Enhancing ecological predictions of tidal flats of the Dutch Wadden Sea using Variational Auto Encoder Features

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Abstract

Tidal flats are among the ecologically richest areas of the world where sediment composition and the macrozoobenthic presence play an important role in the health of the ecosystem. Regular monitoring of environmental and ecological variables is essential for sustainable management of the area. While monitoring based on field sampling is very time-consuming, the predictive performance of these variables using satellite images is low due to the spectral homogeneity over these regions. We tested a novel approach that uses features from a variational autoencoder (VAE) model to enhance the predictive performance of remote sensing images for environmental and ecological variables of tidal flats. The model was trained using the Sentinel-2 spectral bands to reproduce the input images, and during this process, the VAE model represents important information on the tidal flats within its layer structure. The encoded features and the spectral bands together form the input to random forest models to predict field observations of the sediment characteristics such as median grain size and silt content, as well as the macrozoobenthic biomass and species richness. The maximum prediction accuracy of the feature-based approach was close to 62% for the sediment characteristics and 37% for benthic fauna indices. Our method enhances the predictive performance by 15%, for both the sediment and benthic characteristics, thereby contributing to better-informed management of coastal ecosystems.

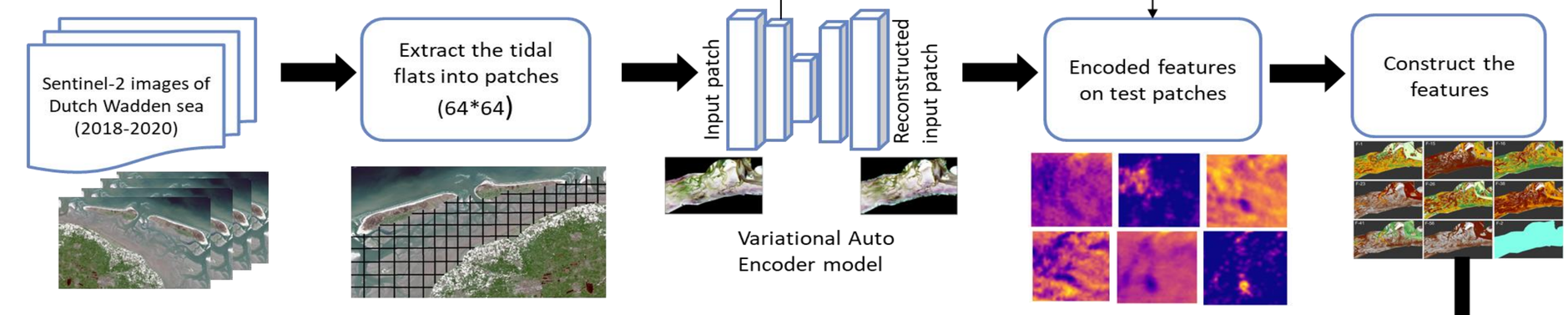
Research questions

- How to extract the VAE features?
- What are the added values of VAE features?
- How well are the ecological variables predicted?
- How much does VAE features contribute?

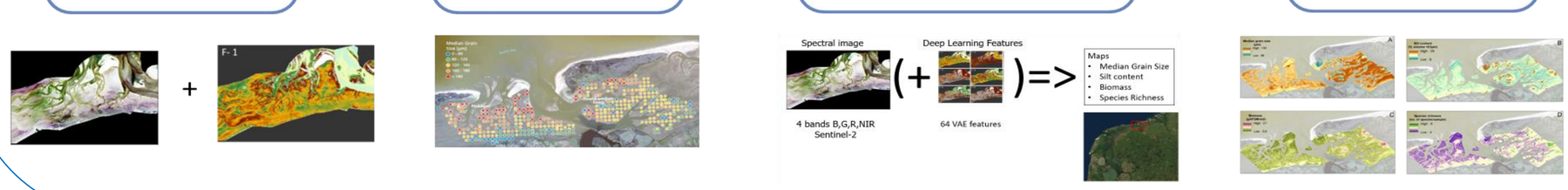
Data

- Sentinel-2 (L1C) R,G,B,NIR
- Synoptic Intertidal Benthic Survey (SIBES) -500*500m grid
- Prediction variables
  - Median Grain size (µm)
  - Silt Content (%)
  - Benthic biomass (gAFDM/m2)
  - Species richness (no. of species/sample)

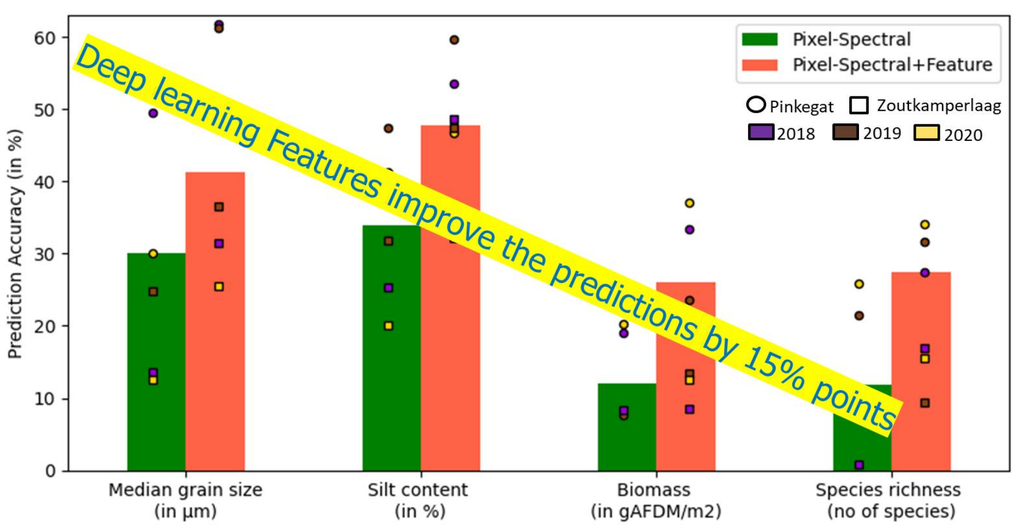
Workflow



- Variational Autoencoder model
  - R, G, B, NIR
  - ResNet-50
  - Encoder-Decoder
  - MSE+KL loss
- Random forest regressor



Predictions-Pinkegat + Zoutkamperlaag for three years



Conclusions

The VAE features clearly show differing spatial expressions of image information, which provided a 15% point improvement over the prediction of the ecological variables. The enhancement of the spectral information with the features extracted from the deep learning model to predict environmental and ecological variables is shown to be an efficient way to elevate the mapping and monitoring of tidal systems as it does not require additional data collection. Our results suggest that features extracted from VAE models may also improve remote-sensing-based mapping in other spectrally poor regions like deserts and snow-covered mountains.

Madhuanand, L., Philippart, C.J.M., Wang, J., Nijland, W., de Jong, S.M., Bijleveld, A.I., Addink, E.A., 2023. Enhancing the predictive performance of remote sensing for ecological variables of tidal flats using encoded features from a deep learning model. GIScience & Remote Sensing. 60. https://doi.org/10.1080/15481603.2022.2163048