CS 3220: Introduction to Scientific Computing

Steve Marschner
Spring 2009

scientific computing: The use of computers to solve problems that arise in science (and engineering, medicine, …).

numerical methods: Algorithms (methods) for solving problems with real numbers by numerical (as opposed to symbolic) means.

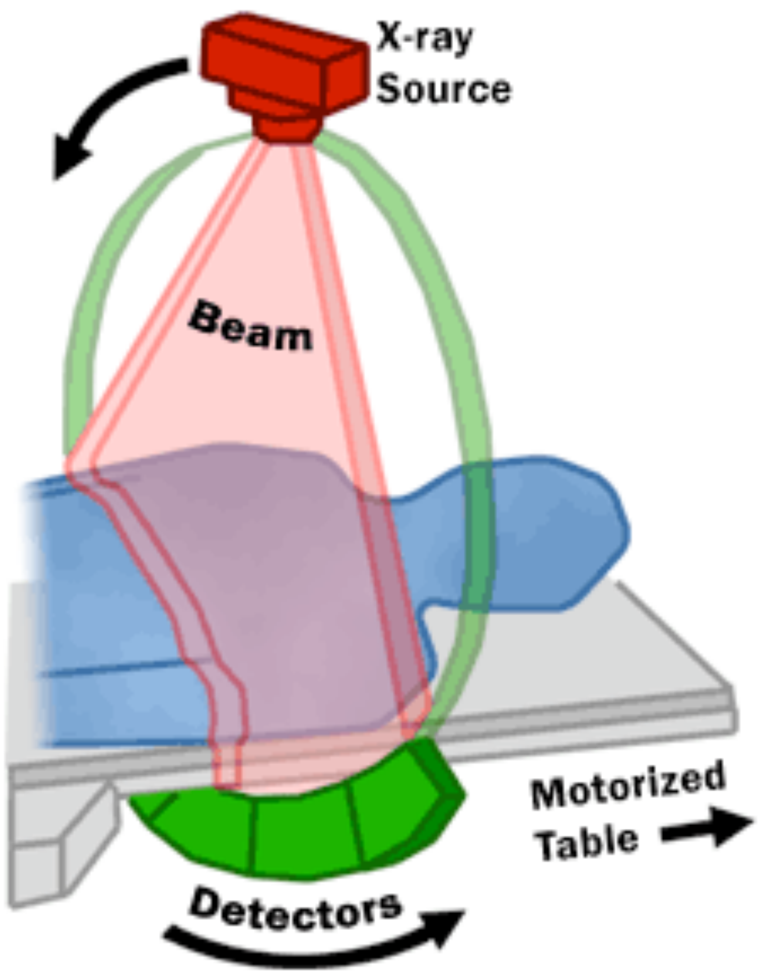
If your variables represent real-valued quantities, you're doing numerical computing. Perhaps surprising are:

- audio (stream of sound pressure samples)
- video (grids of intensity or color samples)
- computational geometry (positions in space)
- computer graphics and vision (geometry, color, light…)
- information retrieval (more on this in a moment)

with abundant computing power, more applications are using numerical methods all the time.

Numerical computing in medicine: computed tomography

a linear inverse problem



U.S. FDA

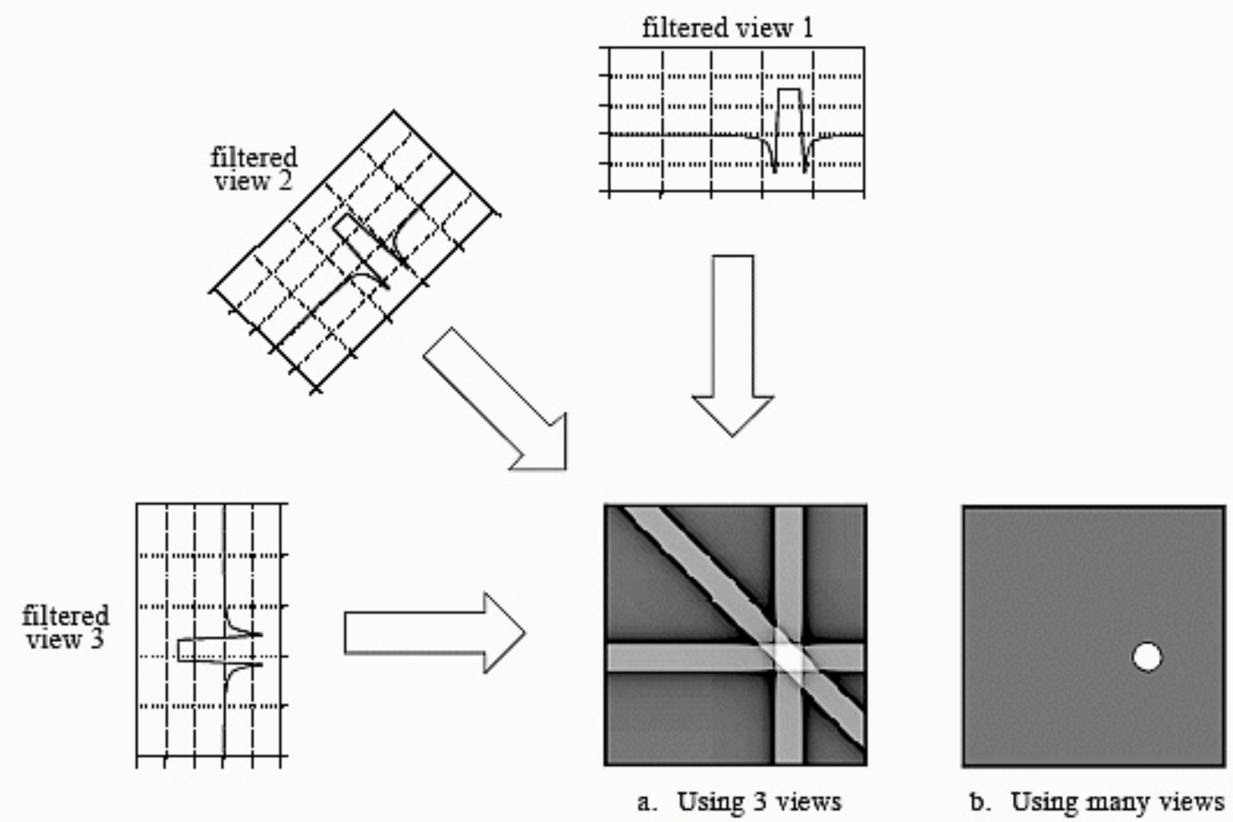
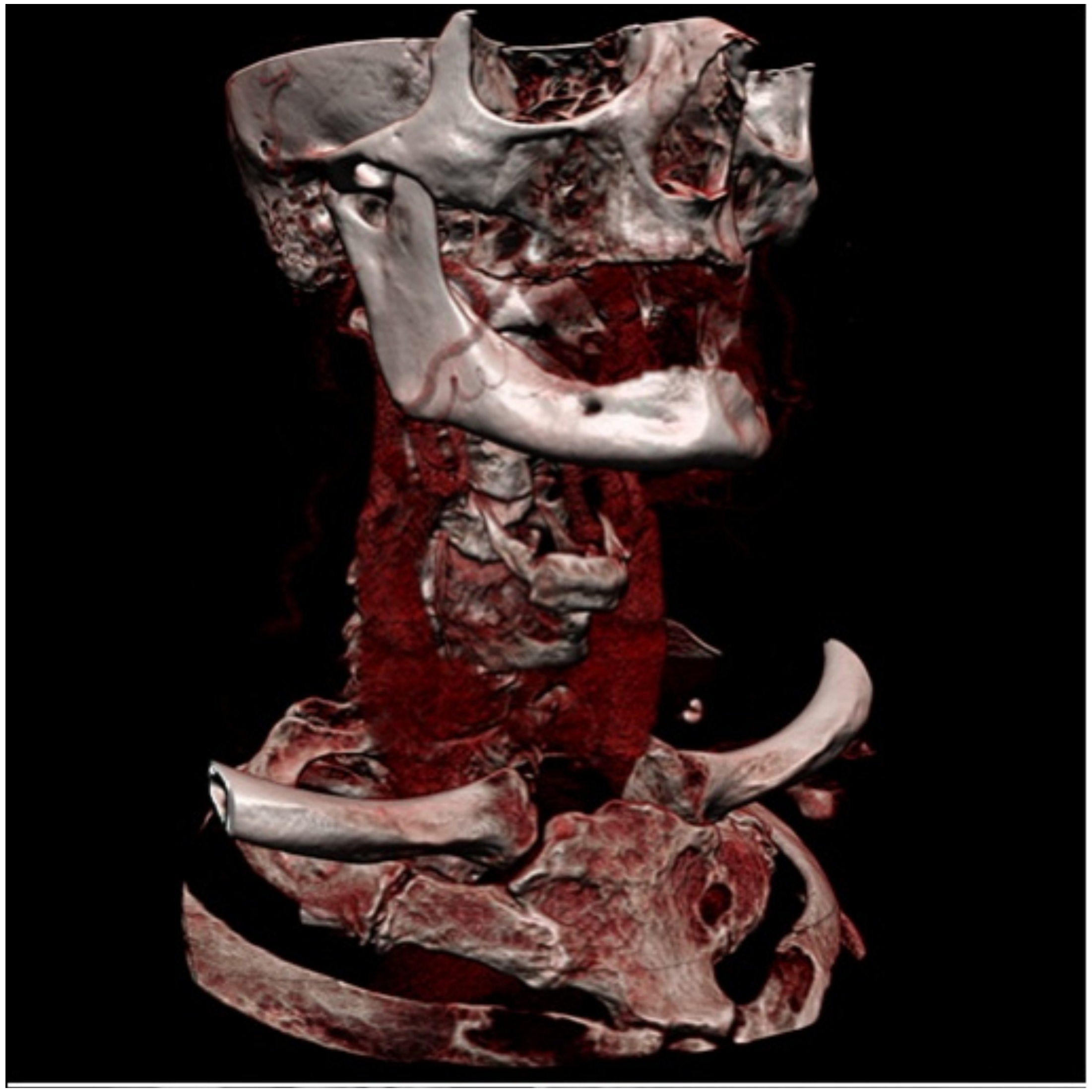


