**NAME:**

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# Computer Science 426 Midterm
# 3/15/07, 1:30PM-2:50PM

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This test is 5 questions. Do all of your work on these pages (use the back for scratch space), giving the answer in the space provided. This is a closed-book exam -- you may use one-page of notes with writing on both sides during the exam. **Please write out and sign the Honor Code pledge before turning in the test.**

***``I pledge my honor that I have not violated the Honor Code during this examination.''***

| Question | Score |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| Total | |

## Q1: Color Models (20 Points)

a) Write the amounts of red, green, and blue primaries (on a scale of 0 to 1) needed to display the following spectral colors in the RGB color model (fill in blanks):

| | | | |
|---|---|---|---|
| Black: | R = | G = | B = |
| Cyan: | R = | G = | B = |
| Pink: | R = | G = | B = |
| Orange: | R = | G = | B = |
| Brown: | R = | G = | B = |
| White: | R = | G = | B = |

b) Write the equations that convert a color in the RGB color model to one in the CMY color model. That is, write three equations that produce C, M, and Y from given R, G, and B (fill in blanks):

C =

M =

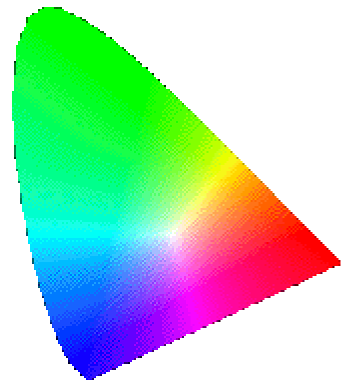
Y =

c) Why is the CMY color model is referred to as a "subtractive" color model? (one sentence)

d) What type of devices is the CMY color model most commonly used for? Why? (two sentences)

## Q1: Color Models (continued)

e) Can every color perceptible to the human eye be displayed as a combination of three primary colors visible to the human eye? Give evidence to support your answer using the CIE Chromaticity diagram provided below (a sentence or two).



f) Draw the HLS color model. Label the axes and key features of the diagram. Label white, black, red, green, blue, and the region representing gray values. (a labeled figure)

g) For what purpose is the HLS color model most useful?

## Q2: Image Processing (20 Points)

a) What is a pixel? (one sentence)
Hint: it is not a little square. it is not a little square. it is not a little square. J

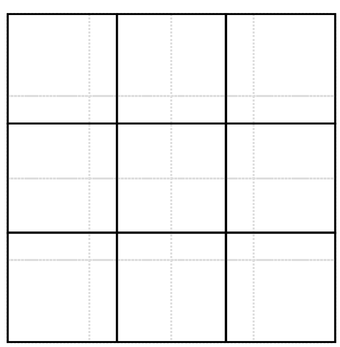
b) Consider resampling the given 5x5 input image in which every pixel has a single value between 0.0 and 1.0 written at the grid points (the input image shows a black "plus sign" on a white background). On the empty grids below, write the pixel values of the output image that would result from resampling the input image at the two different resolutions -- 4x4 and 6x6 -- using the two different resampling methods -- point sampling and triangle filtering. (write numbers directly on the grid points below)

Input image:

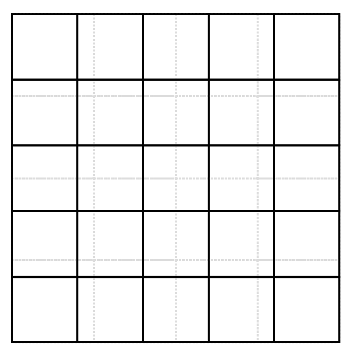
| | | | | |
|---|---|---|---|---|
| 1.0 | 1.0 | 0.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 0.0 | 1.0 | 1.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 1.0 | 0.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 0.0 | 1.0 | 1.0 |

