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Information Systems Theory

Ahmed Eleish

January 29th, 2025

ITWS, ERTH, CSCI 4400/6400

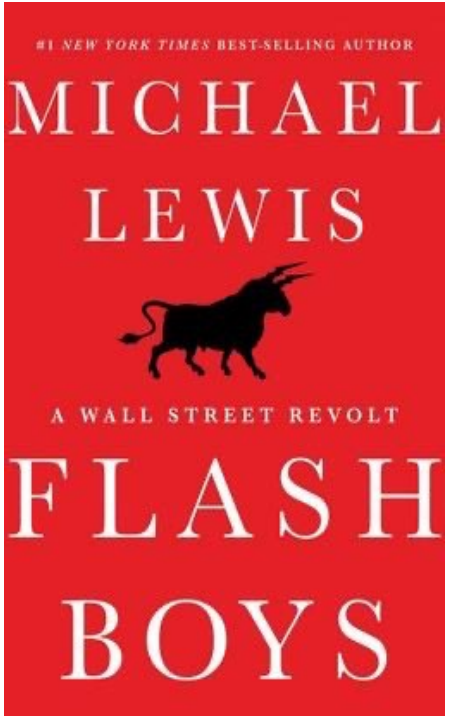
Tetherless World Constellation
Rensselaer Polytechnic Institute

Contents

- Current Events – Xinformatics
- Systems
- Claude Shannon – A little history of Information theory
- Information theory
- In class exercise connecting Your Use Case and Uncertainty of Information (Your Assignment 1)
- Next class and assignments

Xinformatics Current Events: Flash Boys: https://en.wikipedia.org/wiki/Flash_Boys

Flash Boys starts out describing the construction of Spread Networks' secretive new 827-mile cable running as straight as possible, through mountains and under rivers, from Chicago to New Jersey that would reduce the journey time for data from 17 to 13 milliseconds.[7][8] This $300 million project was designed to connect the financial markets of Chicago and New York City.



What is information theory?

- https://www.khanacademy.org/computing/computer-science/informationtheory/info-theory/v/intro-information-theory

Origins of written language

- **https://www.khanacademy.org/computing/computer-science/informationtheory/info-theory/v/language-of-coins-2-8-proto-writing**

Systems

Systems

- **A system has a purpose** - such as to distribute water to plant life, bouncing a communications signal around the country to consumers, or producing information for people to use in conducting business.
- **A system is a grouping of two or more components** which are held together through some common and cohesive bond. The bond may be water as in the irrigation system, a microwave signal as used in communications, or, as we will see, data in an information system.
- **A system operates routinely** and, as such, it is predictable in terms of how it works and what it will produce.

Reference/Resource: https://ezinearticles.com/?Information-Systems-Theory-101&id=2756189

Information = Data + Processing

- Information is not synonymous with data.
- **Data is the raw material needed to produce information**.
- Data by itself is meaningless.
- Data is simply a single element used to identify, describe or quantify an object used in a business, such as a product, an order, an employee, a purchase, a shipment, etc.

Reference/Resource: https://ezinearticles.com/?Information-Systems-Theory-101&id=2756189

- A **data element can also be generated based on a formula** as used in a calculation; for example:

Net-Pay = Gross-Pay - Insurance fees - City-Tax - Union-Dues - …(etc.)

- Only when data is presented in a specific arrangement for use by the human beings, it become information.

Reference/Resource: https://ezinearticles.com/?Information-Systems-Theory-101&id=2756189

- **If the human being cannot act on data or make a decision using data, then it is nothing more than raw data.**
- This implies data is stored, and information is produced.
- It is also dependent on the wants and needs of the human being (the consumer of information).
- Information, therefore, can be defined as ***"the intelligence or insight gained from the processing and/or analysis of data."***

Reference/Resource: https://eziniearticles.com/?Information-Systems-Theory-101&id=2756189

Processing…

- "**processing**" specifies how data is to be collected, as well as its retrieval in order to produce information.
- This is ultimately driven by when the human being needs to make certain actions and decisions.

Reference/Resource: https://ezinearticles.com/?Information-Systems-Theory-101&id=2756189

- Information is not always needed "upon request" (aka "on demand"); sometimes it is needed once daily, weekly, monthly, quarterly, annually, etc.
- To illustrate, **assume we collect data once a week. No matter how many times during the week we make a query of the database, the data will only be valid as of the last weekly update**.
- In other words, we will see the same results every day for one week. However, if we were to collect the data more frequently, such as periodically throughout the day, our query will produce different results throughout the week.

