introduction to informatics

This week
- Optional

Presentations
- Jen Belen
- Christopher Miles

Lecture Notes
- The Nature of Information

Available
- [http://oncourse.iu.edu](http://oncourse.iu.edu) and listed at [http://informatics.indiana.edu/rocha/i501](http://informatics.indiana.edu/rocha/i501)

Also check out
- Links and notes at [http://sciber.blogspot.com/](http://sciber.blogspot.com/)
By Erik Stolterman

- towards problem solving
- beyond computing
- into the natural and social
- synthesis of information technology

A possible parsing of informatics

Informatics

- X-Informatics or Computational X
- Informatics
- Computer Science
- Complex Systems
- Data & Search
- HCID
- Social Informatics
- Security
- Data Mining
- Geo-
- Music-
- Bio-
- Chem-

rocha@indiana.edu
http://informatics.indiana.edu/rocha/i501
How did we get here?
key contributions (most relevant to biocomplexity)

- “The chemical basis of morphogenesis”
  - Reaction-diffusion systems

- “Computing machinery and intelligence”
  - The “Turing Test”

- “On computable numbers with an application to the Entscheidungsproblem”
  - Turing machine, universal computation, decision problem

A fundamental principle of computation

- “On computable numbers with an application to the Entscheidungsproblem”
    - Turing machine, universal computation, decision problem
  - Machine’s state is controlled by a program, while data for program is on limitless external tape
    - every machine can be described as a number that can be stored on the tape for another machine
      - Including a Universal machine
  - distinction between numbers that mean things (data) and numbers that do things (program)

“The fundamental, indivisible unit of information is the bit. The fundamental, indivisible unit of digital computation is the transformation of a bit between its two possible forms of existence: as [memory] or as [code]. George Dyson, 2012.
At every discrete time instance the machine is in a single state.
At every discrete time instance the machine is in a single state.

Program is a state transition table:

<table>
<thead>
<tr>
<th>state</th>
<th>Read symbol</th>
<th>Next state</th>
<th>Write symbol</th>
<th>Tape move</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>left</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>0</td>
<td>1</td>
<td>right</td>
</tr>
</tbody>
</table>
pre-cybernetics developments

1942 meeting

“The Cerebral Inhibition Meeting”
- New York City, May 1942
  - Organized by Frank Freemont-Smith of the Josiah Macy Jr. Foundation

From the human sciences
- Lawrence Frank, Margaret Mead and Gregory Bateson

From the sciences
- Warren McCulloch and Arturo Rosenblueth

Result
- Huge excitement about Rosenblueth’s presentation of concepts from Norbert Wiener and Julien Bigelow
  - Homeostasis, purposeful action (goal-direction), aiming
  - A new paradigm of interdisciplinary research?
- Goal-directed actions
  - Controversial: explaining actions in terms of future events, violating cause and effect
  - Teleological mechanisms
**1942 meeting**

**“The Cerebral Inhibition Meeting”**

- New York City, May 1942
- Organized by Frank Freemont-Smith of the Josiah Macy Jr. Foundation
- From the human sciences:
  - Lawrence Frank, Margaret Mead and Gregory Bateson
- From the sciences:
  - Warren McCulloch and Arturo Rosenblueth
- Result:
  - Huge excitement about Rosenblueth’s presentation of concepts from Norbert Wiener and Julien Bigelow:
    - Homeostasis, purposeful action (goal-direction), aiming
  - A new paradigm of interdisciplinary research?

**Goal-directed actions**

- Controversial: explaining actions in terms of future events, violating cause and effect
- Teleological mechanisms
McCulloch & Pitts

Memory can be maintained in circular networks of binary switches

  - A Turing machine program could be implemented in a finite network of binary neuron/switches
    - Neurons as basic computing unit of the brain
    - Circularity is essential for memory (closed loops to sustain memory)
  - Brain (mental?) function as computing
- Others at Macy Meeting emphasized other aspects of brain activity
  - Chemical concentrations and field effects (not digital)
    - Ralph Gerard and Fredrik Bremmer
Cybernetics was born

post-war science: the Josiah Macy Jr. Foundation Meetings

- **The Feedback Mechanisms and Circular Causal Systems in Biology and the Social Sciences**
  - March 1946 (10 meetings between 1946 and 1953)

- **Interdisciplinary**
  - Since a large class of ordinary phenomena exhibit circular causality, and mathematics is accessible, let’s look at them with a war-time team culture

