Predicting the morphological changes of rivers from remote sensing imagery using Deep Learning

October 30, 2024

1 Goal

The primary objective of this project is to explore the use of deep learning for predicting morphological changes in rivers. This project builds on the work of MSc student Antonio Magherini, who developed the JamUNet model, a U-Net-based convolutional neural network, to predict river planform evolution using satellite imagery data (Magherini 2024).

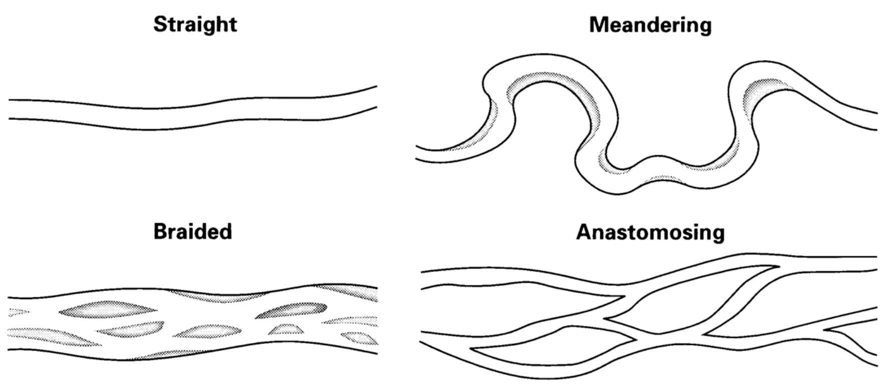

Figure 1: Sketch of straight, meandering, braided and anastomosing channels. Image from `https://tucanada.org/2022/10/14/wandering-waterways/`.

2 Introduction

Predicting river morphological changes is essential for managing water resources, conserving ecosystems, and planning infrastructure, as shifting channels impact both natural and human environments. Braided rivers are especially dynamic, with their complex, interweaving channels that shift frequently due to variable flows and sediment transport (see Figure 1). Traditional models often struggle with this complexity, but deep learning approaches, like the one proposed by (Magherini 2024) can capture aspects of the evolving morphology using satellite imagery (see Figure 2 and 3). His research on the Brahmaputra-Jamuna River, a major braided sand-bed river, demonstrated promising results in capturing river dynamics but left open avenues for further exploration, particularly in enhancing temporal pattern recognition, testing new architectures and exploring other case studies.

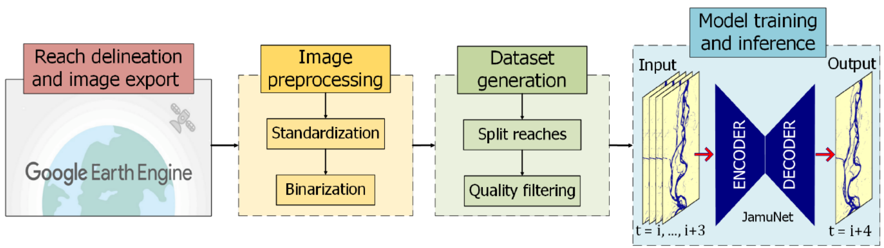

Figure 2: The workflow of JamUNet, from Magherini (2024).

3 Dataset

This project can be carried out using the same primary dataset employed in Magherini (2024): a subset of the Global Surface Water Dataset (GSWD) relative to the Brahmaputra-Jamuna River. The GSWD images are post-processed and pre-classified into "Water" and "Non-water" areas (see Figure 4). Students may also extend the dataset using the scripts employed in Magherini (2024), retrieving additional satellite images using similar preprocessing and acquisition techniques. They can leverage QGIS or Google Earth Engine to investigate additional rivers with similar characteristics. Alternatively, the students can use different data sources, such as raw Landsat and Sentinel imagery.

