Convolutional Neural Networks for Classification of Sea Ice Types in Sentinel-1 SAR Data

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A new algorithm for classification of sea ice types on Sentinel-1 Synthetic Aperture Radar (SAR) data using a convolutional neural network (CNN) is presented. The CNN is trained on reference ice charts produced by human experts and compared with an existing machine learning algorithm based on texture features and random forest classifier. The CNN is trained on a dataset from winter 2020 for retrieval of four classes: ice free, young ice, first-year ice and old ice. The accuracy of our classification is 91.6%. The error is a bit higher for young ice (76%) and first-year ice (84%). Our algorithm outperforms the existing random forest product for each ice type. It has also proved to be more efficient in computing time and less sensitive to the noise in SAR data.

Our study demonstrates that CNN can be successfully applied for classification of sea ice types in SAR data. The algorithm is applied in small sub-images extracted from a SAR image after preprocessing including thermal noise removal. Validation shows that the errors are mostly attributed to coarse resolution of ice charts or misclassification of training data by human experts.

Several sensitivity experiments were conducted for testing the impact of CNN architecture, hyperparameters, training parameters and data preprocessing on accuracy. It was shown that a CNN with three convolutional layers, two max-pool layers and three hidden dense layers can be applied to a sub-image with size 50 x 50 pixels for achieving the best results. It was also shown that a CNN can be applied to SAR data without thermal noise removal on the preprocessing step. Understandably, the classification accuracy decreases to 89% but remains reasonable.

The main advantages of the new algorithm are the ability to classify several ice types, higher classification accuracy for each ice type and higher speed of processing than in the previous studies. The relative simplicity of the algorithm (both texture analysis and classification are performed by CNN) is also a benefit. In addition to providing ice type labels, the algorithm also derives the probability of belonging to a class. Uncertainty of the method can be derived from these probabilities and used in the assimilation of ice type in numerical models.
Given the high accuracy and processing speed, the CNN-based algorithm is included in the Copernicus Marine Environment Monitoring Service (CMEMS) for operational sea ice type retrieval for generating ice charts in the Arctic Ocean. It is already released as an open source software and available on Github: https://github.com/nansencenter/s1_icetype_cnn.