ACM/EE 116
Introduction and Course Admin

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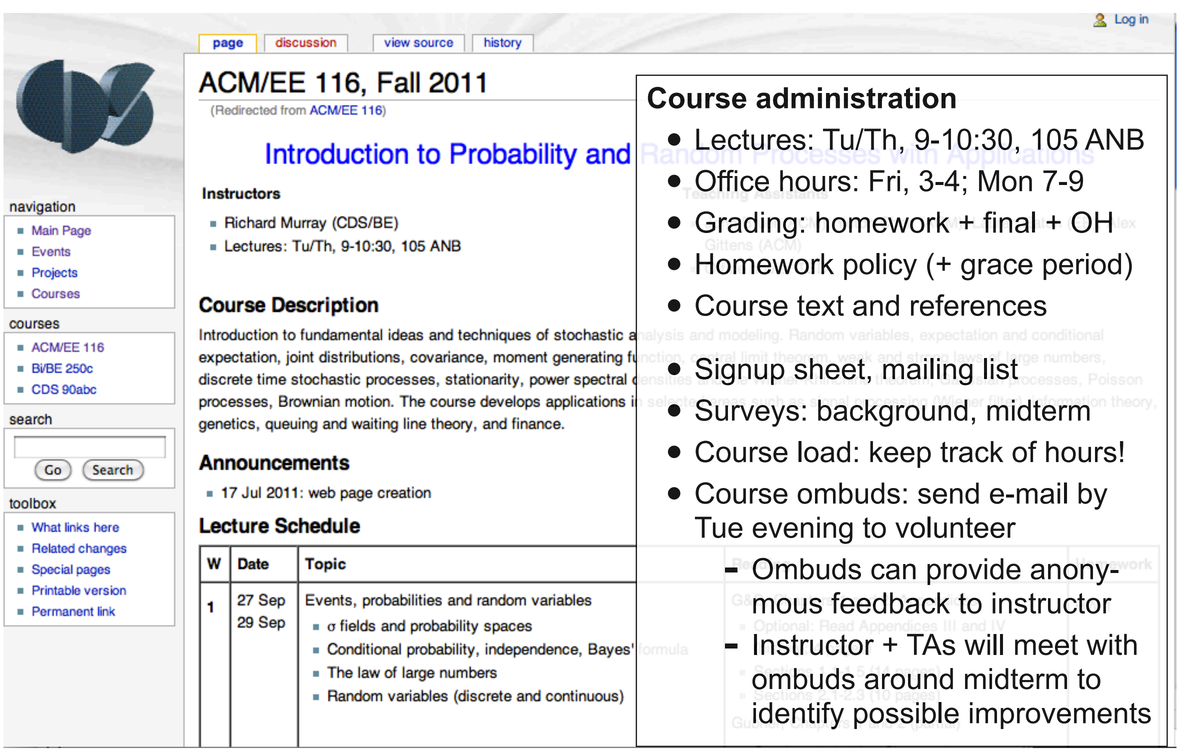
Goals

- Give an overview of ACM/EE 116: course structure & administration
- Describe some of the types of applications that we will be able to solve using the tools taught in this course

Reading (for the week)

- Grimmett and Stirzaker, Chapters 1 and 2 (24 pp; see web for sections)
- (optional) Grimmett and Stirzaker, Appendices III and IV (history; 4 pp)
- (optional) Gubner, Chapter 1 (applications)

