Online Feedback for Structure-from-Motion Image Acquisition

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The quality and completeness of 3D models obtained by Structure-from-Motion (SfM) heavily depend on the image acquisition process. If the user gets feedback about the reconstruction quality already during the acquisition, he can optimize this process. The goal of this paper is to support a user during image acquisition by giving online feedback of the current reconstruction quality. We propose an online SfM method that integrates wide-baseline still-images in an online fashion into a consistent reconstruction and we derive a surface model given the SfM point cloud. To guide the user to scene parts that are captured not very well, we colour the mesh according to redundancy and resolution information. In the experiments, we show that our approach makes the final SfM result predictable already during image acquisition. The method is suited for large-scale reconstructions as obtained by flying micro aerial vehicles as well as on small indoor environments.

We propose a method that supports a user in the acquisition process in two ways: (a) sparse online SfM with accuracy close to offline methods and (b) surface extraction and quality visualization. The workflow of our method is shown in Figure 1.

1 Online SfM for Wide-Baseline Still-Images

To speedup the SfM process to work in realtime on wide-baseline images, we weaken the assumption of most batch-based SfM pipelines that images are captured in random order. We assume that a freshly acquired input image I has an overlap to an already reconstructed scene part. This allows us to split the SfM problem in two tasks that are easier to solve: A localization and a structure expansion part. Hence, we can first localize I within the reconstructed scene according to the method proposed by Irschara et. al. [1]. We compute visual similarity scores to all reconstructed images and perform feature matching between I and the top n scored images. This results in 2D-3D correspondences between I and the reconstructed point cloud. We then localize I by solving the 3-point pose problem in a RANSAC loop. Finally, we expand the map by triangulating new 3D points. To avoid scene drift, we optimize the reconstructed scene by bundle adjustment in a parallel thread. Online SfM allows us to provide feedback within less than 2 seconds if the new acquired image has been integrated into the reconstruction (see Figure 2), which reduces the number of acquired images that are not suited for SfM. Furthermore, we show in the experiments that the accuracy is close to that obtained by offline methods like Bundler [2].

2 Surface Extraction and Quality Visualization

Because it is difficult to estimate the reconstruction quality on a point cloud, we derive a surface model given the sparse points obtained by SfM. The idea is to generate a 3D triangulation of all sparse points that embeds the real surface. To extract the subset of triangles which are on the object's surface, an energy functional is defined and minimized by graph cuts. This method extracts a surface even from a very low number of 3D points as shown in Figure 3. Since the number of 3D points is relatively low, this can be computed within seconds.

The quality of a final (dense) reconstruction mainly depends on two parameters: (a) Redundancy and (b) Ground Sampling Distance (GSD). Since the camera positions and the surface mesh are available, we compute both values and visualize them on the surface model by colouring. The user interactively selects which data is visualized to decide for a new camera position. This supports the user to obtain an equally distributed scene sampling. An example is shown in Figure 4.

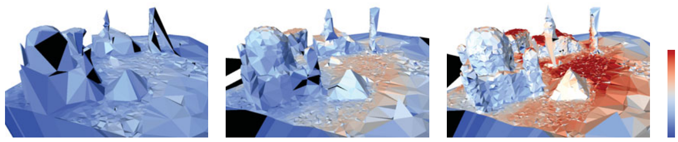
Our interactive method makes the image acquisition for SfM more efficient and allows the user to inspect the final reconstruction already on site. It opens SfM for applications where a certain completeness and accuracy of the reconstruction has to be guaranteed.

[1] A. Irschara, C. Zach, J. M. Frahm, and H. Bischof. From structure-from-motion point clouds to fast location recognition. In *CVPR*, 2009.

[2] N. Snavely, S. M. Seitz, and R. S. Szeliski. Modeling the world from internet photo collections. *IJCV*, 80(2):189–210, November 2008.

(a)

Figure 2: Online feedback of image integration. The result of the image integration is provided within less than 2 seconds to the user. Red bordered images could not be aligned into the reconstruction. This allows the user to adopt the image acquisition.



(a) (b) (c) (d)

Figure 3: (a) - (c) The resulting mesh of the City-of-Sights after 10, 20 and 50 reconstructed images. (d) Colormap. Blue indicates that a low number of cameras observe a triangle. Red indicates that a triangle is seen more than 30 times.

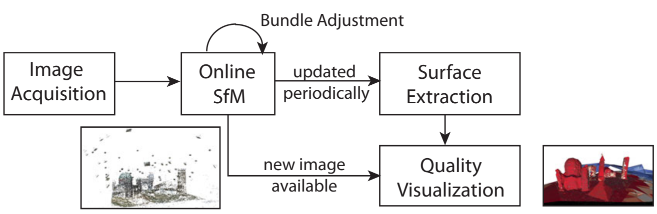
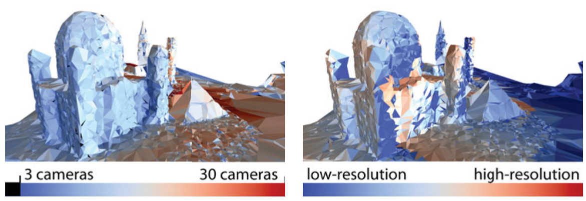


Figure 1: Workflow. Still-images are acquired by the user and integrated into the reconstruction. Periodically, we extract a surface mesh and visualize quality information.



(a) (b)

Figure 4: (a) Surface mesh extracted from a sparse point cloud with overlaid redundancy information. (b) Coloring according to maximum GSD. Best viewed in color.