MIDTERM EXAM OF CS436
WINTER 2007

Lahore University Of Management Sciences

BSc (Honours) Programme

MS Computer Science Programme

Roll # ____________________

Course Title	Computer Vision Fundamentals	**Quarter**	Winter
Course Code	CS436	**Academic Year**	2007-08
Instructor	Sohaib A. Khan	**Date**	25 Jan 2008
Exam	Midterm	**Time Allowed**	100 minutes
		Total Marks	90 (25% of grade)

DO NOT OPEN THIS EXAM UNTIL TOLD TO DO SO.

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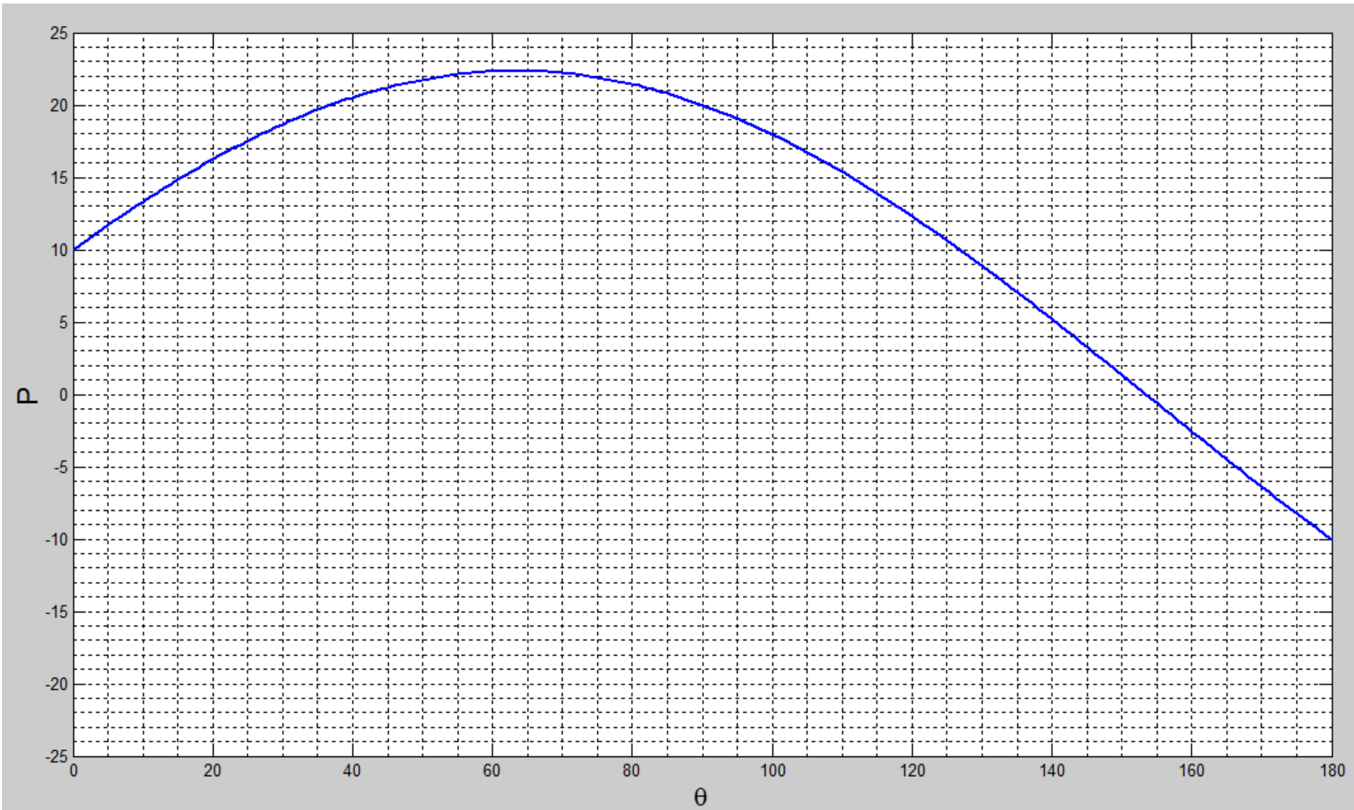
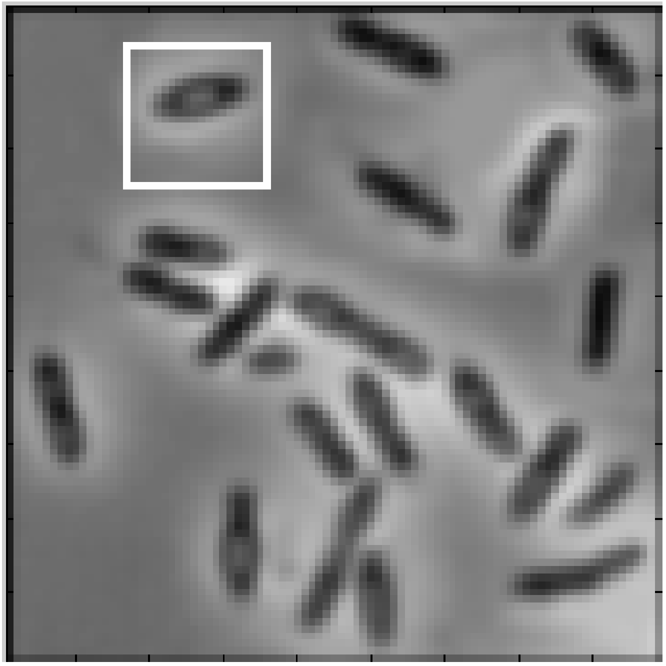
1. [20 points] The figure below shows a plot of the (p, θ) parameter space, generated during the computation of Hough Transform for Lines algorithm. Each cell along the curve gets one vote.

