Human Computer Interaction

6. Vision-based Controls (B)

Course no. ILE5013

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Goals

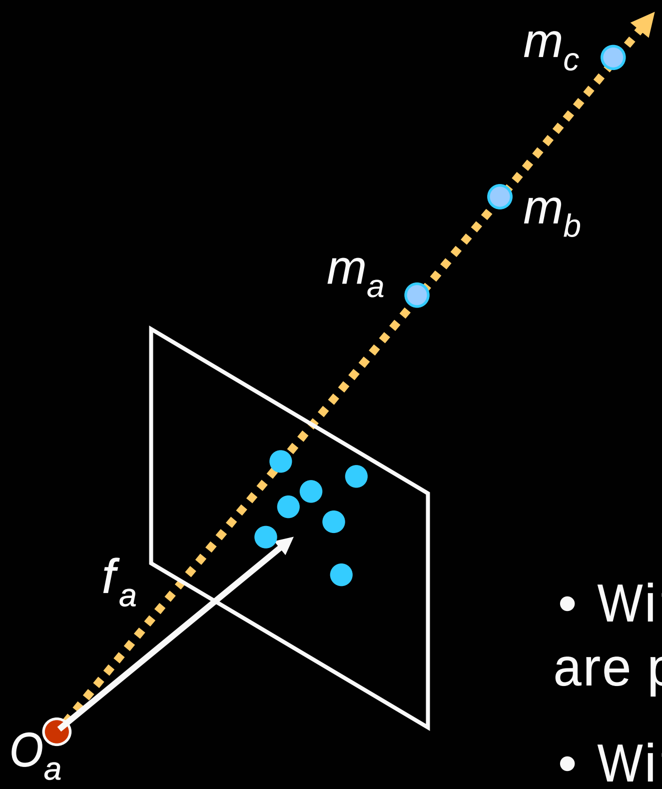
- From 2D to 3D, learn the basic 3D reconstruction.
- Efficient (and simple ?) approaches for real-time user interfaces.

Outline

- Feature extraction
  - Color matching
  - Grouping or clustering
  - Silhouette & foreground
- Motion tracking
  - Filtering and prediction
- 3D position estimation
  - Two views
  - mirrored views

Estimating 3D positions

- Given a projected point set, what are the 3D structure?

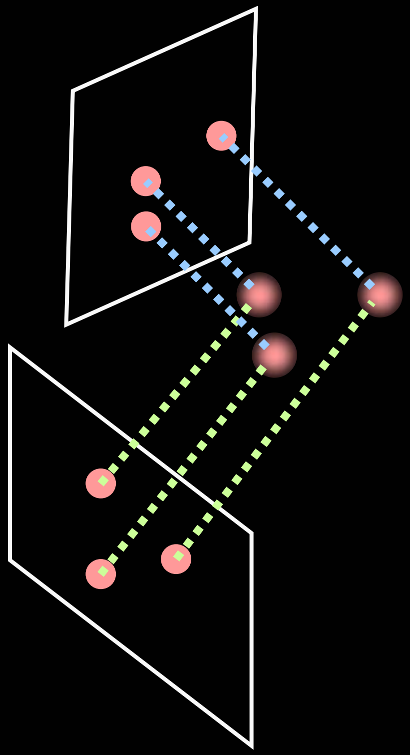


Which one is correct?

- Without other information, all these points are possible!!!
- With prior constraints or at least two views !