Reference/Resource: https://ezinearticles.com/?Information-Systems-Theory-101&id=2756189

I = D + P

- Our formula of "I = D + P" makes an important point:
- If the data is changed, yet the processing remains the same, the information will change.
- Conversely, if the data remains the same, yet the processing changes, the information will also change.

Information **=** **D**ata **+** **P**rocessing

Reference/Resource: https://eziniearticles.com/?Information-Systems-Theory-101&id=2756189

Systems are logical in nature…

- **Systems are logical in nature and can be implemented many different ways**.

- **An information system is a collection of processes** (aka, "sub-systems") to either collect and store data, to retrieve data and produce information, or a combination of both.

Reference/Resource: https://ezinearticles.com/?Information-Systems-Theory-101&id=2756189

Sub-systems: WHAT,WHEN,HOW

- The sub-systems of the system simply define logically WHAT data must be processed, WHEN it must be processed, and who will consume the information (aka "end-users"), but it most definitely does not specify HOW the sub-system is to be implemented.

Reference/Resource: https://ezinearticles.com/?Information-Systems-Theory-101&id=2756189

practicality and cost effectiveness…

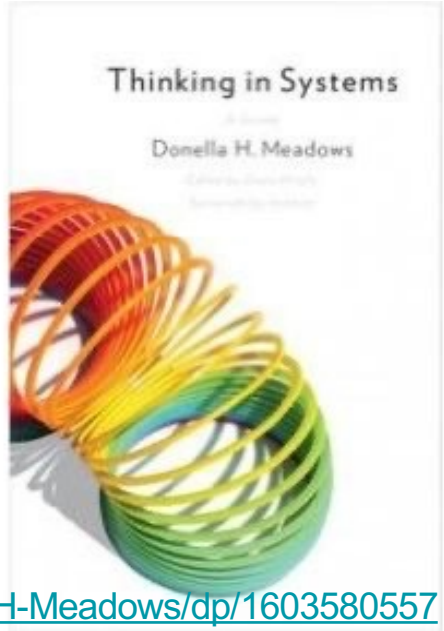
- Developers must determine a suitable approach for implementing each sub-system.
- **This implementation decision should ultimately be based on practicality and cost effectiveness**.

Defining the "workflow"

- Depending on the complexity of the sub-system, several procedures may be involved.
- By defining the procedures in this manner, from start to end, the developers are defining the "workflow" of the sub- system.
- These workflows specifies HOW the data will be physically processed (including how it is to be created, updated, or referenced).

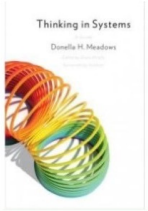
Thinking in systems

- Consists of primarily three things (Meadows)
  - Elements
  - Interconnections
  - Function/ Purpose



Book is available on Amazon:
https://www.amazon.com/Thinking-Systems-Donella-H-Meadows/dp/1603580557

System:



–**A system has a purpose** - such as to distribute water to plant life, bouncing a communications signal around the country to consumers, or producing information for people to use in conducting business on in an organization.

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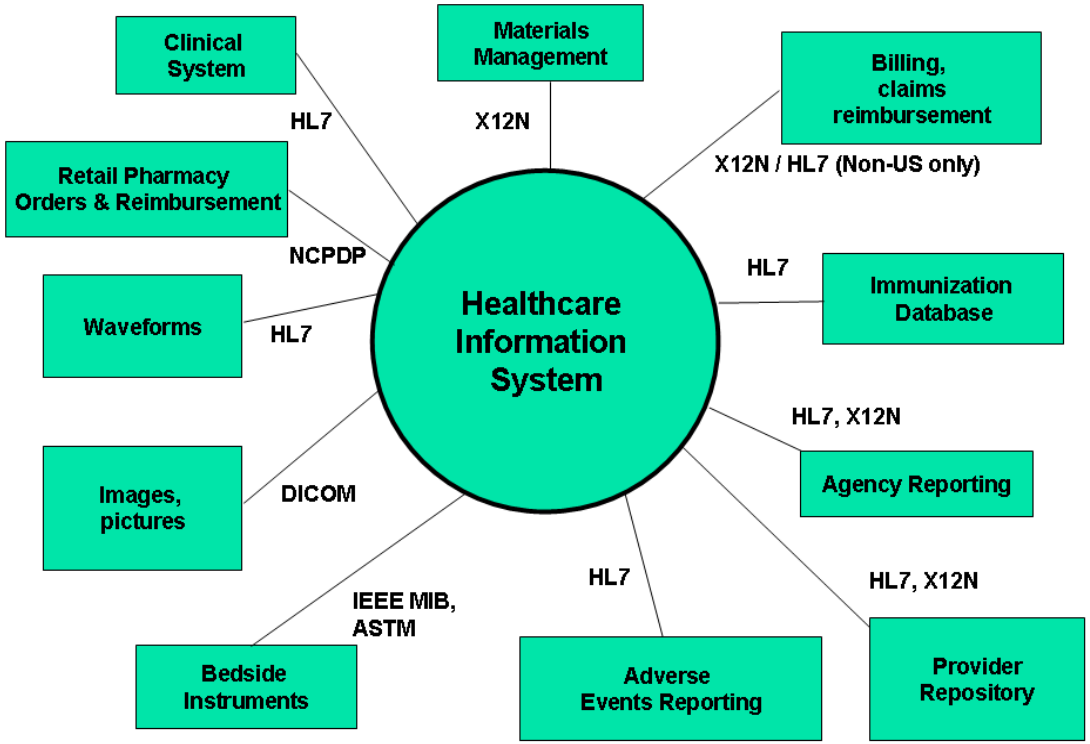
Example