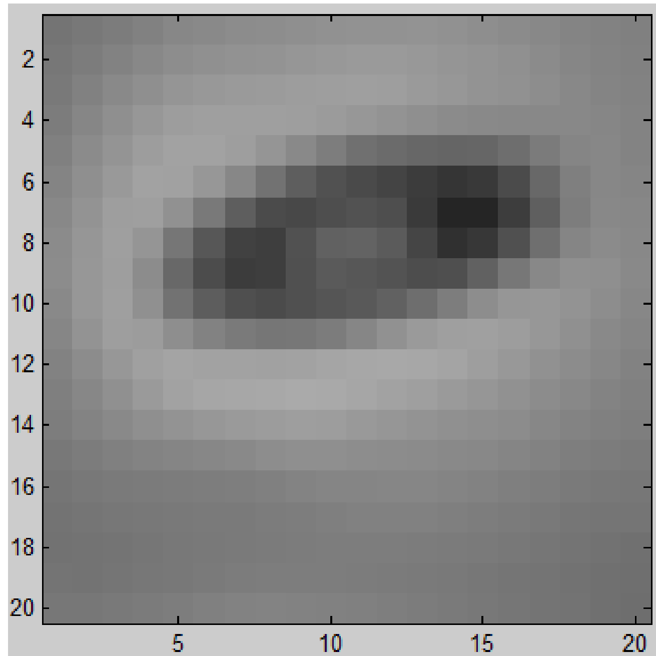
We have not studied Hough Transform yet



Describe the original image which was used to generate this parameter space in as much detail as is possible from the information given. Also mention what information (if any) about the original image *cannot* be inferred from the given figure.

2. [25 (6 + 6 + 7 + 6) points]
You have been tasked with writing a program to analyze images of bacteria taken by a microscope. A sample image is shown below, along with a small blown up portion from the top left of the original image:





The actual gray-level values in the small 20x20 portion of the image are given below:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	117	121	125	130	136	139	141	142	144	146	147	147	148	146	143	140	137	133	131	129
2	120	125	131	137	142	145	147	148	151	153	155	155	153	150	148	145	140	135	132	130
3	122	130	138	144	150	153	155	156	158	159	160	159	155	152	148	146	142	137	133	131
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6	133	144	154	163	162	152	136	115	95	82	75	69	61	54	58	76	105	128	136	134
7	137	148	159	160	146	122	95	76	73	79	83	79	59	38	39	62	96	126	137	136
8	140	151	160	150	119	89	66	64	82	98	100	92	70	49	56	81	112	134	140	137
9	141	152	159	141	105	77	61	63	81	91	88	84	78	80	98	120	137	145	144	138
10	139	152	160	145	115	94	80	76	81	86	90	98	111	126	142	151	152	148	142	136
11	135	148	159	157	143	131	123	119	120	125	135	146	155	160	161	158	152	145	139	134
12	131	141	152	161	165	164	163	162	164	166	168	169	168	165	159	153	146	141	136	131
13	128	136	145	155	163	167	168	169	171	170	167	163	160	155	151	146	141	137	132	129
14	126	132	138	144	148	152	155	157	159	158	154	151	148	145	143	141	136	132	129	127
15	121	125	129	132	134	136	139	142	144	144	142	141	140	139	137	134	131	127	125	123
16	118	121	123	124	125	126	127	129	132	134	134	135	135	133	131	128	126	123	121	120
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18	115	116	117	119	121	122	123	124	125	126	126	126	125	124	123	121	119	117	115	114
19	117	116	118	120	121	123	125	126	126	126	125	124	123	122	120	118	117	115	113	112
20	120	120	122	124	126	129	131	132	131	130	129	127	125	123	121	119	117	116	113	111

In the questions given on the next page, you may assume that the simple finite derivative masks discussed in class (i.e. of type [-1 1]) are used to compute the gradient direction, and the convention of the axes is the same as that discussed in class.

a. On the grid of numbers shown on the previous page, mark a location where the gradient direction is exactly parallel to the horizontal axis, and another location where the gradient direction is exactly parallel to the vertical axis.