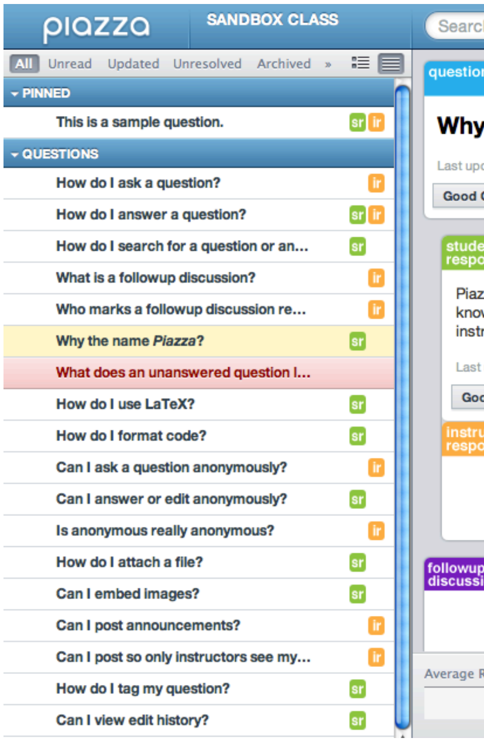
Course Overview



Course administration

- Lectures: Tu/Th, 9-10:30, 105 ANB
- Office hours: Fri, 3-4; Mon 7-9
- Grading: homework + final + OH
- Homework policy (+ grace period)
- Course text and references
- Signup sheet, mailing list
- Surveys: background, midterm
- Course load: keep track of hours!
- Course ombuds: send e-mail by Tue evening to volunteer
  - Ombuds can provide anonymous feedback to instructor
  - Instructor + TAs will meet with ombuds around midterm to identify possible improvements

Piazza



Q&A forum for students to ask (and answer) questions

- Students can post questions for others to see
  - Student posts can be named or anonymous
  - Can post about homework, lectures or anything else related to the course
- Students can respond to questions by other students, or post followup questions
- TAs and instructor can endorse a student response or provide an instructor response

Important notes

- Your questions and answers are stored on a non-Caltech machine => we have limited control
- Information posted *should* only be viewable by other students + instructors
- Use of Piazza is *optional*, but we would like to try it out and get feedback
  - If you use Piazza to post a question or followup, you don't have to sign it at OH

Honor System

What is it?

No member of the Caltech community shall take unfair advantage of any other member of the Caltech community

Why is it important?

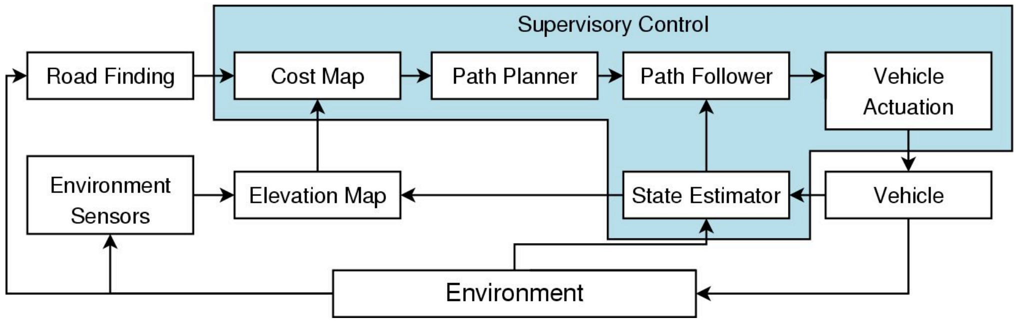
- Provides a framework for ethical conduct in an academic setting
- Supports a *community* of scholars, working together to learn and educate
- Allows greater academic freedom through mutual trust and respect

How does it apply to this class?

- Homework: full collaboration allowed, but write up your own results
  - Plan to re-use material, tuned to what we are trying to teach
  - Not allowed to use solutions sets from previous years, other sources
- Tests: take home, open book, limited time, non-proctored
- Violations: student centered – investigated by the BoC or GRB

Cremean et al, 2006
J. Field Robotics

Application: Autonomous Driving



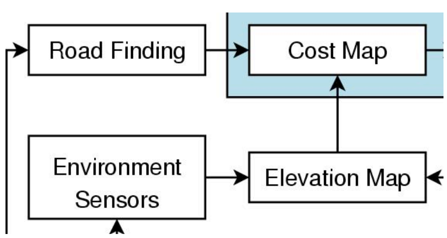
Computing

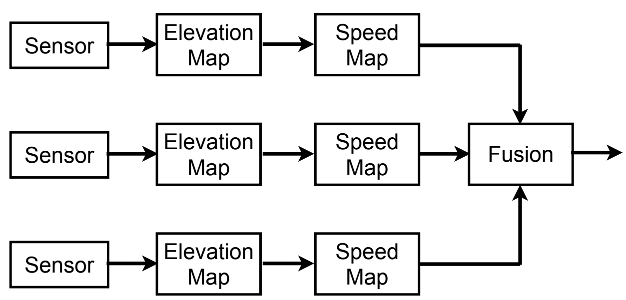
- 6 Dell 750 PowerEdge Servers (P4, 3GHz)
- 1 IBM Quad Core AMD64 (fast!)
- 1 Gb/s switched ethernet