FIGURE 25-17
Filtered backprojection. Filtered backprojection reconstructs an image by filtering each view before backprojection. This removes the blurring seen in simple backprojection, and results in a mathematically exact reconstruction of the image. Filtered backprojection is the most commonly used algorithm for computed tomography systems.

Steven W. Smith—dspguide.com

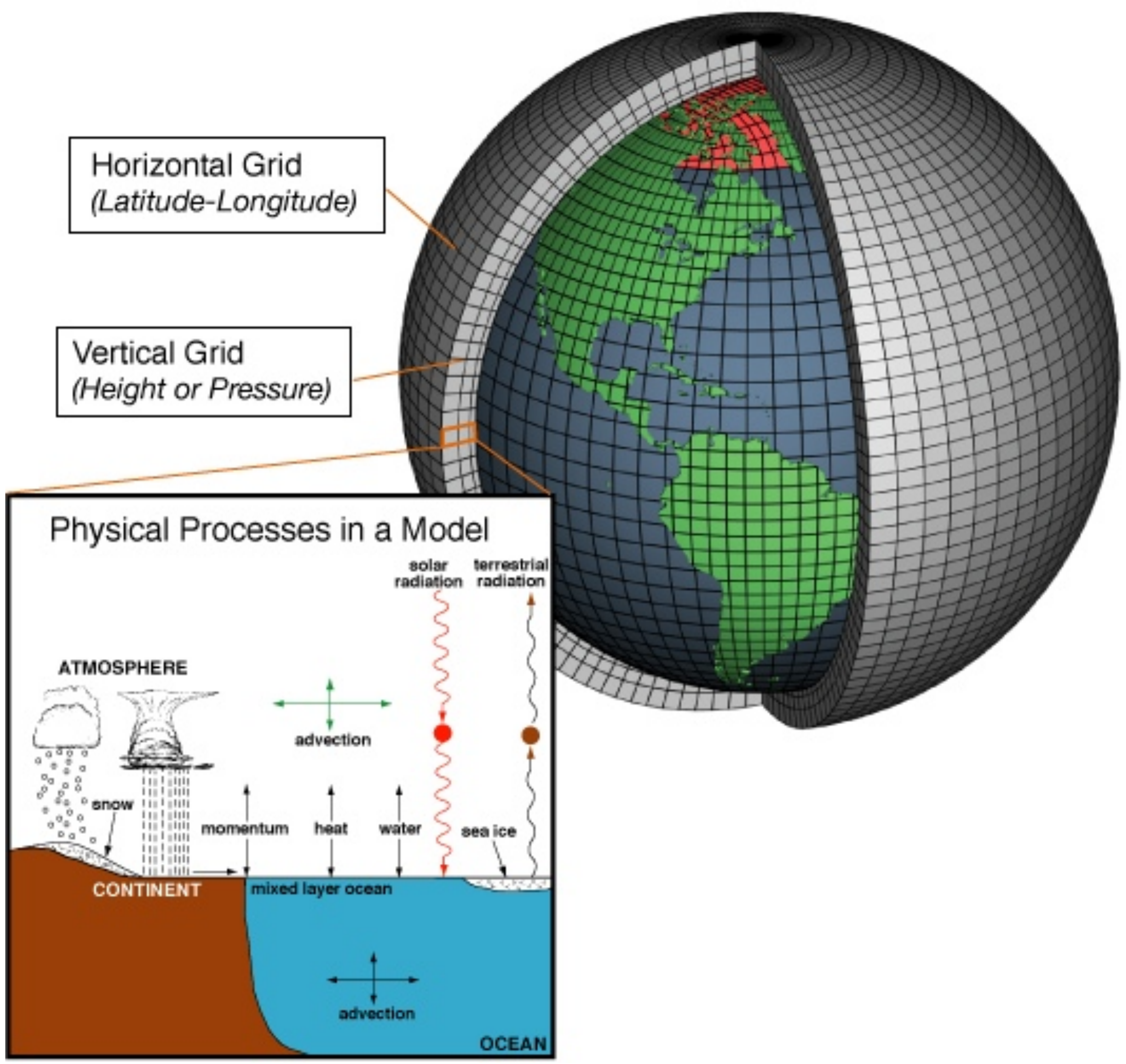
Numerical computing in medicine: computed tomography

