CS530 - Visualization Spring 2013

Topics for Midterm Exam (Thursday, March 7, LYNN G167)

Data Representation and Basic Processing

Grid structure

- geometry vs. topology
- structured vs. unstructured, impact on storage and query complexity
- curvilinear grids
- computational space vs. physical space
- common cell types and relation to different grid structures

Interpolation

- interpolation vs. approximation: basic idea, fundamental role in (scientific) visualization
- linear interpolation in triangles / tetrahedra, barycentric coordinates, inclusion test
- bilinear interpolation in rectangles: basic idea (compounded linear interpolations)
- bilinear interpolation in general quadrilaterals (computational space)
- trilinear interpolation in cuboids: basic idea
- nature of the interpolation along edges (2D and 3D), along faces (3D)
- global continuity and piecewise smoothness of the resulting interpolation over an entire grid.

Visual perception

Human Vision

- roles of vision - properties of vision (overview): strengths and weaknesses
- overview of light properties, large range of luminance values in everyday life, colors as spectral curves
- basic anatomy of the eye: cornea, lens, iris, retina, fovea, optic nerve
- photoreceptors: rods and cones and respective properties
- respective sensitivities of S, M, L cones - spatial distribution of cones vs. rods on the retina - role of ganglia as filters, notion of opponent color response
- notion of center-surround receptive fields associated with ganglia, role as low level edge detector
- pipeline of visual system: retina to optic nerve to LGN to visual cortex (basic knowledge)
- “what” vs. “where” pathways, respective strengths and shortcomings, evolution perspective
- notion of constancy, distal vs. proximal stimulus
- implications of these notions in optical illusions
- role of on center vs off center receptive fields in Hermann grid illusion
- basic principles that explain illusions
- depth cues: motor, monocular, binocular
- basic properties of motion perception

Color Perception

- connections to general human vision (photoreceptors, ganglia, parvocellular division)
- trichromatic color theory:
    - link to 3 types of photoreceptors
    - 3D color space, colors can be described as a combination of red, green, and blue components
    - shortcomings, color blindness

- opponent color theory: link to opponent color response
- perceptual distortions
- color spaces: perceptually based, device derived, intuitive (high level description), examples
    - CIE color space, notion of gamut of human color and chromaticity diagram
    - RGB color space: why is it so popular and why is it a problem?
    - HSV color space: hue, saturation, value

Scalar Field Visualization

Color Visualization

- different uses of colors
- various kinds of univariate colors scales
    - idea behind color model component scale, examples
    - redundant color scales: simultaneous variation of several perceptual dimensions, examples
    - double-ended scale
    - color scales as 1D curve in color space
- multivariate color scales
- Trumbo's principles to evaluate the effectiveness of a color scale

Isosurfacing

- notion of isocontour (level set) and associated properties
- interpretation as boundaries in scalar data sets
- cell-wise extraction in 2D quadrilaterals (piecewise linear approximation), algorithm description ("marching squares")
- ambiguities in 2D: linear model vs. bilinear interpolation, role of saddle point in deciding correct topology.
- marching cubes algorithm in 3D, different cases, lookup table, 15 basic configurations
- ambiguities in marching cubes: on faces, in the interior, link to the complexity of the trilinear interpolation
- complexity of marching cubes: computation, storage
- span space: basic principle and usefulness in practice

Volume Rendering

- motivation, basic idea, physical metaphor used to turn a scalar volume into a visible object
- main differences compared to isosurfacing, respective pros and cons
- volume rendering integral
    - emission, absorption (different models), formulae
    - discrete approximation of VR integral, role of alpha blending, color, opacity
- notion of transfer function, role in volume rendering
- role of gradient in rendering and connection to isosurfacing
- typical applications of VR in visualization
- alpha blending (simple computation with a few objects)
- compositing: first, average, accumulate, MIP
- image order methods:
    - ray casting: basic idea
    - back-to-front vs. front-to-back rendering: basic idea, computation with alpha blending
    - pros and cons of ray casting method (speed, accuracy, memory requirement, ...)
- object order methods:

- projected tetrahedra (PT): basic idea, optical model + encoding with 3D texture lookup, pros and cons
- slice-based rendering: basic idea, image quality aspect, connection with volume rendering integral (alpha blending), mapping to GPU, pros and cons

Transfer Functions for Direct Volume Rendering

- spatial domain vs. value space: basic notion, mapping in between
- transfer functions:
    - why are they fundamental?
    - why are they difficult to design?
    - why are we typically trying to capture boundaries with the transfer function?
- existing approaches (we saw two main ideas):
    - salient isovalues (basic idea)
    - semi-automatic transfer function design (high-level knowledge of the procedure):
        - mapping from spatial domain to 3D histogram of value space to scalar measure of (signed) distance to boundary
        - boundary emphasis function controls the rendering
        - what makes this approach effective / intuitive for the user?
- multidimensional transfer functions: basic idea, motivation (shortcomings of 1D and 2D transfer functions), application to interactive rendering system (example of user interface supporting multidimensional transfer functions)