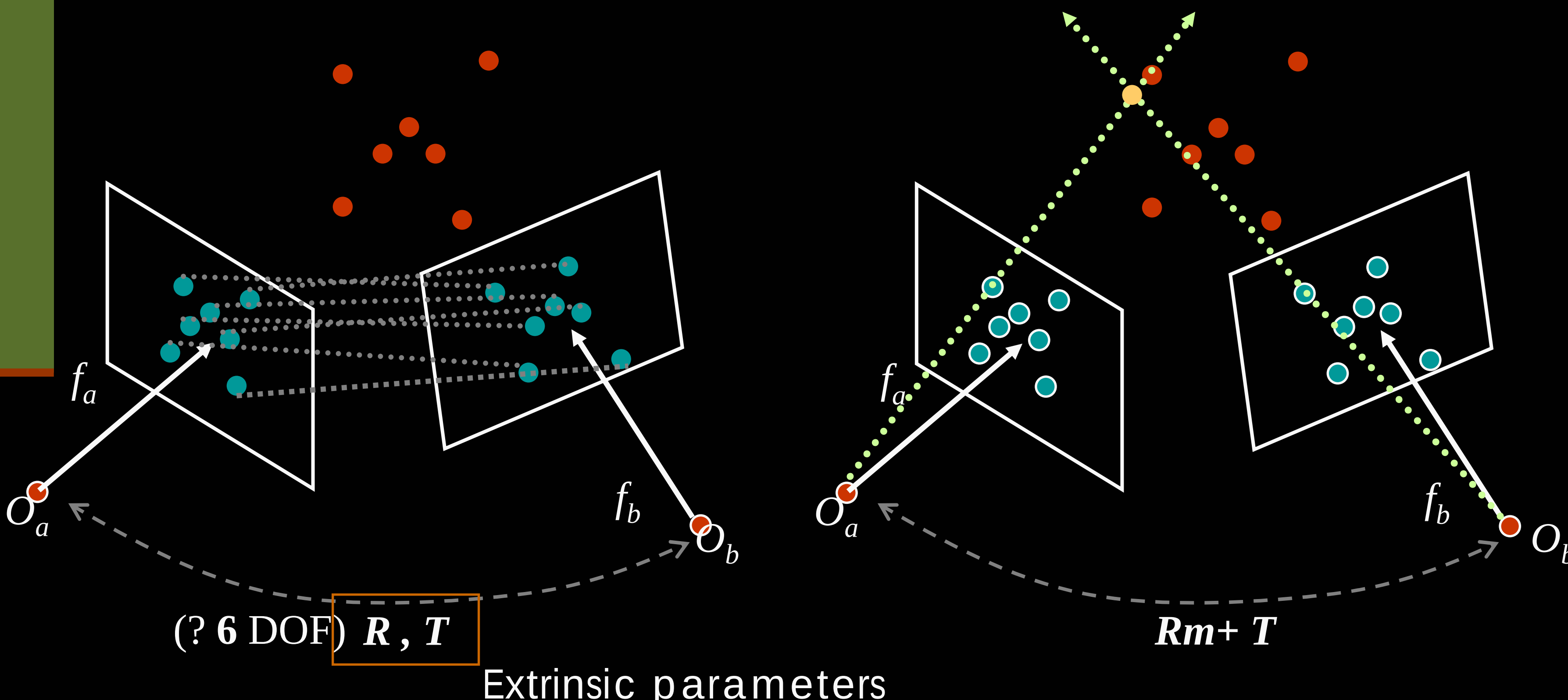
Two Orthogonal Views

- The simplest case:
  - two orthogonal views + parallel projection
- Orthogonal views
  - Calibration problems ?
- Parallel projection
  - When does it work?
- If the applications do not require high accuracy in 3D est., this can be an candidate approach.



Triangulation (Stereo)

- Given some points in correspondence across two or more images (taken from calibrated cameras), $\{(u_j, v_j)\}$, compute the 3D location X

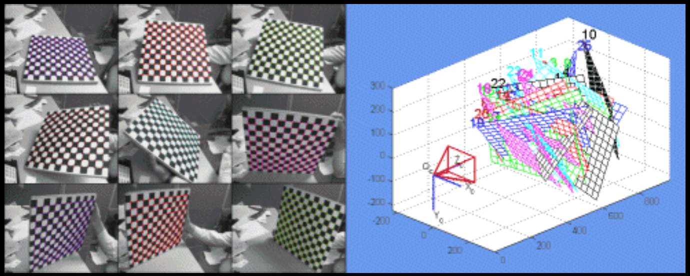


3D Estimation from Two Views

1. Estimate intrinsic camera parameters.
   - E.g. optic center, camera distortion, etc.
2. Estimate extrinsic camera parameters.
   - E.g. motion between two views.
3. Estimate 3D structure by triangulation.

- Refer to textbooks or lecture notes in computer vision (or image-based modeling) courses.

