6.00 Introduction to Computer Science and Programming
Fall 2008

Reminders

Final exam

- I will send out a list of what I think we covered this term
- 2 hours (not 3)
- Comprehensive, but weighted towards end
- Reviews scheduled

Underground Guide

Today’s lecture

- What do computer scientists do?
  - What does this computer scientist do
- Overview of term

What Do
Computer Scientists Do?

What Do Computer Scientists Do?

They think computationally

Computational thinking will be a fundamental skill used by everyone in the world by the middle of the 21st Century.

Just like the three r's: reading, riting, and rithmetic.

Ubiquitous computing and computers will enable the spread of computational thinking.

Computational Thinking: the Process

Identify or invent useful abstractions

Formulate solution to a problem as a computational experiment

Design and construct a sufficiently efficient implementation of experiment

Validate experimental setup

Run experiment

Evaluate results of experiment

Repeat as needed

The Two A's of Computational Thinking[1]

Abstraction

- Choosing the right abstractions
- Operating in terms of multiple layers of abstraction simultaneously
- Defining the relationships the between layers

Automation

- Think in terms of mechanizing our abstractions
- Mechanization is possible
  - Because we have precise and exacting notations and models
  - There is some "machine" below (human or computer, virtual or physical)

[1]Ideas adapted from Jeannette Wing

Examples of Computational Thinking

How difficult is this problem and how best can I solve it?

Theoretical computer science gives precise meaning to these and related questions and their answers

Thinking recursively

Reformulating a seemingly difficult problem into one which we know how to solve.

Reduction, embedding, transformation, simulation

Examples of Computational Thinking

Choosing an appropriate representation or modeling the relevant aspects of a problem to make it tractable

Prevention, detection, and recovery from worst-case scenarios through redundancy, damage containment, and error correction

Using the difficulty of solving hard problems to foil would be evil doers

What One Group Does, My Research Group

Goals

- Help people live longer and better quality lives
  - In collaboration with clinicians
- Have fun pushing the frontiers of
  - Computer Science
  - Electrical Engineering
  - Medicine

Technical areas

- Machine learning, clustering, data mining
- Algorithm design
- Signal processing
- Software systems

Specific Research Activities

Extracting clinically useful information from electrical signals

- Heart, brain, and connected anatomy
- Signal processing, algorithms, clustering, machine learning, …

Predicting adverse cardiac events

- Zeeshan Syed, Phil Sung, Jenna Wiens, Eugene Shih
- Collin Stultz, Ben Scirica

Detecting and responding to epileptic seizures

- Ali Shoeb, Al Kharbouch, Naveen Verma
- Steve Schachter, Trudy Pang, Syd Cash

Technical Skills Utilized

Machine learning, clustering, data mining

- Exploiting patient specificity
- Deriving new medical knowledge from large data sets

Algorithm design

- Computing novel functions
- Making things fast enough to actually use

Signal processing

- Extracting physiological relevant features from noisy signals

Software systems

- Reliability and predictability matters a lot
  - We have used a closed loop neuro-stimulator on humans

Example 1. Treating Epilepsy

Prevalence of ~1%; all ages

All countries

Characterized by recurrent seizures

Generated by abnormal electrical activity in brain

Seizures occur unpredictably

Often lead to injury and prolonged impairment

Multiplicity of manifestations

Acquired

Head Injury

Intracranial Hemorrhage

Infection

Stroke

Inherited

Ion Channelopathy

Defective Neural Organization

Seizure Onset Seems Unpredictable

May result in injury

Fractures, intracranial hematomas, burns, etc.

May result in death

Mortality rate 2-3 times that of general population

Accidents, aspiration, drowning, etc.

SUDEP (annual risk estimated to be 1 per 100 for patients with symptomatic seizures)

Early Detection of Seizure Onset

Two onset times
- Electrographic
- Clinical

Detecting electrographic onset
- Use scalp EEG

Therapeutic value
- Provide warning
- Summon help
- Fast acting drugs
- Neural stimulation

Not Easy

EEG varies greatly across patients

- Epileptics have abnormal baselines
- Generic detectors have not worked particularly well

Pretty consistent patterns for an individual

Use patient-specific detectors

Use machine learning to build patient-specific seizure onset detector. Highly successful retrospective studies

Turn on neural stimulator at start of seizure. Study in progress at BIDMC

Example 2: Predicting Death

Joint work with Collin Stultz and Zeeshan Syed

Acute coronary syndrome (ACS) common: ~1.25M/year in U.S.