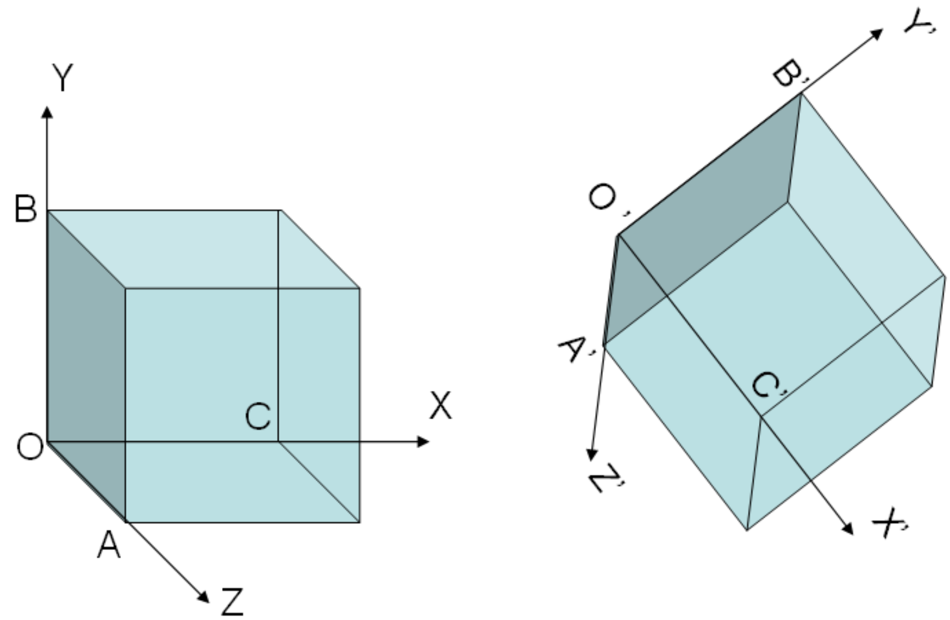
b. Using the convention of axes used in class, compute gradient magnitude and direction at pixel location (8, 16) and (18, 9). [*If you do not have a calculator, you can just plug the values in the appropriate formula*].

c. Your friend argues that the gradient direction value computed at one of the pixels above is more 'reliable' than the other. Do you agree or disagree? Explain your position.

d. By observing the sample images, suggest a simple algorithm to 'detect' bacteria in an image such as this. Also provide a critique of your algorithm, i.e. in which cases will it not work perfectly.

3. [10 points] Show that the eigenvalues of a 3D rotation matrix which rotates about the z-axis by θ degrees are given by 1, $\cos\theta + i\sin\theta$ and $\cos\theta - i\sin\theta$

4. [20 points (3+5+12)]



A cube with its one vertex at the world origin O has undergone a rigid transformation in 3D. After transformation, the origin has moved to $[50, 30, 30]^T$, point A has moved to A′ = $[53.12\ 29.49\ 32.45]^T$ and point B has moved to B′ = $[49.49, 33.71, 31.41]^T$.

a. What is the length of one side of the cube?

b. Find the location of point C′, i.e. location of vertex C after transformation

c. Compute the transformation which moved the cube shown in left figure to the cube shown in the right figure.

5. [15 points] A camera is fixed rigidly to the belly of the aircraft and cannot pan or tilt. The world axes are such that they are fixed at the airport, with the X axis pointing West, the Y axis pointing North and the Z axis pointing upwards. The roll, pitch, and yaw readings of the aircraft are measured as follows: The roll angle is measured from level-wing position as being roll of zero. If the aircraft rolls counter clockwise (when viewed from the nose towards the tail), it is considered positive roll. The pitch is considered positive if the nose is lower than the tail. The yaw is measured as a compass reading. While reporting the angles, the roll transformation is applied before the pitch, and the yaw is applied in the end.

Develop a complete camera model for this aircraft, and justify each step [*Hint: Pay attention to axes conventions and angle measurements*]. The translations from camera center to gimbal and from gimbal to center of the aircraft can be ignored.

MIDTERM EXAM OF CS5310
SPRING 2006

Lahore University Of Management Sciences

BSc (Honours) Programme

MS Computer Science Programme

Roll # ____________________

Course Title	Computer Vision Fundamentals	**Quarter**	Winter
Course Code	CS5310	**Academic Year**	2007-08
Instructor	Sohaib A. Khan	**Date**	25 Jan 2008
Exam	Midterm	**Time Allowed**	100 minutes
		Total Marks	105 (25% of grade)

