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Photo-realistic 3D reconstruction of large-scale indoor environment using sequence of uncalibrated digital images

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3D reconstruction of large-scale indoor environments from digital images is a time-efficient and convenient way of inspecting the structural features of the scene being modelled. Conventionally, laser scanning based technology is used for modelling of large-scale environment in civil and mining industries. Although laser scanning based modelling is accurate and robust, it is not extensively used in surveying of construction site or underground mines due to its high operating and maintenance cost.

This work describes an automated and cost-effective way of reconstructing GPS-denied indoor environment using unordered and uncalibrated digital images of the scene. Here, digital images of large-scale indoor scenes are used to reconstruct photo-realistic and interactive 3D models of the environments. This research outlines an automated, robust and simplistic approach where existing 3D reconstruction algorithms are used effectively to come up with photo-realistic 3D models of different indoor environments.

Here, sequence of digital images from standard point and shoot camera are used to build photo-realistic model of an underground demonstration mine gallery and an indoor corridor. Feature extraction was done from the images using SURF algorithm before the feature points were matched for correspondence using approximate nearest neighbour (ANN) search. The generated sparse point cloud was used to build dense 3D point cloud using real-time plane sweeping algorithm. 3D surface reconstruction of the generated dense point cloud was done using Poisson Surface Reconstruction Algorithm. 3D textures were blended into the 3D surface to obtain photo-realistic 3D reconstructed scenes.

The accuracy of these models are verified against the real scene by taking measurements from both model and actual scenes. These models show an accuracy of upto 99 percent with Root Mean Square Error being from 1.5 to 2.0 cm. Mean Absolute Error was also found to be within 0.7 cm to 1.6 cm. These results demonstrate the effectiveness of using digital images in accurate modelling of large scale environments in mining and civil industries.

While CAD-models require hours of manual modelling and expensive laser-scanners require external AC-powered adapters or high voltage batteries to provide 3D data, the methodology discussed here only requires images of the environment to provide complete and as-accurate (minimum Root Mean Square Error of 1.156 cm, with R-square value of 99%) 3D model of the scene. Having almost zero operating-cum-maintenance cost, the image-based 3D modelling technique discussed here can be effectively implemented in large-scale civil industries to replace laser scanner based indoor modelling and time-consuming traditional surveying techniques.