The first exam covers through lecture 7.1 (and review at start of 7.2) including camera models and single view metrology. The exam does not cover the single view 3D scene reconstruction methods of lecture 7.2 or anything after that. The material in lectures is covered fairly evenly with a little less attention to areas well covered by projects. The lecture "take home" and "quiz" questions in Coursera are good practice questions. The questions below are also good and are of similar style to those that will be offered on the exam. On the exam, you will be allowed scrap paper but not a calculator.

Filtering

1. Design a 3x3 linear filter, such that the output will be
   $im_{out}(i,j) = 4 \cdot im_{in}(i,j) - im_{in}(i-1,j) - im_{in}(i+1,j) - im_{in}(i,j-1) - im_{in}(i,j+1)$
   where (i,j) is a pixel coordinate that is not on the border, and im_{in} and im_{out} are the input image and output of the filter.

   Filter

0	-1	0
-1	4	-1
0	-1	0

2. *W*hich statement about the filter below is most true?

0	0	0
-1	0	1
0	0	0

low pass = sort of averaging, or taking a blur

high pass = increasing variation.

→ if there is a strong difference between the pixel to the left and to the right... we will get a strong response. Thus, we have a high pass filter.

   a. *The filter is a high-pass filter (mostly high frequencies are preserved)*
   b. *The filter is a low-pass filter (mostly low frequencies are preserved)*
   c. *The filter preserves both high frequencies and low frequencies about equally*
   d. *Which frequencies are preserved depends on the input*

Filter

-1	0	1
-2	0	2
-1	0	1

*

Input Image

0	6	0	0
0	1	9	0
9	7	1	2
1	9	3	6

➔

Filter Response

x	x	x	x
x			x
x			x
x	x	x	x

3. What is the response at the circled position?
   a. 19
   b. 10
   c. 1
   d. None of these

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 18 \\ -9 & 0 & 1 \end{bmatrix} = 10 \quad = \text{response}$$

Filter

-1	0	1
-2	0	2
-1	0	1

*

Input Image

0	6	0	0
0	1	9	0
9	7	1	2
1	9	3	6

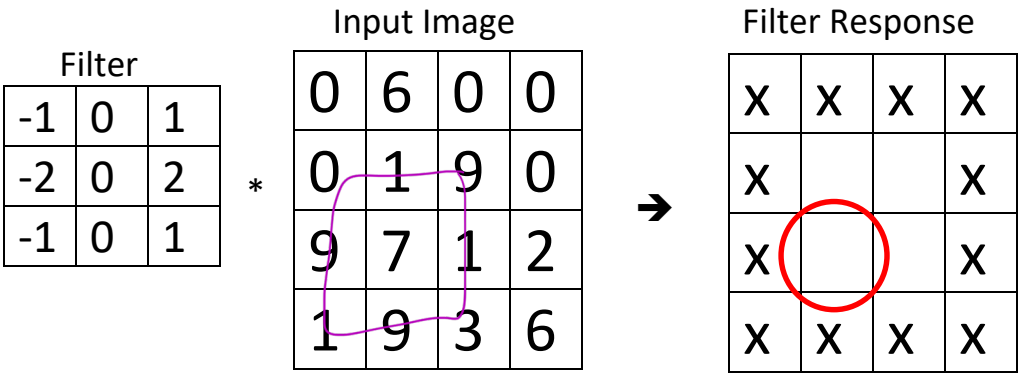
➔

Filter Response

x	x	x	x
x			x
x			x
x	x	x	x

4. What is the response at the circled position?
   a. -18
   b. 16
   c. -12
   d. None of these

$$\begin{bmatrix} -6 & 0 & 0 \\ -2 & 0 & 0 \\ -7 & 0 & 2 \end{bmatrix} = -13 \quad = \text{response}$$



5. What is the response at the circled position?
   a. 3
   b. 23
   c. -5
   d. None of these

$$\begin{bmatrix} 0 & 0 & 9 \\ -18 & 0 & 2 \\ -1 & 0 & 3 \end{bmatrix} = -5$$

6. Match and answer

a

b

c

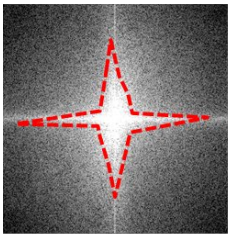
d

not a lot of variation in the horizontal direction, so we would expect to see frequency in the vertical direction.

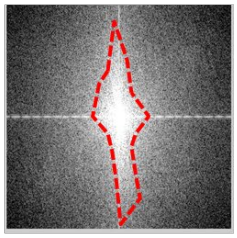
A natural texture, so we expect to see frequency in all directions, but not a ton of variation

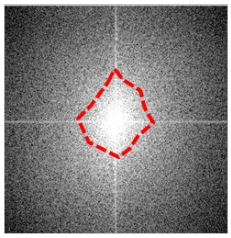
g as the texture does not change much

e

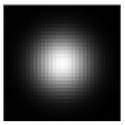


f

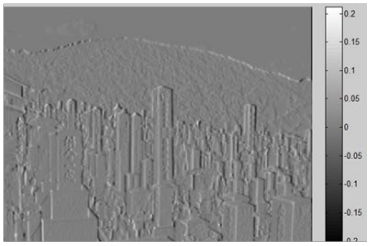




h



i



FFT Images (center is 0 frequency)

i. Which FFT image best matches (a)? f

ii. Which FFT image best matches (b)? g

iii. Object C convolved with Object h produced (d)

iv. Below, write values for a 3x3 filter that when applied to (c) would result in something similar to image (i) → looks like a vertical edge detector.

0	0	0
-1	0	1
0	0	0

7. True or False (2 pts)

$\text{filter2}(A,\ k \cdot B) - \text{filter2}(A,\ k \cdot C) = k \cdot \text{filter2}(A, B - C)$ (k is a scalar)

8. Which of the following is not true about the Fourier transform?
   a. Can be used to improve the speed of linear filtering
   b. Provides a different view of filters that is sometimes easier to interpret
   c. Adds information to the image
   d. Preserves the energy in the image

Templates and image pyramids

9. Suppose we have computed the normalized cross correlation (NCC), where higher means a better match (max value of 1), and sum of squared differences (SSD), where lower means a better match (min value of 0), for two non-uniform patches. Which of the following are true?
   a. NCC=1 if and only if SSD=0 → Can NCC be 1 when SSD != 0? Yes! In fact, this is a key reason to use NCC over SSD. If the two patches are the same structurally, but differ only in terms of a brightness shift, they will have an NCC of 1, but SSD will not be 0.
   b. If SSD=0, then NCC=1 Logically says that if the regions are identical, even looking at intensities, then the NCC will be 1 too
   c. If NCC=1, then SSD=0 Again, not necessarily true
   d. None of these are necessarily true

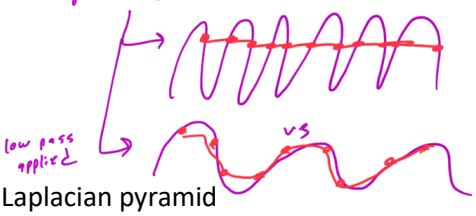
10. Is there any case where NCC is undefined, but SSD can be computed?
    a. No
    b. Yes, if both patches are equal → will result in NCC of 1, or SSD of 0...
    c. Yes, if at least one patch has uniform values → why? Because the std would be 0. std is the term used in the denominator of NCC.

       The SSD can always be computed.
    d. Yes, if either patch has negative values

11. Which of these statements are false?
    a. NCC is invariant to shifts in intensity
    b. SSD is usually a better matching cost/score than NCC for calibrated stereo pairs and tracking in video
    c. NCC is faster to compute than SSD → NCC is slower
    d. NCC is usually a better matching cost/score than SSD for comparing patches of images from images taken at different times or different cameras

12. If you want to downsample an image by a factor of 2, what is the problem with directly sampling pixels on every other row and column, and how can you fix it?
    a. Aliasing, apply a high pass filter before sampling
    b. Aliasing, apply a low pass filter before sampling
    c. Extrapolation, apply a high pass filter before sampling
    d. Extrapolation, apply a low pass filter before sampling
    e. There is no problem

Aliasing is the problem. why does applying a low pass filter before sampling work? We need the sampling frequency to be higher than the image. when it is not, we get aliasing



13. True or False: An image can be losslessly reconstructed from its Laplacian pyramid

↳ upsample and smooth the top of your pyramid
↳ Add the smoothed image to the previous layer to get back the original image → very small loss

↳ lossless? → take image
smooth
downsample
upsample
smooth
→ subtract that from original image to get lap-0. with this method of Laplacian Pyramid construction, you can get it losslessly.

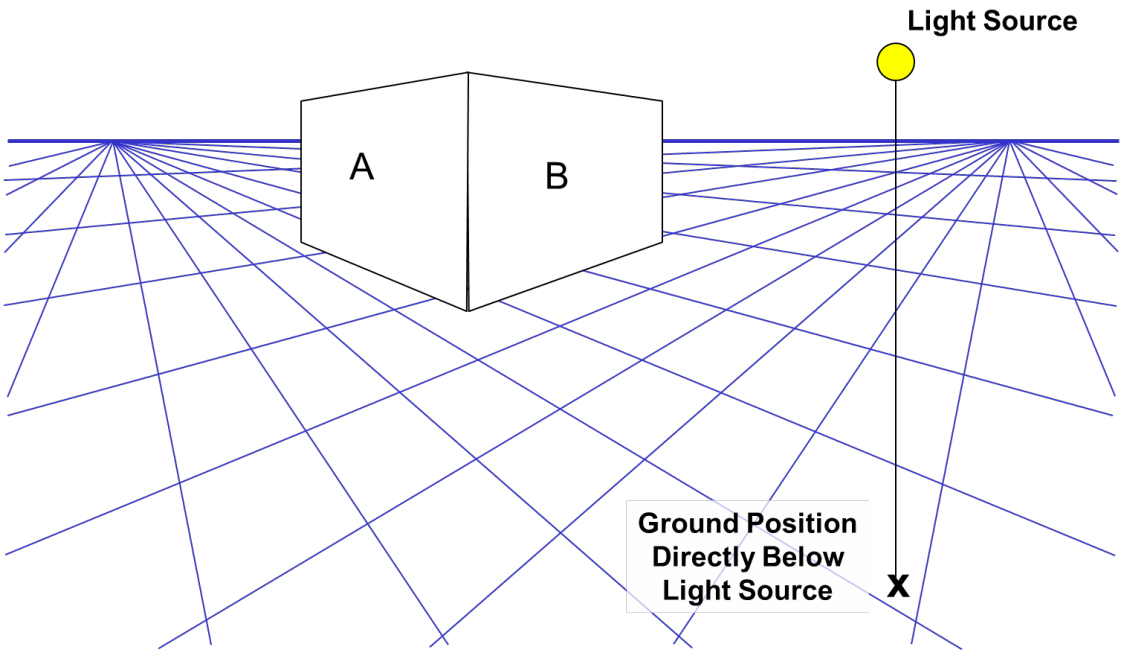
Lighting

14. Under which type of reflection does incoming light scatter from the surface?
    a. Diffuse reflection
    b. Specular reflection
    mirror...

15. Which of the following factors impact the observed intensities of diffusely reflected light? (can choose more than one)
    a. The intensities of the light coming into the reflecting surface
    b. The albedo of the reflecting surface
    c. The orientation of the reflecting surface compared to the direction of incoming light
    d. The orientation of the camera/observer compared to the surface normal
    ↳ the brightness of an object does not depend on our viewing angle

16. Which of the following factors impact the observed intensities of specularly reflected light? (can choose more than one)
    a. The intensities of the light coming into the reflecting surface
    b. The albedo of the reflecting surface → refers to light reflected in a non-directional way
    c. The orientation of the reflecting surface compared to the direction of incoming light
    d. The orientation of the camera/observer compared to the surface normal

17. In the illustration below, assume that each side of the depicted block has the same albedo. Which side will look brighter: side A or side B
    a. A will look brighter
    b. B will look brighter → closer to the light source



18. Imagine that a one-eyed robot is in a dark world, and the only light source is emanating from its eye. Is it possible for the robot to see the shadows that its light source creates?
    a. No → the robot's eye will create shadows, but he won't be able to see them
    b. Yes

19. For each material, indicate whether its reflection can be modeled as Lambertian, specular, or mixed:
    a. Balloon → mixed
    b. Cotton shirt → Lambertian
    c. Polished wood → mixed
    d. Mirror → specular
    e. Cement block → Lambertian

Color

20. Which color space(s) have separate luminance (brightness) and chrominance (color) channels? (can select more than one)
    a. RGB
    b. HSV
    c. L*a*b
    d. YCbCr

Luminance: Saturation, Value, Luminance, —
Chrominance: Hue, a, b, —, —

21. Which color space is based on perceptual studies of just noticeable differences, so that Euclidean distance between nearby color values corresponds to human perception?
    a. RGB
    b. HSV
    c. L*a*b
    d. YCbCr

"perceptual uniformity"

22. What is a disadvantage of the RGB color space compared to others?
    a. The channels are highly correlated, which makes compression harder
    b. People don't intuitively think of color in terms of red, green, and blue values
    c. Both (a) and (b)
    d. None of these

23. If most of the image intensity values are in the mid-range, such that there are few dark or bright pixels, which of these techniques are best to improve contrast?
    a. Gamma adjustment, gamma > 1
    b. Gamma adjustment, gamma < 1
    c. Histogram equalization → when the image has parts that are both too dark and too light

24. If an image looks washed out with many high intensities but not many low, which of these techniques is best to improve contrast?
    a. Gamma adjustment, gamma > 1 → Gamma > 1 for fixing high intensity images
    b. Gamma adjustment, gamma < 1
    c. Histogram equalization

could work

25. If an image is too dark with many low intensities but not many high, which of these techniques is best to improve contrast?
    a. Gamma adjustment, gamma > 1
    b. Gamma adjustment, gamma < 1
    c. Histogram equalization

could work

Pasting: Compositing and Blending

26. Mary wants to cut out the flower region and overlay it on the image of the sunset. She wants to avoid distorting colors or making it look pixelated. What blending method is most appropriate?
a. Use an alpha matte to determine whether the color for each pixel should come from the foreground or background image → won't provide a seamless transition
b. Use Laplacian pyramid blending
c. Poisson blending (or gradient domain editing) → will distort colors.

27. Ann wants to see what her arm will look like if she adds this cat drawing as a tattoo. What blending method is most appropriate to overlay the cat on the arm?
a. Use an alpha matte to determine whether the color for each pixel should come from the foreground or background image
b. Use Laplacian pyramid blending
c. Poisson blending (or gradient domain editing) → will fit in the best, and since we don't care about color we can use it

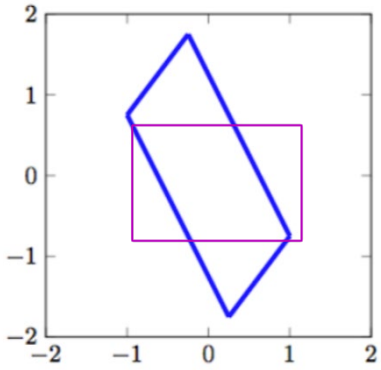
28. Which of the following statements is false?
    a. Poisson blending preserves gradient of the source region without changing the background which is why color is distorted
    b. Pixels are pretty blocky if you use cut and paste
    c. Foreground colors stay the same when we do Poisson blending
    d. One should feather when doing alpha compositing TRUE

Image Warping

29. Which homogeneous coordinate is different from others?
a. (9, 6, 3)
b. (12, 8, 4)
c. (48, 32, 16)
d. (4, 2, 1) → 4:2:1 different ratio than others

30. What properties do affine transformations and projective transformations have in common?
a. Parallel lines remain parallel under projection
b. Origin does not necessarily map to origin → from NOTES
c. Ratios are preserved

31. The figure is the output of applying one of the transformations below to a square with vertices (-1, 1), (-1, -1), (1, 1), (1, -1). Which transformation is it (pick most restrictive possible)?



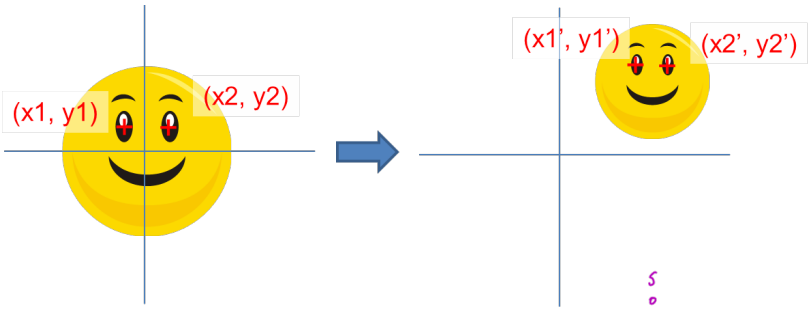
a. Affine → no lines convergence/distortion seen..
b. Projective ~~4 points~~
c. Rigid → rigid cannot change angles like we see... basically can just move the square around and rotate it
d. Similarity → same as rigid, but can change size. still can't change angles

32. What transformations can you model with [a b ; c d]? (can choose multiple)

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

a. ~~Translation~~
b. Scale
c. Rotation about the Origin
d. Shear
e. Affine
f. Perspective

33. For (i-iii): Suppose that the image of a face is scaled uniformly by factor *s* and translated in either direction by t_x and t_y.



$S = 4$

$x = 7$
$y = 8$

$t_x = 2$
$t_y = 6$

i. Write down the equation for a transformed point (*x'*, *y'*) as a function of the original point (*x*, *y*) in terms of t_x, t_y, and s.

