Abstract of Karol Kwiatek's doctoral thesis
"Application of immersive video panoramas in photogrammetric 3D measurements"

The thesis presents the concept of photogrammetric measurements based on immersive video, i.e. video recorded by a mobile immersive camera. The camera records a series of 360° images, which is facilitated by the application of a few cameras, whose perspective centres are at some distance from the common "virtual" perspective centre.

In order to facilitate the use of individual images, the "flawed" spherical panoramas are typically created. They are called immersive panoramas in this thesis. Individual images are projected onto the sphere and are displayed as spherical panoramas that have a common perspective centre. It leads to errors on these panoramas, which affects the accuracy of photogrammetric documentation.

The literature of the subject lacks studies that describe the impact of various parameters responsible for: the creation of immersive panoramas on photogrammetric measurements, the generation of high-resolution point clouds and the creation of movement trajectories of the immersive camera. Previous studies do not contain the accuracy analysis of photogrammetric measurements performed on images generated by multi-sensor, dioptric systems and the evaluation of immersive video features. This dissertation provides results that enable to fill gaps in existing knowledge about immersive video imaging and its application in photogrammetric measurements. Special emphasis is placed on the effect of using immersive images in the available photogrammetric software that uses spherical model.

The aim of this thesis is to examine the potential of immersive cameras in close-range photogrammetry and to develop a methodology of measurements from immersive videos. Due to the nature of immersive images with reference to spherical panoramas, the cognitive aim of the thesis is to analyse the immersive model and to examine differences between the immersive and spherical model, whereas the practical aim of the research is to establish what impact these differences have on photogrammetric measurements using specific, registered immersive videos. Ladybug® 3 by Point Grey Research was used in this research project.

Due to the use of software that uses spherical images (Agisoft Photoscan), the analysis includes the spherical model with immersive imaging errors. The research problem comprises the accuracy analysis of measurements from immersive panoramas which depends on factors influencing immersive video generation and features of the place being registered.

The following hypotheses were formulated: a) immersive videos acquired from mobile mapping systems may be used as a source of photogrammetric data for 3D measurements whose accuracy is a resultant of imagining model geometry; b) immersive video images enable to generate 3D models in the form of high resolution point cloud; c) immersive videos enable to improve accuracy of establishing the camera movement trajectory by integrating SfM method with GNSS/INS measurements.

While testing the hypothesis (a), it was noticed that points of the photographed object located in the distance (D) which equals the sphere radius (R) (from the agreed "virtual" perspective centre) are projected on panorama in the same places as in the spherical model, other points are displaced – and these displacements are called parallaxes. The greatest parallax values are obtained where R is significant and D is small. The shorter the base, the smaller ε angles (between the axis of an individual cameras and observation direction), therefore, the parallax

error is reduced, and the impact of random error in the spatial intersection increases. The selected base for measurements from two panoramas is optimal when the graph of random errors for the intersection depth direction crosses the graph of systematic errors caused by immersion in the same direction. When taking measurements with the same individual cameras it is possible to predict errors that may appear on immersive mages. However, when there is a measurement from two adjacent individual cameras, it is difficult to predict the impact of immersion (the analysed immersive camera is asymmetrical and it consists of five individual cameras located in the same plane).

The research on hypothesis (b) indicates that the increase in the number of panoramas affects the point cloud density, which in turn increases the resolution of the created model. In addition, selection of a small base significantly increases the number of match points between panoramas.

In order to prove the hypothesis (c), the author built a mobile mapping system consisting of positioning, inertial and immersive imaging modules. It was calibrated by establishing the lever arm between the system modules. Rotation and calibration matrices were calculated and data derived from GNSS and INS was compared to data obtained from SfM application. Direct georeferencing was integrated with the panorama network adjustment. In the mobile mapping system the use of indirect georeferencing in immersive images increased accuracy of measurements on control points even three times compared to the situation when direct georeference comes from the SPAN technology that relies on two GNSS antennas and satellite and inertial data that were *post-processed.*

This thesis proves that it is possible to plan photogrammetric measurements based on immersive panoramas with a set accuracy. However, it implies that the field of view is limited and the number of points is reduced. These shortfalls can be compensated for by increasing the number of recorded panoramas (fps). It means a shorter base, which leads to reduction of a parallax error (systematic error), but concurrently, the random error increases. The accuracies obtained confirm the usefulness of the constructed system and the proposed methodology of calibration and integration of observations in some photogrammetric measurements. The system can be used to create models of buildings with LoD4. By following the above rules when taking measurements on immersive panoramas, it is possible to develop 3D models of streets or interiors with accuracy ranging from 0.01 to 0.04 m.