Development of high-precision modeling and optimum view planning methods for 3D as-is model reconstruction of large-scale structures †

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Abstract

Many of infrastructures in japan were intensively constructed during the period of rapid economic growth. Nearly half a century has passed since then, the aging infrastructures are increasing exponentially. Therefore, there is a strong demand for strategic maintenance and updating of enormous of infrastructure buildings, and the use of 3D models is expected as a solution to this problem. In maintenance tasks, it is important for an administrator to understand the correct locations of the deformed region and, however, it is difficult to immediately grasp them in conventional 2D drawing. On the other hand, recently, technologies have been developed to automatically generate 3D as-is models from 3D point clouds measured by TLS (Terrestrial Laser Scanner) and images captured by a camera. Their technologies are expected to be used for efficient maintenance tasks. Thus, there is a need for a technology to generate 3D as-is models that reflect the current geometry of infrastructure buildings with high accuracy and efficiency.

To generate 3D as-is models of infrastructures with accuracy and efficiency, it is necessary to select appropriate scanning approaches and measure object surface without occlusions according to the object or purpose of use, but the following problems prohibit the progress of the technologies; (1) there is the problem that modeling accuracy decrease due to the overlap error in point clouds integration. Point clouds means a set of points captured by TLS and include coordinate values (xyz) and color information (RGB), tens of millions of points can be measured at one time. Whereas, since the region behind the object cannot be measured, the point clouds includes the occlusions. Therefore, we require two process: registration which estimate the scanning positions for the point clouds captured from multiple locations, and modeling which fit a mathematical surface against the point clouds. However, the final as-is model do not satisfy the required accuracy (e.g., error within 5 mm), and the 3D model may not be utilized in practice because the errors of registration and modeling are overlapped: (2) there is the problem that efficiency of the model generation in photogrammetry. SfM (Structure from Motion), which

estimates tie points and camera pose, and MVS (Multi-View Stereo), which generates a high-density 3D model, are necessary to generate a 3D model from many images captured by a camera. However, it is difficult to pre-estimate which camera pose and how many images are needed to reconstruct an accurate model. Therefore, if camera position or the number of images is inappropriate, the correct camera poses cannot be estimated, and the dense model with the degraded region (holes) and low-quality region is generated. Moreover, to avoid this problem, MVS processing takes an enormous amount of processing time when redundant images are captured.

For above two problems, the purpose of this research is to develop a high-quality modeling method and view planning method for generating 3D as-is model reconstruction in large-scale environments. We solve the problems from the following three approaches; (1) To generate accurate 3D as-is models of plant facilities from point clouds, we first extract cylindrical pipes in the plant from a plant point cloud, and develop a method of simultaneous registration and modeling using the cylindrical pipes as markers. The method is able to prevent the overlapping of the errors in each process and reconstruct high-accuracy models: (2) To generate accurate 3D as-is model from a set of images of a concrete building, we predict the geometric quality of 3D as-is model which will be obtained without MVS process only from the SfM result in a short time. Moreover, based on the quality prediction, we develop the algorithm for extracting the regions which are predicted as low-quality and estimating the additional camera poses which can improve the quality in advance: (3) we develop the photogrammetry process which can efficiently generate high-quality 3D models by integrating a smartphone, cloud service, and computer-assisted best-view guidance for optimal camera poses developed in (2). The system aims to achieve a one-day response that completes the process from photography to 3D model generation on the same day.

We applied the above methods to pseudo point clouds and actual point clouds of plant facilities to verify the robustness of the method and to compare with conventional methods about modeling accuracy. Moreover, we also applied the method to a set of images captured from concrete bridge columns and buildings and verified effectiveness of our study. Finally, the feasibility of one-day response in an actual construction site is discussed in terms of processing time.

Key Word: 3D Modeling, As-is Model, Laser Scanning, Registration, Point Clouds, Photogrammetry, SfM, MVS, View Planning

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