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} s & 0 & 0 \\ 0 & s & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

so

$$\begin{bmatrix} s & 0 & st_x \\ 0 & s & st_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad \begin{bmatrix} sx + st_x \\ sy + st_y \\ 1 \end{bmatrix}$$

$x = sx + st_x$
$y = sy + st_y$

ii. Write the transformation in matrix form in terms of t_x, t_y, ~~*s*, *x*, *y*~~, *x'*, and *y'*:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} s & 0 & t_x \\ 0 & s & t_y \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

e. If you are given two pairs of corresponding points: (x1, y1) to (x1', y1') and (x2, y2) to (x2', y2'), how do you solve for the transformation parameters t_x, t_y, *s*? Write down the system of equations in a matrix form (you don't need to solve it):

Key idea: know what the equation for the points is, and then craft a matrix that will result in that value

$$\begin{bmatrix} x_1 & 1 & 0 \\ y_1 & 0 & 1 \\ x_2 & 1 & 0 \\ y_2 & 0 & 1 \end{bmatrix} \begin{bmatrix} s \\ t_x \\ t_y \end{bmatrix} \cong \begin{bmatrix} x'_1 \\ y'_1 \\ x'_2 \\ y'_2 \end{bmatrix}$$

s 0 t_x
0 s t_y
is translation + scale, so...

$s_{x_1} + t_x + 0 = x'_1$
$s_{y_1} + 0 + t_y = y'_1$
$s_{x_2} + t_x + 0 = x'_2$
$s_{y_2} + 0 + t_y = y'_2$

Scale and translate?

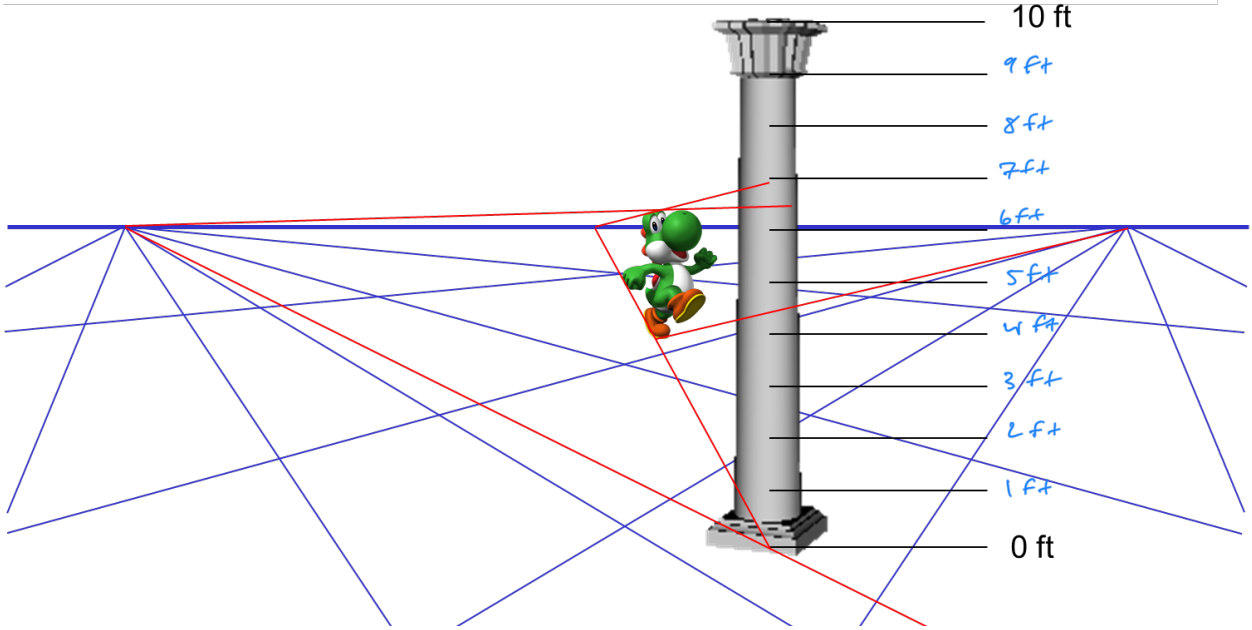
$x'_1 = s_{x_1} + t_x$
$y'_1 = s_{y_1} + t_y$ etc.