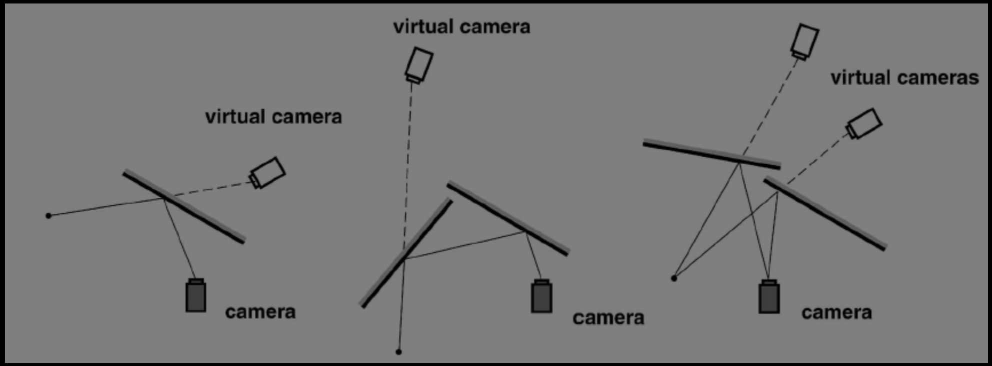
Camera Calibration

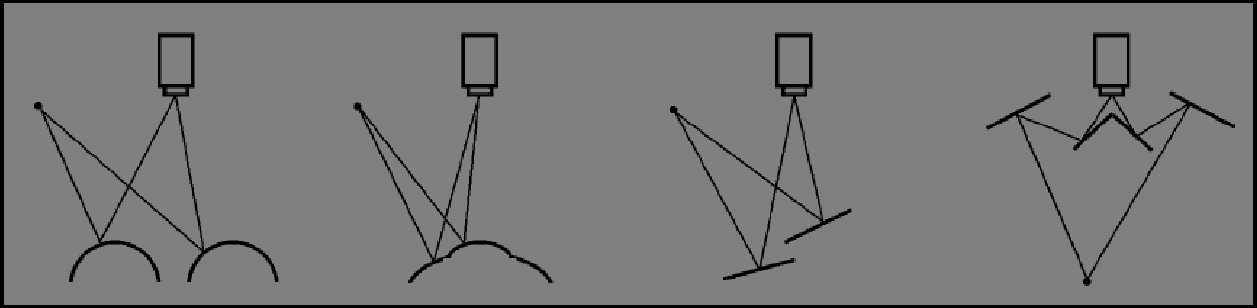


- Public camera calibration tools
  - A flexible new technique for camera calibration
    - http://research.microsoft.com/~zhang/calib/
    - Z. Zhang. A flexible new technique for camera calibration. IEEE Trans. Pattern Analysis and Machine Intelligence, 22(11):1330-1334, 2000.
  - Camera calibration toolbox for matlab
    - http://www.vision.caltech.edu/bouguetj/calib_doc/
  - Tsai's camera model
    - http://www.cs.cmu.edu/~rgw/TsaiDesc.html
    - "A versatile Camera Calibration Technique for High-Accuracy 3D Machine Vision Metrology Using Off-the-Shelf TV Cameras and Lenses", Roger Y. Tsai, IEEE J. Robotics and Automation, Vol. RA-3, No. 4, 1987, pages 323-344.

Estimating 3D Positions

- Using mirrors, we can acquire multi-views with a single camera.

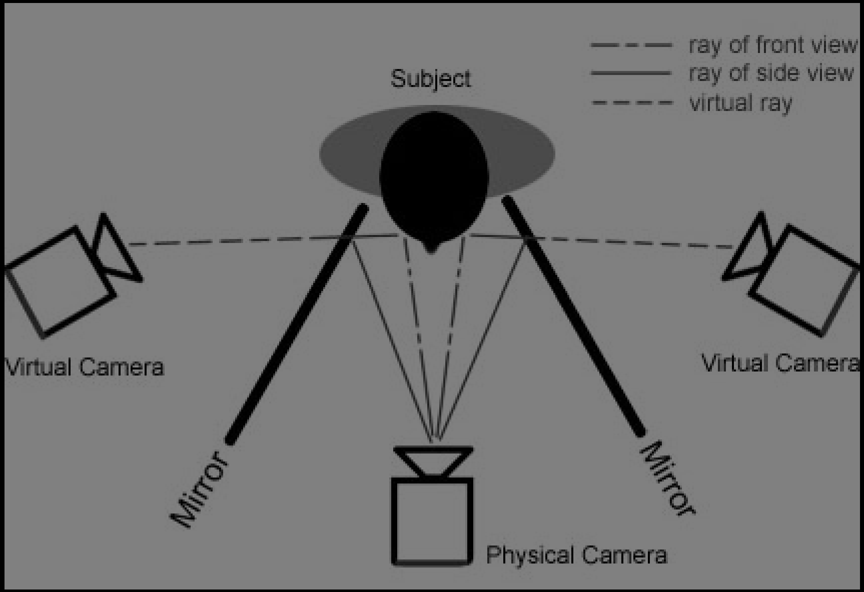




Stereo sensors from a variety of mirrors. J. Gluckman et al. (CVPR'99) (PAMI'02)

