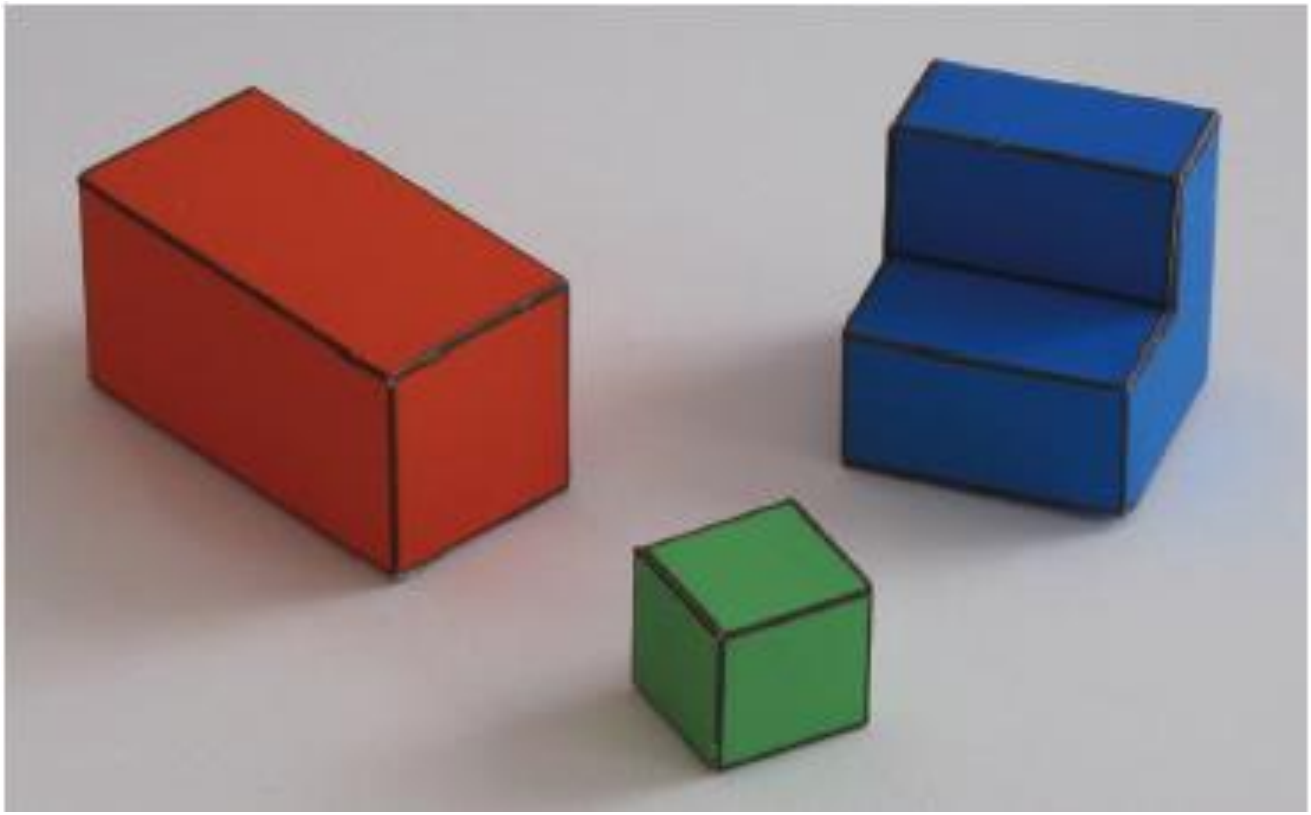
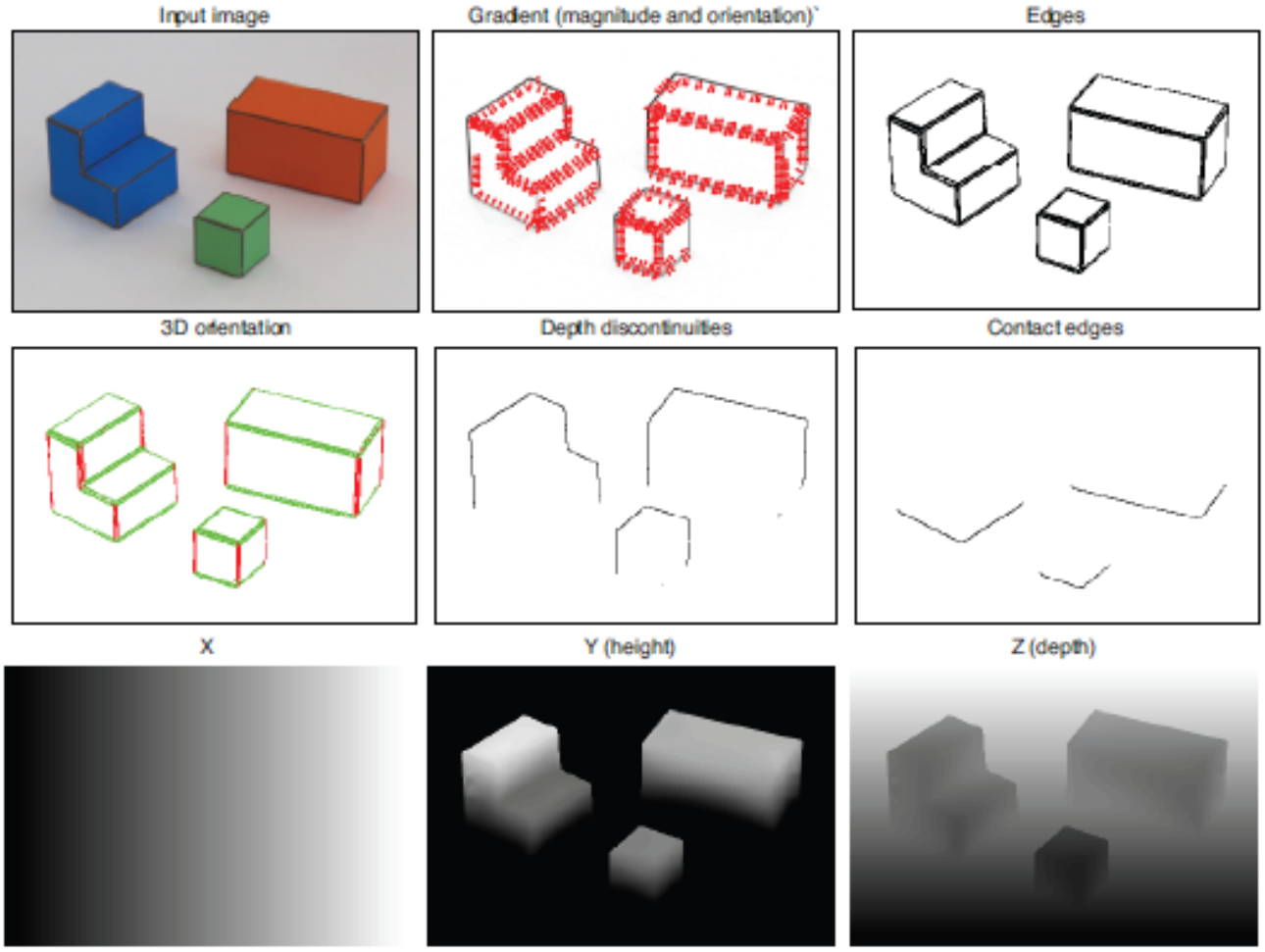
COS 429 PS2: Reconstructing a Simpler World