4 Potential Research Questions

Building on Magherini (2024), students can focus on reproducing the JamUNet model (see Figure

- **Reproduction and Extension of JamUNet**
  - Can the model architecture and results from Magherini (2024) be faithfully replicated, providing a consistent benchmark for further study?
  - Can different convolutions be implemented to better capture the temporal dynamics?

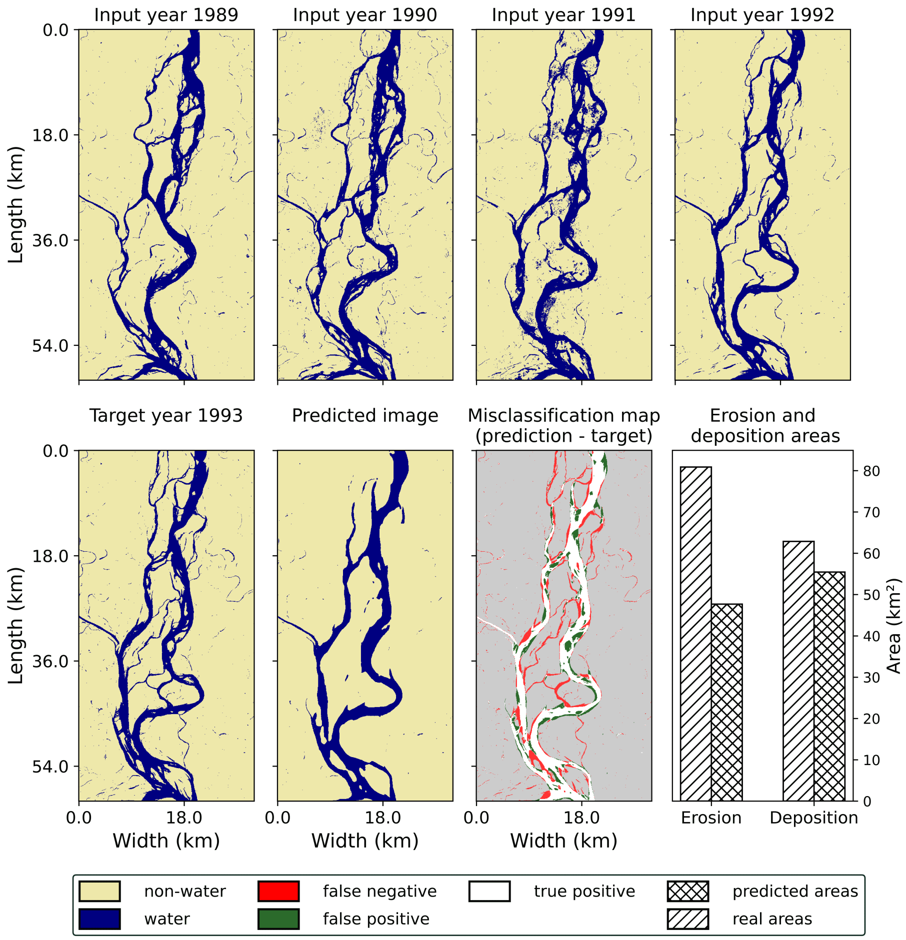

Figure 3: JamUNet predictions for a test sample, from Magherini (2024).

- Can different loss functions lead to better test predictions?

- **Benchmarking with Other Models**
  - Magherini (2024) performed a qualitative comparison against the results of a basic neural network from Jagers (2003). Can this simpler model be implemented for comparison?
  - How does this simpler model actually compare against JamUNet when trained on the same data?

