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Computer Science 426, 1st Midterm

March 13, 2008

This test contains 6 questions, of equal weight, on 11 pages. 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. **Put your name on every page, and 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	
6	
Total	

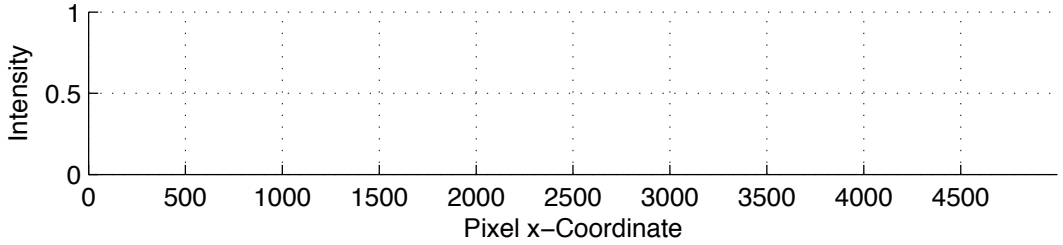
Q1. Image Processing

(a) Given a 5×1 gray-scale image I with the following pixel values:

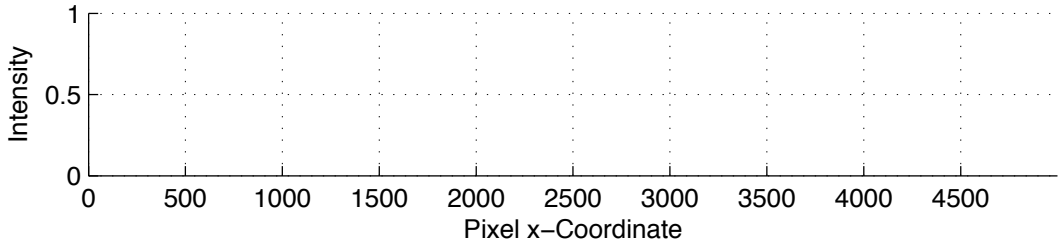
I :	0	0	1	0	0

This image is now to be rescaled to a size of 5000×1, using nearest-neighbor sampling, bilinear sampling, and Gaussian sampling ($\sigma = 500$), respectively. For each sampling type, sketch the resulting intensity profile of the rescaled image: [3 pts.]

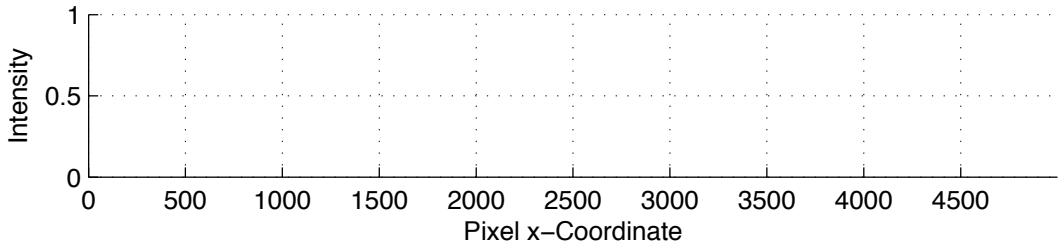
Nearest-neighbor sampling:



Bilinear sampling:



Gaussian sampling ($\sigma = 500$):



(b) Assume you want to detect edges in a gray-scale image. Propose a 3×3 convolution filter g_{edge} that has a maximum response at contrast edges of arbitrary orientation: [2 pts.]

g_{edge} :

(c) Your image may contain noise that you want to remove before applying the edge detection filter from above. To this end, you want to blur the image with a convolution filter g_{blur} before applying g_{edge}. How can the consecutive application of g_{blur} and g_{edge} be efficiently be sped up? *(One sentence only.)* [1 pt.]

(d) Provide the formulae to combine two pixels colors A and B, with respective alphas α_A and α_B, to obtain an alpha-blended pixel color C and its new alpha value α_C according to the OVER composition rule: [2 pts.]

