Geodetic Research and Technical Development Projects on BIM 4.0 and Agriculture 4.0 in the HKA Laboratory on GNSS and Navigation

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The theoretical parts of the presentation are dealing with research and developments (RaD) in the Laboratory of GNSS & Navigation of the Karlsruhe University of Applied Sciences (HKA) on multisensory navigation state and SLAM estimation, and on technologies for intelligent out-/indoor UAV/UAS. The general innovations are based here on the use of SIMPLEX algorithms, both for the related state estimation problems (navigation state and SLAM), and for the UAV flight control algorithms. The use of the BIM model for the indoor UAV flight control, both in photogrammetry and by geometrical in-equations generated by BIM models, are to be mentioned as further innovations. Finally, the use of ambiguity free and cycle-slips resistant GNSS algorithms in the context with SIMPLEX are presented in the theoretical part. The R&D project related parts of the presentation are on the application and further developments of the above navigation state estimation problems, and the flight control methods in the frame of two current RaD projects, each with a duration up to 2023. These three years projects comprise in addition RaD on photogrammetry, image processing, machine learning (ML) and artificial intelligence (AI), automatic BIM model generation and dynamically controlled intelligent autonomous out-/indoor UAS.

The 1st project related focus is on the RaD project "Homogeneous soils assistant for the automatic, construction site-specific recording of soil classes according to the new VOB 2016", shortly HOBA. HOBA is financed as ZIM (Central Innovation Program for SMEs) research and development project by the Federal Ministry for Economic Affairs and Energy (BMWI). HOBA is dealing with RaD of an automatic classification, detection and segmentation and BIM-compliant voxel model generation of construction-site specific soil volumes. HOBA means innovation on the automation in routes construction and digitalization in civil engineering in terms of ITRF/ETRF89 georeferenced digital real-time documentation of excavation work in civil engineering 4.0.
The RaD are carried out with MTS Schrode AG as cooperation partner. HKA is responsible for the development of the hardware, algorithms and software of a compact sensor- and computing system unit, mounted on excavators, briefly called HKA HOBA-Box. The HKA HOBA-Box enables a multisensory 3D geo-referencing of the excavation volume in the ITRF/ETRF89 frame by the navigation state vector $\mathbf{y}(t) = (x^e y^e z^e | \dot{x}^e \dot{y}^e \dot{z}^e | \ddot{x}^e \ddot{y}^e \ddot{z}^e | r^e p^e y^e | \omega^b_{eb,x}\ \omega^b_{eb,y}\ \omega^b_{eb,z} | \dot{\omega}^b_{eb,x}\ \dot{\omega}^b_{eb,y}\ \dot{\omega}^b_{eb,z})^T$. The navigation state $\mathbf{y}(t)$ and the SLAM state vector $\mathbf{y}(t)_{SLAM} = (\mathbf{y}(t), \mathbf{m}(t))$ estimations, are hereby based on GNSS, MEMS, Optical (RGB/ToF-camera) sensor data. The ToF camera is further used for the computation of a ETRF89 / ITRF geo-referenced 3D voxel model of the excavation volume. The HKA HOBA-box will further provide the real-time classification of the soil types by image-based AI/ML algorithms. The recalculation of the classified and geo-referenced 2D images onto the geo-referenced 3D voxel model means to photogrammetry problem of assigning the images pixels to pixels to 3D-voxel model by calculating correspondent points (P,P′) between the two representations, i.e. 2D and 3D again based on $\mathbf{y}(t)$.

The 2nd project related focus of the presentation is on the joint RaD project MITESENS. It is a part of the German agriculture 4.0 research and development program, and dealing with the digitalization and automation in horticulture domain. As one of the Hortico 4.0 RaD projects, MITESENS is financed by the German Federal of Ministry and Food and Agriculture. The HKA RaD is on an UAS (Unmanned Aerial Vehicle based System) for monitoring spider mites in typical plant populations in greenhouse cultivation. The MITESENS UAS (Unmanned Aerial System) performs several tasks in connection with a ground control station and internet access, these as local and cloud-based data exchange interfaces,

respectively. The UAS carries the multispectral camera for the image-based mites detection and monitoring. The HKA flight control platform R&D aims at a seamless autonomous out-/indoor flight and concerns hardware, algorithms and software RaD. The hardware comprises GNSS, MEMS (Micro-Electro Mechanical-Systems) and optical sensors (cameras and lidar), the data communication components (WIFI, Internet), and the motor-controller part. The GNSS/MEMS/optics multisensory UAS flight control system is using the estimated navigation state vector **y**(t) as control instance for the dynamic flight control with an equally parametrized 3D trajectory **y**(t)-desired. The UAS-based georeferenced optics sensors are also used for the obstacle detection, which leads - in case of detected obstacles - to the necessity of modifying in real-time the state **y**(t)-desired, which is synonymous with RaD on dynamic flight control algorithms. The lidar is used for 3D-mapping **m**(t) based on lidar and camera $\mathbf{y}(\mathrm{t})_{\mathrm{SLAM}} = (\mathbf{y}(\mathrm{t}), \mathbf{m}(\mathrm{t}))$. This leads again to a 3D voxel model of the plants in the global ITRF/ETRF89 as spatial references. By an IEEE1588 time synchronization on the flight control box, the time stamp t is also common to the unclassified and the classified multi-spectral 2D-images, s(t) and s(t)', respectively of the plants. In analogy to the HOBA project, the mites classified multi-spectral images s(t)' are computed pixel-wise back to the 3D voxel model **v** on the plants, what finally results in the ITRF/ETRF89 georeferenced spatial 3D time-reference voxel model v(t)' of the mites population. Vertical or horizontal sections (2D ortho maps) can then be derived from the complete 3D information v(t)'.