**Press Release**

**CORSNAV Research Group uses deep-learning for classification of tree species and deadwood in Bavarian Forest National Park**

*The CORSNAV Research Group of Munich University of Applied Sciences (MUAS) has applied a deep-learning based method to classify tree species and deadwood in Bavarian Forest National Park using LiDAR data acquired from an Airborne Laser Scanner.*

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***[Summary]*** BAVARIAN FOREST NATIONAL PARK | RESEARCH PROJECTS – The CORSNAV Research Group under the lead of Prof. Dr. Peter Krzystek, in collaboration with with MUAS' own Digital Transformation Lab (powered by Amazon Web Services), has succeeded in performing classification of tree species and deadwood using PointNet++ deep neural network, with Amazon EC2 GPU Instance providing high performance compute on the cloud for the deep learning workloads. This methodology allows the forester of Bavarian Forest National Park to analyze the forest structure from LiDAR data in shorter time and perform the inventory of diverse tree species as well as map the dispersion of deadwood in the forest.

***[Opportunity/problem]*** Airborne laser scanning (ALS) is widely adopted in many applications of remote sensing, with forest mapping as a concrete example. An ALS unit has the ability to scan terrains with rapid paces and high precision. In comparison with conventional method of forest mapping by sending survey teams to sample sets of trees, it can cover a wider region and also can potentially be less-costly. The resulting LiDAR data itself is a georeferenced 3D point cloud with the strength of reflection on objects caused by the laser pulse (=intensity values). A scan of forest as the LiDAR data can be further segmented into single tree objects, making it possible to perform a classification of each tree based on their species using machine learning. Up until now there has been efforts from researchers to classify single segmented trees into multiple species using learning methods such as random forest, logistic regression, and support vector machines. However, the classification accuracies were deemed unacceptable when more tree species or stages of a deadwood were added as classes to identify. On the other hand, the LiDAR data are of high resolution and can take terabytes of size. To perform a classification of single tree segments from an entire forest such as Bavarian Forest National Park, multiple workstations with high-end graphics would be required to process large batches of data in a short time.

***[Approach/solution]*** Recent development in deep neural networks has now offered the possibility to train 3D data such as point clouds. PointNet++ is a novel deep neural network which can discretise point clouds in a voxel plane. The network itself can be used either to segment point clouds into multiple object classes or for classification of point cloud objects. Moreover, because the network incorporates hierarchical feature learning for each 3D object, additional features from multispectral aerial images of forests can be included to increase the classification accuracy. Deep neural networks unfortunately also require an enormous amount of samples to better generalize objects, which can lead to days or even weeks of training. AWS provides P3 EC2 instance type to accommodate deep-learning tasks, which is configured with multiple high-end graphics cards. With this instance, large

batches of training samples can be processed in parallel, thus reducing training time and increasing efficiency for foresters in performing tree species classification.

***[Customer quote here]***

"*Deep learning might sound unfamiliar to us at first. But after getting acquainted with the workflow provided from CORSNAV Research Group, getting improved accuracy in classifying tree species and deadwood has made us realize how important it is to our work here in Bavarian Forest National Park.* ", said Marco Heurich, a researcher at Bavarian Forest National Park. "*If you imagine how long it would take to perform forest inventory without the help from these technologies (ALS, deep learning). Not to mention that we have to spend more resources on manpower for surveying and on expensive workstation PCs. AWS has also made it possible for us to access high performance computing power that can be scaled to our needs while also cost-aware to our usage."*

***[Customer experience]*** The tested workflow allows forester to perform deep-learning based classification without having to worry about the complicated setup. An automation script is provided to help them run multiple experiments sequentially. The PointNet++ framework with its module dependencies are saved in an isolated environment as a container image, which the forester can easily deploy in multiple EC2 instances via Docker. Training data and the results can be stored in an AWS S3 Bucket, the storage system which works independently from EC2 instances. It is flexible to attach and detach without having to worry about the loss of data in case an EC2 instance suddenly crashes or shut down.

**Customer FAQ (Researcher/Forester)**

Q: What tasks can I accomplish with this solution?
A: You can perform classification of tree species and also deadwood using a deep learning based method.

Q: What is PointNet++?
A: It is a novel deep neural network developed by Charles Qi, Li Yi, Hao Su, and Leonidas Guibas from Stanford University. This network is designed for 3D data such as point clouds and it learns hierarchical features, from fine-grained patterns to broader and complex scenes.

Q: You said that PointNet++ can also be used to segment a point cloud scene into multiple object classes. Can this be done with your workflow too?
A: Yes, the network can be used to segment point clouds. But the focus of this workflow lays on the classification part, not the segmentation.

Q: How fast can a training phase last on the EC2 GPU instance?
A: It depends on the hardware configuration of the EC2 instance. We used the high-end configuration with eight GPUs installed with 128GB graphics memory. A training phase of 2000 samples lasted about half an hour using batch size of 256.

Q: How can I increase the accuracy of my trained network?
A: PointNet++ is able to learn from features of point cloud objects. Additional features such as point cloud normals and intensity might increase the overall accuracy. To better differentiate healthy trees and deadwood, external features from multispectral aerial imagery such as Normalized Difference Vegetation Index (NDVI) can be incorporated to the training data.

Q: Where can I load up my training data and save my results?
A: We recommend that you manage your data in an AWS S3 Bucket. It is scalable in case you want to store a big amount of data. It is also less prone to sudden crash or shut down of an EC2 instance than another storage system of AWS such as EBS.

Q: Do I need prior knowledge of certain programming languages to operate the workflow?
A: Knowledge in Python is required as the deep neural network itself is written using a Python library called PyTorch.

**Stakeholder FAQ (Forest Administration)**

Q: How much does this solution cost? Do we have to pay for any license?
A: The PointNet++ deep neural network is open-source so you don't have to pay for the software license. However, using AWS service such as EC2 instance and S3 Bucket would be charged according to your usage pattern. For more information about pricing please get in contact with AWS Service Desk via https://aws.amazon.com//contact-us/.

Q: Can I deploy my AWS architecture outside of Germany?
A: It is recommended that you deploy your architecture here in Germany. Other countries might have other interpretations on how they regulate the data privacy and protection, which can be a problem if there were data breaches or leakages.

Q: Do we have to train our personnel to take care of the IT stuff (e.g. programming or system administration)?
A: Knowledge in programming languages is advantageous for modifying or extending the PointNet++ for other use cases. So yes, it is recommended to hold workshops for that. Hiring IT specialists such as Solutions Architect from AWS might also be helpful.

Q: Which tree species and deadwood have you identified using this solution?
A: We chose four classes to identify: conifer, broadleaf tree, snag, and dead tree with crowns.

Q: How were the results of your experiments?
A: Using the combination between point cloud features and multispectral features brought the best overall accuracy of about 87% across four classes. There were still confusions in detecting healthy conifer and dead tree with crowns as the dead trees were mostly conifers, thus they have the same structure. The training time lasted for about half an hour with the best EC2 hardware configuration.

Q: Can we perform the classification without GPUs?
A: Deep learning really depends on parallel computation in which a GPU can handle that. Amount of GPU memory also plays an important role in processing batches of training data. The bigger the memory, the more it can process large batches. Therefore the training time can be reduced.