- 15% - 20% of these people will suffer cardiac-related death within 4 years

Stratifying risk key to choosing treatments

- Who gets a defibrillator?
- Who should be treated aggressively with statins

We think that we have a new and better way of doing this

- Morphological variability (MV)
- Tested on ~8000*2*24*60*70 heart beats

Identifying High Risk Cases Vitally Important

Useful to find patients who should be:

- Monitored more closely
- Treated more aggressively

E.g., implanted defibrillators

- Too many: Potentially risky, always expensive (~$50k)
  - 90% of recipients received < 0 medical benefit
- Too few: 100’s of deaths/day potentially avoidable

Approaches to Identifying High Risk Cases

Clinical characteristics

- E.g., gender or high blood pressure

Biomarkers

- E.g., cholesterol levels

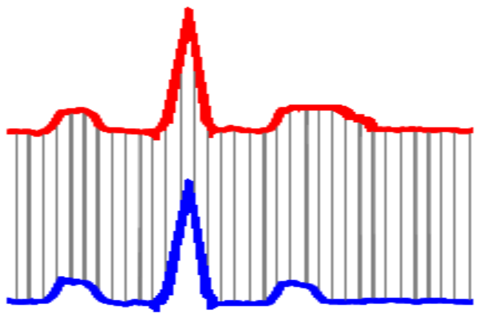
Echocardiography

- Ultrasound to measure, e.g., left ejection fraction

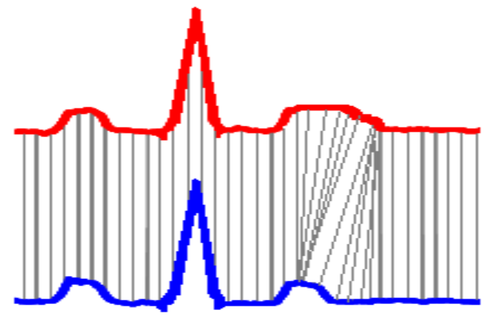
Electrocardiography (ECG)

- Established methods, e.g., HRV and DC
- New method: Morphologic Variability (MV)
  - Measures variability in shape of heart beats

Calculating Morphologic Distance



Euclidean Distance
Sequences are aligned "one to one".



"Warped" Time Axis
Nonlinear alignments are possible.

Use a variant of Dynamic Time-Warping (DTW)

Similar to Smith-Waterman algorithm to align amino acid sequences

Construct distance matrix

Find minimum cost path through it using dynamic programming

One Evaluation

764 patients admitted to hospital with non-ST-elevation ACS

- MI or unstable angina
- But less immediately dangerous than with ST-elevation

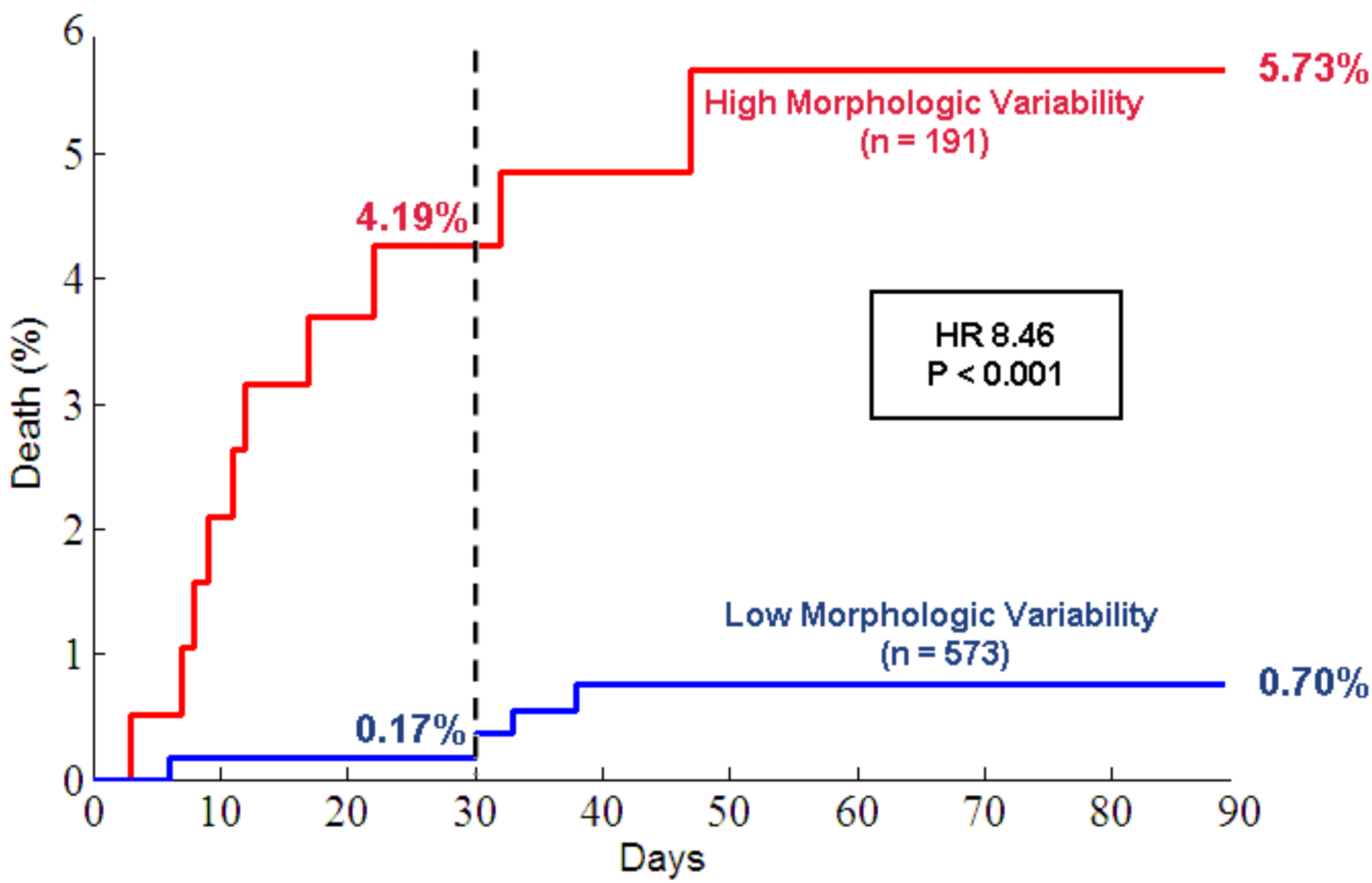
Holter ECG recorded at 128 Hz for 2-4 days within 48 hours of event

