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Coupling Deep Learning and GIS for forest damage assessment based on high-resolution remote sensing data

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Due to global warming, natural disasters such as thunderstorms are becoming more frequent (Brooks, 2013). Such events have a strong impact on forest health, wildlife habitat and can inflict substantial economic losses. Methods to quickly assess damage and to manage disaster in the aftermath of storm events are of high importance for forest management.

As there are large areas affected by storms, assessing the forest damage is time consuming, if done manually using aerial imagery and GIS tools. Time is a crucial factor in disaster management and therefore integrating deep learning with remote sensing data into a GIS environment holds a high potential for accelerating and improving damage assessment.

Convolutional Neural Networks (CNN), a supervised learning architecture, is extensively used in many areas (e.g. interpretation of medical images, 3D reconstructions, objects detection and classification in self-driving cars…). They are efficient in finding patterns within a large amount of data and are widely used in computer vision and images classification (LeCun et al., 1989). We develop an algorithm based on CNNs using a U-net architecture that is trained on labeled damaged areas visible in after-storm aerial orthophotos of a ca. 109 square km forest area in Bavaria (RGB and NIR, 0.2 m spatial resolution). Integration into ArcGIS was achieved with the Python API for ArcGIS and Jupyter Notebooks.

The neural network trained using over 10e7 pixels of labeled data performed, within seconds (depending on the size of the input raster) and resulted in an accuracy of 92% and an intersection over union score of 0.67. These results are promising, considering the complexity of detecting areas of fallen trees. In addition, we found labelling errors in the ground truth that somewhat bias the results as the algorithm performed better than the human labelling procedure.

The next step will be to use a second CNN architecture (Mask-r-CNN) to quantify timber losses due to the storm in terms of volume in addition to areal damage. We will also consider further optimization of the algorithm by assessing the optimal ratio of true positives to false negatives, based on a decision analysis. Overall, our results highlight the potential of deep learning on high resolution imagery for damage assessment following disasters.

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