Sensing

- 5 cameras: 2 stereo pairs, roadfinding
- 5 LADARs: long, med*2, short, bumper
- 2 GPS units + 1 IMU (LN 200)
- 0.5-1 Gb/s raw data rates

Terrain Estimation





Sensor processing

- Construct local elevation based on measurements and state estimate
- Compute speed based on gradients

Sensor fusion

- Combine individual speed maps
- Process “missing data” cells

Road finding

- Identify regions with road features
- Increase allowable speed along roads

LadarFeeder, StereoFeeder

- HW: LADAR (serial), stereo (firewire)
- In: Vehicle state
- Out: Speed map (deltas)
- Multiple computers to maintain speed

FusionMapper

- In: Sensor speed maps (deltas)
- Output: fused speed map
- Run on quadcore AMD64

Optimal Estimation (Kalman Filtering)

System description

$$x[k+1] = Ax[k] + Bu[k] + Fv[k]$$
$$y[k] = Cx[k] + w[k],$$

$$E\{v[k]\} = 0$$
$$E\{v[k]v[j]^T\} = \begin{cases} 0 & k \neq j \\ R_v & k = j \end{cases}$$

- Disturbances and noise are multi-variable Gaussians with covariance R_v, R_w

Problem statement: Find the estimate that minimizes the mean square error $E\{(x[k] - \hat{x}[k])(x[k] - \hat{x}[k])^T\}$

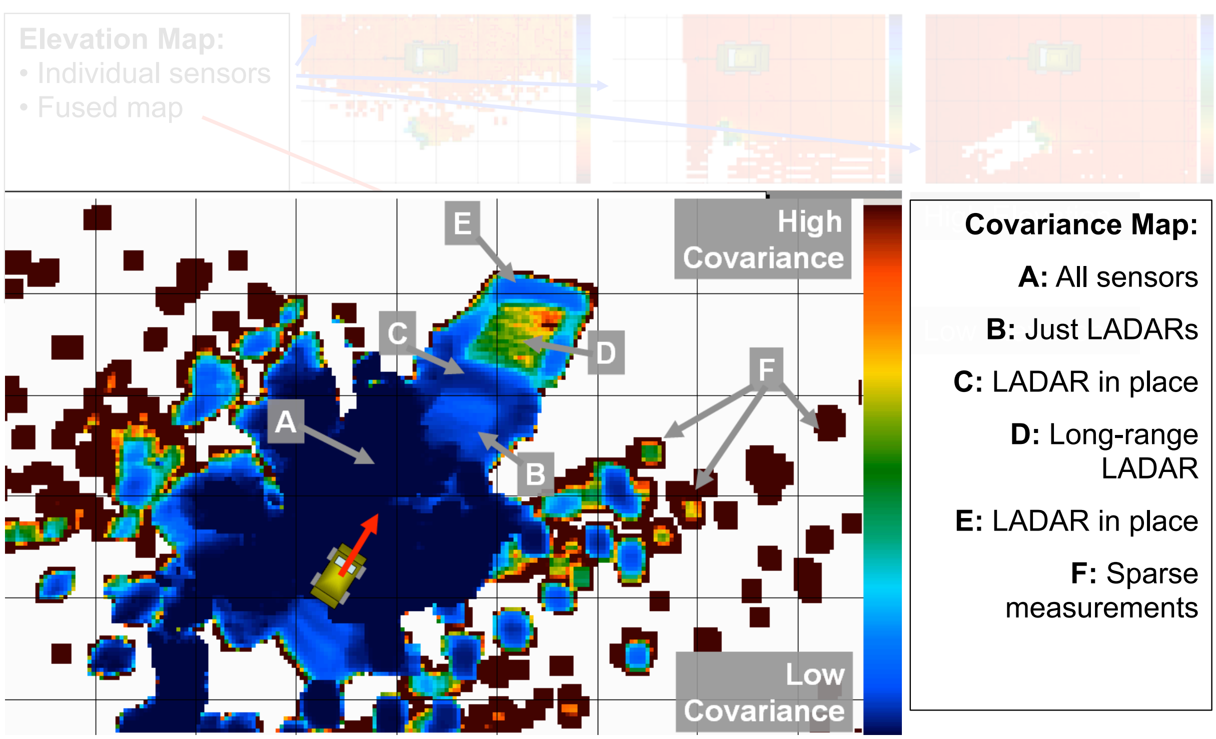
Proposition

- For Gaussian noise, optimal estimate is the expectation of the random process x given the *constraint* of the observed output:

$$\hat{x}[k] = E\{X[k] \mid Y[l], l \leq k\}$$

- Can think of this as a *least squares* problem: given all previous $y[k]$, find the estimate $\hat{x}[k]$ that satisfies the dynamics and minimizes the square error with the measured data.

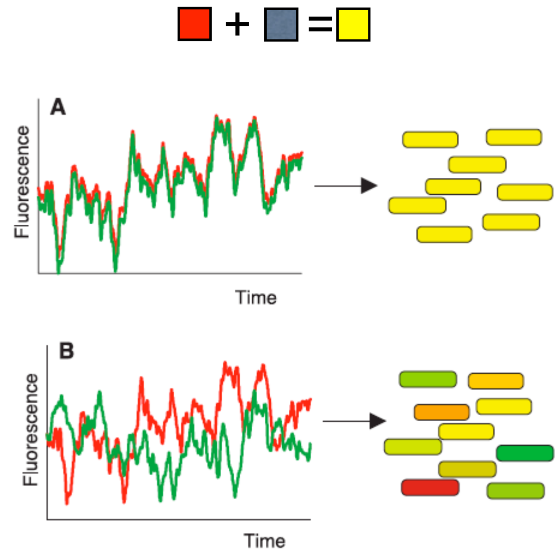
Example: Kalman Filtering for Terrain (Gillula)



Cell Noise (Elowitz et al, 2002)

Noise in cells

- Experiments by Elowitz, Levine, Siggia, Swain. *Science* 2002
- Put RFP and GFP under identical promoters; *should* get yellow
- Results: get range of colors



Extrinsic Noise:

- global to a single cell, but varies from one cell to the next (e.g. cell volume, plasmid copy number)

Intrinsic Noise:

- inherent stochasticity in gene expression (e.g. what order reactions occur in)

$$\dot{x}_i = E(t) \cdot f_i(x_i, I_i(t))$$

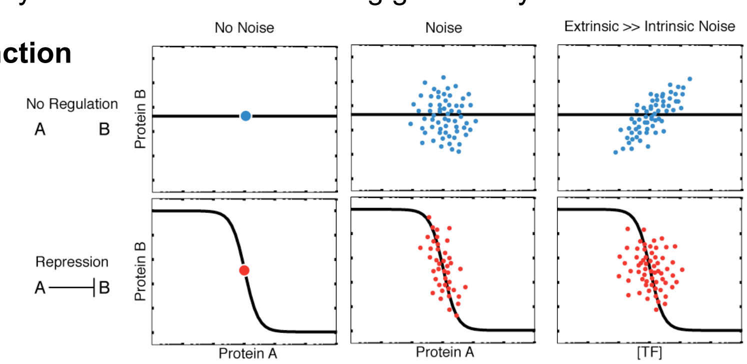
System Identification Using Cell Noise

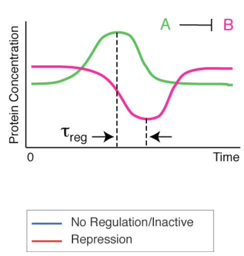
Traditional systems identification

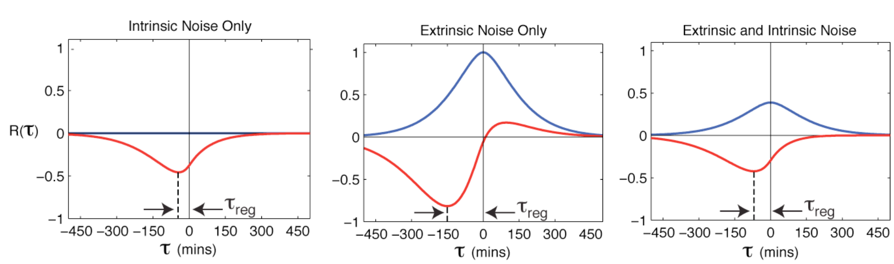
- Engineering: forced response. Difficult to do in in vivo (eg, sinusoids are tricky)
- Biology: gene knockouts; steady state measurements using gene arrays