Due October 16th

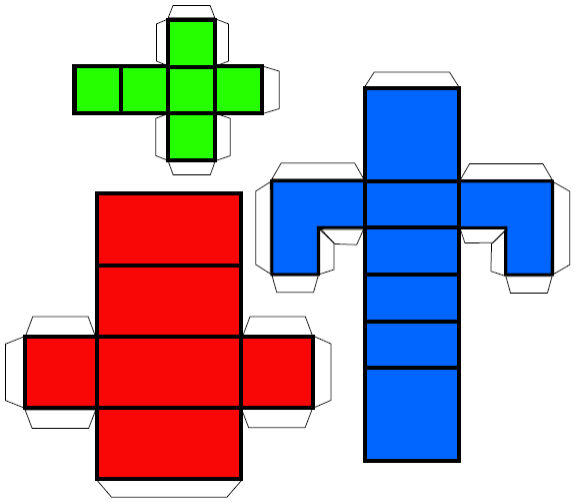
Goal

- Recover the 3D structure of the world



Problem 1: Making the World Simpler

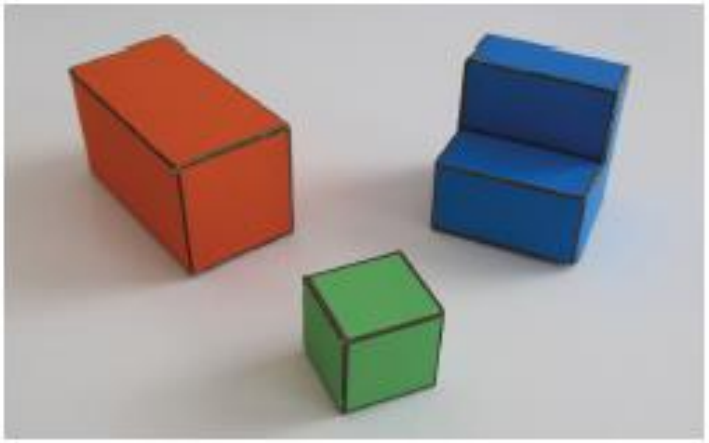
- Simple World Assumptions:
  - Flat surfaces that are either horizontal or vertical
  - Objects rest on a white horizontal ground plane
- Task:
  - Print Figure 1 and create objects for the world
  - Take a picture of the world you created and **add it to the report**

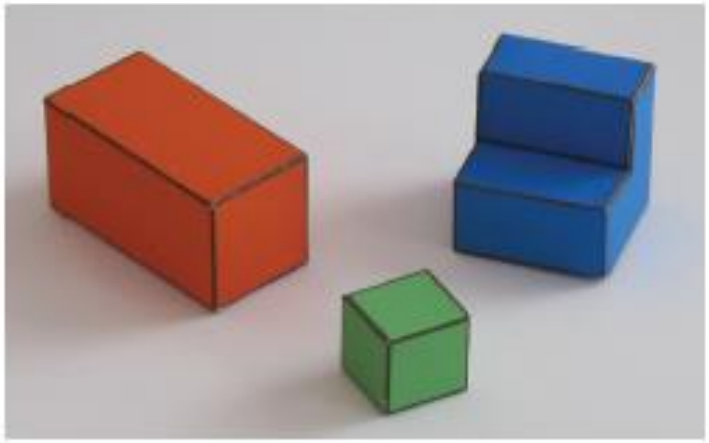


Problem 2: Taking Orthographic Pictures

- Goal:
  - Want pictures that preserve parallel lines from 3D to 2D
    - Willing to accept weak perspective effects