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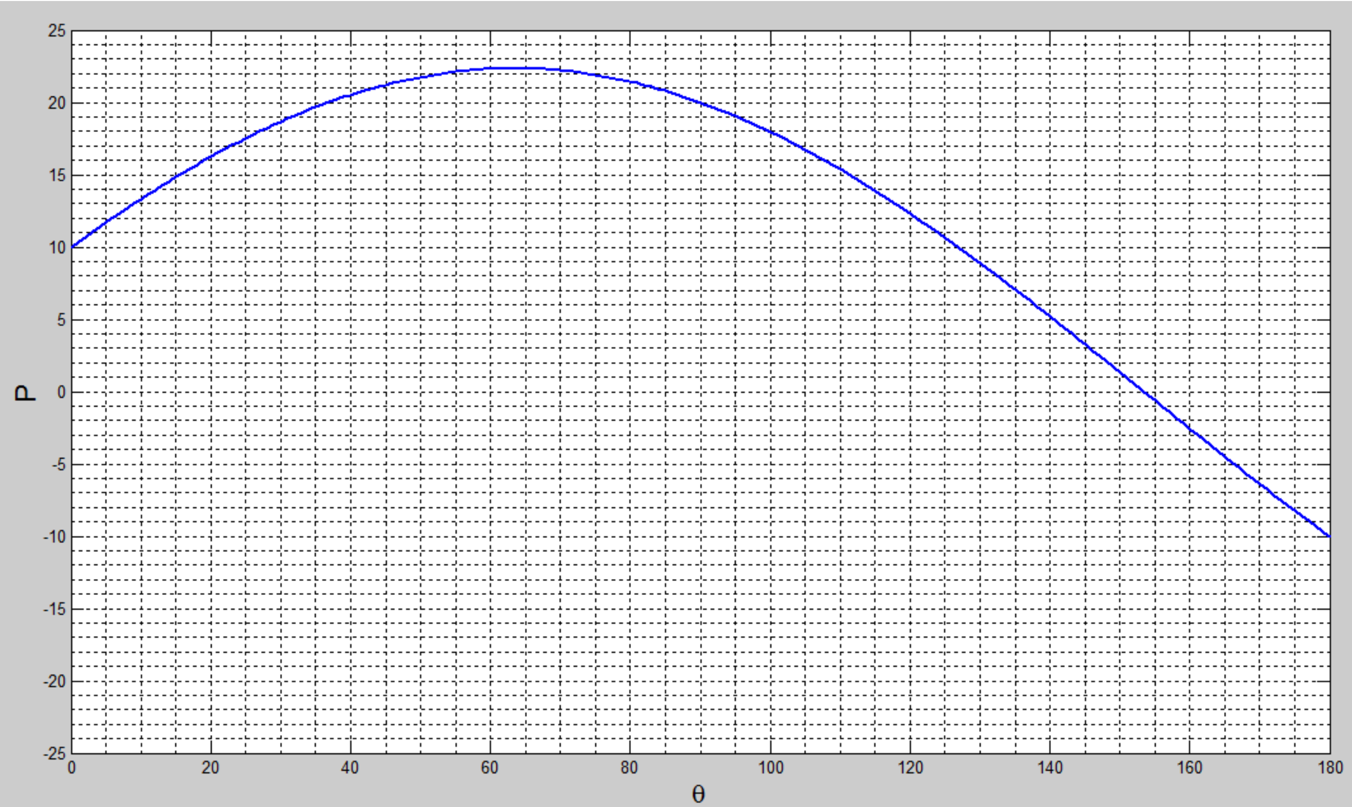

Describe the original image which was used to generate this parameter space in as much detail as is possible from the information given. Also mention what information (if any) about the original image *cannot* be inferred from the given figure.

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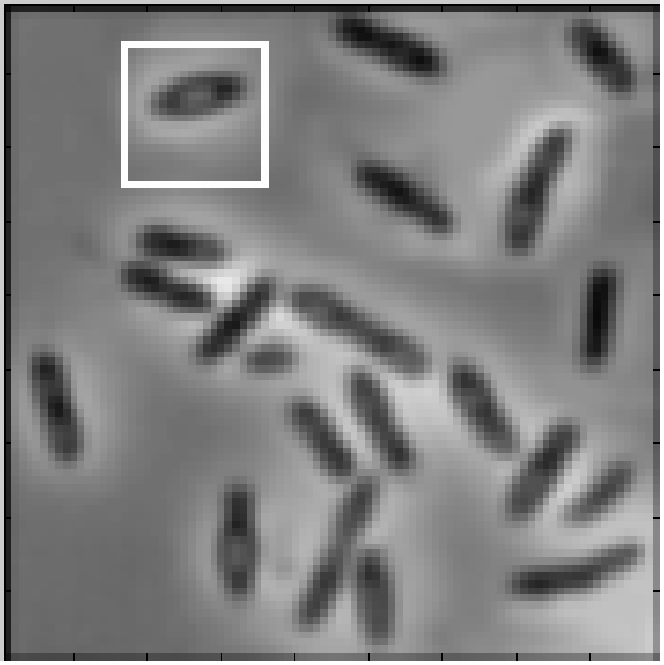