Clinical System
HL7
Materials Management
X12N
Billing, claims reimbursement
X12N / HL7 (Non-US only)
Retail Pharmacy Orders & Reimbursement
NCPDP
Waveforms
HL7
Healthcare Information System
HL7
Immunization Database
HL7, X12N
Agency Reporting
Images, pictures
DICOM
IEEE MIB, ASTM
Bedside Instruments
HL7
Adverse Events Reporting
HL7, X12N
Provider Repository

EOSDIS Science System

NASA's Earth Observing System Data and Information System (EOSDIS)

Learn more about the EOSDIS Science System and details of the EOSDIS Science System's internal and external interfaces.

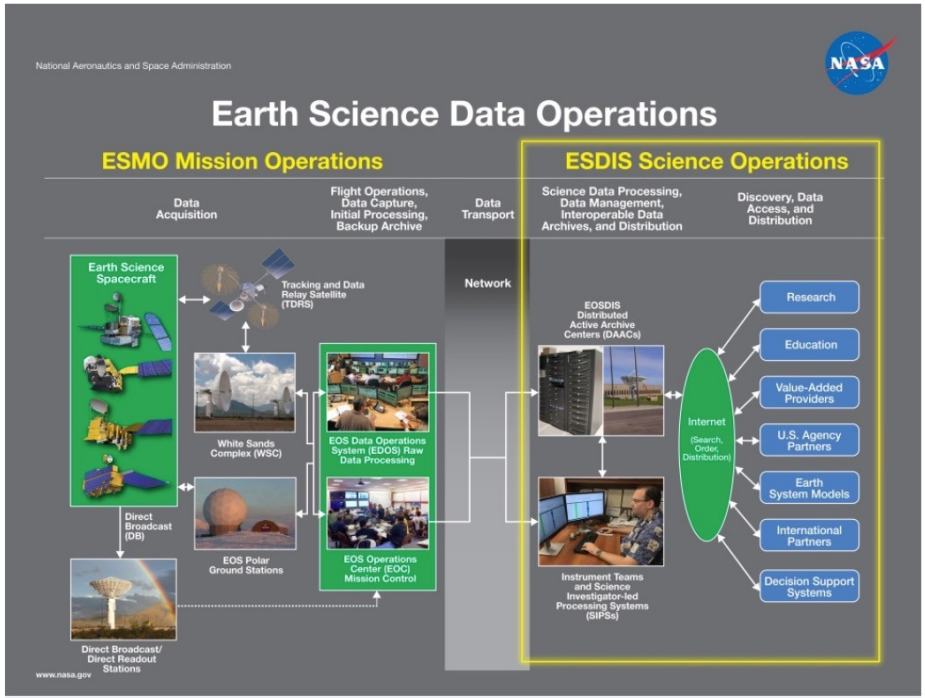


Diagram of Earth Science Data Operations

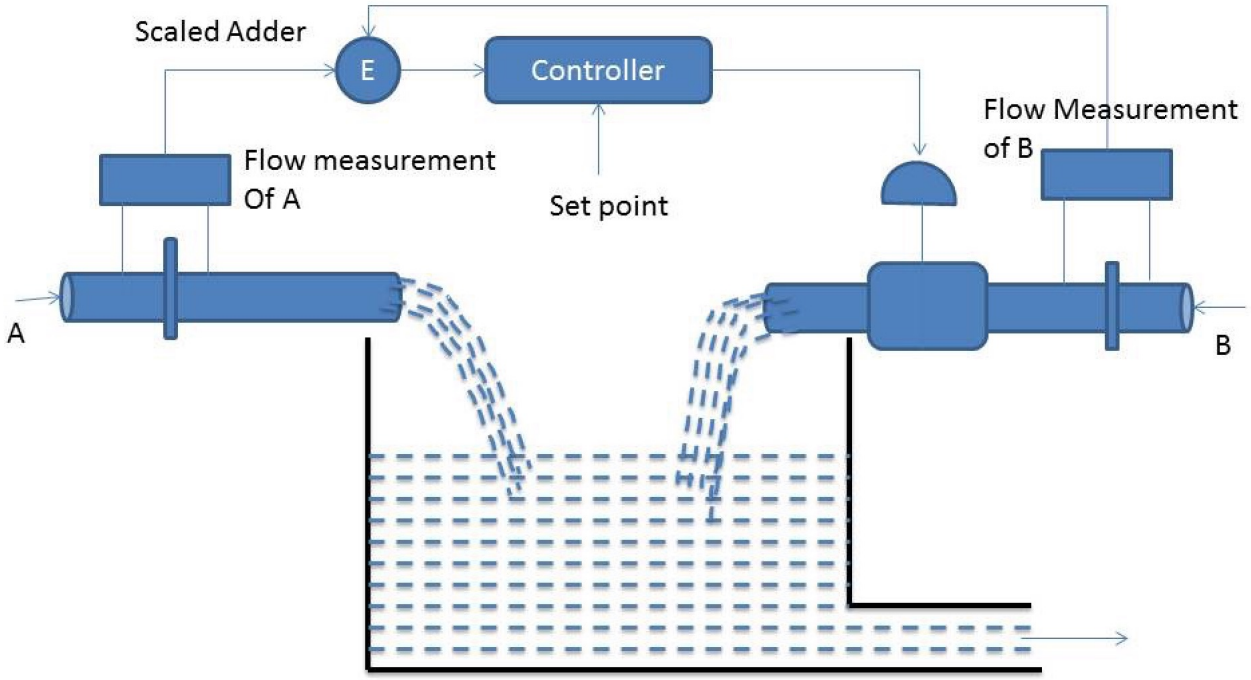
Reference/Image Credit: https://www.earthdata.nasa.gov/eosdis

Twelve Leverage Points

12. Constants, parameters, numbers (such as subsidies, taxes, standards)
11. The size of buffers and other stabilizing stocks, relative to their flows
10. Structure of material stocks and flows (such as transport network, population age structures)
9. Length of delays, relative to the rate of system changes
8. Strength of negative feedback loops, relative to the effect they are trying to correct against
7. Gain around driving positive feedback loops
6. Structure of information flow (who does and does not have access to what kinds of information)
5. Rules of the system (such as incentives, punishment, constraints)
4. Power to add, change, evolve, or self-organize system structure
3. Goal of the system
2. Mindset or paradigm that the system — its goals, structure, rules, delays, parameters — arises from
1. Power to transcend paradigms

