Reconstruction

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Problem Definition

- What we have so far
  - Correspondences using either correlation or feature based approaches
  - Epipolar Geometry from at least 8 point correspondences
- Given a set of valid correspondences
  - Want to compute the 3D position of the points in space that are associated with each correspondence
  - There are different approaches depending on what we know about the cameras

Reconstruction possibilities

Three cases of 3D reconstruction depending on the amount of a priori knowledge on the stereo system

- Both intrinsic and extrinsic known - > can solve the reconstruction problem unambiguously by triangulation. By unambiguously we mean computing the true positions in 3D space of the feature points relative to the stereo cameras.
- Only intrinsic known -> recovery structure and extrinsic up to an unknown scaling factor. Since we do not know the position of the stereo cameras this means that we can know the true distance between the cameras only up to a scale.
- Only correspondences -> reconstruction only up to an unknown, global projective transformation. We will not cover this situation, since this is rather theoretical.

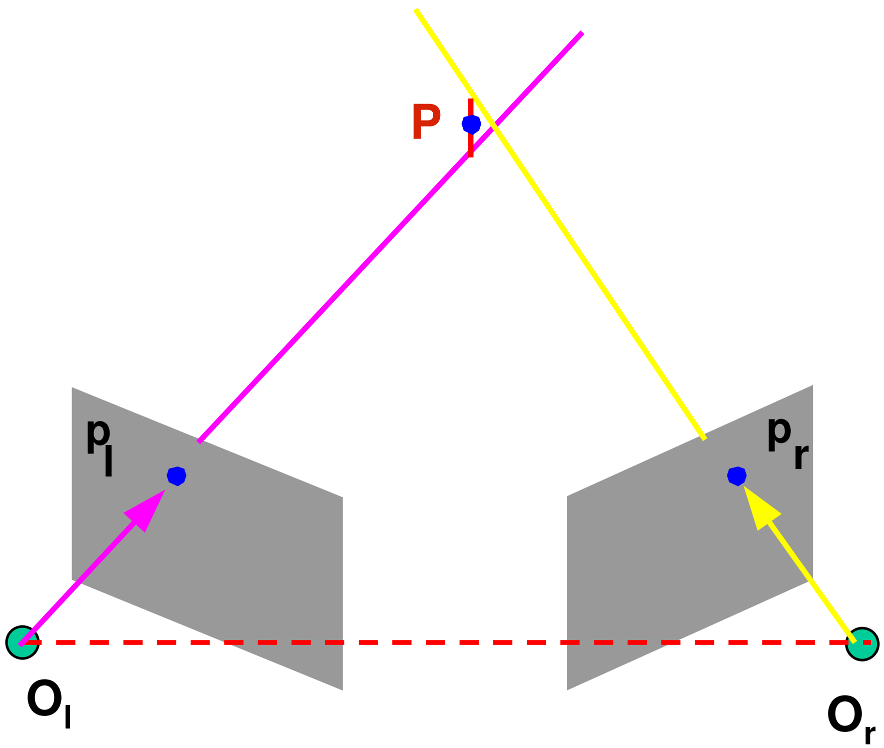
Both intrinsic and extrinsic known

- Occurs when you have calibrated the cameras using standard camera calibration
- Using the intrinsic and extrinsic camera calibration and the pixel co-ordinates of the matching feature points we need to compute the 3D location of that feature point
- Can be done using simple geometric triangulation

Known intrinsic and extrinsic

Solution

- Triangulation: Two rays are known and the intersection can be computed
- Problem: Two rays will not actually intersect in space due to errors in calibration and correspondences, and pixelization
- Solution: find a point in space with minimum distance from both rays



Only intrinsic known

- Compute the fundamental matrix F from at least 8 correspondences
- Use camera calibration to find essential matrix E from the fundamental matrix F
- Estimate T (up to a scale and a sign) from E (=RS) using the orthogonal constraint of R, and then R
  - End up with four different estimates of the pair (T, R)
- Reconstruct the depth of each point using triangulation, and pick the correct sign of R and T
- Results: reconstructed 3D points (up to a common scale);
- The scale can be determined if the true distance of two points (in space) are known

Only intrinsic parameters - details

- Given a set of correspondences
- Use the 8 point algorithm to compute F
- Remember that $\mathbf{F} = \mathbf{M}_r^{-\mathbf{T}} \mathbf{E} \mathbf{M}_l^{-1}$ so using calibration matrix K compute the essential matrix E
- But we know that E = RS and we can use SVD decomposition to get back R, and S (and there translation T) from E
- There are ambiguities that can be resolved by computing the 3D co-ordinates of the matching points
- There are actually four possible combinations for R and T because of some symmetry
- Get 3D data points and extrinsic parameters
- But you only know translation up to a scale factor
    - If you change translation scale still get same pixel coordinates

Reconstruction results

- You get camera position and 3D data points for the correspondences
- Can use camera position for doing augmented reality (adding virtual objects)
- Can use 3D data points to make 3D models of objects
- Basic technology used in many other applications