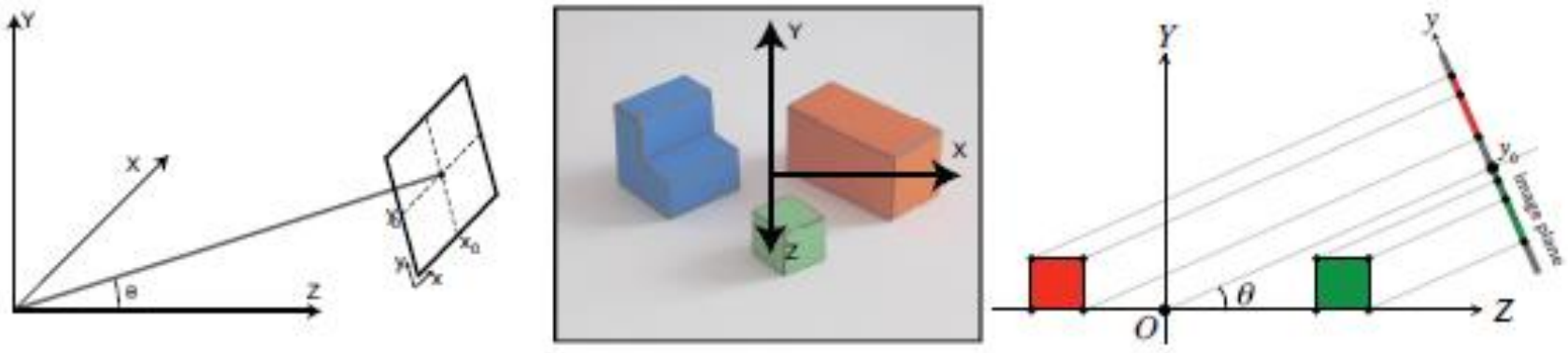
- How:
  - Use the zoom of the camera or crop the central part of a picture
- Task:
  - Take two pictures of the same scene so one image exhibits perspective projection and the other orthographic project and **add it to the report**
  - Want both pictures to look as similar as possible





Problem 3: Orthographic Projection

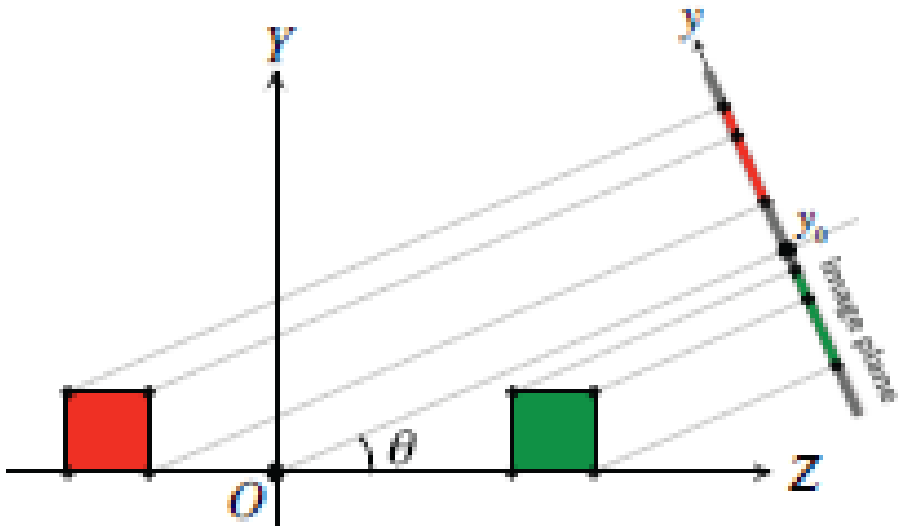
- Two coordinate systems (X, Y, Z) world and (x, y) image
- X axis of world coordinate system aligns with x axis of camera plane
- Y and Z axes of world coordinate system align with y axis of camera plane



- Task:
  - Prove the two projection equations below that relate the 3D world position (X, Y, Z) to the 2D projected camera position (x, y)