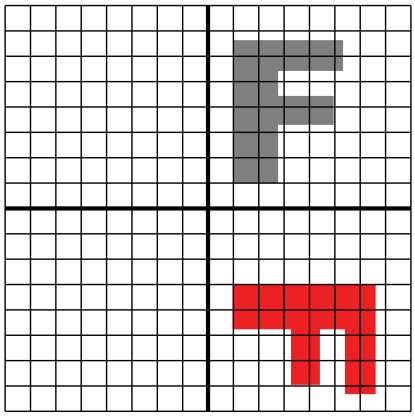
$$C =$$

$$\alpha_C =$$

(e) List two (2) additional composition rules, other than OVER: [2 pts.]

Q2. Transformations and Warps

(a) Consider transformations that move the gray **F** to the red **F** in the figure below.

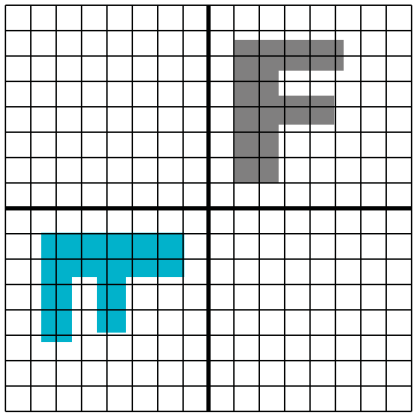


Draw the simplest controls for a Beier-Neely warp that would cause this transformation. [2 pts.]

(b) Write a 3×3 matrix that would express the transformation in (a), considering the origin to be the center of the grid and each square to be of unit size. [3 pts.]

(c) Is there a 2×2 matrix that expresses the same transformation? If so, write it down; or if not, why not? [2 pts.]

(d) Now consider the the transformation that would transform the gray **F** to the blue **F**:



Is there a set of Beier-Neely controls that implements this transformation? If yes, draw the controls; if no, why not? [2 pts.]

(e) What is the minimum size of a matrix that would be capable of expressing a shear in 3-D? [1 pt.]

Q3. Volumetric Representations

(a) An object O be defined as the locus of all points in 3-D where a function f: $\mathbb{R}^3 \rightarrow \mathbb{R}$ assumes negative values. What is such an object representation called? [1 pt.]

(b) Given now two such representations f_1 and f_2 defining two objects O_1, and O_2, respectively. **Prove** that

$$(f_1 \cap f_2)(\boldsymbol{p}) \coloneqq \max\{f_1(\boldsymbol{p}), f_2(\boldsymbol{p})\}, \quad \boldsymbol{p} \in \mathbb{R},$$

defines a set operator $\cap$ that computes the intersection between O_1 and O_2. [3 pts.]