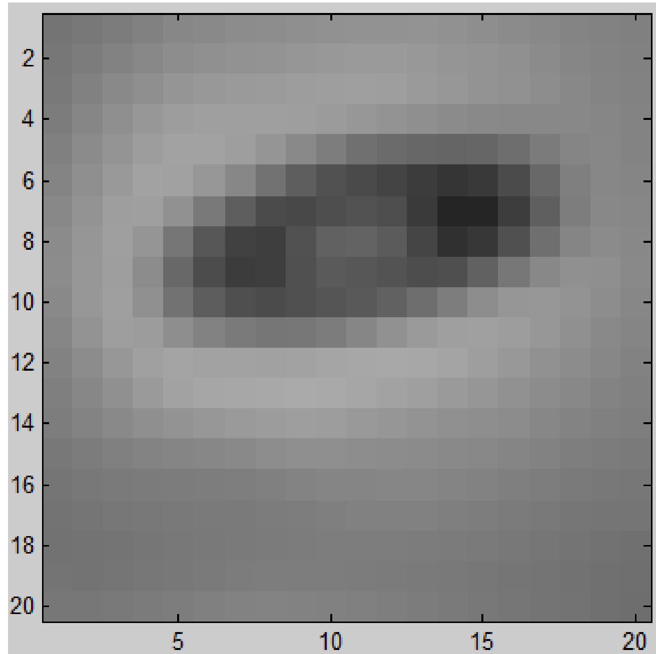

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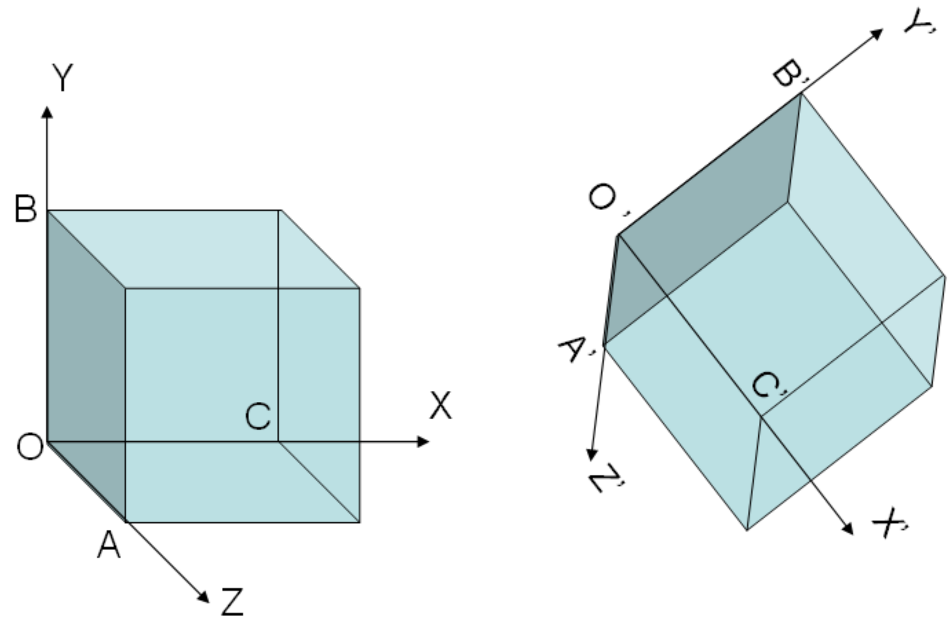

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   Develop a complete camera model for this aircraft, and justify each step [*Hint: Pay attention to axes conventions and angle measurements*]. The translations from camera center to gimbal and from gimbal to center of the aircraft can be ignored.

6. [15 points] Given an arbitrary 3D transformation of the form given below, suggest a way to decompose it into a sequence of simple transformations such as rotations, scalings and translations.

$$\begin{bmatrix} a_1 & a_2 & a_3 & b_1 \\ a_4 & a_5 & a_6 & b_2 \\ a_7 & a_8 & a_9 & b_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

MIDTERM EXAM OF CS436
SPRING 2006

Lahore University Of Management Sciences

BSc (Honours) Programme
MS Computer Science Programme

Roll # ____________________

Course Title	Computer Vision Fundamentals	**Quarter**	Spring
Course Code	CS436 / CmpE 436	**Academic Year**	2006-07
Instructor	Sohaib A. Khan	**Date**	27 Apr 2007
Exam	Midterm	**Time Allowed**	90 minutes
		Total Marks	110 (25% of grade)

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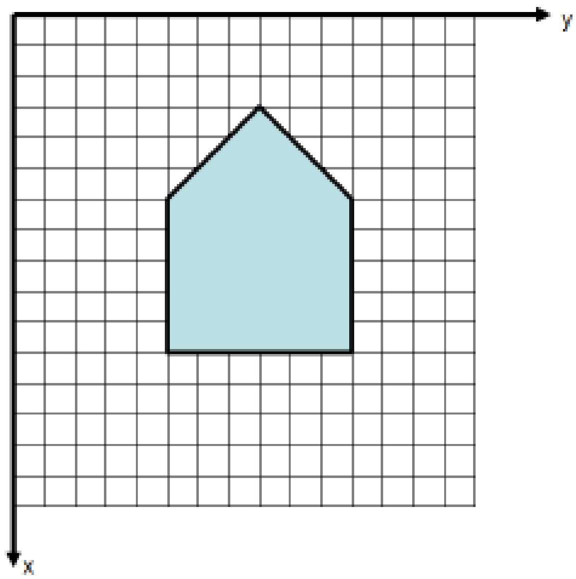
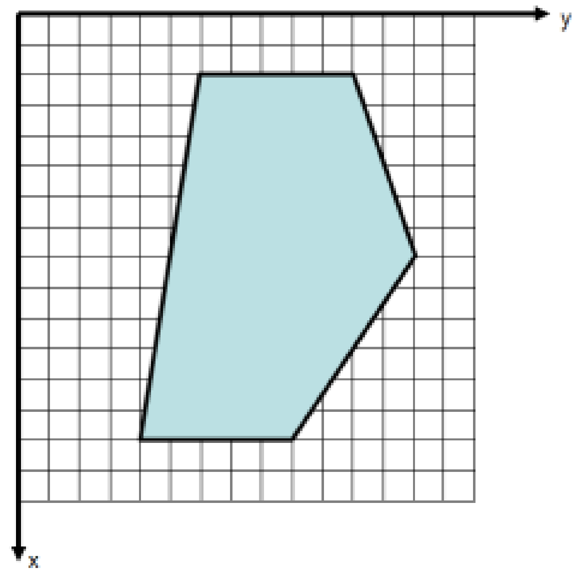
1. [15 points] Without using the Rodriguez formula, derive the rotation matrix which will rotate a point about the vector $[1,1,0]^T$ by θ. The definition of positive rotation in this case is that if you look towards origin from the point $[1,1,0]^T$, then counter clockwise rotation is positive.