5x5 pixels

Output image with **Point Sampling:**

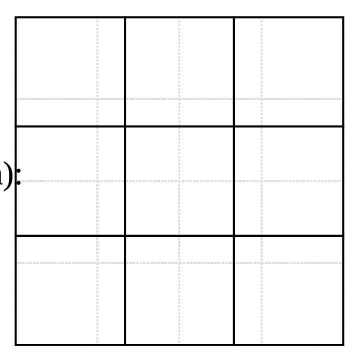


4x4 pixels

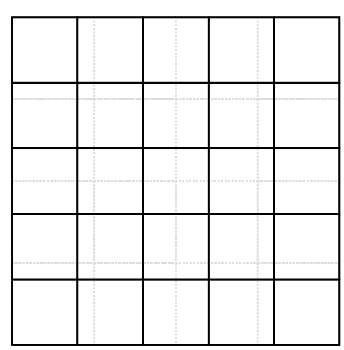


6x6 pixels

Output image with a **Triangle Filter** of radius 1 pixel (bilinear interpolation):



4x4 pixels



6x6 pixels

## Q2: Image Processing (continued)

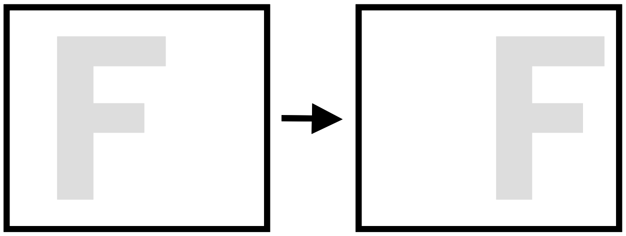
c) Describe the qualitative differences between the input image and the output images produced with the resampling methods in part (b) ( i.e., do the output images look like a black “plus sign” on a white background?). Discuss why the differences occur and what needs to be done to avoid the problem. (a few sentences)

d) What is a sinc filter and why is useful for resampling images without aliasing? Please provide a plot of the sinc filter in the frequency domain to support your answer (a few sentences and a plot)?

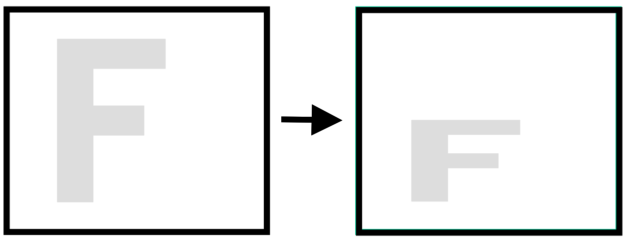
e) Why is the sinc filter not used for image resampling in practice? (one sentence)

## Q3: Transformations (15 Points)

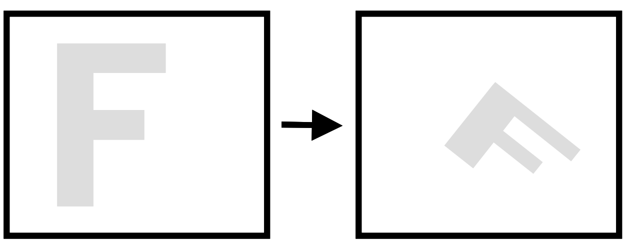
For each of the following image pairs, describe how you could specify the warp that takes the image on the left to the image on the right. Each answer should consist of a sentence, or possibly an equation, or possibly a concatenation of matrices (T(dx,dy), S(x,y), and R(Θ)), and/or possibly labeled pen-marks on the image(s) and a description.

a) 

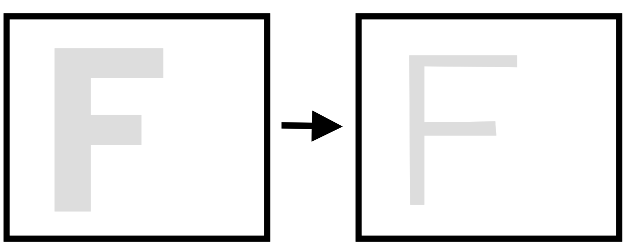
Transformation:

b) 

Transformation:

c) 

Transformation:

d) 

Transformation:

e) For each warp above, identify whether the transformation is linear, affine, projective, or "none of them" (write one of these phrases under each image pair).

