders reproducibility across studies and limits the adoption of
¹⁸ advanced analysis techniques for researchers and clinicians. To address these challenges, we
¹⁹ introduce Fetpipe, an open-source Python library designed to streamline and standardize the
²⁰ preprocessing and analysis of T2-weighted fetal brain MRI data as illustrated in (Figure 1).

²¹ Statement of need

²² Fetpipe is a Python package integrating several established neuroimaging software principles
²³ and tools to create a cohesive and extensible framework, which we summarize in four points.

- ²⁴ 1. **Data Standardization:** Fetpipe expects input data organized according to the Brain Imaging
²⁵ Data Structure (BIDS) standard ([Gorgolewski et al., 2016](#)), promoting interoperability
²⁶ and simplifying data management.
- ²⁷ 2. **Containerization:** Individual processing tools are encapsulated within Docker or Singularity
²⁸ containers. This ensures reproducibility and reduces installation issues, providing a better
²⁹ experience for the end user.
- ³⁰ 3. **Workflow Management:** The Nipype library ([Gorgolewski et al., 2011](#)) is used to
³¹ construct processing workflows: it provides a robust interface for combining different
³² steps from different containers or packages, facilitating data caching and parallelization,
³³ and allowing pipelines to be easily shareable.
- ³⁴ 4. **Configuration:** Pipeline configuration is managed using simple YAML files and the
³⁵ Hydra library ([Yadan, 2019](#)), allowing users to easily select between different modules or
³⁶ parameters without directly modifying the code. The current implementation of Fetpipe
³⁷ integrates modules for:
 - ³⁸ a. **Data preprocessing:** including brain extraction using Fetal-BET ([Faghhihirayesh
et al., 2024](#)), non-local means denoising ([Manjón et al., 2010](#)) and N4 bias-field
correction ([Tustison et al., 2010](#)), all wrapped into a single container built at
https://github.com/fetpipe/utils_container,

- 42 b. **Super-resolution reconstruction:** implementing three widely used pipelines: NeSVoR
- 43 ([Xu et al., 2023](#)), SVRTK ([Kuklisova-Murgasova et al., 2012](#); [Alena U. Uus et al., 2022](#)), and NiftyMIC ([Ebner et al., 2020](#)),
- 44 c. **Segmentation:** implementing BOUNTI ([Alena U. Uus et al., 2023](#)) and the developing human connectome project pipeline ([Makropoulos et al., 2018](#)) and
- 45 d. **Cortical surface extraction:** using a custom implementation available at https://github.com/fetppipe/surface_processing based on ([Bazin & Pham, 2005, 2007](#); [Ma et al., 2022](#)).

50 The objective underlying the conceptualization of Fetppipe is to provide the fetal MRI community with a standardized, reproducible, and flexible open-source platform for preprocessing and analysis. By providing a modular Nipype-based framework, it facilitates the integration of 51 custom community tools through containerized interfaces and clear contribution guidelines. 52 Fetppipe aims to advance research by improving comparability across studies and fostering 53 community collaboration by facilitating the dissemination of new image processing methods 54 for clinical applications. The pipeline is publicly available on GitHub (<https://github.com/fetppipe/fetppipe>).

55 In the future, we plan to supplement Fetppipe with an automated reporting library containing 56 automated quality control ([Sanchez et al., 2026, 2024](#)), subject-wise and population-wise 57 biometry and volumetry ([Esteban et al., 2017](#); [Neves Silva et al., 2025](#)), as well as spectral 58 analysis of surfaces ([Germanaud et al., 2012](#)). We welcome contributions of authors desiring 59 to integrate their method to Fetppipe.

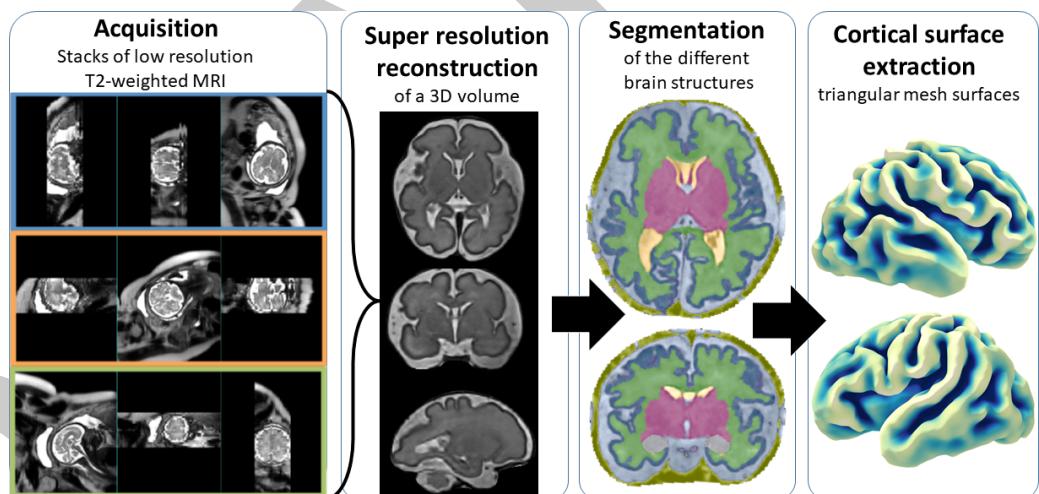


Figure 1: The different steps covered by Fetppipe. Starting from several T2-weighted stacks of thick slices of the fetal brain (*acquisition*), Fetppipe pre-processes data before feeding them to a *super-resolution reconstruction* algorithm that fuses them in a single high-resolution volume. This volume then undergoes *segmentation*, before moving to *cortical surface extraction*.

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