We have not studied Rodriguez formula this time





2. [7+13 points] The shape shown in the left figure is being transformed into the shape shown in the right figure.

    a. What type of displacement model exists between the two transformations? [*Provide a clear argument for your answer. Answer alone is worth zero points*]

    b. Provide a sequence of simple 2D transformation matrices which, when concatenated, will transform the shape shown in the left figure to the one shown in the right figure.

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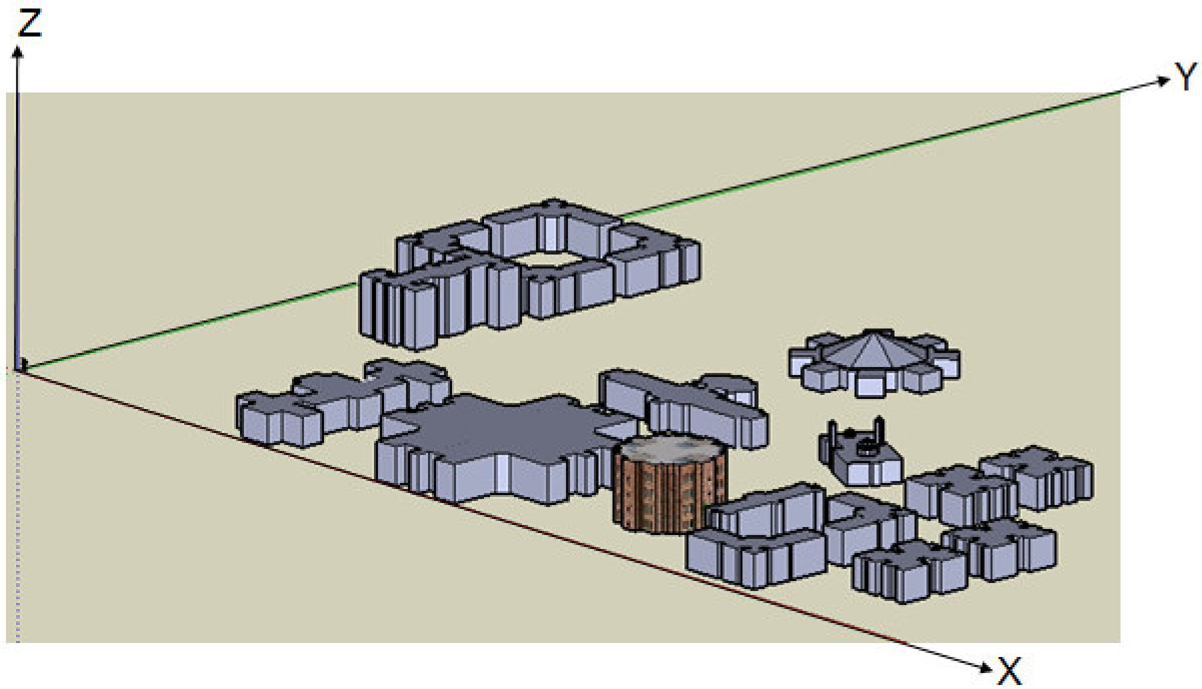
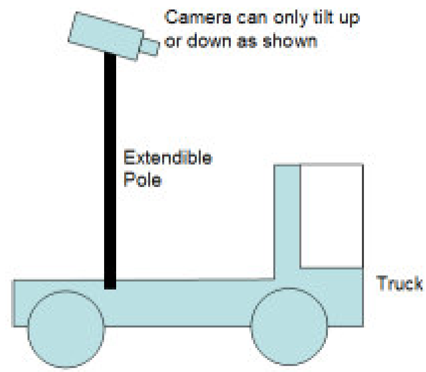


3. [10 points] Consider the rendering of LUMS campus shown in the figure above. Is the camera used in generating the projection an orthographic camera or a perspective camera? [*Provide a clear argument for your answer. Answer alone is worth zero points*]

4. [20 points] Let us say that the LUMS rendering shown in the previous question was actually a real image taken from a camera mounted on a very high pole. The world origin and the world axes are as shown in the figure. The pole is mounted on the back of a truck which can be driven anywhere. The height of the pole is also adjustable. The camera is mounted such that it always looks in the direction of the front of the vehicle, but can be tilted up or down.

   Compute the complete camera model for this case. If you make any assumptions in your solution, clearly state them. As part of your solution, first clearly define all your variables, then show the complete camera model.



5. [15 points] Devise a scheme for detecting parabolas, $y - y_0 = a(x - x_0)^2$ centered at (x_0, y_0) using Hough Transform. Clearly state the parameters, the dimensions of the parameter space, and the algorithm in pseudo code.

   Note: We have not studied this yet, so you can ignore this question.

6. [15 points] There are three steps in any edge detection method. Draw a table similar to the one shown below and fill it out for those three steps, stating how each step is done in each edge detector. Write only key words in the solution, describing each step.

