R&D of a Multisensory System for Excavation Machines for the Real-time Generation of AI/ML classified, Georeferenced and BIM compliant Voxel Models of Soil (ZIM Project HOBA)

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Abstract. The R&D project "Homogeneous soils assistant for the automatic, construction site-specific recording of soil classes according to the new VOB 2016", shortly HOBA, deals with the development of automatic classification, detection & segmentation of construction site specific soil types (http://www.navka.de/index.php/de/weitere-projekte/hoba-project-overview-1). HOBA is financed as a so-called ZIM (Central Innovation Program for SMEs) research and development project by the Federal Ministry for Economic Affairs and Energy (BMWI). Research and development are carried out in the GNSS & Navigation Laboratory (http://goca.info/Labor.GNSS.und.Navigation/index.php) in collaboration with the main industry partners MTS Schrode AG (www.mts-online.de) and VEMCON GmbH (www.vemcon.de).

The aim of the R&D at the HKA is the development of the hardware and software of a compact sensor- and computing system unit, mounted on the excavator, briefly called HKA HOBA-Box (fig. 1). The hardware and software development of the HKA HOBA-Box is an innovative contribution to the BIM-compliant digital real-time documentation of excavation work in civil engineering.

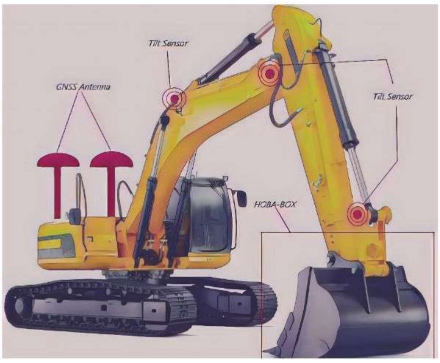

Figure 1 Excavator with distributed sensors and HKA HOBA-Box located in the area of the shovel

The HKA HOBA-Box enables a multi-sensory 3D geo-referencing of the excavation in the ETRF89 / ITRF, based on GNSS/MEMS/Optics (RGB/ToF-camera) sensors. The complete geo-referencing steps of the box are based on a Bayesian sensor-fusion algorithmic fusion in the general NAVKA (www.navka.de) multisensory-multiplatform lever arm design, leading to the full navigation state vector

$$y(t) = (x^e y^e z^e | \dot{x}^e \dot{y}^e \dot{z}^e | \ddot{x}^e \ddot{y}^e \ddot{z}^e | r^e p^e y^e | \omega^b_{eb,x} \omega^b_{eb,y} \omega^b_{eb,z} | \dot{\omega}^b_{eb,x} \dot{\omega}^b_{eb,y} \dot{\omega}^b_{eb,z})^T$$

The Bayesian SLAM (Simultaneous Localization and Mapping) means an extension of $y\ (t)$,, which is based - in the case of HOBA - on the Gauß-Markov-model's information of the optical sensor data of the ToF and the RGB camera. The extension of the parameter space for SALM is on the 3D map $m\ (t)$, and so it leads to $y(t)_{SLAM} = (y(t), m\ (t))$.

The SLAM parameters $y(t)_{SLAM} = (y(t), m\ (t))$ are used for the computation of a so-called ETRF89 / ITRF "voxel"-based 3D model of the excavation volume, based on an Octree-based representation of the environment, using the ToF-camera data.

Furthermore, the HKA HOBA-box will allow the classification of the soil types on the site using image-based AI/ML algorithms, and finally the re-calculation of the classified and geo-referenced 2D images onto the geo-referenced 3D voxel model according to the soil types. Here pixels to pixels in the image have to be assigned to the 3D surface on the model by calculating correspondent points (P, P ′) between the two representations, i.e. 2D and 3D. The part of Machine Learning (ML) introduces a real-time soil texture classification and segmentation on the construction site. The R&D target of the abovementioned BIM-compliant soils assistant, according to the new VOB 2016 - realized as a physical system by HKA HOBA-box - enables civil engineers an insight into the geo-technical properties of the excavated soil, as well as to the borders between these soil types, on the construction site. The mathematical and algorithmic approach for soil classification is the Fully Convolutional Network-Based Semantic Segmentation (FCN). This is a pixel-level classification, which achieves a pixel fine-grained inference. Therefore, it is then the best practice for such application of soil texture labelling on the site.

The improved FCN-based approaches e.g., SegNet & DeepLap, are used as encoders for the training of the soil texture-model via Transfer Learning (TL). The TL is utilized, as it is a well-known method and regarded to shorten the processing time of model training, and therefore decrease the computational efforts considerably. Furthermore, the HKA HOBA-box trains the model on a specific dataset already, as provided by the HKA industry partner i.e. MTS Schrode AG. The dataset i.e., images of the construction site with different present soil types, provides - through a high-precision 2D annotation process - i.e. instance-aware segmentation and detailed precise masks for a corresponding 15 classes of the soil types, which are used for training, testing, and validation.

The respective AI/KL developments are based on Python & C/C++, using both machine learning frameworks, namely TensorFlow 1.x and PyTorch. The re-trained model is converted into an ONNX (Open Neural Network Exchange), which is an open format for ML models allowing interchanging between different ML frameworks.