Numerical computing in medicine: computed tomography



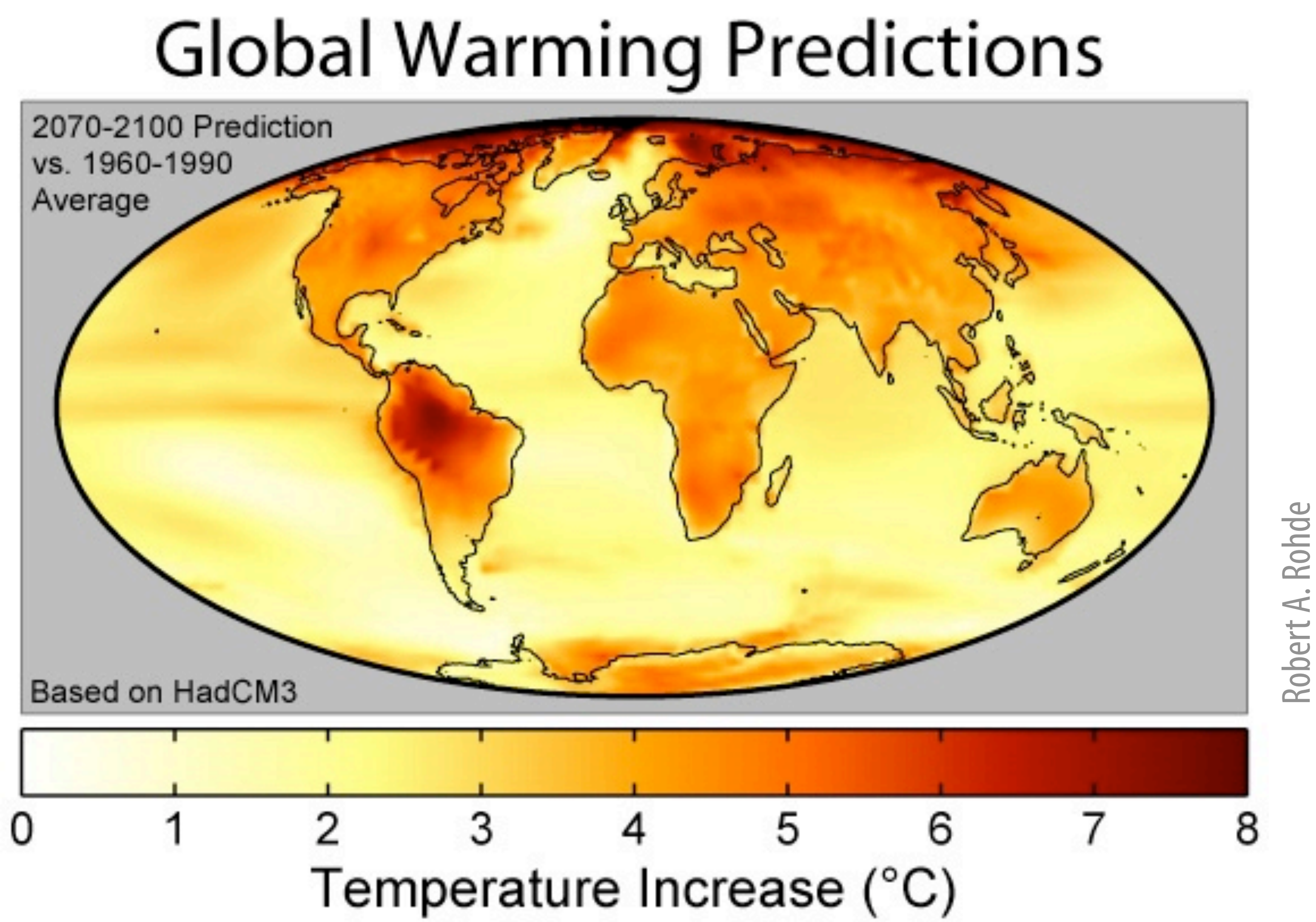
Numerical computing in climatology: predicting global warming

