

Fetpype: An Open-Source Pipeline for Reproducible Fetal Brain MRI Analysis

Thomas Sanchez^{1,2*}, Gerard Martí-Juan^{3*}, David Meunier⁴, Miguel Angel Gonzalez Ballester^{3,5}, Oscar Camara³, Elisenda Eixarch^{6,7}, Gemma Piella³, Meritxell Bach Cuadra^{1,2}, and Guillaume Auzias⁴

¹ CIBM – Center for Biomedical Imaging, Switzerland ² Department of Diagnostic and Interventional Radiology, Lausanne University Hospital and University of Lausanne, Switzerland ³ BCN MedTech, Department of Engineering, Universitat Pompeu Fabra, Spain ⁴ Aix-Marseille Université, CNRS, Institut de Neurosciences de La Timone, France ⁵ ICREA, Barcelona, Spain ⁶ BCNatal | Fetal Medicine Research Center (Hospital Clínic and Hospital Sant Joan de Déu, Universitat de Barcelona), Barcelona, Spain ⁷ Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain and Centre for Biomedical Research on Rare Diseases (CIBERER), Barcelona, Spain * These authors contributed equally.

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Software

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Summary

Fetal brain magnetic resonance imaging (MRI) is crucial for assessing neurodevelopment *in utero*. However, fetal MRI analysis remains technically challenging due to fetal motion, low signal-to-noise ratio, and the need for complex multi-step processing pipelines. These pipelines typically include motion correction, super-resolution reconstruction, tissue segmentation, and cortical surface extraction. While specialized tools exist for each individual processing step, integrating them into a robust, reproducible, and user-friendly end-to-end workflow remains difficult. This fragmentation limits reproducibility across studies and hinders the adoption of advanced fetal neuroimaging methods in both research and clinical contexts.

Fetpype addresses this gap by providing a standardized, modular, and reproducible framework for fetal brain MRI preprocessing and analysis, enabling researchers to process raw T2-weighted acquisitions through to derived volumetric and surface-based outputs within a unified workflow.

Statement of need

Fetpype is an open-source Python package designed to streamline and standardize the preprocessing and analysis of T2-weighted fetal brain MRI data. The package targets the fetal neuroimaging community, where methodological heterogeneity and complex software dependencies have historically limited reproducibility and comparability across studies.

Existing fetal brain MRI tools typically focus on individual processing steps and require customized code for pre- and post-processing, as well as to connect different modules, making it difficult to reproduce processing results across studies. Fetpype addresses these challenges by providing a configurable, containerized, and Nipype-driven solution that integrates state-of-the-art fetal MRI processing tools into a cohesive pipeline. By emphasizing reproducibility, extensibility, and ease of use, Fetpype lowers the barrier to applying advanced fetal MRI analysis methods and facilitates consistent processing across sites, scanners, and studies. In doing so, Fetpype improves comparability across studies and supports community collaboration by facilitating the dissemination of new image processing methods for clinical applications. The pipeline is publicly available on GitHub (<https://github.com/fetpype/fetpype>).

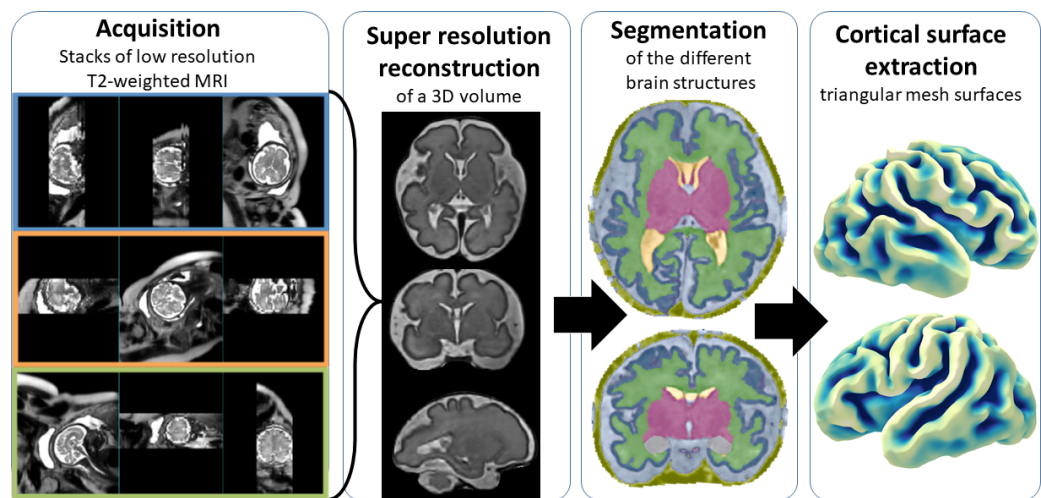


Figure 1: The different steps covered by Fetpype. Starting from several T2-weighted stacks of thick slices of the fetal brain (*acquisition*), Fetpype pre-processes data before feeding them to a *super-resolution reconstruction* algorithm that fuses them in a single high-resolution volume. This volume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

