UC Berkeley EECS
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Computational Structures in Data Science

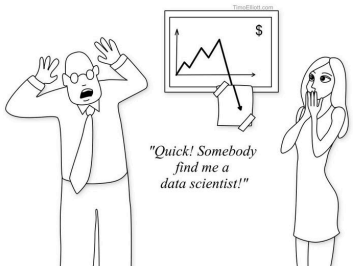
Lecture #15: Data Science & Information Summary

April 26, 2018 http://inst.eecs.berkeley.edu/~cs88

Administrivia

- This is the last lecture. Next week: Q&A for finals in the same room
- Please fill out survey from school of data science (see Piazza). Extra Credit of 90% fill out rate.
- Finals: See Piazza
- Thank you:
  - TAs!
  - Lab Assistants!
  - UC Berkeley Staff!

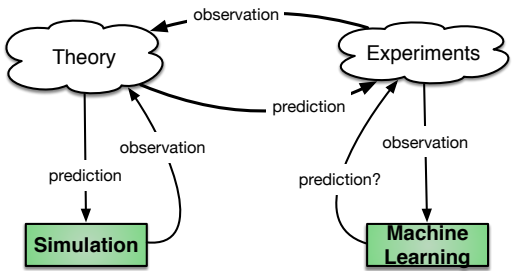
What is Data Science?



What is Data science?

https://www.youtube.com/watch?v=TzxmjbL-i4Y

What is Data SCIENCE?



Scientific Method + Automation

Data and Observations

- **Data = observations.**
- **Information = Reduction of uncertainty: H=-S**
- **Intuition: Information = certainty.**
- **Measurement Unit for Information: (binary) digits. 1 bit = {0,1} with p(0)=p(1)=0.5**

Examples:

- **How many digits of certainty can I achieve calculating Pi in a number of computation steps?**
- **Error: How many digits of a measurement are certain? How many uncertain?**
- **Description length: How many digits do I need to count all states of a system?**

Binary Digits (bits)

- **Common uses:**
  - **Expression of memory capacity: 1 byte = 8 bits.**
  - **Expression of transfer capacity: bits/s.**
- **Universal unit of adaption:**
  - **sqrt(G)/g (bits/generation) of adoption of a species due to sexual reproduction. G = Genome.**
- **Complexity:**
  - **Recorded binary decisions are bits. Future recorded binary decisions (computations) are bits.**
  - **The dimensionality of a binary number = bits.**

Bits are universal: Everything expressed as a number can be measured in bits because numbers can be measured in bits.

Complexity...

- **Which tree:**
  - **Is taller? Measure height in meters**
  - **Has more volume? Measure height and circumference in meters**
  - **Is more complex? Measures number of branches in bits**

Useful Knowledge

- Number of bits in a decimal number N: ceil($\log_2$ N)
- Python: `x.bit_length()`
- Number of files with n bits: 2^n.

- Entropy in Physics: Uncertainty S. Base e.
- Entropy in EE/CS: Information H. Base 2.
- So correction: H=-S/ln 2.

- Entropy H is the expected minimum description length in bits for a set of observations with certain occurrence probabilities.
- Both information and uncertainty are measured in bits.

Useful Knowledge II

- Compression, generalization, quantization: Reduction of bits.

- Compression: lossy and lossless.
  - Lossless compression is never universal. For example, gzip cannot compress all files.
  - Lossy compression: Cannot uncompress all files without losing bits.

- Quantization, generalization, machine learning: lossy compression.

Let's have some fun!

https://www.youtube.com/watch?v=Vo9Esp1yaC8

Galton Board

- 12 bits needed to encode path for 1 ball

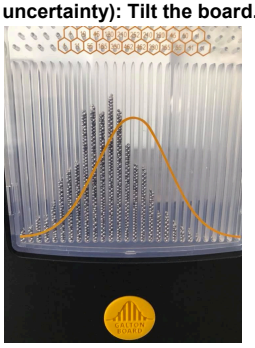
- Lossy compression to 5 bits (32 bins)

- Result: 7 bits of uncertainty left create a Gaussian

- Spread of distribution defined by uncertainty left:
  - 12 bits of bins would create a flat distribution
  - 0 bits (1 bin) would reduce the uncertainty to 0 at the cost of energy (balls slow down and queue up)

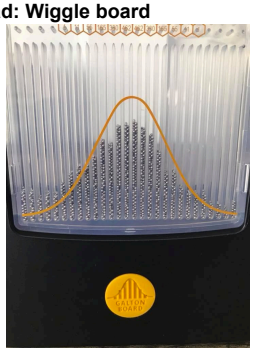
Galton Board: Variations

- Bias (lack of uncertainty): Tilt the board.



Galton Board: Variations

- Wider spread: Wiggle board



More on this

- Extra Lectures: https://www.youtube.com/playlist?list=PL17CtGMLr0Xz3vNK31TG7mJlzmF78vsFO
- Book in production: Computation, Data and Science (check back soon). http://compdatascience.org
- More on Galton Boards: http://galtonboard.com/video

The Future of Data Science

- Data science will become an engineering discipline
- Measurements instead of tuning
- Processes instead of guessing
- Integration with other sciences, just like any other engineering discipline
- Data Science will have more and more societal impact

"I was going to write an angry post about Facebook's emotional manipulation study, but then I got distracted by all the happy cat pictures they showed me."

Summary: CS88 a journey!

- Data type: values, literals, operations,
- Expressions, Call expression
- Variables
- Assignment Statement
- Sequences: tuple, list
- Dictionaries
- Data structures
- Tuple assignment
- Function Definition Statement
- Conditional Statement
- Iteration: list comp, for, while
- Lambda function expr.
- Higher Order Functions
  - as Values, Args, Results
- Higher order function patterns
  - Map, Filter, Reduce
  - Function factories
- Recursion
  - Linear, Tail, Tree
- Abstract Data Types
- Mutation
- Iterators and Generators
- Object Oriented Programming, Classes
- Exceptions
- Declarative Programming
- Distributed Computing

CS88: Final slide

Thank you so much!