Application of structure from motion technique for engineering geological mapping of underground rooms

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PRIMENA STRUCTURE FROM MOTION TEHNIKE ZA INŽENJERSKOGEOLOŠKO KARTIRANJE PODZEMNIH PROSTORIJA

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Početkom 2020. godine za potrebe rekonstrukcije i adaptacije tunela izvršena su inženjerskogeološka istraživanja koja su obuhvatila detaljno inženjerskogeološko rekognosciranje i kartiranje glavnog tunelskog hodnika i svih podzemnih prostorija kao i geofizičko profiliranje. Rad prikazuje mogućnost primene tehnike generisanja modela objekta na osnovu snimaka dobijenih kamerom pri kretanju oko objekta (engl. Structure from motion - SfM) za 3D rekonstrukciju jedne podzemne prostorije tunela „Čajkino brdo“ u Vrnjačkoj Banji za potrebe inženjerskogeološkog kartiranja i parametrizacije.

SfM predstavlja fotogrametrijsku tehniku određivanja 3D strukture objekta, pozicija i orijentacija kamere iz sekvenci dve ili više dvodimenzionalnih slika istog objekta, ali iz različitih položaja kamere (pasivnog senzora). Za razliku od klasične fotogrametrije gde je neophodno poznavanje spoljašnjih i unutrašnih parametara snimaka, SfM proces 3D rekonstrukcije okruženja je prilično automatizovan i lakši jer je najčešće samo potrebno napraviti dovoljan broj fotografija sačinjenih istim senzorom sa različitih položaja. Snimanje se odvija u vidljivom delu spektra i princip 3D rekonstrukcije okruženja je analogan ljudskom vidu, koji na sličan način formira 3D sliku. Primena SfM tehnike u podzemnim prostorijama je kompleksna usled izostanka prirodnog osvetljenja, nemogućnosti GPS pozicioniranja senzora i ograničenog prostora, koji su ključni za njihovu uspešnu primenu i kvalitetne rezultate 3D rekonstrukcije. Dodatni problem predstavljaju senke, koje mogu otežati kvalitetno automatsko povezivanje snimaka, a koje se formiraju primenom veštačkih izvora osvetljavanja da bi se formirao snimak u vidljivom delu spektra. Kod fotogrametrijske rekonstrukcije modela objekta bitno je i da površina objekta bude matirana, tj. bez sjajnih reflektujućih površina kakve su najčešće površine stena u tunelima.

Tokom istraživanja izvršeno je ogledno fotogrametrijsko snimanje odabrane prostorije i obrada dobijenih snimaka primenom SfM tehnike. Snimanje je izvršeno korišćenjem mobilnog telefona Huawei P10 Pro i Xiaomi Mija 360° sferne kamere. Snimanje mobilnim telefonom je vršeno „iz ruke“ i sa „visine očiju posmatrača“ tako da se ostvari najveći mogući preklop između snimaka. Snimanje sfernom kamerom je izvršeno uz pomoć stativa, postavljanjem sferne kamere u pravilnom mrežnom rasporedu na tri različite visine.

Na osnovu snimaka dobijenih na ovaj način, primenom SfM tehnike generisana su dva različita 3D oblaka tačaka koja su upoređena i na osnovu kojih je izvršeno inženjerskogeološko kartiranje podzemne prostorije. 3D oblak tačaka je procesiran, uključujući urazmeravanje, orijentaciju, odnosno rotiranje prostorije u realan položaj i uklanjanje suvišnih tačaka. Na ovaj način, a nakon procesiranja, izvršeno je inženjerskogeološko kartiranje zidova i svoda podzemne prostorije, odnosno određivanje indeksa hrapavosti stenske mase, definisanje strukturnog sklopa tj. utvrđivanje karakterističnih familija pukotina (manuelno i automatski), izradu karakterističnih profila svetlog otvora i analizu njihove stabilnosti uz kritički osvrt.

APPLICATION OF STRUCTURE FROM MOTION TECHNIQUE FOR ENGINEERING GEOLOGICAL MAPPING OF UNDERGROUND ROOMS

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For the "Čajkino brdo" tunnel reconstruction and adaptation, at the beginning of 2020, an engineering geological investigation was performed. These investigations included detailed engineering geological reconnaissance and mapping of the main tunnel corridor, all underground rooms and geophysical profiling as well. The paper presents the possibility of applying the Structure from Motion (SfM) technique for 3D reconstruction of a selected underground room inside the "Čajkino brdo" tunnel in Vrnjačka Banja as part of engineering geological mapping and parameterization.

SfM is a photogrammetric technique for determining the 3D structure of an object, the position and orientation of the camera from sequences of two or more 2D images of the same object, but from different camera positions (passive sensor). Unlike classical photogrammetry, where the external and internal parameters of images are known, the SfM process of 3D reconstruction of the environment is quite automated and easier since it is usually necessary only to take a sufficient number of photos with the same sensor but from different positions. Imaging takes place in the visible part of the spectrum and the principle of 3D reconstruction of the environment is analogous to human vision, which similarly forms a 3D image. The application of SfM technique in underground conditions is complex due to the lack of natural light, limited space and the inability of GPS positioning, which are crucial for their successful application and quality results of 3D reconstruction. An additional problem is a shadow, which can significantly complicate the quality of automatic aligning of images. Shadows appear as a consequence of the use of artificial lighting, which is necessary to form an image in the visible part of the spectrum. During the photogrammetric reconstruction of the object model, the surface of the object must be matte, ie. without glossy reflective surfaces like the surfaces of rocks in tunnels.

During the investigation, experimental photogrammetric imaging of the selected underground room was performed and the obtained images were processed using the SfM technique. The recording was done using a Huawei P10 Pro mobile phone camera and a Xiaomi Mija 360 ° spherical camera. Photographing with a mobile phone was done "from the hand" and from the height of the observer's eyes with acquiring the greatest possible overlap between images. Spherical camera imaging was performed using a tripod, placing the spherical camera in the regular grid network layout at three different heights.

Based on the images obtained in this way, two different 3D point clouds were generated using the SfM technique. The results were compared and based on them, the engineering geological mapping of the underground room was performed. The 3D point cloud was processed, including scaling, orientation and rotating the point cloud to a realistic orientation and removing redundant points. In this way, after processing, the engineering geological mapping of the walls and rooftops of the underground room was performed. From the point clouds following engineering geological parameters were defined: the roughness index of surfaces and geological structural setting (characteristic joint families by manual and automatic mode), the characteristic profiles of the light profile and the analysis of their stability, with a critical review.