Computer Graphics and Visualization
Advancement to Candidacy Oral Exam

1. Mathematical Foundations

(a) **Linear Algebra**: linear independence, matrix and vector norms, iterative and direct methods for solving linear systems, block matrices, factorizations (QR, LU, SVD), eigenvalues and eigenvectors.

(b) **Optimization & Approximation**: Newton's method and gradient descent in $n$ dimensions, least squares, numerical quadrature, splines, interval arithmetic, radial basis functions, orthogonal functions, spherical harmonics.

(c) **Probability & Statistics**: random variables, statistical independence, expectation and variance, probability density functions, cumulative distribution functions, the Law of Large Numbers.

(d) **Topology**: curvature, geodesics, exponential maps, Frenet and Darboux frames, shape operators, Gauss maps, manifolds, Euler characteristic, genus, Betti numbers, homeomorphism, diffeomorphism, homology, homotopy equivalence, compactness, connectedness, Cauchy sequences.

(e) **Computational Geometry**: Voronoi diagram, delaunay triangulation, convex hulls, alpha shapes, arrangements and duality, intersection of geometric primitives.

(f) **Signal Processing**: Fourier series, Fourier transform, FFT, convolutions, filtering, projection-slice theorem.

2. Rendering, Visualization, and Image Processing

(a) **Hidden surface removal**: Z-buffering, BSP trees, ray tracing.

(b) **Physically-based rendering**: classical ray tracing, the rendering equation, path tracing, sampling methods (e.g. Monte Carlo), the radiosity method, basic radiometry (radiance, irradiance, BRDF, etc.).

(c) **Rendering Architectures**: classical rendering pipeline, graphics processing units.

(d) **Non-photorealistic rendering**: real-time, texture, environment, bump, normal mapping, GPU programming.

(e) **Color and Displays**: basic color models, high dynamic range, basics of visual perception, sampling, reconstruction, aliasing and quantization, gamma correction, dithering.
(f) **Spectral Analysis of Images**: basic image enhancements, segmentation, geometric transformation and compression.

(g) **Visualization** volume rendering, iso-surface extraction algorithms, splatting, tensors and tensor visualization, flow visualization, biomedical visualization.

3. **Geometric Modeling**

   (a) **Parametric curves and surfaces**: Bezier curves and surfaces, B-spline curves and surfaces, NURBS surfaces.

   (b) **Meshing and Remeshing**: mesh simplification, subdivision surfaces, level-of-detail rendering, mesh fairing/smoothing, Quaternion interpolation of vectors.

1 Suggested Readings


10. *Introduction to Ray Tracing*, Glassner

11. *Advanced Global Illumination*, Dutre, Bekaert, and Bala.


15. *Curves and Surfaces for CAGD*, Farin.

2 Suggested Courses

Candidates will be expected to have taken these courses or their equivalents.


3 Affiliated Faculty

Arvo, Eppstein, Goodrich, Gopi, Jain, Meenakshisundaram, Mujumder.