EE599: Computational Differential Geometry for Engineers

Instructor: Anand A Joshi Office: EEB 426 Email: ajoshi@sipi.usc.edu

Course Overview: The course will deal with the basic material of differential geometry of curves and surfaces and its application to engineering problems. In this course, the students will be familiar with the concepts of differential and Riemannian geometry such as vectors, tensors, manifolds, differential forms, topological and geometric invariants, vector fields and integration on manifolds. We will also discuss computational methods such as finite element methods and level set methods on manifolds. Some applications in Computer Vision, Signal and Image Processing and Machine Learning will be discussed.

Prerequisite: The course is self-contained; however students should have good background in calculus and familiarity with Matlab or C++.

Texts: There is no required text. Tutorial articles/online resources for each of the major topics studied will be provided. Supplemental course notes will be posted each week.

Following are recommended:

A. M. Bronstein, M. M. Bronstein, R. Kimmel, Numerical geometry of non-rigid shapes, Springer, 2008. ISBN: 978-0-387-73300-5.
B. Lee, John M. Introduction to smooth manifolds. Vol. 218. Springer, 2012.
C. ftp://ftp.math.ucla.edu/pub/camreport/cam10-35.pdf

Grading:

1. *Home Works 30%* Weekly home works will be given for students to sharpen their understanding of concepts introduced in class, and deepen their understanding of each imaging modality.

2. *Mid-Term Exam: 30% 2 hour* midterm exams will be given in class during the 8th week. The exams will test student comprehension of concepts and techniques

presented up to week 7.

3. Class Project: 40% Students will work in teams of 2 people. I will help students choose a project or students can select their own projects.

COURSE OUTLINE

Week 1: Theory of Curves tangents, arc-length, curvature, torsion, fundamental theorem of curves.

Week 2: Local theory of surfaces, parametric representation of surfaces, tangent plane, gauss map, Gaussian, mean and principle curvature.

Week 3-4: Smooth manifolds, diffeomorphisms, projective space, Grassmannian manifold.

Week 5-7: Differentiation on manifolds, integration, Riemannian metric, geodesics, tensors, covariant and contravariant tensors

Week 9: Midterm, Laplacian on manifolds and its properties.

Week 9-10: Finite Element Methods, Linear finite element and variational formulation of problems, Galerkins method. Diffusion on manifold.

Week 11-12: Applications to computer vision, harmonic and conformal mapping, minimal surfaces, texture mapping, Level Set Methods, geodesic active contours, geodesic curvature flow.

Week 13-14: Manifold Learning Methods: linear approaches, principle component analysis, multidimensional scaling, Non-linear approaches: Local linear embedding, ISOMAP, Laplacian Eigenmap.

Week 15: Project presentations

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP.

Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.