sensing & sensors

CMU SCS RI 16722 S2009

MW(& some F) 12:00 -13:20 NSH1305

Mel Siegel <mws@cmu.edu>

+1 412 983 2626

office: NSH A421

office hours: MW 14:00-15:00

and very flexibly by appointment

the provost says I should tell you:

Classroom activities may be taped or recorded by a student if made immediately accessible to all students presently enrolled in the class, but may not be further copied, distributed, published or otherwise used for any other purpose without the express written consent of Mel Siegel.

today's agenda

- what we'll cover & how we'll approach it
  - first sensing, then sensors
- administrative stuff
  - the provost says I should tell you ...
  - calendar
    - final exam: only if needed to resolve ambiguity
- overall structure of the course
  - lectures: I talk, you question, we discuss
  - presentations: you talk, we question, we discuss

  - homework: reinforce & expand on class

why “sensing & sensors”?

- I teach you about *sensing*
  - fundamental measurement science
  - natural quantities and phenomena
    - what we want to measure
    - what we must understand to measure well
  - engineering for measuring successfully
- you teach each other about *sensors*
  - it changes too fast for me to keep up with 100%
  - hot topics change from year to year
  - some of you have more hands-on

in the first few weeks …

- I’ll teach you the fundamentals
  - I’ll assign some exercises
  - I’ll comment, coarsely grade, and return
    - I’m lousy at it ... better if we get a TA ...
- you’ll start work on your part of the job
  - identify area of current interest
  - learn sensing & sensor challenges
  - find who is doing most interesting research
  - critique state-of-the-art available sensors
  - present lecture – I’ll guide your preparation
  - you’ll assign & grade a related homework set

after the first few weeks …

I'll do "sensing" for about 40 minutes …

- review troublesome concepts
- touch highpoints of recent assignments
- introduce new material
- discuss issues that might make modeling and/or engineering real solutions hard

then for about 40 minutes …

- student will present "sensors" topic (~30 min)
  - I'll interrupt with impromptu treatments of topics

you introduce but don't seem to

how I'll order of your presentations

assign a rank:
- PhD students in Robotics = 1
- PhD students elsewhere = 2
- MS students & staff in Robotics = 3
- MS students elsewhere = 4
- Seniors = 5

sort by rank, then alphabetically

here is the tentative outcome:
- 16722-S2009-syllabus.xls
- you can agree among yourselves on swaps etc with my permission (usually it will be ok)

grading

- my goal is to give everyone an A
  - and feel good about it because it is deserved
  - I understand that people come from different
    - backgrounds
    - different levels of preparation
    - different interests
    - different needs for the content in thesis research etc
  - so give me your honest best & you will get an A

challenge

if you come to my office
- not understanding something
- and you still don't understand it when you leave

I'll give you $20 cash

final exam

scheduled for ???

I'll cancel it if you all are getting A-s already

if I feel there are differences that dictate differential grading I will give an exam:

- I will select slides from the student lectures
- and ask you to answer questions about ...
  - the underlying fundamental sensing principles
  - the nature and importance of the sensing applications

kinds of questions I & *you* will ask

level 0: why was this slide (or the last few slides) included? what is the new idea?

level 1: how and why does this new idea complement the topic we are studying?

level 2: can you integrate this new idea into the course as a whole, e.g., to solve problems you couldn't solve before?

level 3: can you integrate it into your life experience, e.g., to recognize, pose, and propose solutions to new problems?

warning: insufficient information!

I will rarely give you enough information for you to solve any problem completely

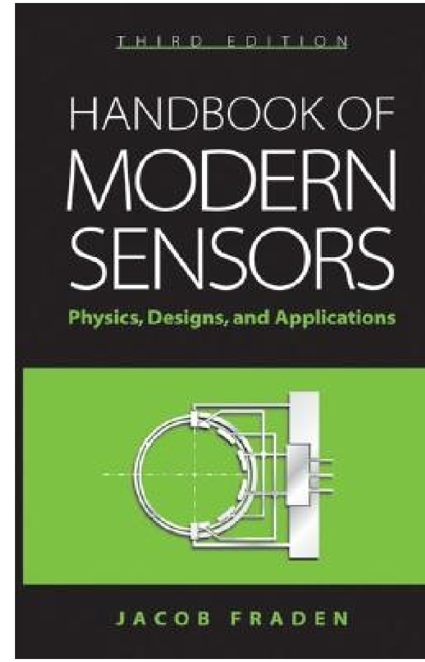
most of the additional information that you need is easy to find on the web