partial differential equations



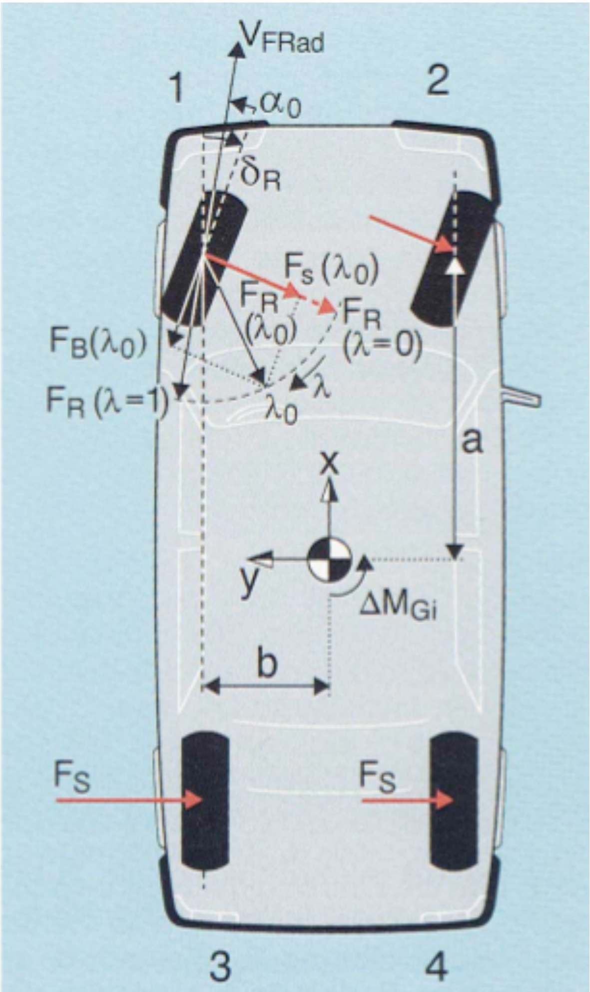
NOAA

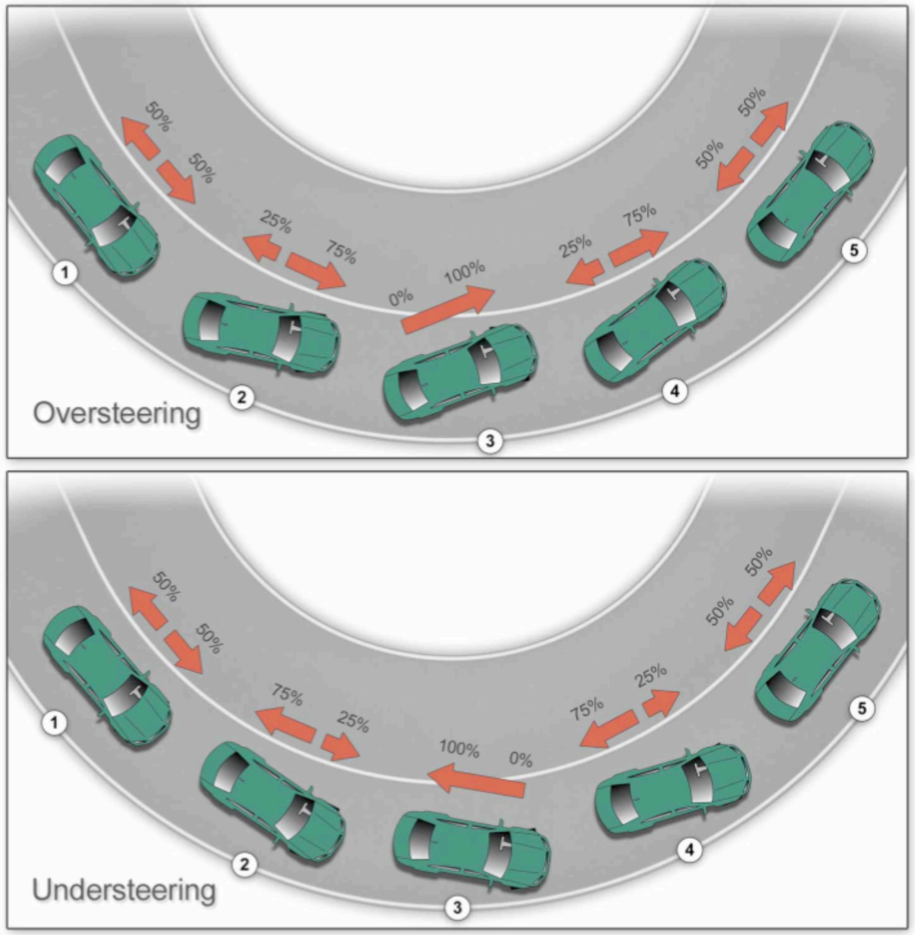
Numerical computing in climatology: predicting global warming



Numerical computing in cars: electronic stability control

images from:
Liebemann et al. "Safety and Performance Enhancement: The Bosch Electronic Stability Control (ESP)" in *The 19th International Technical Conference on the Enhanced Safety of Vehicles (ESV)*