   Note: We have not studied LOG Edge Detector this time, so you can ignore that column.

	LOG Edge Detector	Canny's Edge Detector
Step 1: [Write name of step here]		
Step 2: [Write name of step here]		
Step 3: [Write name of step here]		

7. [15 points] The following is a MATLAB function for Non-Maxima Suppression step of Canny's Edge Detector. Fill in the blanks in the code. Use the convention of axis that we normally use in class. Clearly describe your solution too by means of a figure.

```
function nms = NonMaximaSuppression(M, Phi);
% M is gradient magnitude image, Phi is gradient direction

nms = M;
Phi = 180/pi * Phi;

%quantize Phi...
qPhi = zeros(size(Phi));
qPhi(((Phi > 45-22.5) & (Phi <= 45 + 22.5)) | ((Phi > 225-22.5) & (Phi <= 225+22.5))) = 1;
qPhi(((Phi > 90-22.5) & (Phi <= 90+22.5)) | ((Phi > 270-22.5) & (Phi <= 270+22.5))) = 2;
qPhi(((Phi > 135-22.5) & (Phi <= 135+22.5)) | ((Phi > 315-22.5) & (Phi <= 315+22.5))) = 3;

for r = 2:size(M,1)-1
    for c = 2:size(M,2)-1
        %pick appropriate neighbors
        if qPhi(r,c) == 0
            n1 = M(____,____);

            n2 = M(____,____);
        elseif qPhi(r,c) == 1
            n1 = M(____,____);

            n2 = M(____,____);
        elseif qPhi(r,c) == 2
            n1 = M(____,____);

            n2 = M(____,____);
        else
            n1 = M(____,____);

            n2 = M(____,____);
        end;
        if (M(r,c) < n1) | (M(r,c) < n2)
            nms(r,c) = 0;
        end;
    end;
end;

out_nms = nms/max(max(nms)) * 255;
```

MIDTERM EXAM OF CS5310
SPRING 2006

A FEW PROBLEMS ARE DIFFERENT FROM THE PREVIOUS EXAM

Lahore University Of Management Sciences

BSc (Honours) Programme
MS Computer Science Programme

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Course Code	CS436 / CmpE 436	**Academic Year**	2006-07
Instructor	Sohaib A. Khan	**Date**	27 Apr 2007
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		Total Marks	115 (25% of grade)

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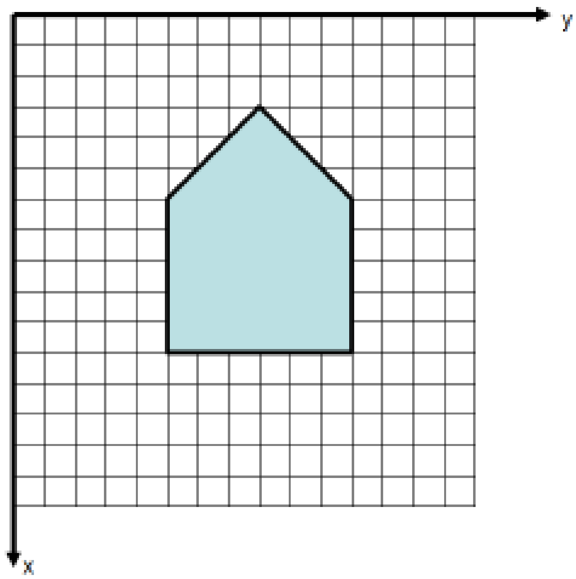