- **Transfer Learning Applications**
  - Transfer learning involves adapting a model pre-trained on a large dataset to a specific problem, often leading to improved performance

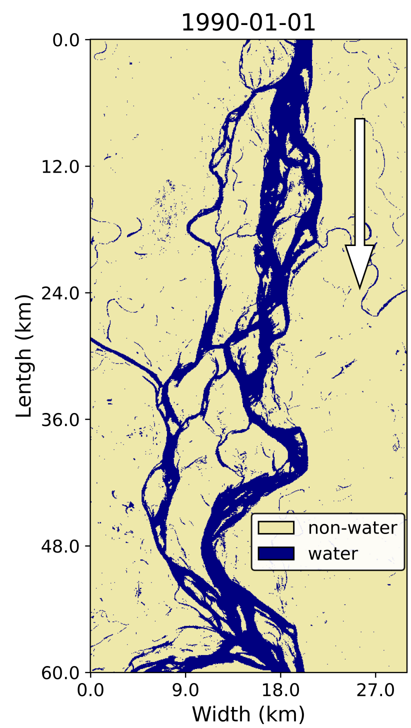

Figure 4: A sample image from the dataset used in Magherini (2024).

with less training data. Can we fine-tune Prithvi (Jakubik et al. 2023)—a large Deep Learning foundational model for geospatial analysis—for river morphology prediction? How does it perform compared to JamUNet, which was trained from scratch on a small dataset?

– Similarly, TorchGeo—–a library of geospatial data and pre-trained models—–offers pre-trained models for trannsfer learning (Stewart et al. 2022). Can we fine tune them for river morphology prediction, and how does their performance compare to JamUNet?

5 Tentative Timeline

The students will be expected to work in teams to tackle the research questions outlined above, or others they deem more interesting.

- Week 1-2: Formation of groups, assignment of roles, introduction to project.
- Weeks 3-4: Literature review (starting from the Reference section at the end of this document), exploration of the dataset, definition of research

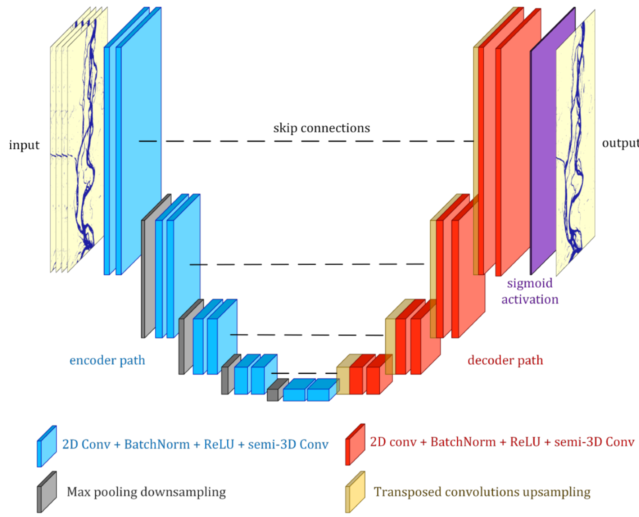

Figure 5: The JamUNet model of Magherini (2024).

questions, basic practice with specialized tools (see below), construction of benchmarks.

- Weeks 5-9: Conduct experiments, gather results, and verify findings.
- Week 10: Final presentation.

6 Tools and Resources

- Programming languages: Python
- Frameworks: PyTorch, TorchGeo, foundational models, Google Earth Engine, ...
- Computational resources: each group will be provided with RunPod machines (i.e., good GPUs)
- Datasets: see sections above

References

Jagers, Hendrik Reinhard Albert (2003). "Modelling planform changes of braided rivers". In.

Jakubik, Johannes et al. (2023). *Foundation Models for Generalist Geospatial Artificial Intelligence*. arXiv: `2310.18660 [cs.CV]`. URL: `https://arxiv.org/abs/2310.18660`.

Magherini, Antonio (Oct. 2024). "JamUNet: Predicting the Morphological Changes of Braided Sand-Bed Rivers with Deep Learning". Master's thesis. MA thesis. Delft, Netherlands: Delft University of Technology. URL: https://resolver.tudelft.nl/uuid:38ea0798-dd3d-4be2-b937-b80621957348.

Stewart, Adam J et al. (2022). "Torchgeo: deep learning with geospatial data". In: *Proceedings of the 30th international conference on advances in geographic information systems*, pp. 1–12.