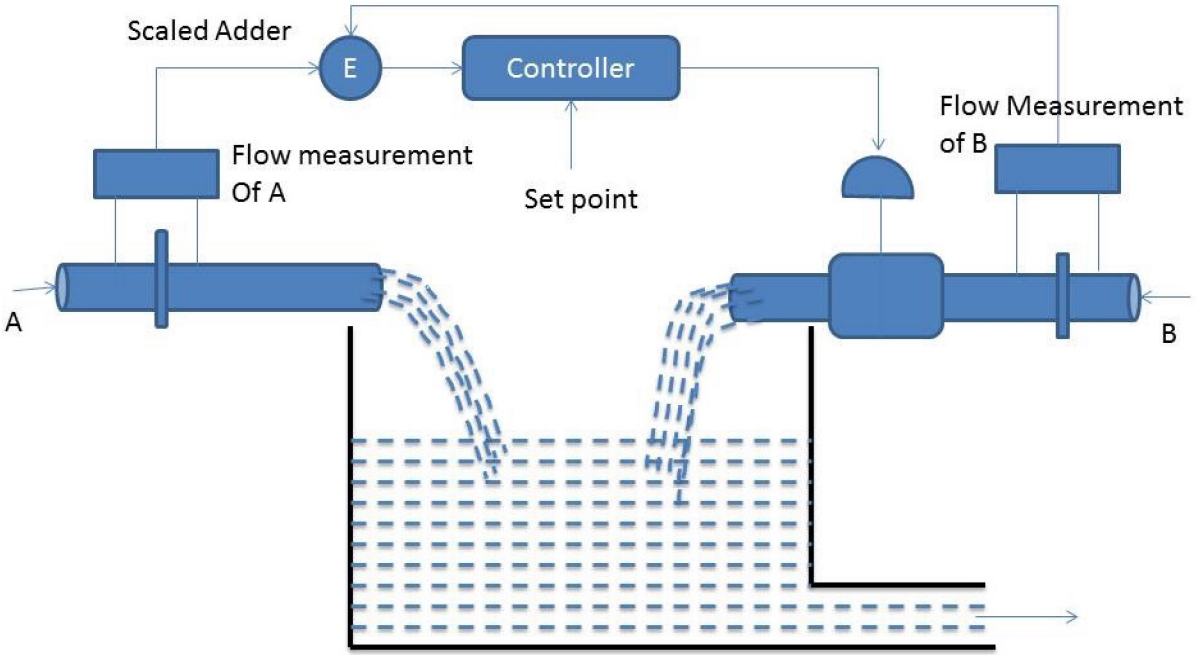
Before next week's lecture:
Read: http://en.wikipedia.org/wiki/Twelve_leverage_points

Example of Ratio Control System



Twelve Leverage Points Here?

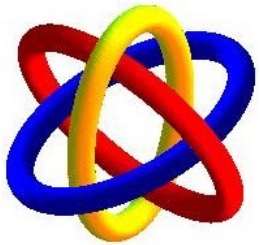
Example of Ratio Control System



Information Systems

First information system?

- *The first on-line, real-time, interactive, data base system was double-entry bookkeeping which was developed by the merchants of Venice starting in ~ 1200 A.D. Paciolo 1494*

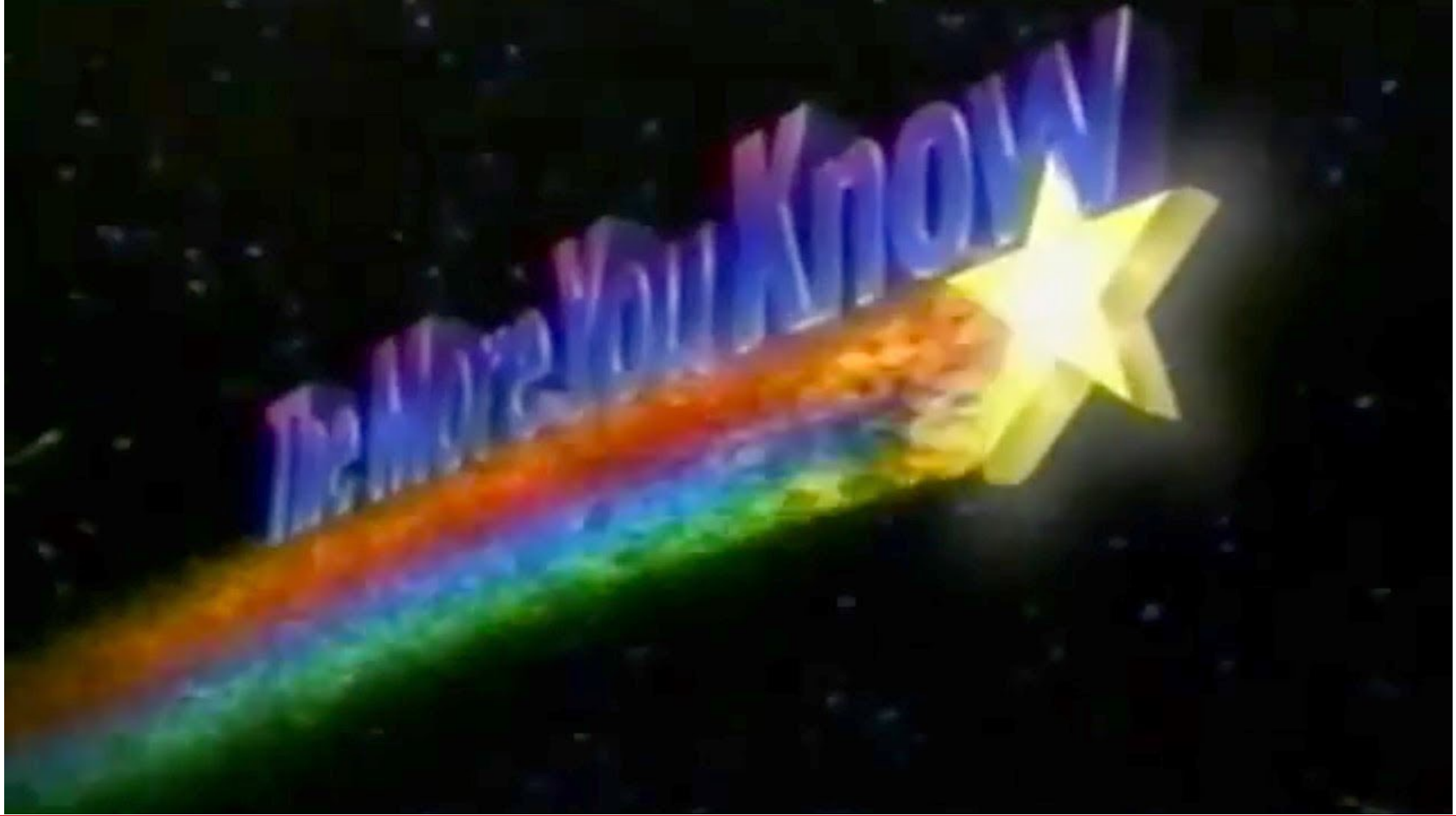


28

Luca Pacioli is the one on the left. (Nobody knows who the guy on the right is.)

Museo di Capodimonte

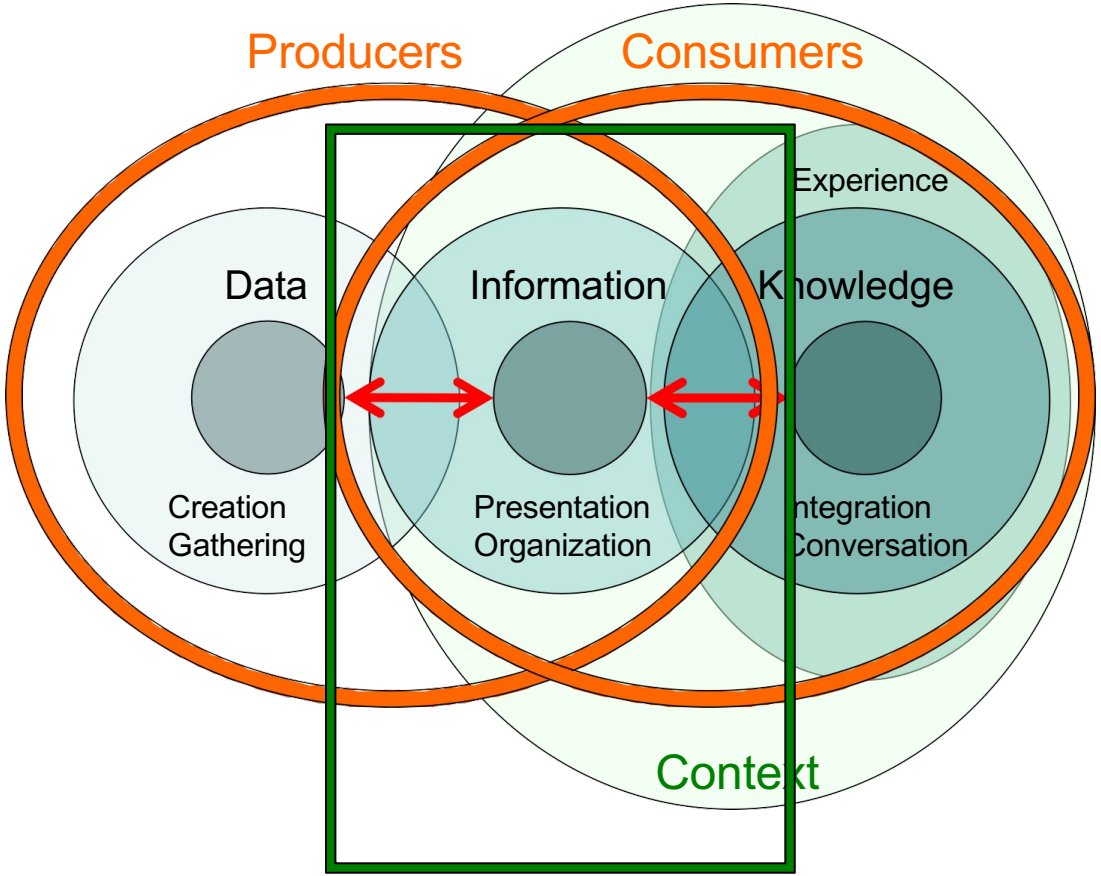
Resource/Reference/Image Credit:
https://www.npr.org/sections/money/2012/10/04/162296423/the-accountant-who-changed-the-world


The More You Know

Details on first info sys.