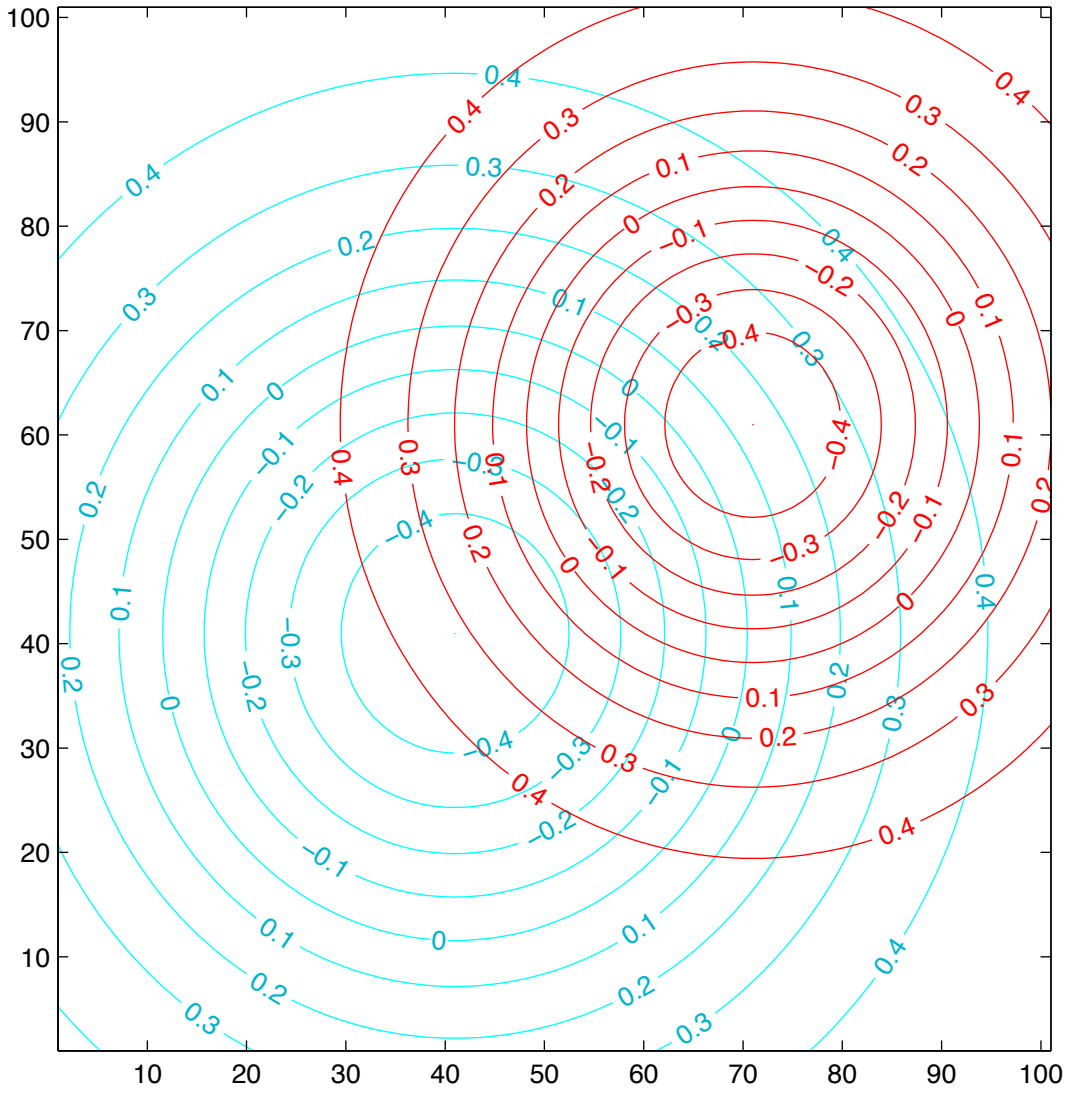
(c) Propose a definition of the complement f^{C} of a representation f that swaps inside and outside of the object defined by f: [1 pt.]

