Objective
To calibrate a single camera with fixed internal parameters in an unknown planar scene.

Motivation

Movable environments contain many large planar surfaces, the ground plane being particularly common one. Such structures render the standard self-calibration techniques inappropriate.

[Teffa, ECCV'08] showed that calibration from a planar surface is possible, but no closed form monocular solution has as yet been proposed.

We can rarely guarantee full knowledge of the metric structure of the scene, or the precise motion.

However, we can often be certain that the orientation of the camera, with respect to the surface on which it rests, is unchanged during a motion.

Planes and the Absolute Conic

The absolute conic is a point conic at infinity invariant to Euclidean motion as a set. Its image, the IAC, depends only on the camera internal parameters.

If the IAC is known, the calibration is an easy.

We can solve for the IAC from 5 or more points that lie on it (or fewer if the calibration parameters are constrained).

Planes intersect the absolute conic in the circular points.

By detecting the images of these intersections in three or more views, we can calibrate via the IAC.

Problem
How do we detect the circular points?

- We can detect circular points in one view, then transfer them into the others using plane-induced homographies.
- In previous work, detecting these initial points required stereo [Snavely et al., ECCV'08] or an iterative search [Teffa, ECCV'08].

Closed-form monocular solution

If the vanishing line of the plane is fixed during motion, then the circular points are fixed, because they must remain on L and on the absolute conic.

If the circular points are fixed in the scene, their images are also fixed.

The fixed image points are given by the homography of a homography induced by the plane.

The vanishing line, L, is fixed if the same plane is in the set of planes invariant to the motion.

These planes are perpendicular to the rotation axis.

Therefore of rotation must be normal to the scene for an involutory L. The translation can be anything.

Analytical proof: Rotation B has real eigenvector v, the axis orientation, and complex eigenvectors e and e’ are orthogonal to v, i.e. v.v = v.e = 0.

If v = n, the plane normal, then e and e’ are also eigenvectors of the calibrated image transform B = B.d ‘tan’, where r is any translation and d any scene distance. Conjugacy means that if e = e, the images of the complex invasions, are normal eigenvectors of B = B.RM; the plane-induced homography for the motion.

If the rotation axis is normal to the scene plane (a plane-normal motion), the complex invasions (eigenvectors) to a plane-induced homography lie on the image of the absolute conic.

Algorithm

To calibrate a camera from a horizontal plane:

1. With the camera at a different altitude for each motion, calculate plane-induced homographies B to motions about some vertical axis when viewing the scene plane.
2. Eige-recompute and find the circular points of each B. Their complex conic eigenectors.
3. Fit the IAC to the points using the Direct Linear Transform [Fisheye and Zisserman, 2001]. Cholesky decompose its inverse (the DTC) to give K, the calibration matrix.

We need three homographies for complete calibration, otherwise we are not known.

Simulations

- Simulations show that even for the minimal number of motions, this method will outperform a pure rotation calibration [Fisheye, LIC'08; Agapito et al., LIC'08] where the axis offset was greater than 10km.
- The algorithm is not sensitive to the precise angle of the rotation axis to the scene (5 ⎯ with near enough orthogonal).

Real scene tests

Through testing in real scenes confirms good accuracy, particularly where there is large control over the orientation of the camera. Tests included the following:

- Initial tests (example image pair to the left).
- Direct calibration from an actual scene where the camera is above a vertical plane, in a similar set of circumstances, but not cylindrical.
- Plane: approximately, but still with obvious bias; B again very nearly rigid using a near fixed calibration. This gives a deviation of 1pt.

The process also yields a model for the IAC.

Rectification

Calibration for the circular points and focal length (other parameters known) from just two input images allow us to get rectifications of unknown scene planes: