École Polytechnique Fédérale de Lausanne
School of Architecture, Civil and Environmental Engineering
Civil Engineering & Environmental Science and Engineering Sections
Laboratory of SusTainable River Engineering, Energy, and Morphodynamics (STREEM)

Project Proposal - AI for river morphology

Professor responsible: Prof. Mirko Musa (mirko.musa@epfl.ch)
Assistant responsible: Antonio Magherini (antonio.magherini@epfl.ch)
Delivery of final report: TBD

Figure 1: Brahmaputra River (braided) at the border between India and Bangladesh.

Introduction

Predicting the morphological changes of rivers is crucial for water management studies, infrastructure planning, ecosystem conservation, among many other purposes. For achieving this, river engineers set up physics-based models, like BASEMENT, Delft3D, etc., which solve traditional physical laws. These models generally provide reliable predictions for basic river morphologies or reaches with limited extensions. However, they are often less accurate when modelling and forecasting the (long-term) evolution of meandering and specifically braided rivers (Figure 1). In recent years, AI algorithms were successfully applied to different contexts and fields. To this end, these models could become a relevant alternative for river morphological predictions, supported by the use of various satellite imagery collections, freely available online (e.g., Google Earth Engine).

Preliminary research on a braided river shows that deep-learning models can capture the most relevant aspects of the morphological evolution (Magherini, 2024a). However, finer details and more complex

situations cannot be predicted yet (Figures 2 and 3). The promising results and current limitations leave open avenues and unanswered questions for further exploration. The student will develop his own research plan, highlighting and proposing research directions in accordance to relevant literature, his interests, and the suitability within the project. The existing model and datasets are already available online (Magherini, 2024b).

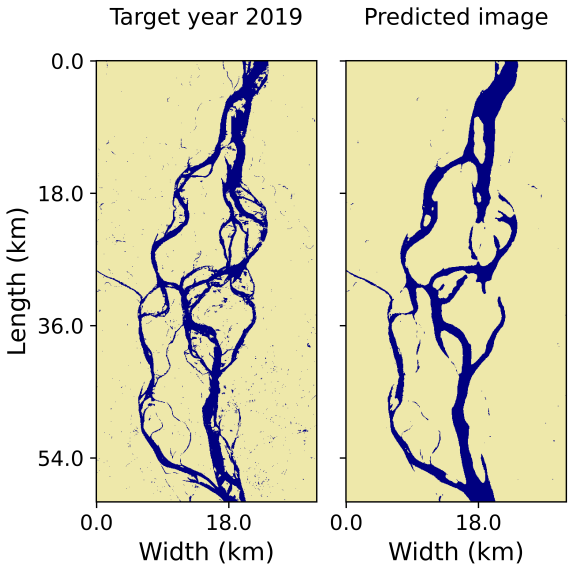

Figure 2: Real (left) and predicted (right) images of the morphological evolution of the Brahmaputra River. Blue areas represent the river, whereas yellow areas represent all other land-uses.

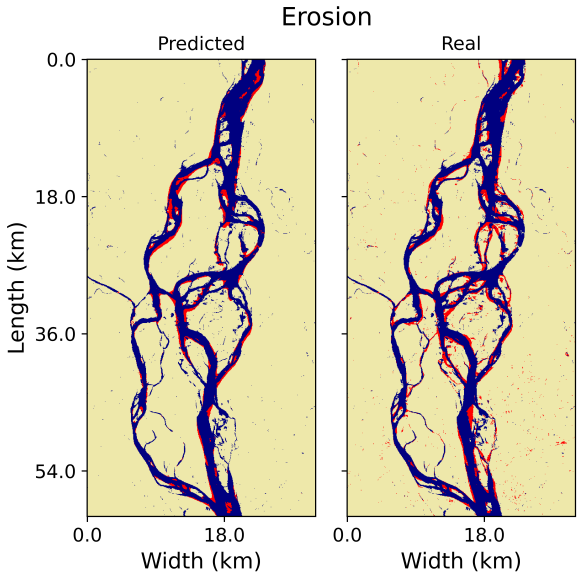

Figure 3: Prediction of the areas of erosion (red pixels) of the Brahmaputra River and comparison with the real areas.

Project Objectives

The project is open to be developed as a Bachelor/Master Semester Project, a Master's Thesis, or a combination of both. Depending on this, the objectives and deliverables will be adapted accordingly. In any case, the main objective of the project is to advance the research on artificial intelligence application and modelling for predicting the morphological evolution of (braided) rivers. Several strategies and suggestions are already available, like enhancing temporal pattern recognition, testing new architectures and losses, testing the model on different rivers, including physics-induced loss terms, etc. This can be done by generating new worldwide datasets of rivers, developing new deep-learning models, or improving the existing ones. In detail, by the end of the project we expect to reach (some of) the following objectives:

- Retrieving available satellite imagery collections and assessing their potential use for river morphological modelling.
- Retrieving additional hydrologic or hydraulic data (discharge, water level, sediment grading, etc.) to assist the modelling task.
- Implementing a deep-learning model for predicting the planform evolution of (braided) rivers.
- Training, validating, and testing the model with the available datasets. Testing with additional datasets would be ideal.
- Identifying challenges and limitations in the prediction of planform evolution of rivers.
- Suggesting improvements and future research directions.

- Developing the ability to interpret model outputs and assess its performance.

Prerequisites

- Machine Learning/Deep Learning background, preferably with successful results on Bachelor or Master courses as CIVIL-226 (Introduction to machine learning for engineers), CIVIL-127 (Programming and software development for engineers), CIVIL-611 (Frontiers of Deep Learning for Engineering), or related courses from other Schools.
- Programming experience, preferably but not necessarily with Python.
- Basic knowledge of hydraulics and river morphology is helpful but not required.
- Basic knowledge of satellite imagery and Google Earth Engine is helpful but not required.

Expected Deliverable

The student will prepare a report documenting the methodology, results, discussion, limitations, conclusions, and future research directions of the project. The document should include at minimum:

- Introduction of the topic, with a clear definition of the research gaps and relevant literature supporting the study.
- Description of the model setup, including architectural choices, loss functions and metrics.
- Description of the dataset(s) and the preprocessing techniques adapted.
- Presentation of the results in terms of metric scores and visual outputs generated by the model.
- Interpretation of the predictive capabilities, linked with the undergoing morphological processes (if the student has an hydraulic engineering background or similar).
- Discussion of methodology, results, and limitations of the research (data, model, assumptions, etc.).
- Identification of the main challenges associated with modeling natural river environments with artificial intelligence and suggestions for future research.

References

Magherini, A. (2024a, October). *JamUNet: Predicting the morphological changes of braided sand-bed rivers with deep learning* [Master's thesis, TU Delft]. https://repository.tudelft.nl/record/uuid:38ea0798-dd3d-4be2-b937-b80621957348

Magherini, A. (2024b, November). JamUNet GitHub repository. https://github.com/antoniomagherini/jamunet-morpho-braided