Collision

You are to determine the exact time when two geometric objects that are moving in 3D will collide. One of the objects is a disk (circular rim and its interior), and the other object is a triangle (also including its interior). Each of these objects is moving along its own linear path with constant velocity and no rotation. Describe an algorithm that determines whether these two objects will collide, and if they will, gives the exact time of the collision.

Disks

You are given a set of disks in the plane: Di=Disk(Ci,ri) is a disk of radius ri and center Ci. Think of them as schools. Define the Voronoi region Vi of Di (i.e. the region to be served by school Di), explain in detail how you would represent and compute it (the precise model of Vi, not an approximation of it), provide the asymptotic complexity of your algorithm and discuss numerical robustness issues. Give examples of what such a tool could be used for in design, analysis, animation, simulation. Suggest ways of improving the computational efficiency of your solution.

Meshes

You are given a connected manifold triangle mesh. Outline a fully automatic algorithm that you could implement in a day and which cuts such a mesh into pieces so that the cuts correspond, at least in obvious cases, to where a human would cut. For example, one may cut the mesh representing a dog to separate the head, legs, tail from the body. Similarly, your algorithm should be able to separate the fingers of a hand. First provide a mathematical formulation of where the cuts should be and what they are. Then, provide a high level outline of your approach and enough details to guide a skilled developer. Analyze the computational complexity of the approach and discuss its limitations.

Endless Reflections

An artist has constructed a room that is filled with spheres of various sizes. Every one of them has a mirrored surface, except for a single spherical light source. The walls, floor and ceiling are also mirrors. Your task is to create rendering software that will make a synthetic image of this room from the point of view of an invisible virtual camera (maybe viewing the room through a very tiny hole). Your software should create an image that is a good match to the real room. Describe your rendering algorithm. Make realistic assumptions about the properties of the mirrors and the light source. What will the image of this room look like? How will your renderer avoid getting hung up in infinite regress of reflections?
**Texture**

You have a 3D model of a hilly terrain in Ireland. The terrain is very smooth (C2), but hilly, and all green because there is only grass on it. No salient points. The 3D model is a fine triangle mesh approximation. You also have a picture of the real thing, taken from an unknown point P on the ground. It is a panoramic picture (half-sphere) taken with a fish-eye lens of which the axis of symmetry is aligned with the surface normal at P. Provide an algorithm for computing P. Then, explain how to attach the texture to the model (note that the texture will only cover the visible portion of the terrain). Finally, explain how you would compute another camera location Q, such that, if you were to obtain a second panorama from Q, the area of the remaining (untextured) part of the terrain that is now textured using the panorama from Q is maximized.

**Bezier**

Below is a diagram indicating the sixteen control points for specifying a cubic Bezier tensor product patch, S(u,v).

Answer each of the following questions, and **justify** your answers.

a) Which control points are guaranteed to be interpolated by the surface?
b) The tangent plane to a point on the surface is determined by that point and any two linearly independent vectors which are tangent to the surface at that point and thus span the plane. Two such tangent vectors are □S/□u and □S/□v evaluated at the point of interest. Which control points determine the tangent plane to the surface at u = v = 0?  
c) Which control points determine the normal to the surface at u = v = ½?  
d) Will the surface lie within the convex hull of its control points?
Presence

a) Defining Presence. There are at least two common definitions of presence, as used in relation to virtual reality. Provide at least two of these definitions, and discuss briefly which one you prefer, and why.

b) Discuss how the VR definitions of presence may or may not be useful when discussing augmented reality. Provide pros and cons to the prevailing definitions.

c) Consider the statement "Even if we could create technology like the Star Trek Holodeck, users can never be truly feel present in a virtual reality system." Do you agree or disagree? Why or why not?

Tracking

The prevailing view of how to solve the outdoor tracking problem for augmented reality includes the use of computer vision techniques. However, these techniques cannot work in isolation; additional technology, infrastructure, and data will be needed to make the robust across a variety of scenarios.

a) Discuss what additional technologies might help, and discuss the strengths and weaknesses of each technology.

b) Discuss what kinds of data could useful, and discuss the issues with generating, maintaining, transmitting and using this data.

c) How will user-generated content help such a system?