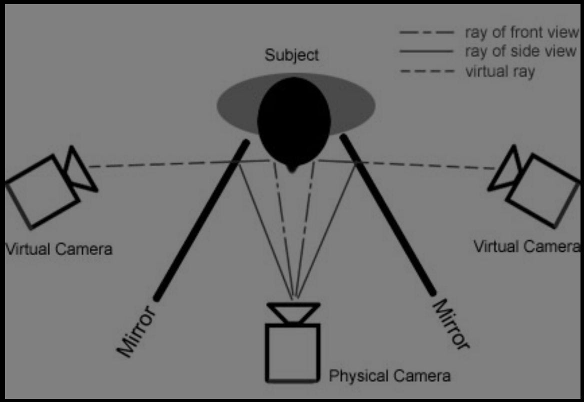
Mirrored Views

- Using planar mirrors can make reconstruction much easier.
- The simplest case:
  - Mirrors placed at 45-degree included angles.
  - Problem:
    - Calibration
    - Projective views
    - …



Reconstruction from Mirrored Views

- E.C. Patterson et al.(CA'91):
  - Assumed that the mirror and camera was vertical.
- S. Basu et al. (CVPR workshop'97)(ICCV'98):
  - Lip position evaluation via R, t estimation between virtual cameras.



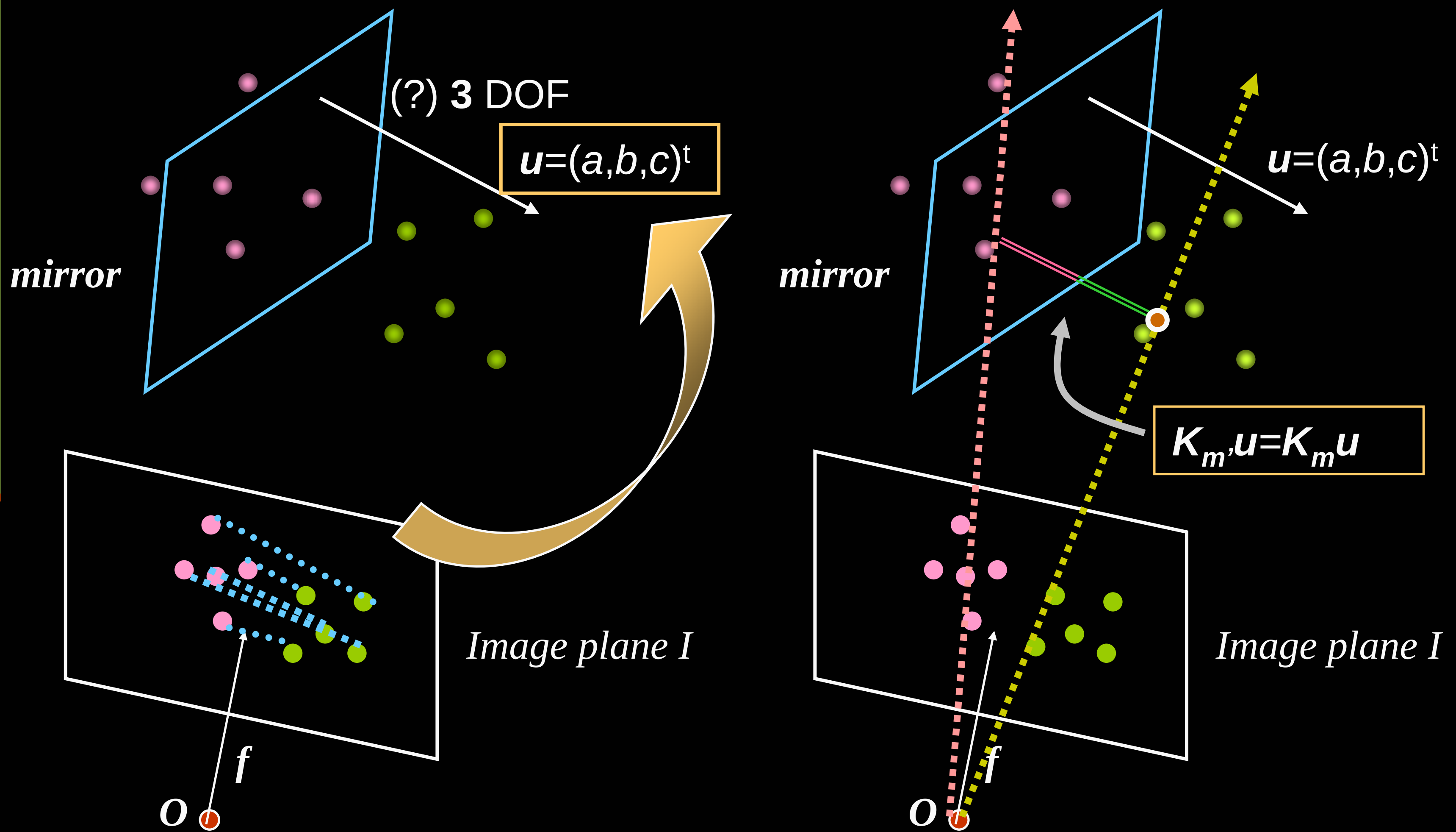
- I.-C Lin et al. (CG&A'02)(TVC' 05)
  - Efficient and reliable algorithms for calibration and 3D reconstruction in planar mirror configuration.
  - For dense facial motion tracking.