$$f^{\mathrm{C}}(\boldsymbol{p}) \coloneqq$$

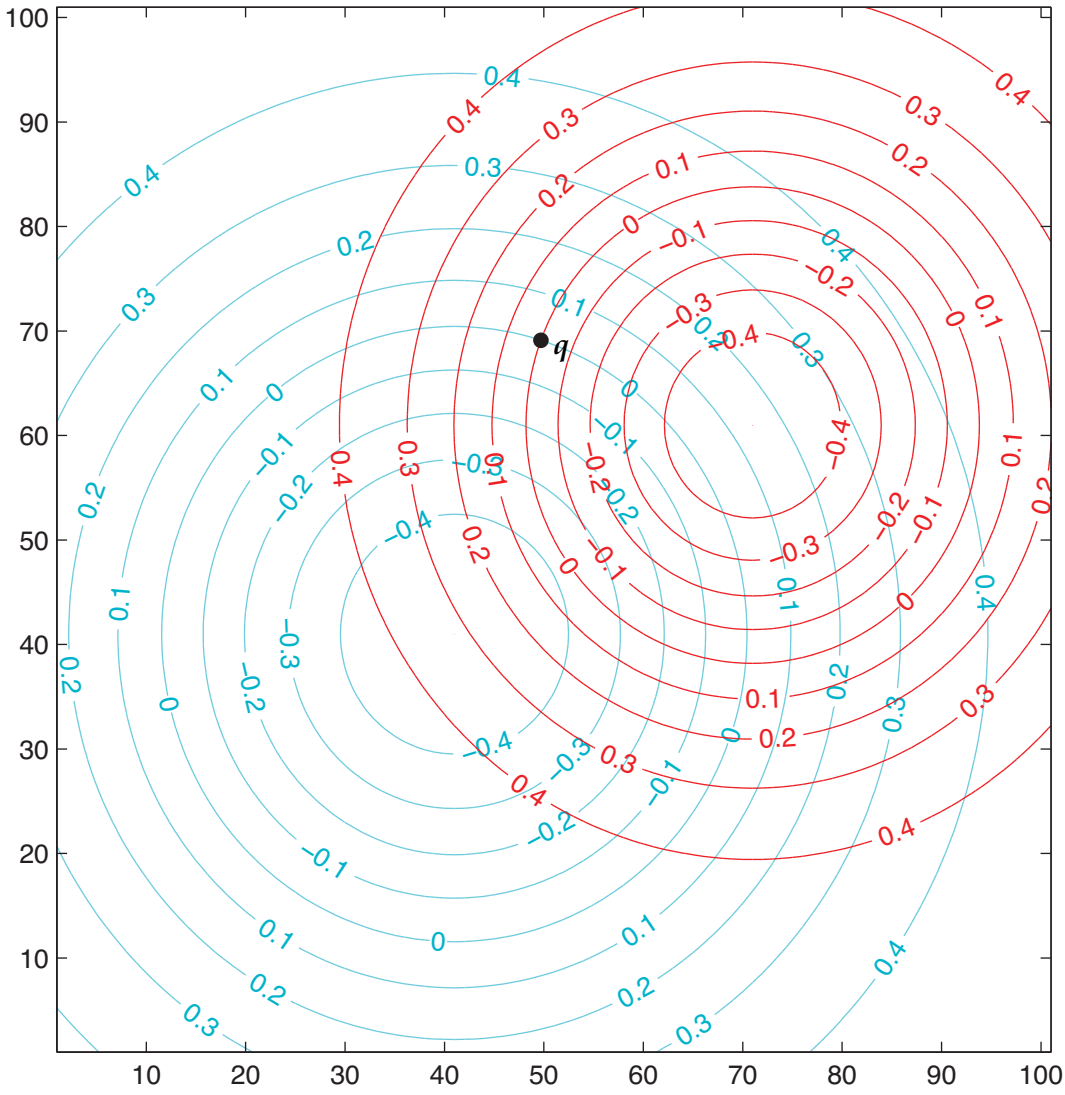
(d) Provide a definition of the $\cup$ operator to compute the union of two objects denoted by f_1 and f_2. **Hint:** Naturally, your definition has to be consistent with the equation in (b) and your answer in (c), so that $(f_1 \cup f_2)^{\mathrm{C}} = f_1^{\mathrm{C}} \cap f_2^{\mathrm{C}}$. [1 pt.]

$$(f_1 \cup f_2)(\boldsymbol{p}) \coloneqq$$

(e) Outline the result of $f_1 \backslash f_2$ (which is the same as $f_1 \cap f_2^C$) in the following 2-D cross section. f_1 is plotted in blue, f_2 is plotted in red. Plotted are curves of constant values, as in a topographic map: [1 pt.]



(f) Now assume that f_1 and f_2 are two spherical basis functions that together define a *blobby model*. Outline the resulting model surface in the plot below. **Hint:** The denoted point $\boldsymbol{q}$ lies on that surface. [3 pts.]



Q4. Meshes and Subdivision Surfaces

(a) What is a watertight mesh? (*One sentence only!*) [1 pt.]