- “Every transaction gets entered twice in financial records. If one day you sold three gold coins' worth of pepper, you would write that the amount of cash you had went up by three gold coins. You would also write in that the amount of pepper you had went down by three gold coins' worth.
- Before double-entry, people just kept diaries and counted their money at the end of the day. This innovation allowed merchants to see every aspect of their business in neat little rows. “ (NPR)

Data-Information-Knowledge *Ecosystem*



Presentation

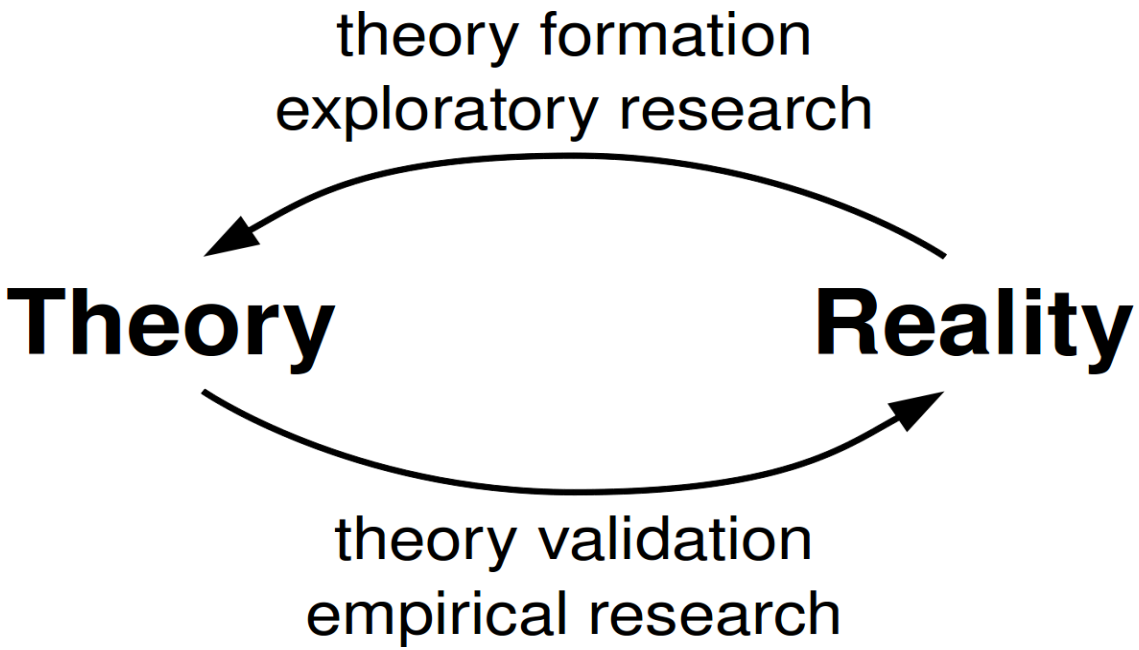
- Separation of content from presentation!!
  - The double-entry example (debit/ credit -/+)

- Is developed based on a solid understanding of minimizing information uncertainty
  - Start with content
  - Look at any context and structural considerations
  - Account for cognitive and social factors to reduce uncertainty (e.g. for humans: color, …)

Organization

- Organization of information presentation, e.g. layout on a web page, in a table, or figure, or report
  - Of the double-entry bookkeeping…
- Also (again) content, context and structure
- Think about how you organize your
  - Class notes
  - Calendar and assignment schedule
  - Your social life
  - Assignments
  - Do, or do not, connect with others' ways of organizing
- A system??
  - Elements, Interconnections, Function/ Purpose