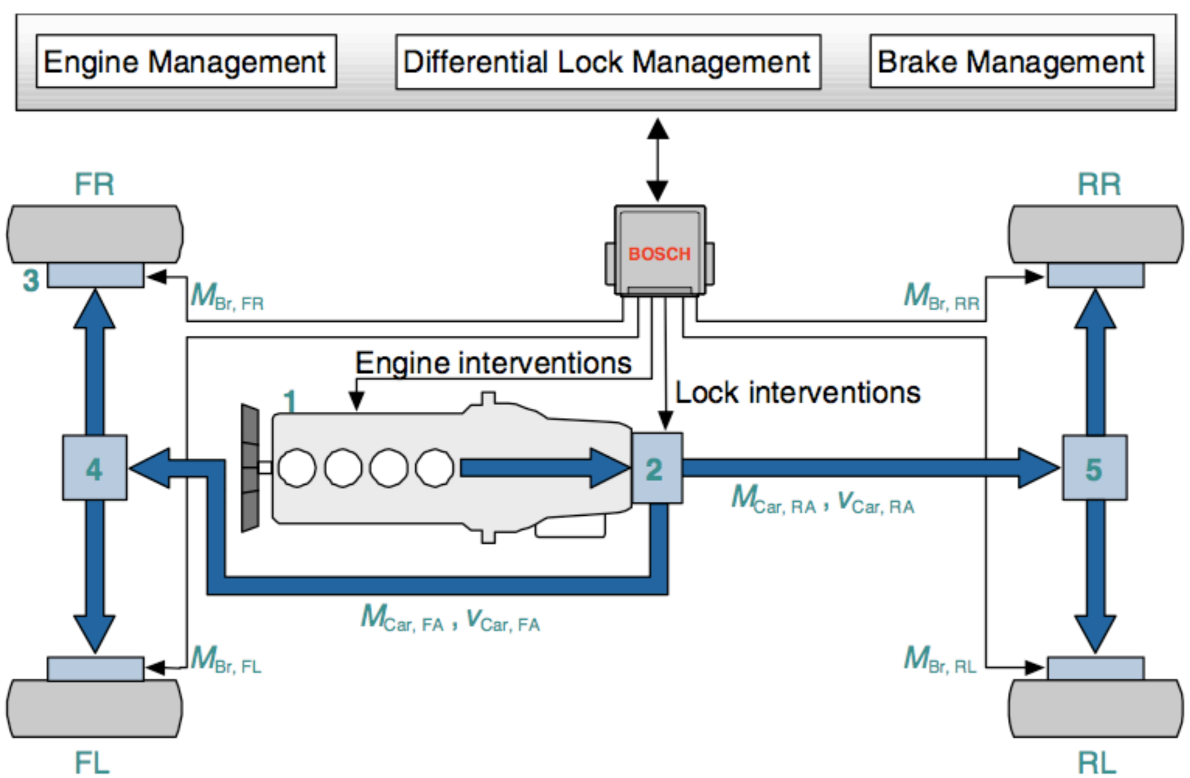


Yaw rate control at work

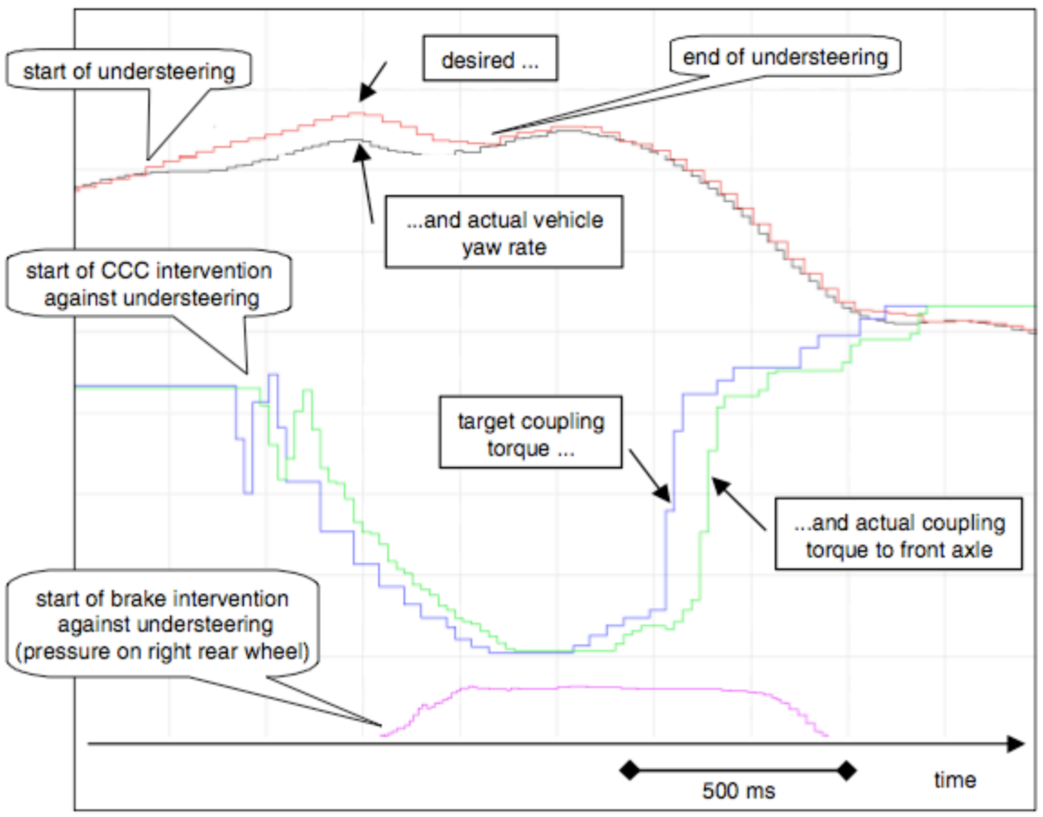
Fifth Gear—demo of Bosch ESP system

Numerical computing in cars: electronic stability control

ordinary differential equations



Liebemann et al.

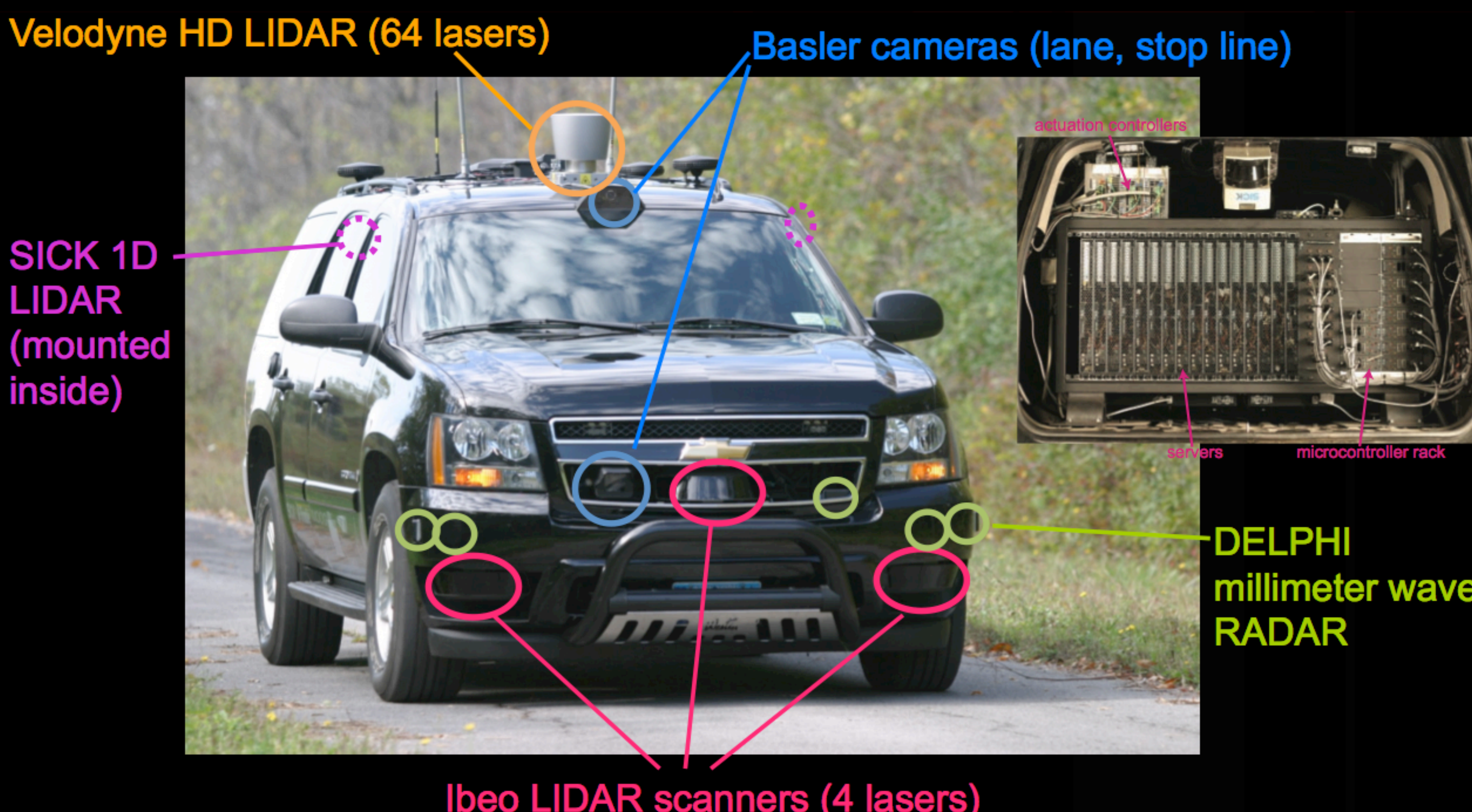


Liebemann et al.