Interaction Techniques

Consider the typical VR environment, where people sit in one place with a head-worn display on and use devices to control their motion through the environment (travel) and their interaction with the environment (manipulation).

a) There are two classes of 3D interaction techniques, roughly classified as "ray-casting" and "image plane" techniques. Define these techniques, give specific examples of both classes of techniques (preferably more than one each), and discuss the kinds of interactions they are well suited for (and not well suited for).

b) How does your discussion change if you consider CAVE environments, instead of HMD-based environments?

c) How does your discussion change if you consider video-mixed HMD-based AR environments, instead of HMD-based VR?

c) How does your discussion change if you consider optical-see-through HMD-based AR environments, instead of HMD-based VR?
Optics

Explain the design challenges and tradeoffs that must be confronted when designing a head-mounted display for:
1) VR use, and
2) AR use,
In particular, describe how a VR HMD is similar and different from an AR HMD. Since with AR, the tracking methods and the kinds of augmentations will relate to the HMD design, be explicit about this in your discussion. You must be sure to consider all of the gear that a user may wear on his/her head.

PERCEPTION (Answer 2 of 4)

Optical Flow

Explain Michal Irani's use of subspace constraints in optical flow. Specifically, what is really going on? Can you explain in laymen's terms why there are such constraints? Then, how does she take advantage of them to improve optical flow estimation? Finally, how come these constraints do not hold for longer sequences, and can you think of subspace constraints that would hold for longer sequences, perhaps subject to some assumptions...

Stereo/Graphics

Your job is to render an animation video for 3D viewing for a new series of 3D televisions.

a) One of the parameters given to you about the TV is the likely viewing distance between the observer and the screen. Does that matter? Would an observer 2 meters from the screen get the same experience as one who is 4 meters from the screen? Justify your answer mathematically.

b) Are there any other parameters that would matter, say viewing angle? Why or why not?

c) Obviously, the left and right channel images will be different. But some of the pixels might be in the same location e.g. "a pole is rendered 3 pixels wide at a location 5 pixels from the left side of the frame in both images." Which pixels are rendered the same in the two images? Do you have a choice about which objects render at the same location in the two images? You might consider the following in your answer: in the human visual system, which pixels have "zero disparity" on your retina when you look at a real scene - not an image of a scene?

d) When doing rendering, it might be fair to say that anti-aliasing is always better then rendering without anti-aliasing. In stereo, we have "half occluded pixels" - pixels that come from parts of objects that are visible from one eye but not the other. Therefore there are "occlusion edges" in the scene. Tom argues one should disable antialiasing at these edges. Dick says that's ridiculous. You, Harry, need to decide. First, describe what you think are Tom and Dick's arguments, and then say which you think is right. (That is, why might antialiasing at occlusion boundaries be a bad idea - and do you agree?)
Features of Features

Within the past ten years the computer vision community has made tremendous progress in identifying effective features for problems in matching and categorization. Give two examples of widely-used feature representations. One of your example features should be suitable for the problem of finding correspondences between images, as is needed for example in structure from motion. The other example feature should be suitable for a categorization problem, such as object or scene categorization. For each of your two feature examples, explain briefly how it could be used to solve a specific perception task. Most people would agree that the features in use today are significantly more effective than those used 10 years ago. If you had to identify the single most important insight that led to improved feature representations, what would it be? Explain. Choose one of your two example features and identify its most critical weakness (the property that, if it could be improved, would make the biggest difference in improved performance.) Explain your choice.

The Dimensions They Are A Changin’

Recently there have been several interesting SIGGRAPH papers from Shai Avidan and his collaborators which explore the concept of “seam carving,” a technique for solving the problem of resizing an image or video in a way that does not introduce certain kinds of visual artifacts (e.g. in the case of an image, beyond simply uniformly scaling the image dimensions). This problem is sometimes called “content aware resizing.” What is the main algorithmic idea that underlies this body of work? In what sense is the method “content aware?” How is the method an improvement over a simple uniform linear rescaling of the image/video dimensions? What fundamental assumptions underlie this work? To what degree do the authors provide experimental validation of their assumptions? What is the relationship between this work and the problems of retiming and retargeting video? Concretely, suppose I had a video clip of the ballet “Swan Lake.” Suppose I wanted to reduce the running time for the video by one half. How effective would seam carving be in solving this problem? Explain.