3D Tracking in Mirror-reflected Multi-views

“Mirror Mocap” (illuminated by UV light)

3D Position estimation

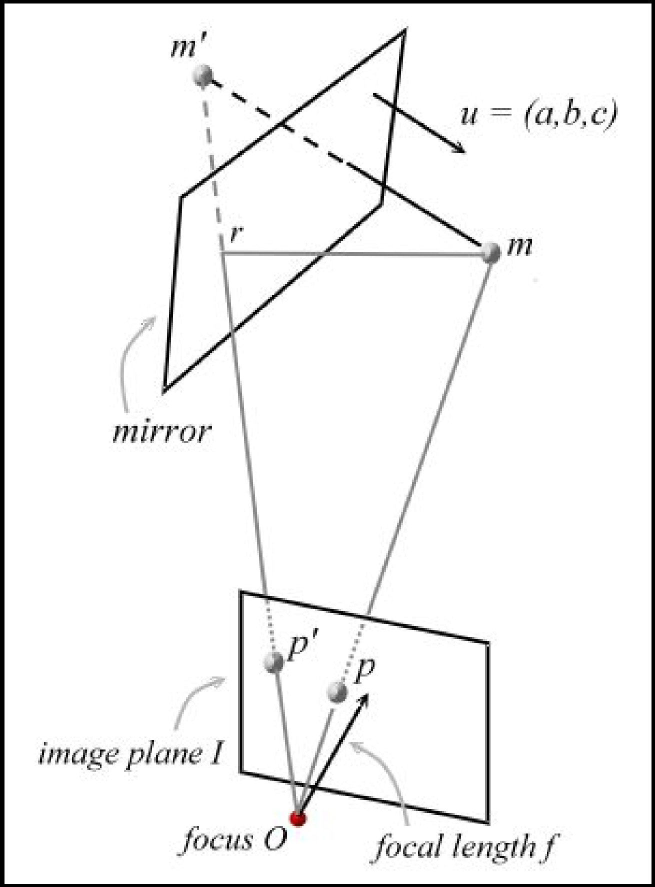
- Estimating 3D positions by evaluating the mirror plane's parameters.



3D Position estimation

- Given real vs. mirrored projected point correspondences.