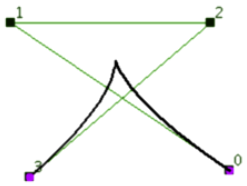
(b) Given a polygonal mesh stored as a *winged edge* data structure, how can you easily tell whether the mesh is watertight? (*One sentence only!*) [1 pt.]

(c) Given a triangle mesh with n faces, m edges, and k vertices. How many faces, edges, and vertices remain after the *edge collapse* of one of its internal (non-boundary) edges? [2 pts.]

(d) *"In any polygonal mesh, an ordinary vertex has always exactly 6 adjacent edges."* True or false? Explain your answer in *one sentence*. [2 pts.]

(e) The Loop subdivision scheme produces a tangent-continuous limit surface. How can one introduce *creases* into the limit surface, that is, how can the Loop subdivision scheme be extended to produce sharp ridges that are not tangent-continuous? (*One or two sentences.*) [2 pts.]

(f) How are gaps in adaptive subdivision meshes prevented? Draw a picture and explain in *one sentence*. [2 pts.]



Q5. Splines, Subdivision and Continuity

(a) For the following locations enter the degree of continuity (C0, C1, C2, ...?) in the space provided to the right: [7 pts.]

(a.1) a point on the interior of a typical cubic Bezier curve? _____

(a.2) a "cusp" like the one in that atypical cubic Bezier curve drawn above? _____

(a.3) a "joint" in a cubic B-spline curve? _____

(a.4) a point roughly half way between two joints in a cubic B-spline curve? _____

(a.5) a joint in a cubic Bezier spline curve, with which the two neighboring control points are collinear? _____

(a.6) an "extraordinary point" on a Loop subdivision surface? _____

(a.7) a "non-extraordinary" point on a Loop subdivision surface. _____

(b) If your answers for (a.1) and (a.2) are the same, explain how that can be? If they are different, explain how that can be? (*One or two sentences.*) [1 pt.]

(c) What kind of curve has *all three* of these properties: C2 continuity, local control, and interpolation of its control polygon? [1 pt.]

(d) What is the effect of extraordinary vertices on the limit surface of the Catmull-Clark subdivision? (*One sentence only.*) [1 pt.]

Q6. Miscellaneous

(a) Circle those of the following objects that be can modeled using a swept surface: [2 pts.]

(a.1) a martini glass

(a.2) a cartoon hand

(a.3) a star fish

(a.4) a garden hose



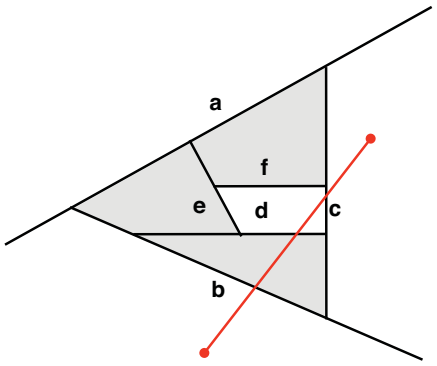

(b) Write TRUE or FALSE after each of the following statements: [3 pts.]

- A Loop subdivision surface lies within the convex hull of its control mesh. _____
- A butterfly subdivision surface lies within the convex hull of its control mesh. _____
- A voxel is a little cube of constant density. _____

(c) Why is blue used for blue-screen matting (instead of red, for example)? *(One sentence.)* [1 pt.]

(d) Name one advantage and one disadvantage of *marching tetrahedron* over *marching cubes*. [2 pts.]

(e) Computer games use BSPs to represent static scene geometry. A common problem is to find out whether an object is visible from a certain vantage point. This problem can be solved by connecting object and viewpoint with a line segment and recursively subdividing the line segment at the BSP's split planes—see the figure below for an example BSP with such a line segment (in red):



Whenever the recursive algorithm reaches a leaf node, the current line segment spans this spatial region associated with the node. When, during the recursive execution, do you know that the object is **not** visible from the chosen viewpoint? [2 pts.]