About the course

- **Instructors:**
  - Haibin Ling (hbling@temple, Wachman 305)

- **Hours**
  - Lecture: Tuesday 5:30 - 8:00pm, TTLMAN 403B
  - Office hour: Tuesday 3:00 - 5:00pm, or by appointment

- **Textbook**
  - Papers assigned in the class.

Grading & Project

- **Homework:** 20%
  - One page summary and critiques about papers presented in the class
  - Need to submit at least 15 times
  - Due (electronically) BEFORE the start of the class in which the paper will be presented – NO extension

- **Paper Presentation:** 25%
  - Present at least one paper
  - Responsible to the discussion in class

- **Projects:** 55%
  - Topics suggested by the instructor or found by the students
  - Small team, preferred 1-2 students per team.
  - Midterm: 15%
  - Final: 20%
  - Report: 20%

Course Content

- **Introduction in high level**
  - Each student is expected to know for details of a selected topic (paper presentation and project)

- **State-of-the-arts in frontier topics**

- **Paper presentation and summary for improve understanding**

- **Course project**

Tentative Schedule

- **Aug. 27 – General introduction**
- **Sep. 3 – Background introduction – statistical methods**
- **Sep. 10 – Background introduction – optimization**
- **Sep. 17 – Segmentation**
  - Paper selection due.
- **Sep. 24 – Feature and representation**
- **Oct. 1 – Matching and registration**
- **Oct. 8 – Shape analysis**
- **Oct. 15 – Face recognition**
  - Project proposal presentation.
- **Oct. 22 – Category and scene classification**
- **Oct. 29 – Object detection**
- **Nov. 5 – Visual tracking (single target)**
- **Nov. 12 – Visual tracking (multiple targets)**
- **Nov. 19 – Activity understanding and final project presentation (group 1)**
  - Thanksgiving
- **Dec. 3 – Final project presentation (group 2)**
- **Dec. 10 – Project report due.**

Students introduction

- **Name**
- **Advisor (if any)**
- **Background or your current research (if any)**
- **Any topics of particular interest (if any)**
- **Send an email to me**

Image formation - Cameras
How do we see the world?

- Let's design a camera
  - Idea 1: put a piece of film in front of an object
  - Do we get a reasonable image?

Pinhole camera

- Add a barrier to block off most of the rays
  - This reduces blurring
  - The opening known as the aperture

Pinhole camera model

- Pinhole model:
  - Captures pencil of rays – all rays through a single point
  - The point is called Center of Projection (focal point)
  - The image is formed on the Image Plane

Dimensionality Reduction Machine (3D to 2D)

- Points → points
  - But projection of points on focal plane is undefined
- Lines → lines (collinearity is preserved)
  - But line through focal point projects to a point
- Planes → planes (or half-planes)
  - But plane through focal point projects to line

Projection properties

- Many-to-one: any points along same ray map to same point in image
- Points → points
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Modeling projection

- The coordinate system
  - We will use the pinhole model as an approximation
  - Put the optical center (O) at the origin
  - Put the image plane (\(\Pi\)) in front of O

Source: J. Ponce, S. Seitz

Homogeneous coordinates

- Is this a linear transformation? \((x, y, z) \rightarrow (f'x/z, f'y/z)\)
  - No — division by z is nonlinear

Trick: add one more coordinate:

\[
\begin{bmatrix}
  x \\
  y \\
  z \\
  1
\end{bmatrix} \rightarrow \begin{bmatrix}
  x/w \\
  y/w \\
  z/w \\
  1
\end{bmatrix}
\]

Converting from homogeneous coordinates

\[
\begin{bmatrix}
  x \\
  y \\
  z \\
  w
\end{bmatrix} \Rightarrow \begin{bmatrix}
  x/w \\
  y/w \\
  z/w \\
  w
\end{bmatrix}
\]

Perspective Projection Matrix

- Projection is a matrix multiplication using homogeneous coordinates:

\[
\begin{bmatrix}
  1 & 0 & 0 & 0 \\
  0 & 1 & 0 & 0 \\
  0 & 0 & 1/f' & 0 \\
  0 & 0 & 1/f' & 1
\end{bmatrix} \begin{bmatrix}
  x \\
  y \\
  z \\
  1
\end{bmatrix} \Rightarrow \begin{bmatrix}
  f'x/z \\
  f'y/z \\
  z
\end{bmatrix}
\]

divide by the third coordinate

In practice: lots of coordinate transformations...

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In practice: lots of coordinate transformations...

- Camera to pixel coord. trans. matrix
- Perspective projection matrix
- World to camera coord. trans. matrix
- 3D point

Home-made pinhole camera

Why so blurry?

http://www.debevec.org/Pinhole
Shrinking the aperture

- Why not make the aperture as small as possible?
  - Less light gets through
  - Diffraction effects...

Adding a lens

- A lens focuses light onto the film
  - Rays passing through the center are not deviated

Thin lens formula

\[ \frac{1}{D'} + \frac{1}{D} = \frac{1}{f} \]

Any point satisfying the thin lens equation is in focus.
Real lenses

Lens flaws: Vignetting

Radial Distortion
- Caused by imperfect lenses
- Deviations are most noticeable for rays that pass through the edge of the lens

Illumination condition
- Light and color