- *you **must** reference your sources carefully!*
- if you can't find what you need, then use your common sense and life-experience to make reasonable estimates (or guesses)
- describe what you did and why
- describe how a differing reality will affect

assignments

- will appear in green font among slides
  - location is a clue about topic and purpose
- some students don’t like them inserted
  - but I think it is important to integrate
    - exercises with the material it is intended to complement
  - and it automatically tells you when the
    - assignment is due:
      - **the Monday after I reach that slide in class**
- I hate grading ... if I let your homework
  - dribble in I will put off grading & returning

textbook



Jacob Fraden

Handbook of Modern Sensors:

Physics, Designs, and Applications

ISBN 0387007504, AIP Press 2004, 590 p.

expensive (~$75) but I think worth it

usefully updated several times since 1st edition

if you work in sensing and/or with sensors

get in the measurement spirit

review: units for not-so-dummies

one sure way to get conversions right:

- write relationships like 640 acre = 1 mi^2 in the form (640 acre)/(1 mi^2) = (1 mi^2)/(640 acre) = 1
- multiply whatever you have by the form of the number 1 that gives you the units you want

example: a candy bar has 10 gm.fat and 20 gm.carbs; how many food-calories is that?

- 1 gm.fat = 9 food.calories
- 1 gm.carbs = 4 food.calories
- 1 candy.bar = 10 gm.fat * (9 food.cal/gm.fat) +
  20 gm.carbs * (4 food.cal/gm.carbs)

our deal: do it my way or your way; if you do it my way

$$\frac{1\, mile^2}{640\, acre} = \frac{640\, acre}{1\, mile^2} = 1$$

$$1\ gm.fat = 9\ food.calorie$$

$$1\ gm.carbs = 4\ food.calorie$$

$$1\ candy.bar = 10\ gm.fat + 20\ gm.carbs$$

$$1\ candy.bar = (10\ gm.fat)\frac{(9\ food.calorie)}{(1\ gm.fat)} + (20\ gm.carbs)\frac{(4\ food.calorie)}{(1\ gm.carbs)}$$

$$1\ candy.bar = 90\ food.calorie + 80\ food.calorie$$

$$1\ candy.bar = 170\ food.calorie$$

for next Monday

1) Read "The Crash of Flight 143" by Peter Banks (several URLs; also "Gimli Glider"). Discuss it from the measurement expert's perspective.
2) Show that your body's power demand, about 2000 food.calorie/day, is about the same as a 100 watt light bulb's.
   [Hints: 1 food.calorie = 1 kilocalorie; the calorie is a unit of energy; power is energy per unit time; 1 watt = 1 joule/second.]
3) Compare your metabolism -- your power demand per kg of your body mass -- to the sun's.
   ref: http://scienceworld.wolfram.com/astronomy/Sun.html
   Surprised? After thinking about it, why is it so?

4) Compare the energy density in typical batteries to the above-referenced candy bar, and to a liquid fuel like gasoline.

[Hint: read the appendices in Fraden.]

Surprised?

What is the implication for mobile robots running on batteries?

advice: significant figures

most of the examples I use and the problems I assign are intended to give you an internalized feeling for the relative size of real-world things

if I ask you, for example, to show that your daily intake of ~2000 food-calories (kcal) means you are running at about the same power as a 100 watt light bulb …

it is inappropriate and misleading to show your calculation and state your result to 8 or 6 or even 4 decimal places! 1 or 2 is appropriate.

example:
an end-to-end sensing system

the camera

camera (Latin word for chamber or room)

- a light-tight box
- a light-sensitive sensor on one inside face
  - actually a two-dimensional array of sensors
- an image-former in the opposite face of the box
  - usually start with a “pinhole lens”
  - then work up to ideal lenses
  - then real lenses later

[note: video is just a sequence of “still” frames]

you need to know ...

luminance (or illumination) at the scene location

- is natural light enough, or must I add a “flash”?

some measure of the sensor’s “sensitivity”

distance from scene to camera?

distance from luminaire to scene?

how much light reaches the sensor?

- from the scene, of course
  - what about light “not from the scene”?
- “light collecting effectiveness” of the lens
- how long is it on (“shutter speed” or “flash time”)?

area of each pixel, or the pixel count, or what, exactly, do you need to know about the image sensor to predict the signal given the illumination?

never forget!

EVERY MEASUREMENT IS AN INTEGRAL

the source must have a finite (non-zero) area

its luminance (or illumination) must
encompass a finite spectral (color) range

the sensor must have a finite area

the source & the sensor must be coupled by
a
channel of finite (non-zero) capacity
e.g., the solid angle of the lens as seen
from
the source and the solid angle of the lens
as seen from the sensor