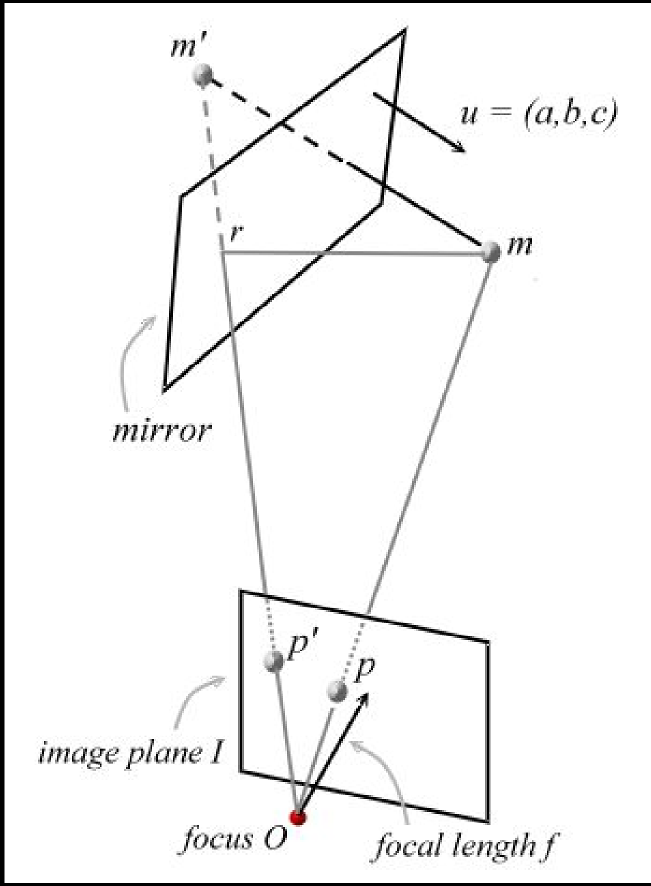
- Known: p_i , p_i' , f.
- Unknown: m_i, m_i', u, d.
- Calculating 3D positions via mirror plane estimation.



The geometric representation of physical point *m*, reflected point *m'*, and the projected point *p* and *p'*.

3D Position estimation (cont.)

- We assumed that the mirror is flat.
- Calculating 3D positions via evaluation of the mirror plane.



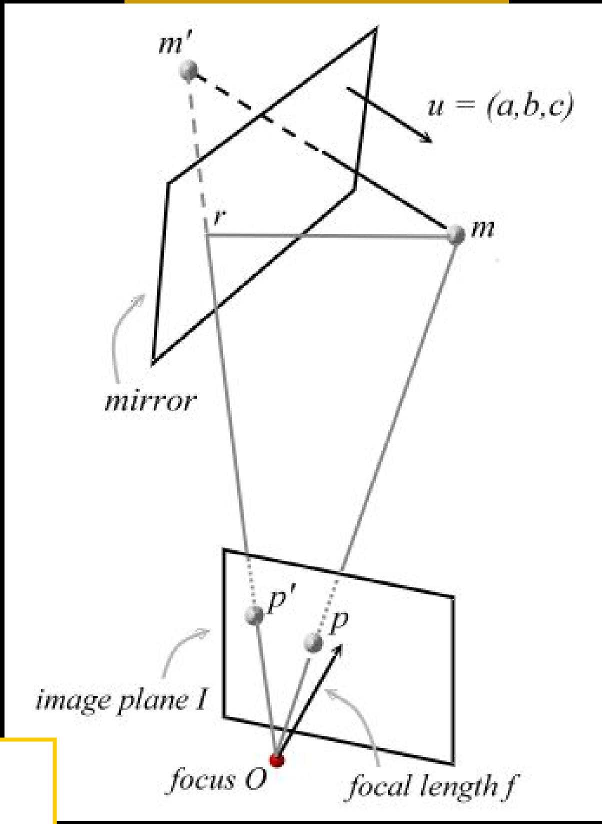
- Properties:
  - $ax+by+cz=d$, $u=(a, b, c)^t$, $|u|=1$. (1)
  - $m_i'=m_i + ku$. (2)
  - $(m_i' - \Theta)=H_u(m_j - \Theta)$, where H_u is the Householder matrix. (3)

3D Position estimation (cont.)

- Since m_i , m_i' and u are coplanar,

$$(p_i')^t U p_i = 0, \text{ where } U = \begin{bmatrix} 0 & -c & b \\ c & 0 & -a \\ -b & a & 0 \end{bmatrix}$$

- Approximate the mirror plane by a least square method.



$$\begin{bmatrix} (y_{p1} - y'_{p1}) f & (-x_{p1} + x'_{p1}) f & (x_{p1} y'_{p1} - y_{p1} x'_{p1}) \\ (y_{p2} - y'_{p2}) f & (-x_{p2} + x'_{p2}) f & (x_{p2} y'_{p2} - y_{p2} x'_{p2}) \\ \vdots & \vdots & \vdots \\ (y_{pn} - y'_{pn}) f & (-x_{pn} + x'_{pn}) f & (x_{pn} y'_{pn} - y_{pn} x'_{pn}) \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} = 0$$

3D Position estimation (cont.)

