Automated Evaluation of 3D Reconstruction Results for Benchmarking View Planning

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To obtain complete 3D object reconstructions using optical measurements, several views of the object are necessary. The task of determining good sensor positions to achieve a 3D reconstruction with low error, high completeness and few required views is called the Next Best View (NBV) problem. Solving the NBV problem is an important task for automated 3D reconstruction. However, comparison of different planning methods has been difficult, since only few dedicated test methods exist. We present an extension to our NBV benchmark framework presented in [1], that allows for faster, automated evaluation of large result data sets. We show that the method introduces insignificant error, while considerably reducing evaluation runtime and increasing robustness.

The NBV benchmark consist of the evaluation of five object details of a test object. These details pose different challenges to view planning algorithms. They are the 'tripod', which occlude other areas of the test object; the 'sinusoidal face', which is a smoothly curved free form; the 'notch" as a rectangular concavity; the 'negative half sphere', whose reconstruction is challenging regarding it's constrained visibility and the 'whole basic object', which assembles all the individual details in one test object.

These object details get evaluated regarding different reconstruction quality criteria. They are the average reconstruction error e_{av}, average point distance *apd*, the homogeneity of the point distribution, the percental surface coverage *cov* of an object detail and the number of views n needed for object reconstruction. For further details please refer to [1].

Practical use of the benchmark was limited for dense 3D reconstructions (eg. from optical 3D sensors using fringe projection) with millions of points due to long calculation runtime. Therefore we tried to decrease runtime by decreasing the number of points to consider. However, the present implementation proved unstable regarding point count decimation.

But the methods employed in the context of mesh simplification were not. One widely used evaluation framework called 'Metro' (Cignoni et al. [2]) calculates among other things the average distance of one surface to another. They define the distance $e(p, S)$ of the point p to the surface S as

$$e(p, S) = \min_{p' \in S} d(p, p') \,, \qquad (1)$$

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with d being the euclidean distance in R^3. The average distance $E_m(S_1, S_2)$ of the surface S_1 to the surface S_2 can then be written as

$$E_m(S_1, S_2) = \frac{1}{|S_1|} \int_{S_1} e(p, S_2)\, ds\,. \tag{2}$$

We can now express e_{av} as the distance $E_m(S_S, S_R)$ between the ground truth surface S_R and the scan S_S. Furthermore we redefined average point distance *apd*. By calculating the area per point A_p, we could express *apd* as the distance between center of hexagons with that area:

$$apd = \sqrt{\frac{2A_p}{\sqrt{3}}}\,. \tag{3}$$

Figure 1 shows some results. By reducing the more than two million 3D points resulting of a planning run with eight views using a robot mounted, fringe projection based optical 3D sensor, we achieved feasible benchmark run times *including* some remaining manual operation of less than 15 minutes at 200000 points. This is a big improvement compared with several hours needed before.

The right figure shows the error to be expected exemplary by the absolute error for coverage. While error increases with further point count reduction, it stays below 2.5% for relevant target point count of 200000 points. Other reconstruction quality criteria were insignificantly affected by point reduction.

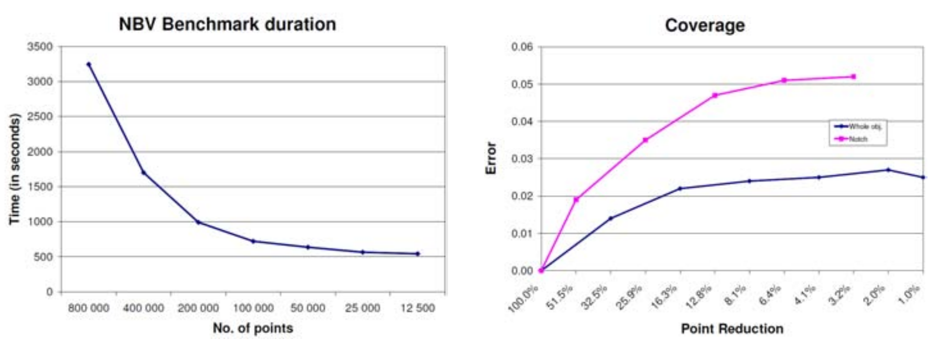

Fig. 1. NBV benchmark duration and error in coverage calculation against point count and point reduction rate, respectively.

References

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