Cool Applications: CS + Biology (and friends)

Dave Abel

April 20th, 2016
Schedule

- Wednesday (Today): Randomness, CS + Bio!
- Friday (4/22): What CS to take next? Graphics!
- Monday (4/25): Dave’s Research
- Wednesday (4/27): Last Day! Whole Term Recap + Final Review
- March 10th: Writing Assignment Due
- March 15th: Python Project Due
- March 19th: Final Exam, 2pm in LIST 120.
Yurt, Round Two

- If you want to go, email me with subject “Yurt”

- Specify which time you’d like to go:
  - **5 slots left:** Monday, May 9th from 2pm-3pm
  - **1 slots left:** Tuesday, May 10th from 11am-noon
Writing Assignment

- Writing Assignment Rubric Released
  - Find a few academic articles or papers that discuss how CS has affected a different topic of interest to you.
  - Write a short reflection paper summarizing and analyzing the topic, focusing on the technical explanation and on how computer science concepts are relevant to it.
  - Due May 10th.
  - 800-1200 words (~2 pages)
Python Project

- Python Project Rubric Released
  - Due May 15th.
  - Stencil Code Released.
  - More than happy to help in office hours, over email.
Other Notes

- No more labs! Don’t go to your lab tomorrow.
- No more regular homework (writing assignment is the last homework).
- Final Exam review session will be held closer to reading period.
- My office hours will be changing during reading period.
Randomness
Randomness

- Earlier notion of randomness from Theory!
- The higher the Kolmogorov complexity, the more random an object is.
Randomness

- But how about events? Really, we want this:

pick random 1 to 10
Randomness

- But how about events? Really, we want this:

pick random 1 to 10

- But suppose we didn’t have this block. How could we write a block to carry out random operations?

pick random 1 to 10
Randomness

- Everything has been so deterministic:
Randomness & Crypto

plaintext

encrypted text

decrypted text

Alice

Bob

Eve
Randomness & Crypto

Randy

Eve
Randomness & Crypto

“"I have figured out a way to simulate random coins!”

Randy

Eve
Randomness & Crypto

Randy

“I have figured out a way to simulate random coins!”

Eve

“No way…”
Eve gets to see Randy’s “random” guess, and the coin.
Randomness & Crypto

Eve

Randy

Gets to see, let's say, 1000 answers from both.
Q: Can Eve correctly guess which box is Randy?
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If Eve can be right more than 1/2 the time, Randy isn’t Random.
(Psuedo)-Randomness

- **Definition:** A process is *pseudorandom* if an adversary, Eve, cannot distinguish the process from a truly random process!
(Psuedo)-Randomness

- **Definition:** A process is *pseudorandom* if an adversary, Eve, cannot distinguish the process from a truly random process!

- **Q:** Can humans do this?
Psuedorandomness

- **Definition:** A process is *pseudorandom* if an adversary, Eve, cannot distinguish the process from a truly random process!

- Q: So how do we achieve this?

- A: One Way Functions!
OWFs as Pseudorandom Generators

- Intuition: If it’s easy for you to figure out why something happened, then it’s not really random.

- One Way Function: It’s hard to figure out the input, given the output.
Why Did I Cheat Before?

• An object that generates pseudorandom numbers is called a PseudoRandom Generator, or PRG
Why Did I Cheat Before?

- An object that generates pseudorandom numbers is called a PseudoRandom Generator, or PRG.

- PRGs require what is called a “seed”, which is effectively the input to the OWF.
Once we use this seed once, we can reset the seed by combining the output of our PRG with the old seed:
Why Did I Cheat Before?

- Once we use this seed once, we can reset the seed by combining the output of our PRG with the old seed:

\[
\text{Private Key} = \text{seed}
\]
OWFs as Pseudorandom Generators

- Intuition: If it’s easy for you to figure out why something happened, then it’s not really random.

- One Way Function: It’s hard to figure out the input, given the output.

- Conclusion: we can extend One Way Functions to create Pseudo Random Number Generators (and not cheat)!
Computation meets Biology

› Computation and:

1. Medicine
2. Genetics
3. Sustainability
4. Neuroscience
5. Evolution
Digital Physics

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**Panel 1:**

I'm stuck in this desert for eternity.

**Panel 2:**

I don't know why. I just woke up here one day.

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**Panel 3:**

I never feel hungry or thirsty.

**Panel 4:**

I just walk.

**Panel 5:**

Sand and rocks.

**Panel 6:**

Stretched to infinity.

As best as I can tell.
Computation as a Tool for Understanding Reality

- Newton: use math to model the laws of the world.
- Turing: “the extent and limitations of mechanistic explanations of nature”

1. Computation + Medicine
Medical Diagnosis

- INPUT: A patient’s symptoms
- OUTPUT: A medical diagnosis
Medical Diagnosis

+ a Database!