Yaw rate control by braking

Fifth Gear—demo of Bosch ESP system

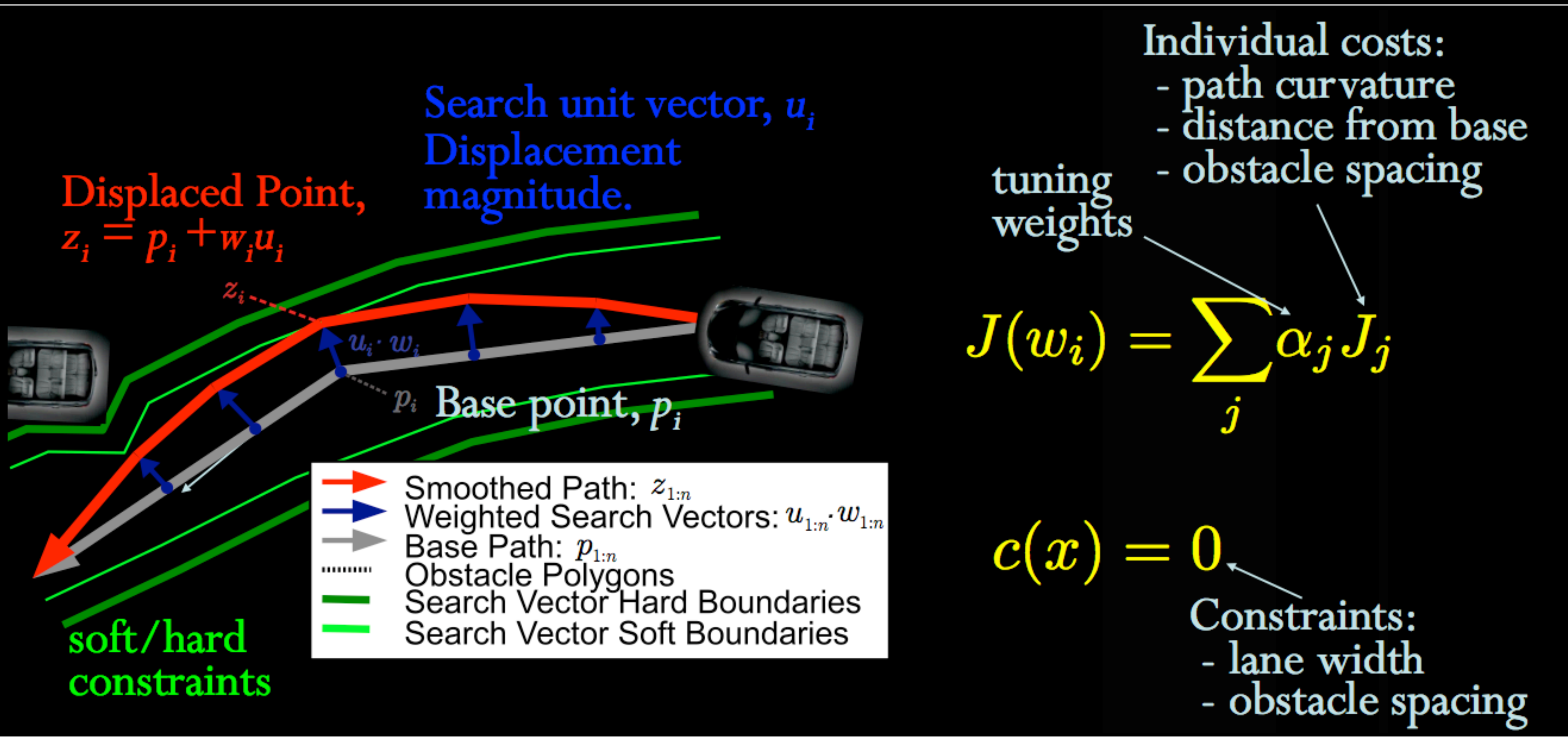
Numerical computing in autonomous vehicles: path planning



Mark Campbell—Cornell DARPA Urban Challenge team

Numerical computing in autonomous vehicles: path planning

constrained nonlinear optimization

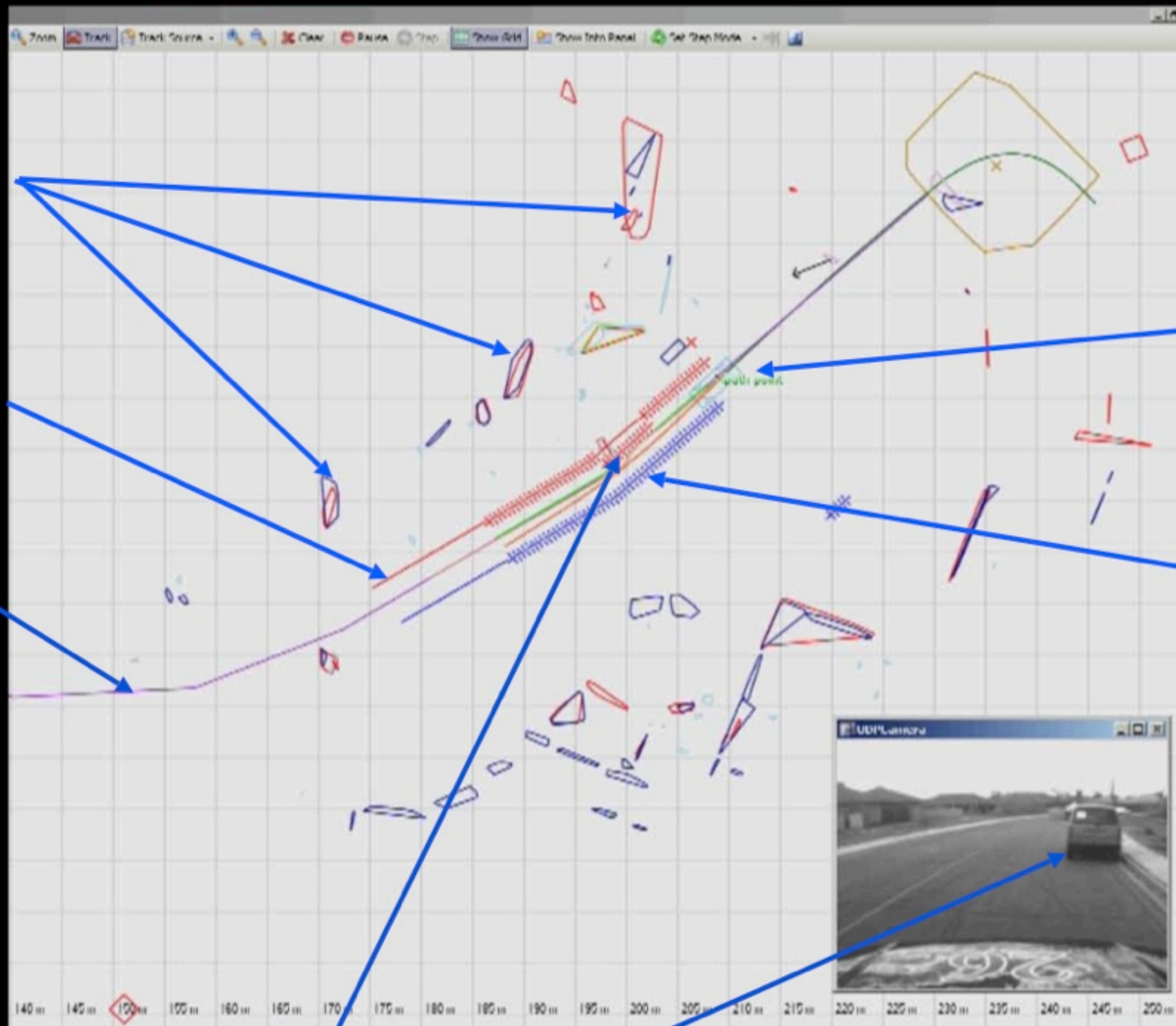


Mark Campbell—Cornell DARPA Urban Challenge team

convex hulls of obstacles

lane boundaries

RNDF (map)