$$x = \alpha X + x_0$$

$$y = \alpha(\cos(\theta)Y - \sin(\theta)Z) + y_0$$



Problem 4: Geometric Constraints

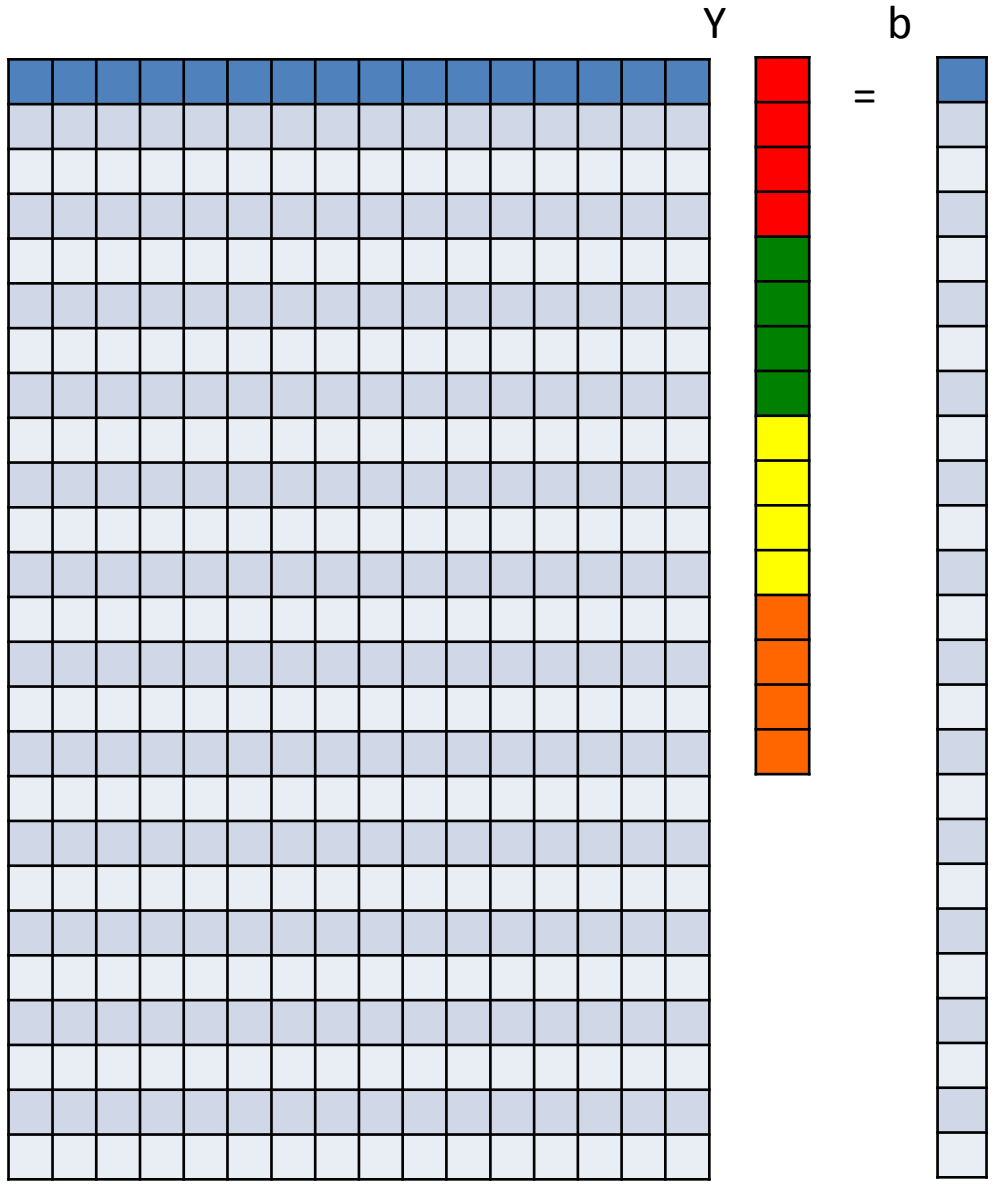
- Find edges with corresponding strengths and orientations
- End goal is to find X(x, y), Y(x, y), Z(x, y)
  - Given our coordinate system: X(x, y) = x
  - Harder to find Y and Z since one dimension was lost due to projection
    - Create linear system of equations of constraints

- Color threshold determines ground from objects
  - On the ground Y(x, y) = 0
- Assume parallel projection
  - All 2D vertical edges are 3D vertical edges
    - Fails occasionally