## Q4: 3D Object Representations (15 Points)

We learned about several different 3D object representations with different properties. For each of the following scenarios, please describe which 3D object representation you think would be best and provide one sentence explaining why.

a) Simulating the deformations and topological changes of the wax blobs inside a “lava lamp”

b) Designing the outer surface for the nose of the next space shuttle

c) Animating a character that moves by rotating parts connecting rigid parts.

d) Visualizing the temperature of air at every point within a wind tunnel simulation.

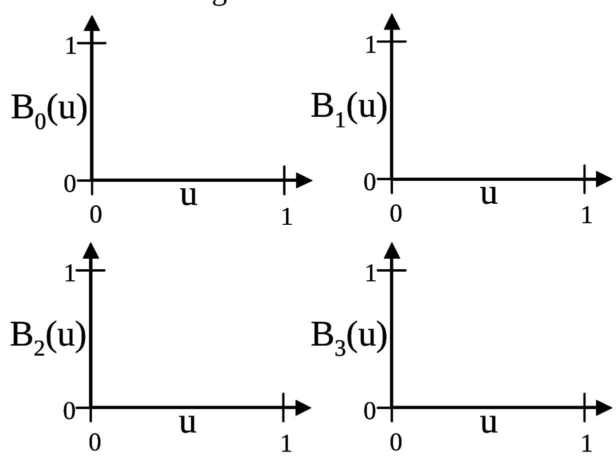
e) Rendering a 3D terrain model of the earth (a globe) with accurate altitude samples at 1m resolution throughout the entire world.

## Q5: Parametric Curves (30 Points)

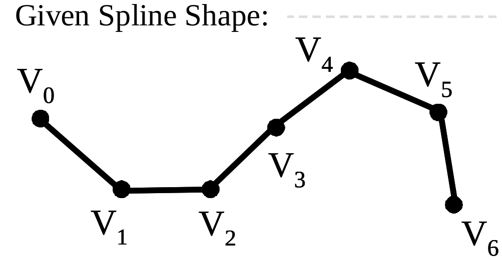
This question considers the relationship between the blending functions, shapes of splines, and properties of splines. Assume that a piecewise parametric spline is partitioned into segments, with the first segment defined by control points $V_0$, $V_1$, $V_2$, and $V_3$, the second defined by control points $V_1$, $V_2$, $V_3$, and $V_4$, and so on. For each segment, a parameter *u* varies from 0 to 1 along the length of the segment, and the point $Q_i(u)$ on segment *i* is defined by: $Q_i(u) = B_0(u)V_{i+0} + B_1(u)V_{i+1} + B_2(u)V_{i+2} + B_3(u)V_{i+3}$, where $B_i(u)$ is a cubic polynomial.

For parts (a)-(e), the blending functions, the spline shape, OR the spline properties are provided, and you must fill in the other two to match. For example, in part (a), the blending functions are provided in the box on the left, and you must draw the spline shape resulting from using these blending functions to draw a spline for the control points shown in the box on the top right (mark the joints between segments with a dot), and you must list properties of that spline in the box on the bottom right, selecting from the following properties: interpolates control points, lies within convex hull of control points, guaranteed to be $C_0$ at joints, guaranteed to be $C_1$ at joints, and guaranteed to be $C_2$ at joints. In other parts, the spline shape or the spline properties are provided, and you must supply the other two (make reasonable assumptions based on the appearance of the curves)

a) Draw Blending Functions:

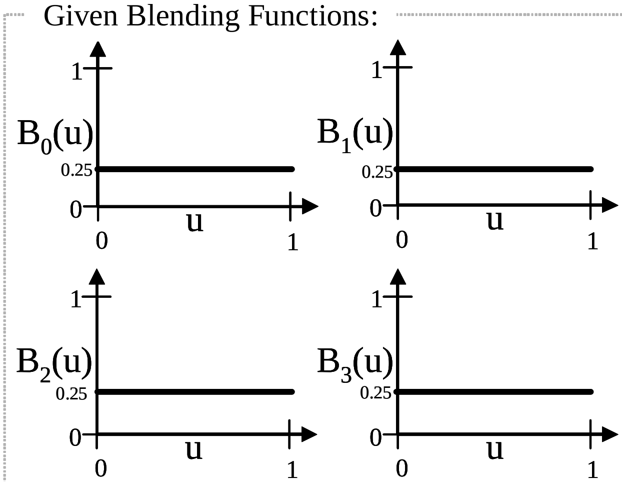



Given Spline Shape:

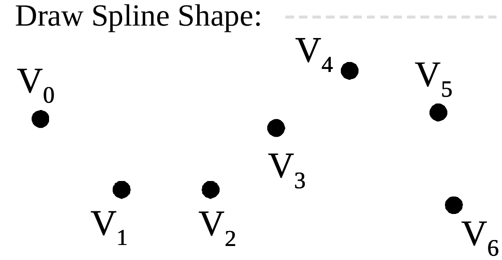



List Spline Properties:

b) Given Blending Functions:



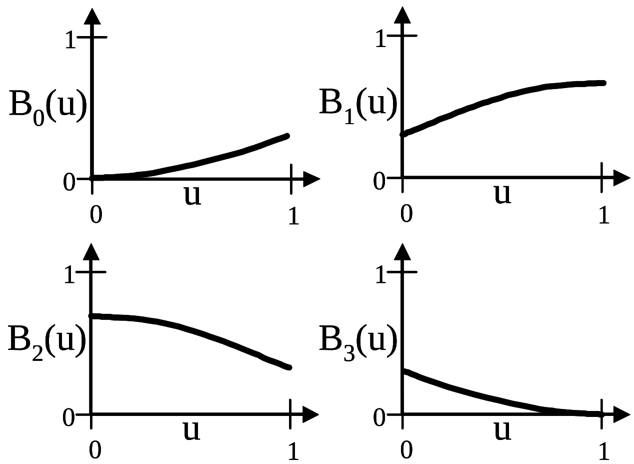

Draw Spline Shape:



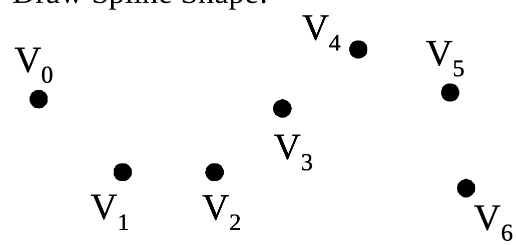

List Spline Properties:

## Q5: Parametric Curves (continued)

c) Given Blending Functions:

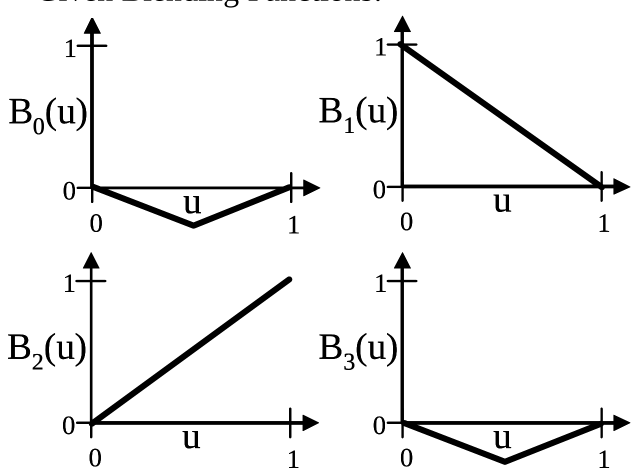



Draw Spline Shape:

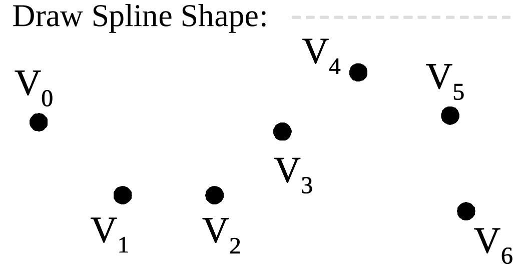



List Spline Properties:

d) Given Blending Functions:

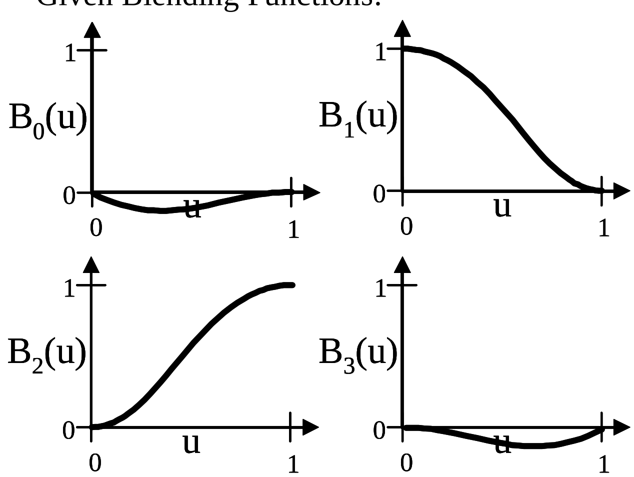



Draw Spline Shape:

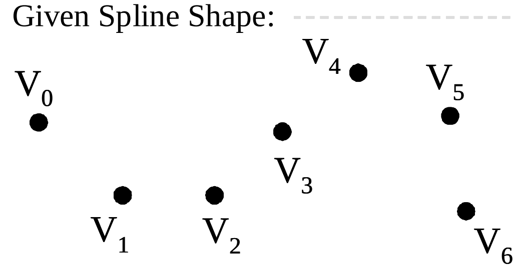



List Spline Properties:

e) Given Blending Functions:



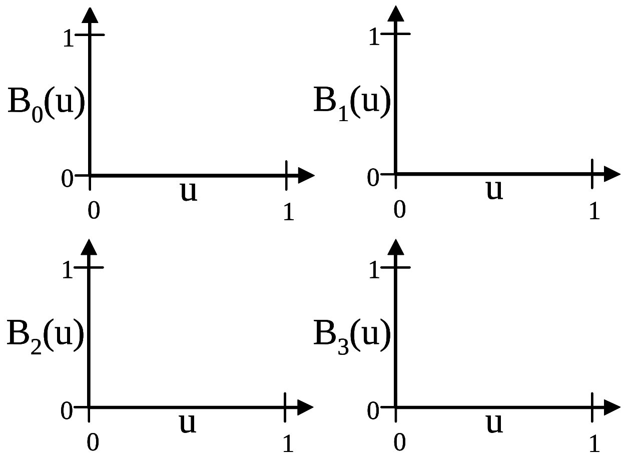

Given Spline Shape:



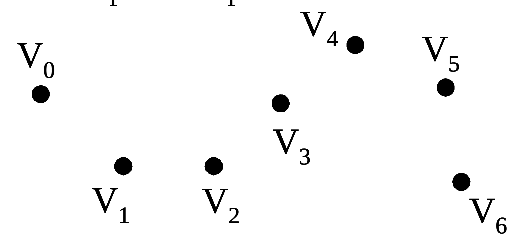

List Spline Properties:

## Q5: Parametric Curves (continued)

f) Draw Blending Functions:




Draw Spline Shape:




Given Spline Properties:

**convex hull, $C_0$, $C_1$,**
**not $C_2$, not interpolating**
**(hint: there are many acceptable answers)**

g) Why do computer graphics applications use cubic polynomials for their piecewise-polynomial parametric curves rather than higher-order polynomials? (one or two sentences)

h) The blending functions for a cubic B-Spline Curve are provided below. Use them to provide a mathematical derivation to show that a B-Spline has the convex hull property.

$B_{i-3}(u) = 1/6 - 1/2u + 1/2u^2 - 1/6u^3$
$B_{i-2}(u) = 4/6 - u^2 + 1/2u^3$
$B_{i-1}(u) = 1/6 + 1/2u + 1/2u^2 - 1/2u^3$
$B_{i-0}(u) = 1/6u^3$