(Summary of Ph.D. Thesis 2002 / 01 / 12)

Maximum Likelihood 3D Reconstruction of Structured Scenes From One or More Uncalibrated Views

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Statement : A method of maximum likelihood 3D reconstruction of structured scenes is obtained using a constraint-based approach.

Abstract The thesis addresses the problem of estimating the coordinates of 3D points from their perspective projections observed in one or more images, and from auxiliary information on the geometry of the scene, such as coplanarity, alignment, symmetry etc. We assume that some 2D points are given and that some geometric properties of the scene are known à-priori, and will compute the maximum likelihood reconstruction of the scene, under the assumption of i.i.d. gaussian errors in the observations.

Background It is well known that, from the projections alone of some 3D points in a single image, the depth of the 3D points cannot be uniquely determined. However, if some geometric properties of the viewed object are known, it may be possible to disambiguate the situation and obtain a unique reconstruction.

Previous methods that solve this problem exploit a limited set of geometric properties [1, 9, 2, 10] and it is most often [1, 9, 10] impossible to characterize the error in the obtained solution. Moreover, few single-view methods can use many images, and if they do, it is at the cost of some complications.

Practical improvements and technical contributions The proposed method improves over previous methods by extending the situations in which single-view reconstruction can be used [5], and by computing the maximum likelihood reconstruction, whose error can be statistically characterized [6].

The increased generality of our method is obtained by using an extended set of geometric properties. Moreover, the method can be used unchanged with many images. We show empirically that the errors in the observations can be considered gaussian, independent and identically distributed and implement the corresponding maximum likelihood estimator.

In order to solve the maximum likelihood reconstruction problem we use a differentiable parameterization for collections of 3D points that are subject to some geometric constraints. In developing this parameterization, a problem of matrix analysis had to be solved which we believe to constitute a contribution in itself.

This problem is solved by proving the following property : given a differentiable matrix-valued function A such that the rank of $A(x)$ does not depend on x, we show that there exists a differentiable matrix-valued function B, such that the columns of $B(x)$ form an orthonormal basis of the nullspace of $A(x)$. A simple method to compute this function is also given. Because this result does not appear in textbooks [3, 8] or other literature, we intend to submit it for publication in a journal.

Conclusion We define and benchmark a reconstruction method that presents practical improvements over the previous state-of-the-art, and verify experimentally the probabilistic assumption on which our method is based.

The articles [7, 4] are other publications related to this thesis. Complete bibliography can be found in my curriculum vitae.

References

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