IT575: Computational Shape Modeling
Credits: 3-0-0-3
Instructor: Aditya Tatu

1. Course Title: Computational Shape Modeling.

2. Credit structure: 3-0-0-3.

3. Course Type: Elective for M.Tech (MI) specialization. Open to B.Tech semester 6 and 8 students, and PhD.

4. Prerequisites: Essential Mathematics (M.Tech/PhD), Calculus(SC105) and Algebraic structures(SC116) for B.Tech. Some familiarity with metric, norms and inner products (in finite dimensional spaces) will be helpful.

5. Course overview: The shape of an object plays a central role in several vision and graphics algorithms, be it object recognition or generating plausible variations of an object. The course begins with 2D objects : extracting and distinguishing shapes of objects from object boundaries extracted from images.

   The course then deals with shape of objects represented by 3D data. An introduction to the differential geometry of curves and surfaces in $\mathbb{R}^3$ will be provided. Representation of surfaces using meshes, and extracting shape information from meshes will be discussed. We will also discuss discrete approximations of surface features on meshes. In order to summarize shape information from two meshes coming from the same object, the meshes need to be registered with each other. We will discuss issues and algorithms for mesh/point cloud registration.

   Towards the end of the course, shape deformation techniques will be presented. Students will be asked to implement most of the algorithms discussed in the course.

6. Detailed Contents:

   (a) Shape from 2D object boundaries.

      i. Shape of objects represented by landmark points. Bookstein coordinates and Shape space of triangles.
      ii. Generalized Procrustes analysis.
      iii. Shape variability analysis - Active Shape models.

   (b) 3D objects

      i. Introduction to differential geometry of curves and surfaces in $\mathbb{R}^3$.
      ii. Discretization of surfaces into meshes.

   (c) Differential geometry on meshes and applications.

      i. Fast marching method.
      ii. Computing Normal, gradient of a function on a mesh.
      iii. Laplace-Beltrami operator and its eigenfunctions.

     iv. Applications of Laplace Beltrami operator.

  (d) Rigid Shape matching

     i. Iterative closest point matching.

     ii. Correspondence between 3D objects.

  (e) Non-rigid shape analysis:

     i. Multidimensional scaling.

     ii. Spectral embedding.

  (f) Shape deformation/editing models:

     i. Laplacian Mesh Editing.

     ii. Embedded Deformation for Shape manipulation.

7. References

  (a) Andrew Pressley, Elementary Differential Geometry, Springer 2010.

  (b) Christopher Small, The Statistical Theory of Shape, Springer 1996.

  (c) Alexander M. Bronstein, Michael M. Bronstein and Ron Kimmel, Numerical Geometry of Non-rigid Shapes, Springer, 2003.

  (d) Mario Botsch, Leif Kobbelt, Mark Pauly, Pierre Alliez and Bruno Lèvy, Polygon Mesh Processing, A K Peters Ltd., 2010.

8. Evaluation:

  (a) About 5 assignments involving coding in MATLAB/Python and writing reports in LaTeX. - 60%

  (b) One End-sem examination. - 20%

  (c) Paper reading and presentation. - 20%