Semantic Segmentation on Landslide Containment Devices

Summary

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Identifying the flexible slope stabilization system components is an essential work for predictive maintenance of these systems to prevent vital landslide hazards. The landslide containment components and applying further anomaly detection can be done by advanced autonomous systems. Semantic segmentation models capable of pixel-level component detection and related models help to understand the context of an environment and are therefore commonly used when context is required.

The objective of this thesis is to evaluate the performance of state-of-the-art semantic segmentation models based on detecting mesh and wire in landslide containment devices. According to the results, the most reliable model will be selected for image analysis. Different combinations of model parameters are grid searched to find an optimum model. Conclusively, the models will be valuable for the maintenance of landslide containment devices. This project is part of a bigger project that is held by Modelway S.r.l. and the company is assisted in the creation of this thesis. The consideration of this thesis is the landslide containment devices and mainly detecting two main components, which are customarily referred to as ”mesh” and ”wire”.

In this thesis, acquired images are captured in both horizontal and vertical orientations. Then images are cropped into 3 pieces. These cropped images are square in shape, later they are resized as 512x512. Two different datasets are created, one with data augmentation implemented (rotation, flipping, adding random noise and saturation adjustment) and so extended dataset, and the other is the original one.

In this thesis, separate U-Net models are used to conduct further research on semantic segmentation of wire images and mesh images using a neural network.

As evaluation metrics, mean intersection over union (IoU), Dice Coefficient and pixel accuracy are indicated. However, selecting the best model will be only considered on mIoU.

	Wire	Wire with augmentation	Mesh	Mesh with augmentation
Mean IoU	51.1%	**52.1%**	87.2%	**87.8%**
Dice coeff.	67.7%	68.5%	93.1%	93.5%
Pixel accuracy	96.9%	96.8%	91.7%	92.1%
Pixel accuracy wire or mesh only	60.4%	63.3%	90.0%	94.4%

Table 1.1: standard U-Net results on test set of mesh and wire images separately for mesh and wire models

The obtained results on test set of standard U-Net model trained on wire and mesh images, with and without data augmentation employed are reported in Table 1.1.

separate U-Net++ models are used to conduct further research on semantic segmentation of wire images and mesh images using a neural network. Therefore, comparison of two models is shown in Table 1.2.

U-Net vs U-Net++	U-Net wire	U-Net++ wire	U-Net mesh	U-Net++ mesh
Mean IoU	52.1%	**56.1%**	87.8%	**89.3%**
Dice coeff.	68.5%	71.8%	93.5%	94.4%
Pixel accuracy	96.9%	97.2%	92.1%	93.2%
Pixel accuracy wire or mesh only	63.3%	66.6%	94.4%	93.6%

Table 1.2: comparison of U-Net and U-Net++ models trained on data augmentation applied data.

U-net++ model gave good results, even better than U-Net model. However, there is no big difference between the two model performances. Since the standard U-Net model is a lighter weight and less complex network compared to U-Net++, and the performance of both models is good enough, it is better to investigate the U-net model rather than UNet++

The following experiment aims to determine if multi-class semantic segmentation approach leads to improve the detection of mesh and wires. Annotated data was pre-processed by labeling each pixel with a value of 0 indicating the background, 1 for the mesh, and 2 for the wire.

Multiclass	Average	Background	Mesh	Wire
Mean IoU	**63.9%**	79.9%	80.8%	30.8%
Dice coeff.	**75.1%**	88.8%	89.4%	47.1%
Pixel accuracy	**72.0%**	90.8%	89.9%	35.3%

Table 1.3: U-Net results on test set with average evaluation value in the first column, background only in the second, mesh only in the third and wire only in the last column.

The performance of the model decreased significantly (compared to binary semantic segmentation application), especially in the detection of wire. Therefore, there is a compromise between employing a single model to detect both objects at pixel-level and accurately obtaining the segmentation results. As this thesis aims to identify an optimal model with high evaluation scores on test set, it will continue to focus on the binary semantic segmentation approach.

After model selection, the focus turned on the grid search to with different combination of hyper-parameters. During grid search different loss functions, optimizers, different number of encoder decoder blocks and different filter sizes are employed. The results showed that the best model for wire is U-Net with dropout layers, Adam optimizer and binary cross entropy loss. The best model for mesh is achieved by U-Net with smaller encoder decoder blocks, Adam optimizer and binary cross entropy loss with learning rate 0.0001 on data augmentation applied dataset.

Best Model	Best model for mesh	Best model for wire
Mean IoU	**90.2%**	**58.1%**
Dice coeff.	94.8%	73.5%
Pixel accuracy	93.8%	97.3%
Pixel accuracy wire or mesh only	95.1%	68.2%

Table 1.4: Best model results for mesh and wire are reported.

Future work is using the best model with best parameters to identify the objects in landslide containment devices and applying an anomaly detection technique to detect abnormal regions accordingly.