Constraints

- Vertical Edges: $\frac{\partial Y}{\partial y} = \frac{1}{\cos(\theta)}$
  - Equals $\frac{1}{\cos(\theta)}$ using the projection equations proved earlier
- The vector **t** = ($-n_y$, n_x) is the direction tangent to an edge
- Horizontal Edges: $\frac{\partial Y}{\partial t} = \nabla Y \cdot t = -n_y \frac{\partial Y}{\partial x} + n_x \frac{\partial Y}{\partial y} = 0$
  - Equals 0 since the Y coordinate does not change for horizontal edges
- **Task:**
  - Write the derivative constraints for Z(x, y) **in the report**
    - $\frac{\partial Z}{\partial y}$, $\frac{\partial Z}{\partial t}$, $\frac{\partial^2 Z}{\partial x^2}$, $\frac{\partial^2 Z}{\partial y^2}$, $\frac{\partial^2 Z}{\partial y \partial x}$

A simple inference scheme



Constraint weights →

$A\,Y = b$

$Y = (A^T A)^{-1} A^T b$

Matlab
Y = A\b;

Problem 5: Approximation of Derivatives

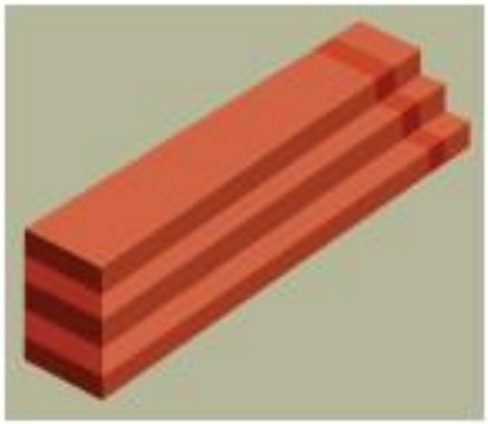
- Want to use constraints from Problem 4 to determine Y(x, y) and Z(x, y)
  - Two constraints missing from existing code
- Task:
  - Write two lines of code (lines 171 and 187)
  - Copy these two lines and **add them to the report**

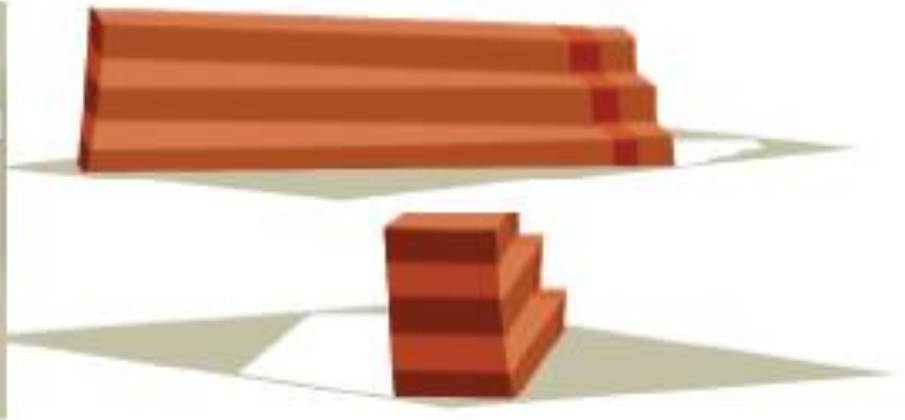
Problem 6: A Simple Inference Scheme

- Write the constraints as a system of linear equations
- Task:
  - Run simpleworldY.m to generate images for the report
  - Include some screen shots of the generated figures and **include in report**

Extra Credit 1: Violating Simple World Assumptions

- What if we violate our assumptions?
  - Show examples where the reconstruction fails
  - Why does it fail?





Extra Credit 2: The Real World

- Take pictures of the real world
  - How can we modify this assignment to getter better 3D reconstruction in the real world?
    - Try to handle a few more situations
- Possible final project?

What to Submit:

- One PDF file report
- One ZIP file containing all the source code, and a “simpleworldY.m” file that takes no parameters as input and runs directly in Matlab to generate the results reported in your PDF file.

PDF Report

- (1) Take a picture of the world you created
- (2) Submit two pictures – one showing orthographic projection and the other perspective projection
- (3) Prove the two projection equations
- (4) Write the constraints for Z(x, y)
- (5) Fill in missing kernels (lines 171 and 187) and copy code into report
- (6) Show results and figures output by simpleworldY.m
- [Optional] Extra credit