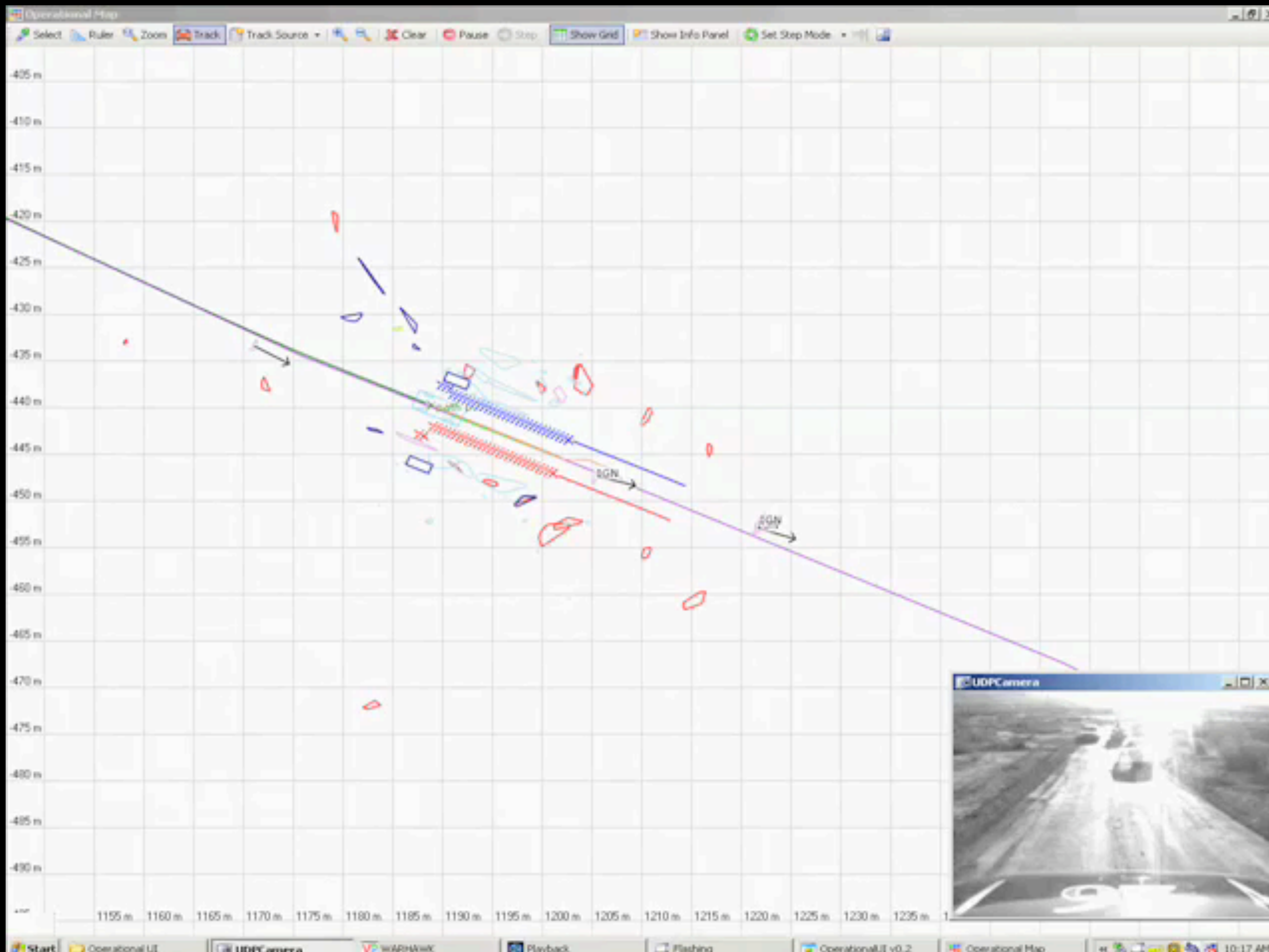


Ego-vehicle

planner constraints

constraints around parked car

Mark Campbell—Cornell DARPA Urban Challenge team



Mark Campbell—Cornell DARPA Urban Challenge team

Numerical computing in games: physics engines

ordinary differential equations

Crytek GmBH—advertisement for CryEngine 2 game engine

Numerical computing in movies: realistic lighting

Hand with Reflecting Sphere. M. C. Escher, 1935. lithograph

Gene Miller & Ken Perlin, 1982

Numerical computing in movies: realistic lighting

numerical integration (quadrature)