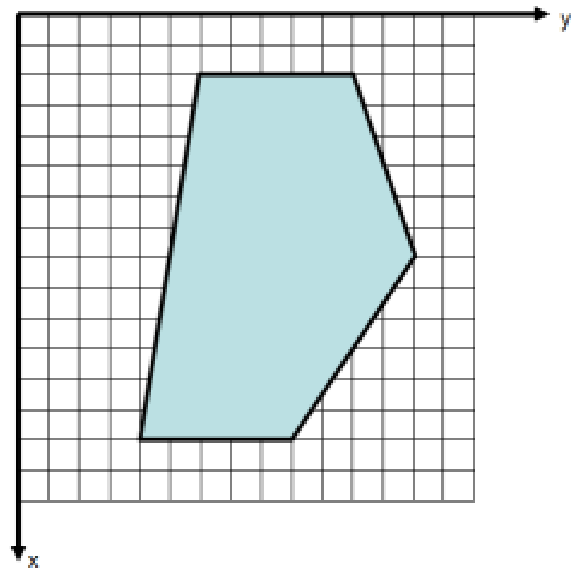

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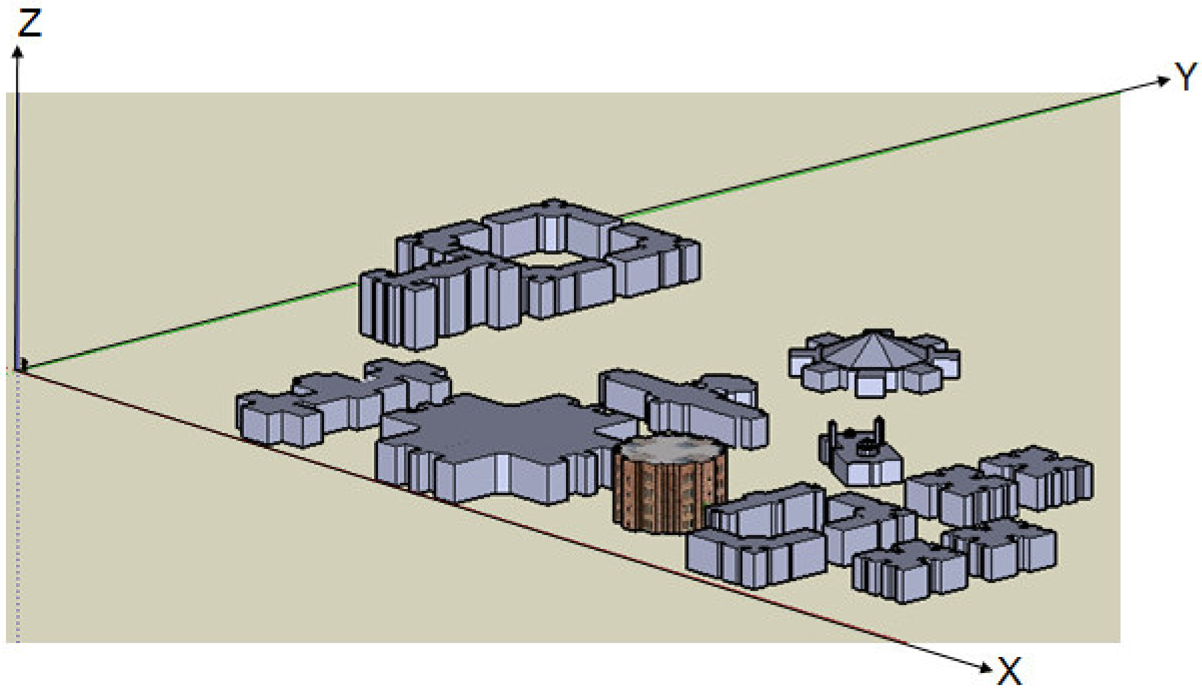
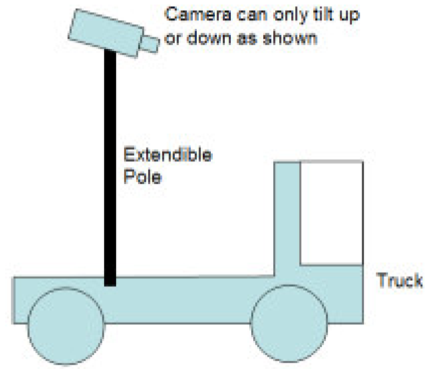


3. [10 points] Consider the rendering of LUMS campus shown in the figure above. Is the camera used in generating the projection an orthographic camera or a perspective camera? [*Provide a clear argument for your answer. Answer alone is worth zero points*]

4. [20 points] Let us say that the LUMS rendering shown in the previous question was actually a real image taken from a camera mounted on a very high pole. The world origin and the world axes are as shown in the figure. The pole is mounted on the back of a truck which can be driven anywhere. The height of the pole is also adjustable. The camera is mounted such that it always looks in the direction of the front of the vehicle, but can be tilted up or down.



   Compute the complete camera model for this case. If you make any assumptions in your solution, clearly state them. As part of your solution, first clearly define all your variables, then show the complete camera model.

5. [20 points] In the setup in the previous question, suppose we are interested in finding the angle of tilt of the camera from just image measurements. You can drive the truck anywhere you want to. Suggest how the angle of tilt of the camera can be determined through a simple procedure.

6. [15 points] Is every orthonormal matrix a rotation? Provide concrete mathematical arguments for your answer.

7. [15 points] The following is a MATLAB function for Non-Maxima Suppression step of Canny's Edge Detector. Fill in the blanks in the code. Use the convention of axis that we normally use in class. Clearly describe your solution too by means of a figure.

```
function nms = NonMaximaSuppression(M, Phi);
% M is gradient magnitude image, Phi is gradient direction

nms = M;
Phi = 180/pi * Phi;

%quantize Phi...
qPhi = zeros(size(Phi));
qPhi(((Phi > 45-22.5) & (Phi <= 45 + 22.5)) | ((Phi > 225-22.5) & (Phi <= 225+22.5))) = 1;
qPhi(((Phi > 90-22.5) & (Phi <= 90+22.5)) | ((Phi > 270-22.5) & (Phi <= 270+22.5))) = 2;
qPhi(((Phi > 135-22.5) & (Phi <= 135+22.5)) | ((Phi > 315-22.5) & (Phi <= 315+22.5))) = 3;

for r = 2:size(M,1)-1
    for c = 2:size(M,2)-1
        %pick appropriate neighbors
        if qPhi(r,c) == 0
            n1 = M(____,____);

            n2 = M(____,____);
        elseif qPhi(r,c) == 1
            n1 = M(____,____);

            n2 = M(____,____);
        elseif qPhi(r,c) == 2
            n1 = M(____,____);

            n2 = M(____,____);
        else
            n1 = M(____,____);

            n2 = M(____,____);
        end;
        if (M(r,c) < n1) | (M(r,c) < n2)
            nms(r,c) = 0;
        end;
    end;
end;

out_nms = nms/max(max(nms)) * 255;
```