- Deducing from symmetric properties, depths are in proportion to *d*. (similar to *T* in stereovision)

$$\begin{bmatrix} \left(\frac{2a^2-1}{2f}\right)x_{pi} + \left(\frac{ab}{f}\right)y_{pi} + ac & \frac{x'_{pi}}{2f} \\ \left(\frac{ab}{f}\right)x_{pi} + \left(\frac{2b^2-1}{2f}\right)y_{pi} + bc & \frac{y'_{pi}}{2f} \\ \left(\frac{ac}{f}\right)x_{pi} + \left(\frac{bc}{f}\right)y_{pi} + \frac{2c^2-1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} z_{mi} \\ z'_{mi} \end{bmatrix} = d \begin{bmatrix} a \\ b \\ c \end{bmatrix}$$

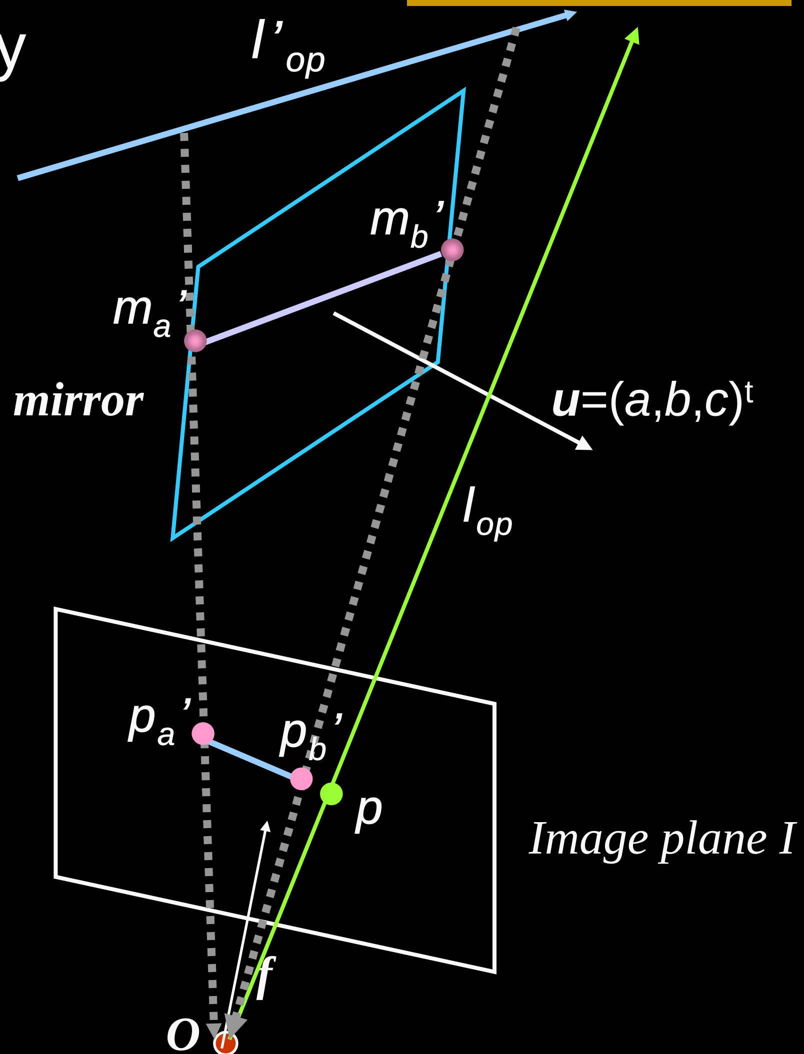
- (z_{mi} and $z_{mi'}$)can be estimated by a least square method. The 3D positions are reconstructed by scaling data.

Potential 3D Candidates

- Constructing 3D candidates by *mirrored epipolar lines*.

$$(p')^t U p = 0$$

$$\begin{bmatrix} x'_p & y'_p & 1 \end{bmatrix} \begin{bmatrix} -cy_p + b \\ cx_p - a \\ -bx_p + ay_p \end{bmatrix} = 0$$



Conclusion

- Efficient (or simple) 3D reconstruction algorithms are introduced.
- 3D vision-based controls can provide more flexibility.
- The process time and device requirement will increase for 3D.
- Choose an appropriate method according to accuracy, budgets, process time, devices, etc.