CS 4/6/791Y Mathematical Methods for Computer Vision

(listed as "Scientific Visualization")

Fall 2003

Prerequisites

Calculus I-III, Probabilities and Statistics, Data Structures and basic knowledge of image manipulation. Background on Linear Algebra will be very useful. Courses on image processing, computer vision, pattern recognition, machine learning, neural networks, artificial intelligence, and genetic algorithms are recommended, but not required. Good programming skills are essential.

Credit hours: 3.0

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Office Hours: TR: noon - 1:00 pm and by appointment.

Required Text:

No text is required for this class. Reading assignments, based on notes and papers, will be posted on the web on a weekly basis.

Objectives

Computer Vision systems have many potential applications. *Robots* who can see are more likely to interact with the real world in a satisfactory manner; they can choose objects, avoid obstacles, plan routes, calculate their velocity and orientation, identify dangerous situations, etc. Such robots will be useful in exploring dangerous or very distant environments (e.g. other planets, inside nuclear reactors). Computer Vision can be used to help cameras follow the trajectory of people and vehicles, for example for *traffic monitoring*; it can help in the *identification of faces* for security clearance; it can be used for converting 2D images into *3D models* that can then be rotated and manipulated, for example to present medical or sporting images from a better angle; they can be use for inspecting *medical images* for identifying tumors and other ailments.

Over the next decade, it is anticipated that Computer Vision systems will become commonplace, and that vision technology will be applied across a broad range of business and consumer products. This implies that there will be strong industry demand for computer vision engineers - for people who understand vision technology and know how to apply it in real-world problems. This course will cover some of the most important mathematical tools needed for computer vision research. It is mostly suited for mainly students who are interested in doing research in the area of Computer Vision.

Why a course on mathematical methods for computer vision?

Computer Vision is a broad-based field of computer science that requires students to understand and integrate knowledge from numerous disciplines such as Image Processing, Computer Graphics, Pattern Recog-

nition, Machine Learning, Neural Networks, Genetic Algoritnms, Fuzzy Logic, and Artificial Intelligence. Students are expected to strong background in calculus, linear algebra, probabilities, statistics, geometry, and algorithms. Scientists engaged in this field inevitably have to learn many things about a discipline in which they did not receive formal training. Computer science and electrical engineering majors, however, do not necessarily have an interdisciplinary background. In an effort to makeup for students' weak background, many instructors either spend too much time on teaching background concepts or just skip the mathematical details and proceed immediately to demos and implementation. The purpose of this course is to help bridge the gap for more students to do research in computer vision by teaching them some of the most important and essential mathematical tools used in computer vision research.

What we plan to cover in class

Topics to be covered in class include (tentatively):

- Review (linear algebra, probabilities, calculus, pattern recognition)
- Image Processing Transformations (Fourier Transform, Wavelet Transform)
- Numerical Methods (e.g., grad descent, Newton)
- Bayes rule, Maximum Likelihood, MAP
- Density Estimation, Mixtures of Gaussians, EM Algorithm
- Neural Networks (e.g., Backpropagation, RBF)
- Support Vector Machines
- Bayesian (Belief) Networks
- Hidden Markov Models
- Genetic Algorithms
- Information Fusion
- Kalman filtering
- Algorithms (e.g., dynamic programming, greedy, MST, Shortest paths)
- Fuzzy Logic

How the course will be taught

Our goal is to emphasize those mathematical techniques which have been extensively evaluated and demonstrated to be useful in practical applications. Our emphasis will be on the application aspect of these mathematical technqiues in computer vision. We will try to cover at least one technique each week. Once we have discussed the necessary mathematical details, we will concentrate on discussing applications.

Course Policies

Exams/Quizzes: There will be no exams but there will be short quizzes every time we complete a topic (they will be announced at least one class period in advance).

Course Project: there will a course project which should be done on an individual basis. Specific project ideas will be discsused in class. You will be using C++ or Matlab. You will be required to turn in regular progress reports and a final report which should include a description of the problem, a description of your approach, and your evaluation of the results. You will be also required to do a presentation of your project work at the end of the semester.

Presentations: each student is required to present a few papers to the rest of the class. The presentations should be professional as if it was presented in a formal conference (i.e., slides/projector).

Regular attendance is highly recommended. If you miss a class, you are responsible for all material covered or assigned in class. Late programming assignments will be penalized 10% of the points assigned per day (weekends count as one day). If you are unable to hand in an assignment by the deadline, you must discuss it with me **before** the deadline in order to avoid the late penalty. *A missed quiz may be made up only if it was missed due to an extreme emergency.*

Grading Scheme

Quizzes: 30%
Course Project: 40%
Presentations: 30%

Important dates

10/17/2003 - last day for dropping classes
11/27/2003 - Thanksgiving Day
12/9/2003 - last day of classes