ENSC-887: Computational Robotics
2012 Detailed Outline (Updated January 25; to be revised further)

Part I: Computational and Algorithmic Fundamentals of Robotics

Lecture 1.

- Introduction and overview. Several Handouts for the basics to be covered in the next few lectures.

Lecture 2.

- Algorithmic complexity: NP-completeness and O notation. 2 handouts from Horowitz and Sahni. Same material is covered in Appendix B from Latombe.
- The complexity of ruler folding – paper by Hopcroft, Joseph and Whitesides.
- Graph search techniques. Appendix C from Latombe. Appendix H.1 and H.2 from Choset et al. `Reading`.

Lecture 3.

- Basic notions from mathematics: affine space, metric, inner product, elementary point set topology: closure, compactness, etc.; path connectedness, continuity, homeomorphism, diffeomorphism. Appendix A from Latombe, and/or Appendices B and C (up to C.4) from Choset et al.
- Notion of a manifold: diffeomorphisms and charts. Parts of Chapter 2 from Latombe, in particular Section 3.2; read it as representing a general surface rather than C-space). Also Section 3.4 in Choset et al.

Lecture 4.

- Basic notions from geometry: convex set and convex combination of points, convex hull (page 70-72), convex cones, etc.; Minkowski sum (page 278), Voronoi diagram (page 168-182), page numbers refer to corresponding selected sections from O'Rourke.
- Geometric modelling: Representing polygons and polyhedra. Appendix F.1 Choset et al. 3 handouts from Mantyla. `Reading`.

Lectures 5

- Basic kinematics. Representation of orientations. 3 handouts from Craig (mention Chapters) and Sections 4.1 and 4.2 (Chapter 2) in Latombe, mainly parameterizations of SO(3), Jacobians. Section 3.3 onwards in Chapter 3 and Appendix E in Choset at al.

`Assignment I`

Lecture 6. The Configuration Space. Chapter 2 from Latombe: Sections 1-9, exclude Sections 4.3, 5.2, 5.3, 5.4.

- The basic motion planning problem as a motivation for the notion of Configuration Space (Cspace). Cspace obstacles for pure translation in 2 and 3-dimensions.
- Notion of completeness, resolution completeness for motion planning algorithms.

Lecture 7.

- Computation and representation of Cspace obstacles in 2 and 3-dimensions. Chapter 3 from Latombe: until Section 1.6. Summary of 1.7 and summary of Section 2.

Lecture 8. Basic search techniques in motion planning: Roadmap Methods. Chapter 4 from Latombe: up to Section 3.

Lecture 9. Basic search techniques in motion planning: decomposition methods. Chapter 5 from Latombe: Sections 1 and 2.

Lecture 10. Basic search techniques in motion planning: Approximate cell decomposition methods. Chapter 6 from Latombe: Sections 1, 2, and 5.1. Exclude Sections 3,4.

Lecture 11. Basic search techniques in motion planning: Potential field based methods. Chapter 7 from Latombe: Sections 1-5. Exclude Section 4.3.

`Assignment II`
`Project Selected`

Part II: Topics in Robot Planning

- Gross Motion Planning

1. Practical motion planners for manipulator arms – case studies of four planners: SANDROS, paper by Chen and Hwang; Sequential Search, paper by Gupta and Zhu. Randomized planning (Section 5, Chapter 7) from Latombe; Probabilistic Roadmaps, papers by Kavraki et al. and by Juan-Manuel Ahuactzin et al. Student led discussions. Class 12 and 13.
2. Efficient algorithms for collision detection. Papers by Gilbert, Johnson and Keerthi; Lin and Canny. Noborio and Arimoto. Greenspan. Student led discussion. Class 14.
3. Motion Planning in time-varying environments: Chapter 8 from Latombe. Paper by Fujimura on time-optimal motion planning. Student led discussion. Class 15.

- 3D Range Sensors and Sensor based planning: papers and material TBD

- Grasp Planning

    1. Grasp Planning: constructing grasps.
       Paper by Nguyen; Faverjon and Ponce. Student led discussion. Class 16.
    2. Pushing, squeezing and grasping. Papers by Mason; Brost. Class 17.

- Mobile Manipulation and Planning with Uncertainty: papers and material TBD

Part III: Projects

- Student Presentation of Projects.

Evaluation

1. Assignments: 20% for assignments.
2. Exam: 20%
3. Participation: This includes your advance preparation, your presentations and your participation in class discussions. 20%
4. Project: 40%

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