Image Morphing

34. Put these operations in the correct order to perform morphing: (op1) determine corresponding points; (op2) compute average shape; (op3) define triangulation; (op4) warp both images toward the average shape; (op5) cross dissolve.
    a. (op2) -> (op1) -> (op3) -> (op4) -> (op5)
    b. (op1) -> (op2) -> (op4) -> (op3) -> (op5)
    c. (op1) -> (op3) -> (op2) -> (op4) -> (op5) → from notes on Morphing process
    d. (op3) -> (op1) -> (op2) -> (op4) -> (op5)

35. What is the lowest parameter transformation that can map from any point in any one triangle to a corresponding point in any other triangle?
    a. Translation
    b. Similarity
    c. Affine
    d. Perspective

Single View Metrology and Camera Model



36. The column is 10 ft tall with the lines evenly marking 1 ft increments, and Yoshi (dinosaur) is on the ground. What is the approximate (within 0.5 ft) height of Yoshi?

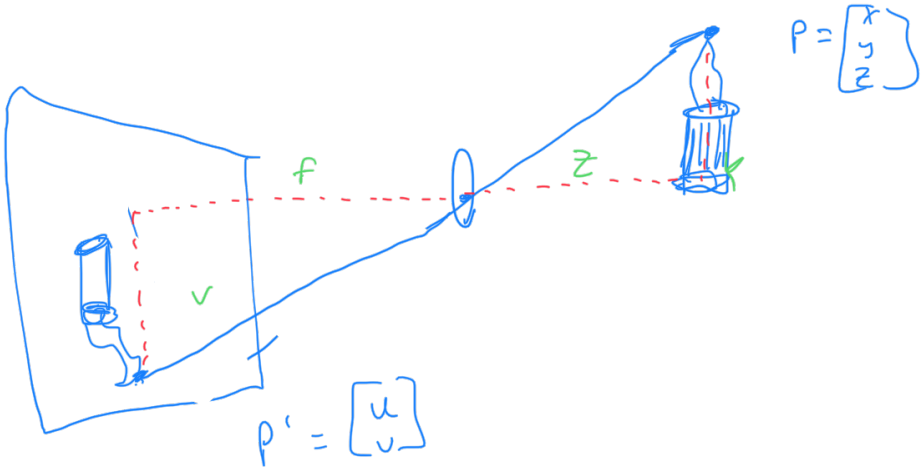
a. 4.5 ft
b. 6.0 ft
c. 6.5 ft
d. 7.0 ft
e. None of these are within 0.5 ft

37. The column is 10 ft tall with the lines evenly marking 1 ft increments, and Yoshi (dinosaur) is on the ground. What is the approximate (within 0.5 ft) height of the camera?

a. 4.5 ft
b. 6.0 ft → where horizon intersects column
c. 6.5 ft
d. 7.0 ft
e. None of these are within 0.5 ft

look at notes...

38. Draw a diagram of the projection of a 3D point onto an image pixel and label: vertical component of 3D position *Y*; distance from camera along camera axis *Z*; pixel column *u*; pixel row *v*; principal point u_0, v_0; focal length *f*; center of projection (aka camera center).



39. Suppose a point's position is X, Y, Z in the camera's 3D coordinates. Given focal length f and principal point (u0, v0), what is the pixel row *v* of the projected point.
    a. $v = \frac{fY}{X} + v_0$
    b. $v = \frac{X}{fY} + u_0 + v_0$
    c. $v = fY + Zv_0$
    d. $v = \frac{fX}{Z} + u_0$
    e. None of these are correct

40. Complete the intrinsic parameter matrix that projects from a 3D point to a 2D homogenous image coordinate. Assume zero-skew and unit aspect ratio.

$$w\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & u_0 \\ 0 & f & v_0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

41. Let (X=2, Y = 0, Z = 10), f=2, u0 = 0.5, v0=0.5. Solve for u.
    a. 0.9
    b. 0.7
    c. 0.4
    d. 0.5

$$\begin{bmatrix} 2 & 0 & 0.5 \\ 0 & 2 & 0.5 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 2 \\ 0 \\ 10 \end{bmatrix}$$

4

42. Suppose you are taking a picture in low-light conditions and your first photo looks grainy. Which of the following can increase the amount of light coming into the camera without changing the field of view? (can select more than one)
    a. Increase aperture
    b. Decrease aperture
    c. Increase focal length
    d. Decrease focal length
    e. Increase shutter time
    f. Decrease shutter time

43. How can you increase the field of view?
    a. Increase aperture
    b. Decrease aperture
    c. Increase focal length
    d. Decrease focal length
    e. Increase shutter time
    f. Decrease shutter time