› INPUT: A patient’s symptoms

› OUTPUT: A medical diagnosis

= symptoms

= diagnosis
K Nearest Neighbor

- = class one
- = class two
- = class three

K = 3
K Nearest Neighbor

- Labels are now diagnoses
- Training Data are symptoms
- Medical Diagnosis as ML!
IBM’s Watson
Kidney Donors

• Suppose a friend needs a kidney, and you want to donate yours to help your friend.

• Kidneys have a “type”, similar to blood; your friend needs a kidney of the right type.

• So instead you donate your kidney to a donor community; you give a kidney of any type, and get a kidney back for you friend of the right type.
Kidney Donors

› But once people get their kidney, they’ll often back out of the donation!

› So instead, surgeons have started doing simultaneous kidney transplant surgeries, all at once, between circles of people.
Kidney Donors

‣ But once people get their kidney, they’ll often back out of the donation!

‣ So instead, surgeons have started doing simultaneous kidney transplant surgeries, all at once, between circles of people.
Remember Circles + Lines?
Circles + Lines!

Circle: an object (a location in this case)

Line: a relation between objects (tram, in this case)
Called a “Graph”

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Kidney Donors

- But once people get their kidney, they’ll often back out of the donation!

- So instead, surgeons have started doing simultaneous kidney transplant surgeries, all at once, between circles of people.
Find the Cycles!
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INPUT:

OUTPUT: A list of cycles

(with about x100000 more circles)
Find the Cycles!

INPUT:

OUTPUT: A list of cycles

(with about x100000 more circles)

Computational Solutions!
Medical Imaging
Medical Imaging

Understanding Brain Region Functionality

[Ng, Milazzo, Atmman, 2015]
2. Genome Sequencing

- DNA: molecule for carrying genetic information
- Four “bit” values: A, G, T, C
Genome Sequencing

› Goal: understand what is going on in the DNA.

› Application: Cancer Research.
Genome Sequencing

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- Application: Cancer Research.
Genome Sequencing

• The tool we have for reading DNA gives us snippets:

AGAGATTAGCTAGCAATCGCGGGATAGCGCTAGCTAGCACGAGGGAGTTCCTAGAC
Genome Sequencing

- The tool we have for reading DNA gives us snippets:
Genome Sequencing

- Problem: Recreate DNA from snippets

INPUT:
- 1
- 3
- 5
- 2
- 4
- 6

OUTPUT: AGAGATTAGCTAGCAATCGCGGGATAGCGCTAGCTAGCACGA
Genome Sequencing

- Problem: Recreate DNA from snippets

**INPUT:**

1 3 4 1 5 2 4 2

**OUTPUT:**

AGAGATTAGCTAGCAATCGCGGGATAGCGCTAGCTAGCACGA

**Computational Solutions!**
Computation & Genome Sequencing

- Used for better understanding cancer mutations, cancer growth, occurrences of cancer, treatment.

- Used for computational evolutionary biology; evaluate disorders, changes of a species over time.

- And more!
3. Computation and Environmental Science
RL + Sustainability

- Reinforcement Learning:
  - Learn through reward/punishment
  - Learn a model of the world
  - Maximize long term reward
Renewable Resource Allocation (RRA)

- Resource Allocation: How to distribute a resource to a variety of entities that need/want it?

- Renewable Resource Allocation: How should our strategy differ when the resource is renewable?

- We have 10 carrots planted.

- As of Friday, each carrot that is still planted will create two more carrots.

- 20 people each want a carrot, now.
RL + RRA
The Pacific Halibut

Idea: If RL can solve Mario and Go, it ought to be able to solve other problems in the real world of similar difficulty.
The Pacific Halibut

1. Learn a model of fish hatchery behavior

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The Pacific Halibut

1. Learn a model of fish hatchery behavior
2. Simulate into the future what happens when making certain policy decisions
3. Find the strategy that maximizes reward

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4. Computational Neuroscience
Vision
Diagnosing Alzheimers

[Rudzicz et. al 2015]
Brain Computer Interfaces
Brain Computer Interfaces

A Lower Limb Exoskeleton Control based on Steady State Visual Evoked Potential

No-Sang Kwak¹, Klaus-Robert Müller¹,² and Seong-Whan Lee¹

¹ Department of Brain and Cognitive Engineering, Korea University
² Machine Learning Group, TU Berlin
And Many More!

- Computational Evolutionary Biology
- Biological Computation (use DNA to compute!)
- Computational Pharmacology, Drug Discovery
- Computational Epidemiology
- … the list goes on!