Ph.D. Computer Science Qualifier 2

Geometric Computing, Computer Graphics, and Visualization

The Qualifier 2 exam will take place at a fixed weekly 60 minute time slot. The candidate will be expected to demonstrate breadth (1) and depth (2) of knowledge in computer graphics and visualization. During the exam, the candidate will be asked to explain fundamental concepts and then to sketch an approach for solving a research problem. This includes identification of challenges to overcome, use of prior work, formulation of possible solution (algorithm), and sketching the implementation and validation of the proposed solution.

1. Comprehension of Computer Graphics and Visualization Concepts

The candidate is expected to be familiar with all the following fundamental concepts covered in graduate-level graphics courses. The concepts must be mastered well enough to solve complex problems and not merely to state the definition.

Graphics

- Representations: points, directions, triangles, triangle meshes, implicit and parametric representations of curves and surfaces
- Mathematical tools: vector and matrix operations, transformations, coordinate systems, linear and nonlinear optimization methods
- Planar pinhole camera model: calibration, construction, projection, navigation, change of focal length, change of resolution, epipolar geometry
- Other pinhole camera models: cylindrical, spherical, fisheye, panoramas
- Rasterization: line rasterization, triangle rasterization, z-buffering, screen and model space interpolation of rasterization parameters
- Color models: CIE XYZ, RGB
- Shading techniques: Gouraud and Phong shading
- Illumination and reflectance models: Phong model, Cook-Torrance model, basic BRDFs
- Texture mapping: projective texture mapping, environment mapping, shadow mapping, bump mapping, normal mapping, environment mapped reflections and refractions
- Ray tracing
- Antialiasing
- Hierarchical space subdivisions: BSP tree, quadtree, octree, k-d tree
- GPU programming: general concepts

Visualization

- Data structure for visualization: cell complex, spatial queries, interpolation

Scalar visualization

- isosurface extraction: Marching Cubes, span space, view-dependent methods
- direct volume rendering: basic principles, multidimensional transfer functions, dual domain interaction

Vector visualization

- streamlines, stream surfaces, seeding problematic
- texture-based methods: LIC, image-based methods

Tensor visualization

- glyphs: ellipsoid representation
- isotropy vs. anisotropy, different anisotropy types
- hyperstreamlines

2. Knowledge of Prior Work in Area of Research

The candidate will be asked to provide the summary, strengths, and weaknesses of the state of the art in areas relevant to the candidate's Ph.D. research. The topics are grouped below into several categories. For each candidate, a subset of one or more of these topics will be agreed upon to form part of the examination.

1. Rendering acceleration: geometric simplification, visibility and occlusion culling, impostors
2. Rendering of View-dependent Effects: reflections, refractions, occlusions
3. 3D Reconstruction: device calibration, methods to acquire depth, tracking and correspondence, point and surface reconstruction, validation and visualization
4. Image-Based Rendering: image morphing, view morphing, depth images, image warping, layered depth images, light fields and lumigraphs
5. Geometric Modeling: CSG, Brep, geometric constraints, medial axis, robustness
6. Physically-based modeling: spectral rendering, BRDF modeling, Monte Carlo global illumination
7. Animation: kinematics, dynamics, collision detection, path planning, and deformation
8. Topology-based scalar visualization: Morse theory, Reeb graph, topological cleaning
9. Advanced flow visualization: vector field topology, feature-based methods, GPU-based dense methods
10. Advanced tensor field visualization: superquadrics glyphs, topology, texture representations
11. DTI visualization: glyph placement, tracking, clustering, volume rendering, stochastic connectivity visualization
12. Volume rendering: hardware implementation, lighting, interpolation, uncertainty
13. Procedural modeling: L-systems, shape-grammars, procedurally based modeling of geometrical structures (e.g., plants, buildings)