Idea: use noise as a forcing function

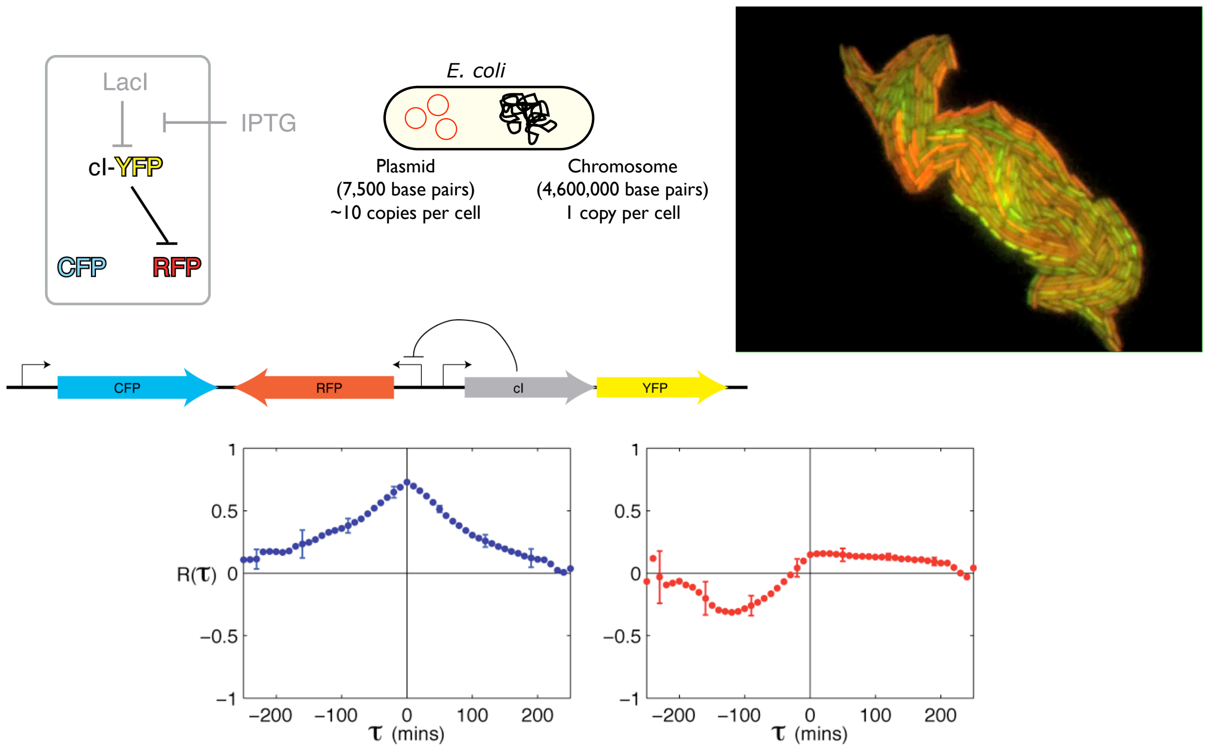
- Steady state distributions are not enough if extrinsic noise is present
- Need to use correlation data instead







System ID of a Synthetic Circuit (Dunlop, Elowitz & M)



Course Outline

Week	Topic	Reading	HW
1	Introduction; probability spaces	GS, Ch 1,2	1
2	Discrete random variables	GS, Ch 3	2
3	Continuous random variables	GS, Ch 4	3
4	Generating functions	GS, Ch 5	4
5	Convergence of sequences of random variables	GS, Chapter 7	5
6	Introduction to random processes	GS, Ch 8 + notes	6
7	Discrete time random processes	GS, Ch 9 + notes	7
8	Continuous time random processes	GS, Ch 9 + notes	8
9	Advanced topics: diffusion processes, Itō's formula	GS, Ch 13	9
10	Review for final		F

Goal: Balance between theory and applications

- Build on a rigorous mathematical basis (sigma fields)
- Develop useful techniques and show how these can be applied to real problems
- Challenge: broad set of backgrounds and interests => will try to use various feedback mechanisms to insure that we are covering the distribution well