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A Comparison of Machine Learning Algorithms for the Segmentation and Classification of Snow Micro Penetrometer Profiles on Arctic Sea Ice

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Snow-layer classification is an essential diagnostic task for a wide variety of cryospheric science and climate research applications. Traditionally, these measurements are made in snow pits, requiring trained operators and a substantial time commitment. The SnowMicroPen (SMP), a portable high-resolution snow penetrometer, has been demonstrated as a capable tool for rapid snow grain classification and layer type segmentation through statistical inversion of its mechanical signal. The manual classification of the SMP profiles requires time and training and becomes infeasible for large datasets.

Here, we introduce a novel set of SMP measurements collected during the MOSAiC expedition and apply Machine Learning (ML) algorithms to automatically classify and segment SMP profiles of snow on Arctic sea ice. To this end, different supervised and unsupervised ML methods, including Random Forests, Support Vector Machines, Artificial Neural Networks, and k-means Clustering, are compared. A subsequent segmentation of the classified data results in distinct layers and snow grain markers for the SMP profiles. The models are trained with the dataset by King et al. (2020) and the MOSAiC SMP dataset. The MOSAiC dataset is a unique and extensive dataset characterizing seasonal and spatial variation of snow on the central Arctic sea-ice.

We will test and compare the different algorithms and evaluate the algorithms' effectiveness based on the need for initial dataset labeling, execution speed, and ease of implementation. In particular, we will compare supervised to unsupervised methods, which are distinguished by their need for labeled training data.

The implementation of different ML algorithms for SMP profile classification could provide a fast and automatic grain type classification and snow layer segmentation. Based on the gained knowledge from the algorithms' comparison, a tool can be built to provide scientists from different fields with an immediate SMP profile classification and segmentation.

King, J., Howell, S., Brady, M., Toose, P., Derksen, C., Haas, C., & Beckers, J. (2020). Local-scale variability of snow density on Arctic sea ice. *The Cryosphere*, 14(12), 4323-4339, <https://doi.org/10.5194/tc-14-4323-2020>.