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

1. *Linear Algebra and its Applications*, Strang.
2. *Fundamental of Matrix Computations*, David Watkins.
3. *Solving Least Squares Problems*, Lawson & Hanson.
4. *Numerical Recipes*, Press et al.
5. *Elementary Differential Geometry*, O'Neill.
6. *Elements of Algebraic Topology*, Munkres.
7. *Topology*, Munkres.
8. *Computational Geometry: Algorithms and Applications*, de Berg, et al.
9. *Interactive Computer Graphics*, Angel.
10. *Introduction to Ray Tracing*, Glassner
11. *Advanced Global Illumination*, Dutre, Bekaert, and Bala.
12. *Digital Image Processing*, Woods & Gonzalez.
13. *The Scientist and Engineer's Guide to Digital Signal Processing*, Steven W. Smith.
14. *Non-photorealistic rendering*, Gooch & Gooch.
15. *Curves and Surfaces for CAGD*, Farin.
16. *Level of Detail for 3D Graphics*, Luebke, Watson, Cohen, Reddy, and Varshney.

2 Suggested Courses

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

1. CS 206, *Scientific Computing*: Optimization, stochastic methods, mathematical programming, orthogonal functions, approximation, differential equations.
2. CS 211B, *Advanced Topics in Computer Graphics*: Geometric modeling, miltiresolution techniques, topological properties.
3. EECS 204, *Advanced Computer Graphics*: Physically-based image synthesis, Monte Carlo methods, radiometry, advanced ray tracing techniques.

3 Affiliated Faculty

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