- ~160M heart beats

Examined only one channel

90 day follow-up for cardiovascular death

Mortality Curves Using Quartile



Wrapping Up the Term

Five Major Topics

- Learning a language for expressing computations – Python
- Learning about the process of writing and debugging a program
- Learning about the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem
- Learning a basic set of recipes – algorithms
- Learning how to use simulations to shed light on problems that don't easily succumb to closed form solutions

Why Python?

Relatively easy to learn and use

- Simple syntax
- Interpretive, which makes debugging easier
- Don’t have to worry about managing memory

Modern

- Supports currently stylish mode of programming, object-oriented

Increasingly popular

- Used in an increasing number of subjects at MIT and elsewhere
- Increasing use in industry
- Large and ever growing set of libraries

Writing, Testing, and Debugging Programs

Take it a step at time

Understand problem

Think about overall structure and algorithms independently of expression in programming language

Break into small parts

Identify useful abstractions (data and functional)

Code and unit test a part at a time

First functionality, then efficiency

Start with pseudo code

Be systematic

When debugging, think scientific method

Ask yourself why program did what it did, not why it didn't do what you wanted it to do.

From Problem Statement to Computation

Break the problem into a series of smaller problems

Try and relate problem to a problem you or somebody else have already solved

E.g., can it be viewed as a knapsack problem

Think about what kind of output you might like to see, e.g., what plots

Formulate as an optimization problem

Find the min (or max) values satisfying some set of constraints

Think about how to approximate solutions

Solve a simpler problem

Find a series of solutions that approaches (but may never reach) a perfect answer

Algorithms

Big O notation

- Orders of growth
  - Exponential, Polynomial, Linear, Log
- Amortized analysis

Kinds of Algorithms

- Exhaustive enumeration, Guess and check, Successive approximation, Greedy algorithms, Divide and conquer, Decision Trees, Dynamic programming

Specific algorithms

- E.g., Binary search, Merge sort

Optimization problems

- Knapsack problems

Simulation

An excuse (and framework) to learn a bit about probability and statistics

An excuse to build interesting programs

The power of random choice

- Much of the world is or appears to be stochastic
- Can be used to solve problems that are not inherently random

Assessing the quality of an answer

- Not always obvious

Building models of parts of the world

Pervasive Themes

Power of abstraction

Systematic problem solving

What Next

Many of you have worked very hard

Only you know your return on investment

- Take a look at early problem sets
- Think about what you'd be willing tackle now

Remember that you can write programs to get answers

There are other CS courses you could take

- 6.01, 6.034, 6.005, 6.006