Real environment,
computed objects

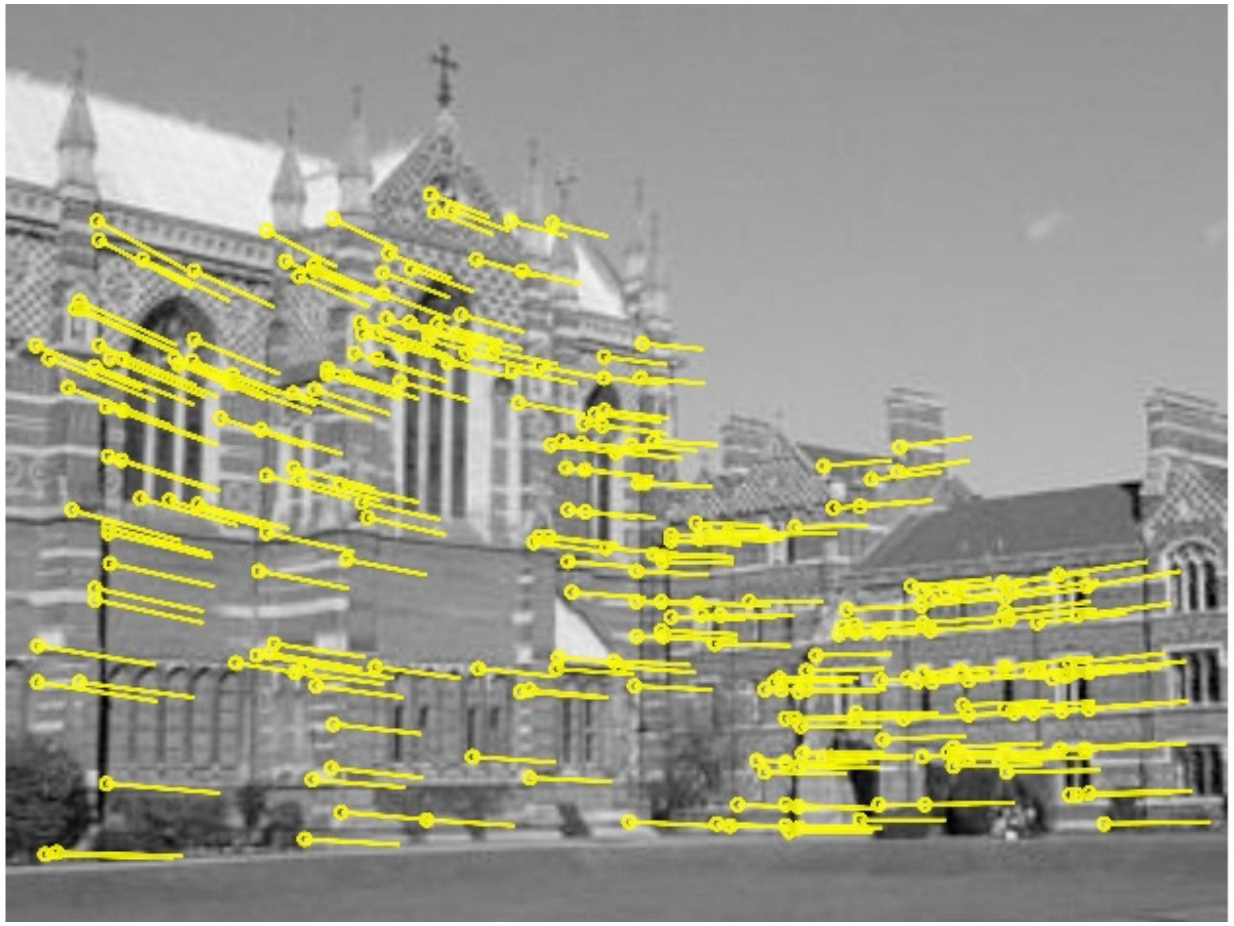
Jonas Unger

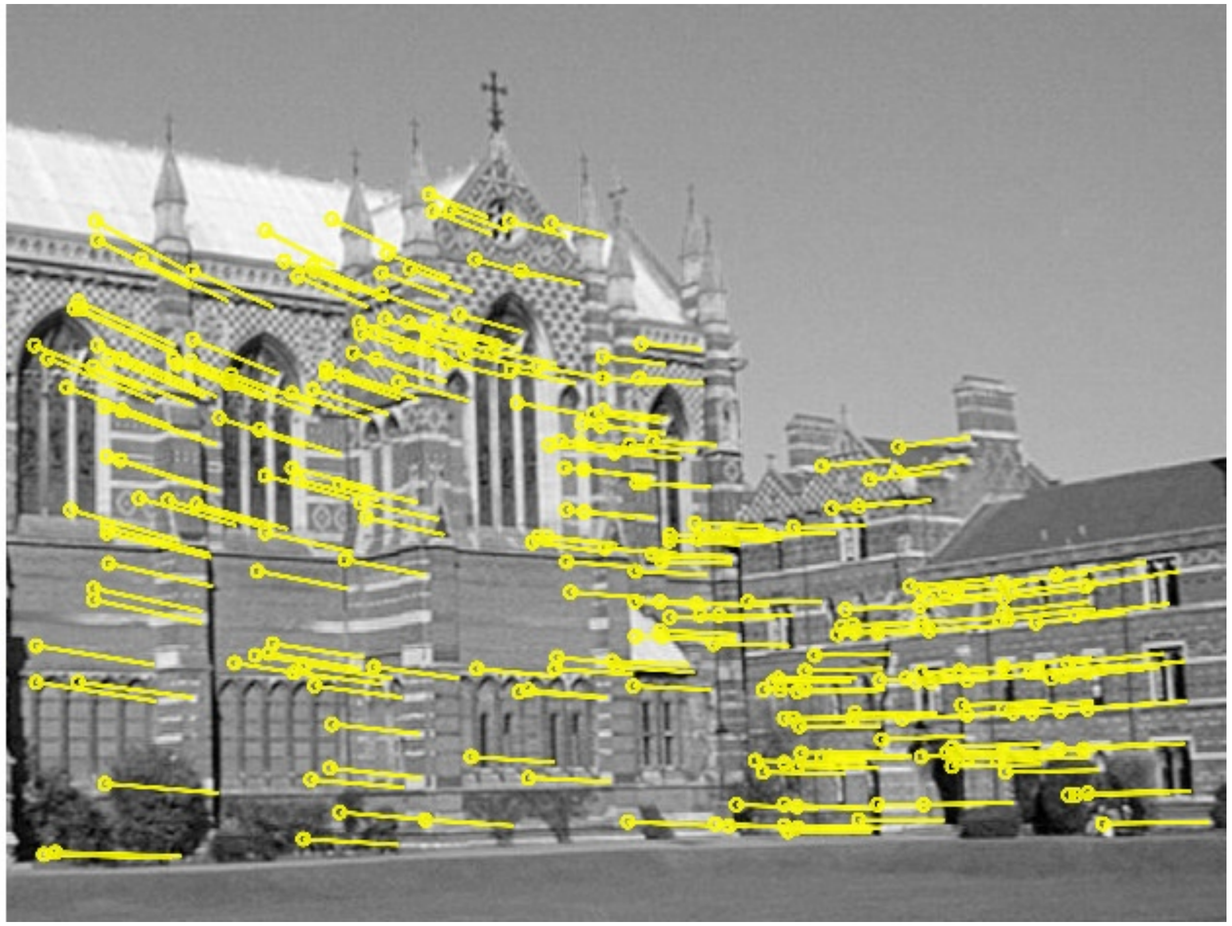

KING KONG
© 2005 Universal Studios. Used With Permission.

Numerical computing in movies: camera tracking

numerical differentiation

nonlinear optimization





Torr & Zisserman, in Vision Algorithms: Theory and Practice, 2000

Camera footage

Rendered model added

Scenespector Systems—VooCAT product demo
Zaha Hadid Architects—proposed Guggenheim Vilnius museum

Numerical computing in information retrieval: Google's PageRank

matrix eigenvalues

Idea 1: **importance = citation count** — simple integer exact answer

Idea 2: **importance = citation count weighted by importance** — now it is a self-referencing definition for a real-valued quantity (and it must be approximated numerically)

Computing PageRank works out to be a linear algebra problem: finding the largest eigenvalue of a matrix.

course themes

discrete — continuous

exact — approximate

accuracy, stability, and robustness

> "Never in the history of mankind has it been possible to produce so many wrong answers so quickly!"
> —Carl-Erik Fröberg

prerequisites

calculus, linear algebra

some programming experience

Matlab

CS1132: Transition to Matlab
A one-credit course for students who know another language (e.g. Java) and need to map the ideas over to Matlab.

Informational meetings:

today 3:35 Hollister 307
tomorrow 4:40 Hollister 3:14

course mechanics

http://www.cs.cornell.edu/Courses/cs3220