State of the field

Fetal brain MRI analysis relies on a range of specialized tools that address individual processing steps, particularly motion correction and super-resolution reconstruction. Widely used reconstruction frameworks include SVRTK (C++) (Kuklisova-Murgasova et al., 2012; Alena U. Uus et al., 2022), NiftyMIC (Python) (Ebner et al., 2020), and NeSVoR (Python/PyTorch) (Xu et al., 2023). While increasingly distributed as containers, these tools rely on distinct data organization schemes as well as custom pre- and post-processing steps. Downstream processing tools for brain extraction, segmentation, and surface reconstruction show similar diversity, combining Python scripts, compiled binaries, and domain-specific imaging libraries (Bazin & Pham, 2005; Faghihipirayesh et al., 2024; Makropoulos et al., 2018; Alena U. Uus et al., 2023). As a result, constructing an end-to-end fetal MRI workflow typically requires custom scripting to orchestrate multiple containers, manage data formats, and handle intermediate outputs, limiting reproducibility and accessibility.

Fetpype was built to address these limitations by providing a unified, Python-based framework to integrate existing containerized tools for fetal brain MRI analysis. By enforcing data formatting following the widely-used Brain Imaging Data Structure (BIDS) standard (Gorgolewski et al., 2016), and leveraging containerized execution and Nipype-based workflow management (Gorgolewski et al., 2011) and Hydra-based configuration (Yadan, 2019), Fetpype provides a standardized and scalable environment for reproducible end-to-end fetal brain MRI analysis on both local workstations and large-scale computing clusters.

Software design

Fetpype is built around four core design principles: data standardization, containerization, workflow orchestration, and flexible configuration:

- Data Standardization:** Fetpype expects input data organized according to the BIDS standard (Gorgolewski et al., 2016), promoting interoperability and simplifying data management.
- Containerization:** Individual processing tools are encapsulated within Docker or Singularity containers. This ensures reproducibility and reduces installation issues, providing a better

- 69 experience for the end user.
- 70 3. **Workflow Management:** The Nipype library ([Gorgolewski et al., 2011](#)) is used to
- 71 construct processing workflows: it provides a robust interface for combining different
- 72 steps from different containers or packages, facilitating data caching and parallelization,
- 73 and allowing pipelines to be easily shareable.
- 74 4. **Configuration:** Pipeline configuration is managed using simple YAML files and the
- 75 Hydra library ([Yadan, 2019](#)), allowing users to easily select between different modules or
- 76 parameters without directly modifying the code. The current implementation of Fetpype
- 77 integrates modules for:
- 78 a. **Data preprocessing:** including brain extraction using Fetal-BET ([Faghihpirayesh](#)
- 79 [et al., 2024](#)), non-local means denoising ([Manjón et al., 2010](#)) and N4 bias-field
- 80 correction ([Tustison et al., 2010](#)), all wrapped into a single container built at
- 81 https://github.com/fetpype/utls_container,
- 82 b. **Super-resolution reconstruction:** implementing three widely used pipelines: NeSVoR
- 83 ([Xu et al., 2023](#)), SVRTK ([Kuklisova-Murgasova et al., 2012](#); [Alena U. Uus et al.,](#)
- 84 [2022](#)), and NiftyMIC ([Ebner et al., 2020](#)),
- 85 c. **Segmentation:** implementing BOUNTI ([Alena U. Uus et al., 2023](#)) and the
- 86 developing human connectome project pipeline ([Makropoulos et al., 2018](#)) and
- 87 d. **Cortical surface extraction:** using a custom implementation available at
- 88 https://github.com/fetpype/surface_processing based on ([Bazin & Pham, 2005,](#)
- 89 [2007](#); [Ma et al., 2022](#)).

90 The overall processing workflow is summarized in [Figure 1](#).

91 Research impact statement

92 Fetpype is the result of a longstanding collaboration within a European consortium of researchers

93 specializing in fetal neuroimaging. Its default configurations and processing workflows have

94 been the result of extensive testing to achieve robust processing on data acquired across multiple

95 hospitals in France, Spain, and Switzerland, covering a range of scanners and acquisition

96 protocols.

97 The framework has been used to process large-scale fetal MRI datasets within the consortium,

98 has contributed to a first publication ([Sanchez, Mihailov, et al., 2026](#)), and is supporting

99 ongoing research projects. Fetpype is used by multiple research groups and has begun to receive

100 external contributions, including pull requests that integrate additional processing methods.

101 This suggests that Fetpype addresses a clear methodological need and can serve as shared

102 community infrastructure for fetal brain MRI research.

103 In the future, we plan to supplement Fetpype with an automated reporting library containing

104 automated quality control ([Sanchez, Zalevskiy, et al., 2026](#); [Sanchez et al., 2024](#)), subject-wise

105 and population-wise biometry and volumetry ([Esteban et al., 2017](#); [Neves Silva et al., 2025](#)),

106 as well as spectral analysis of surfaces ([Germanaud et al., 2012](#)). We welcome community

107 contributions, particularly implementations of new methods that can be integrated into the

108 existing containerized workflow framework.

109 AI usage disclosure

110 GitHub Copilot, integrated within Visual Studio Code, was used during software development

111 to assist with code completion and implementation. ChatGPT (GPT-5.2) was used for

112 proofreading and language refinement of the manuscript. The authors take full responsibility

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