Coastal Zone Monitoring & Evolution Forecasting Using Remote Sensing & Artificial Intelligence

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- Artificial Intelligence enables the automatic construction of models from data
- Deep learning and Genetic Programming are employed for two complementary projects
- Forecasting coastal bathymetry evolution from space is the long term goal

Importance of Coastal Zones

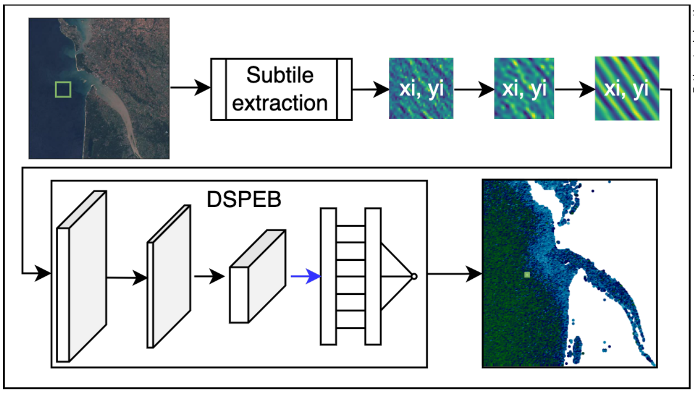
Coastal communities represent 37% of the global population:
- 600 million people in coastal areas (<10 m above sea level)
- 2.4 billion people within 100 km of the coast

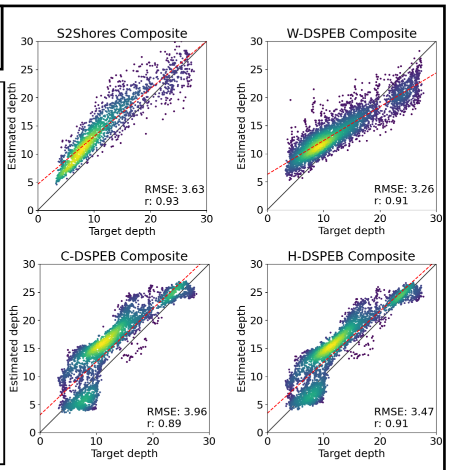
Coastal zones are crucial for different **societal & economical** factors:
- Fishing is a major source for food and income in developing societies
- Fisheries contribute $100 billion per year and about 260 million jobs to the global economy

Climate change and coastal zone studies are interrelated:
- Sea level rise leads to coastal erosion, inundations, storm floods, contamination of freshwater reserves and food crops, among others
- Increasing seawater temperatures provide more energy for storms that develop at sea, leading to more intense tropical cyclones globally

Project 1: Satellite Derived Bathymetry using Deep Learning

Here, we developed a technique, named Deep Single-Point Estimation of Bathymetry (DSPEB), for estimating coastal bathymetry from Sentinel-2 imagery using Convolutional Neural Networks. The neural network is trained on 400*400 m preprocessed subtiles in order to estimate a single depth point at a time. Further details on works and variants of DSPEB in [1, 2, 3].





Project 2: Forecasting Shoreline Change using Cartesian Genetic Programming

CGP allows us to encode a system of equations into a graph structure that can be evolved using a genetic algorithm in order to maximize its performance. The new system of equations can then be interpreted at the end of evolution. Here, we evolve ShoreFor and guide its evolution by assessing its performance at multiple sites from around the world.

Further technical details in [4].

ShoreFor

$$\frac{dx}{dt} = c(F^+ + rF^-) + b$$

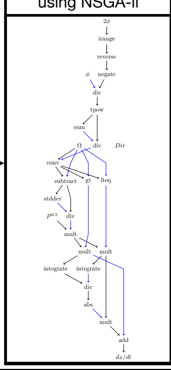
$$\Omega_{eq} = \frac{\sum_{i=1}^{2\phi} \Omega_i 10^{-i/\phi}}{\sum_{i=1}^{2\phi} 10^{-i/\phi}}$$

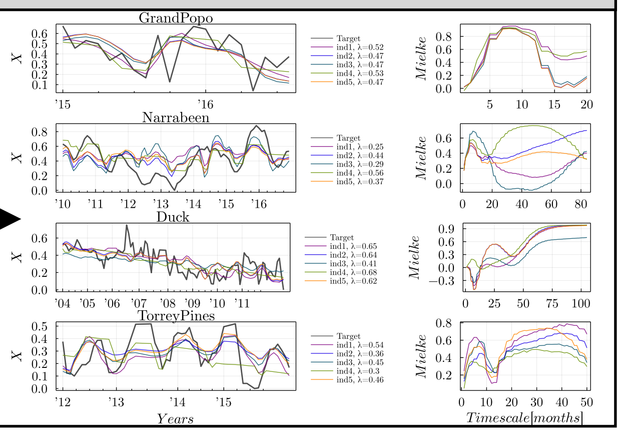
$$F = P^{0.5}\frac{\Delta\Omega}{\sigma_{\Delta\Omega}}$$

$$r = \left| \frac{\sum_{i=0}^{N} \langle F_i^+ \rangle}{\sum_{i=0}^{N} \langle F_i^- \rangle} \right|$$

$$\Omega = \frac{H_{s,b}}{wT_p}$$

Genetic Improvement using NSGA-ii





Future Thesis Directions

- Forecasting the evolution of global shoreline clusters using CGP and satellite-derived shoreline datasets
- Experimentation on the extension of the CGP-ShoreFor model to bathymetry features, where the DSPEB part of the work could be coupled with our CGP work in to order to forecast coastal bathymetry evolution from satellite imagery

References

[1] Al Najar, Mahmoud, et al. "Satellite derived bathymetry using deep learning." *Machine Learning* (2021): 1-24.
[2] Al Najar, Mahmoud, et al. "Coastal Bathymetry Estimation from Sentinel-2 Satellite Imagery: Comparing Deep Learning and Physics-Based Approaches." Remote Sensing 14.5 (2022): 1196.
[3] Al Najar, Mahmoud, et al. "A Combined Color and Wave-based Approach to Satellite Derived Bathymetry Using Deep Learning." *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences* 43 (2022): 9-16.
[4] Al Najar, Mahmoud, et al. "Genetic improvement of shoreline evolution forecasting models." *Proceedings of the Genetic and Evolutionary Computation Conference Companion*. 2022.
[5] Masselink, Gerd, et al. "The extreme 2013/2014 winter storms: hydrodynamic forcing and coastal response along the southwest coast of England." *Earth Surface Processes and Landforms* 41.3 (2016): 378-391.

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