1. Camera models

A camera is a mapping between the 3D world (object space) and a 2D image.

It will be seen that all cameras modelling central projection are specializations of the general projective camera. The anatomy of this most general camera model is examined using the tools of projective geometry. It will be seen that geometric entities of the camera, such as the projection centre and image plane, can be computed quite simply from its matrix representation. Specializations of the general projective camera inherit its properties, for example their geometry is computed using the same algebraic expressions. The specialized models fall into two major classes – those that model cameras with a finite centre, and those that model cameras with centre “at infinity”. Of the cameras at infinity the affine camera is of particular importance because it is the natural generalization of parallel projection. This chapter is principally concerned.

3. Camera models with details about Pin-hole camera

The basic pinhole model ,We consider the central projection of points in space onto a plane. Let the centre of projection be the origin of a Euclidean coordinate system, and consider the plane Z = f, which is called the image plane or focal plane. Under the pinhole camera model, a point in space with coordinates X = (X, Y, Z) T is mapped to the point on the image plane where a line joining the point X to the centre of projection meets the image plane.

To computes that the point (X, Y, Z) T is mapped to the point (f X/Z, f Y/Z, f) T on the image plane,

Ignoring the final image coordinate.

(X, Y, Z)T → (f X/Z, f Y/Z) T

describes the central projection mapping from world to image coordinates. This is a mapping from Euclidean 3-space IR3 to Euclidean 2-space IR2. The centre of projection is called the camera centre. It is also known as the optical centre. The line from the camera centre perpendicular to the image plane is called the principal axis or principal ray of the camera, and the point where the principal axis meets the image plane is called the principal point.

2. Projections: Orthogonal, Euclidean, Affine and Perspective

**Orthogonal projection**

Orthogonal projection also referred to as Orthographic projection, used to be called analemma . is a means of representing three-dimensional objects in two dimensions. It is a form of parallel projection, in which all the projection lines are orthogonal to the projection plane, resulting in every plane of the scene appearing in affine transformation on the viewing surface. The obverse of an orthographic projection is an oblique projection, which is a parallel projection in which the projection lines are not orthogonal to the projection plane.

Consider projection along the Z-axis. This mapping takes a point (X, Y, Z, 1) T to the image point (X, Y, 1) T, dropping the Z-coordinate. For a general orthographic projection mapping . Writing t = (t1, t2, t3). An orthographic camera has five degrees of freedom, namely the three parameters describing the rotation matrix R, plus the two offset parameters t1 and t2. An orthographic projection matrix P = [M | t] is characterized by a matrix M with last row zero, with the first two rows orthogonal and of unit norm, and t3 = 1.

**Euclidean**

The development of the sections to this point has implicitly assumed that the world and image coordinate systems are Euclidean. Ideas have been borrowed from projective geometry (such as directions corresponding to points on π∞) and the convenient notation of homogeneous coordinates has allowed central projection to be represented linearly.

This is easily achieved, for suppose the world coordinate frame is projective, then the transformation between the camera and world coordinate frame is again represented by a 4 × 4 homogeneous matrix, Xcam = HX, and the resulting map from projective 3-space IP3 to the image is still represented by a 3 × 4 matrix P with rank 3. In fact, at its most general the projective camera is a map from IP3 to IP2, and covers the composed effects of a projective transformation of 3-space, a projection from 3- space to an image, and a projective transformation of the image. T

However, it is important to remember that cameras are Euclidean devices and simply because we have a projective model of a camera it does not mean that we should eschew notions of Euclidean geometry. Euclidean and affine interpretations. Although a (finite) 3 × 4 matrix can obtain a rotation matrix, a calibration matrix K, and so forth, Euclidean interpretations of the parameters so obtained are only meaningful if the image and space coordinates are in an appropriate frame. In the decomposition case a Euclidean frame is required for both image and 3-space. On the other hand, the interpretation of the null-vector of P as the camera centre is valid even if both frames are projective – the interpretation requires only collinearity, which is a projective notion. The interpretation of P3 as the principal plane requires at least affine frames for the image and 3-space. Finally, the interpretation of m3 as the principal ray requires an affine image frame but a Euclidean world frame in order for the concept of orthogonality (to the principal plane) to be meaningful.

**Affine**

The affine camera, PA. As has already been seen in the case of P∞, a general camera matrix of the affine form, and with no restrictions on its elements,

It has eight degrees of freedom, and may be thought of as the parallel projection version of the finite projective camera.

The affine camera covers the composed effects of an affine transformation of 3-space, an orthographic projection from 3-space to an image, and an affine transformation of the image.

The camera models of this section are seen to be affine cameras satisfying additional constraints, thus the affine camera is an abstraction of this hierarchy. For example, in the case of the weak perspective camera the rows of M2×3 are scalings of rows of a rotation matrix, and thus are orthogonal.