- **Participants**

- **Key concepts**
  - Homeostasis, Circular causality
    - requiring **negative feedback** (postulated to be very common)
    - Present state becomes input for action at next moment: **State-determined systems**
    - The mathematics were finally accessible
Cybernetics was born

post-war science: the Josiah Macy Jr. Foundation Meetings

- The Feedback Mechanisms and Circular Causality and how they apply between 1946
- Interdisciplinary
  - Since a large class of ordinary phenomena exhibit circular causality, and mathematics is accessible, let's look at war-time team culture
- Participants
- Key concepts
  - Homeostasis, Circular causality
  - requires negative feedback (postulated to be very common)
  - Present state becomes input for action at next moment: State-determined systems
  - The mathematics were finally accessible

Input + A → B → Output
post-war science

- **Synthetic approach**
  - Engineering-inspired
  - Supremacy of mechanism

- **Postwar culture of problem solving**
  - Interdisciplinary teams
  - Cross-disciplinary methodology

- **All can be axiomatized and computed**
  - Mculloch&Pitts’ work was major influence
    - A *Turing machine* (any function) could be implemented with a network of **simple binary switches** (if circularity/feedback is present)

Warren S. McCulloch
Margaret Mead
Claude Shannon

Macy Conferences: 1946-53
other key concepts

- Norbert Wiener and Arturo Rosenblueth
  - Goal-directed behavior and negative feedback (control)
  - Homeostasis and circular causality
    - In machines and biology
- Automata Theory (Von Neumann)
- Communication and Information
  - The fundamental idea is the message, even though the message may not be sent by man and the fundamental element of the message is the decision” (Norbert Wiener)
  - Shannon’s Information and Wiener’s Communication Theory
  - Natural semiotics (McCulloch and others later get into Peircean Semiotics)
- “functional equivalence” of systems (general systems)
  - Bio-inspired mathematics and engineering and computing/mechanism-inspired biology and social science
British Cybernetics

Turing as cybernetician

- The Ratio Club (starting in 1949)
  - British cybernetics meetings
    - William Ross Ashby, W. Grey Walter, Alan Turing, etc
  - "computation or the faculty of mind which calculates, plans and reasons"
  - Also following Wiener’s use of “Machina ratiocinatrix” in Cybernetics (1948), following Leibniz’ “calculus ratiocinator”
The Ratio Club (starting in 1949)

- British cybernetics meetings
- "computation or the faculty of mind which calculates, plans and reasons"
- Also following Wiener’s use of "Machina ratiocinatrix" in Cybernetics (1948), following Leibniz’ "calculus ratiocinator"

Notes: Back row (from the left): Harold Shipton, John Bates, William Hick, John Pringle, Donald Sholl, John Westcott, and Donald Mackay; middle row: Giles Brindley (guest), Turner McLardy, Ross Ashby, Thomas Gold, and Albert Uittery; front row: Alan Turing, Gurney Sutton (guest), William Rushton, George Dawson, and Horace Barlow

Source: Image courtesy of the Wellcome Library for the History and Understanding of Medicine, London
Shannon’s mouse

controlling information to achieve life-like behavior

- **trial and error algorithm**
  - information as reduction of uncertainty in the presence of alternatives (combinatorics)

- **lifelike behavior**
  - trial and error to **learn** path from many alternatives
  - adapts to new situations

- **how is learning achieved?**
  - Correct choices, **information** gained from reduced uncertainty, must be **stored in memory**

- **memory of information** as a design principle of intelligence in uncertain environments
  - 75 bit memory
  - stored in (telephone) switching relays
    - Brain as (switching) machine

![Shannon's mouse](image)
Herbert Simon: Law discovery means only finding pattern in the data; whether the pattern will continue to hold for new data that are observed subsequently will be decided in the course of testing the law, not discovering it. The discovery process runs from particular facts to general laws that are somehow induced from them; the process of testing discoveries runs from the laws to predictions of particular facts from them [...] To explain why the patterns we extract from observations frequently lead to correct predictions (when they do) requires us to face again the problem of induction, and perhaps to make some hypothesis about the uniformity of nature. But that hypothesis is neither required for, nor relevant to, the theory of discovery processes. [...] By separating the question of pattern detection from the question of prediction, we can construct a true normative theory of discovery— a logic of discovery.
Participation: 15%.
- class discussion, especially about readings
- engagement in class

Paper presentation and handout: 15%
- Choose from reading list (course sites and OnCourse)
  - Due September 4, 2014
  - Exception: Weaver and Simon papers (September 2nd presentation), need 2 volunteers by August 28th
- Covering key paper points, handling discussion
- Think-Pair-Share

Black Box assignments: 35%
- 2 assignments during the semester.
  - 15%, Assignment I: Due October 15
  - 20%, Assignment II: Due November 19

GRFP Research proposal: 35%
- Elevator pitch and proposal
  - due December 11, 2014
- **Week 2**

- **Week 4**
  - **Presentations**
      - Eunjeong Cheon
      - Hannah Rawcliffe
  - **Lecture**
  - **Optional**
  - **Lecture Notes**
    - The Nature of Information