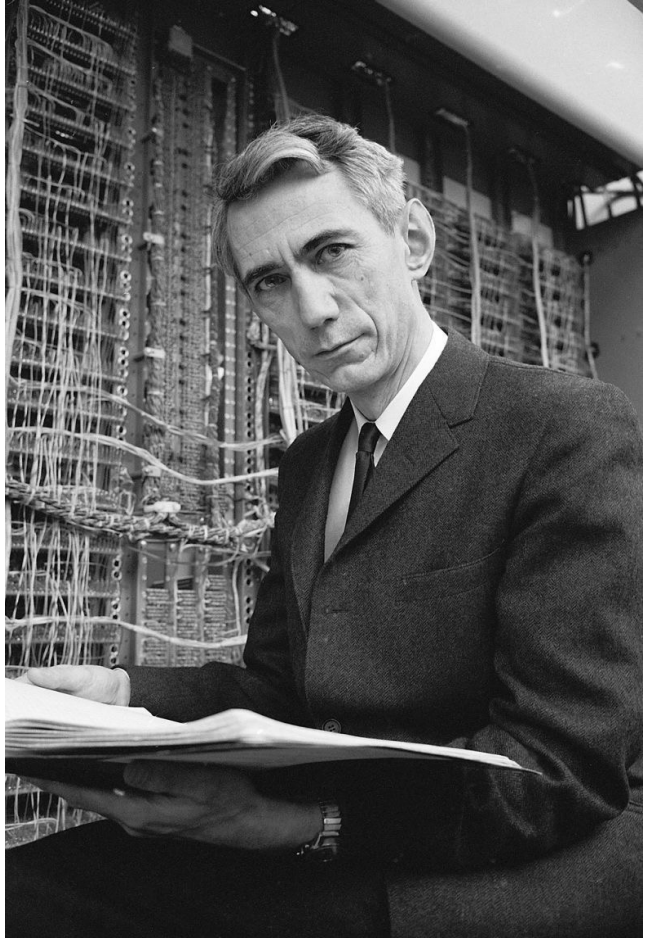
All take a deep breath



Information Theory

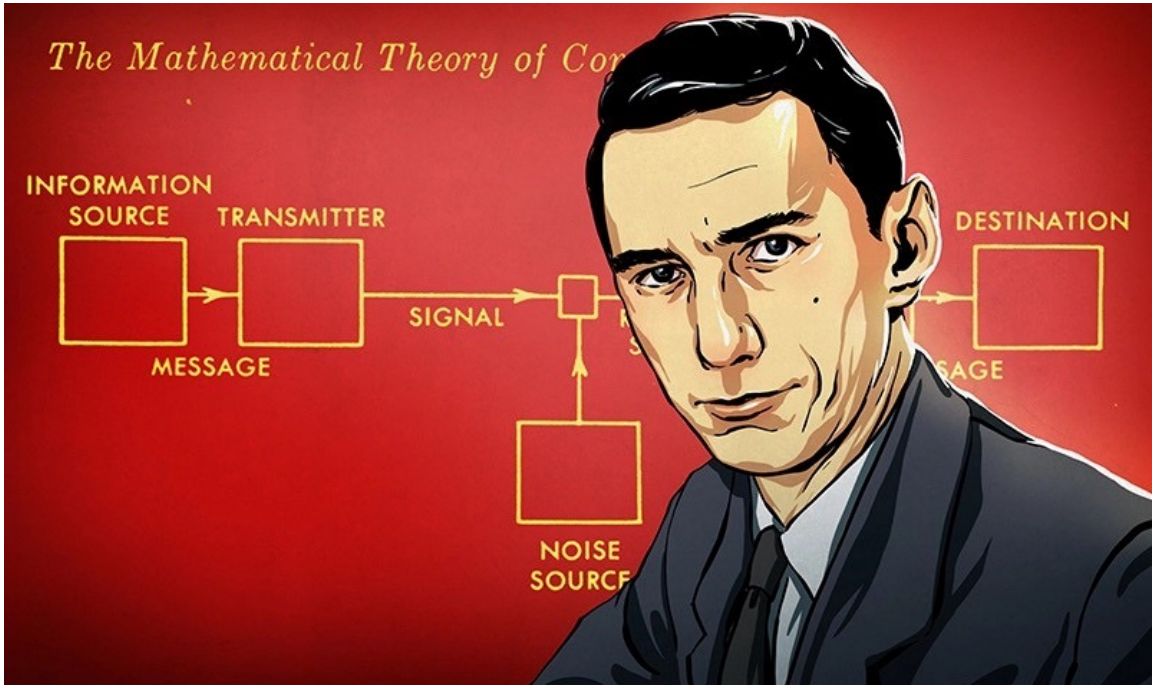
Claude Shannon A Little Bit of Science History

From: The Idea Factory: Bell Labs and the Great Age of American Innovation by John Gertner, 2012.



What is Information Entropy: Shannon's Formula

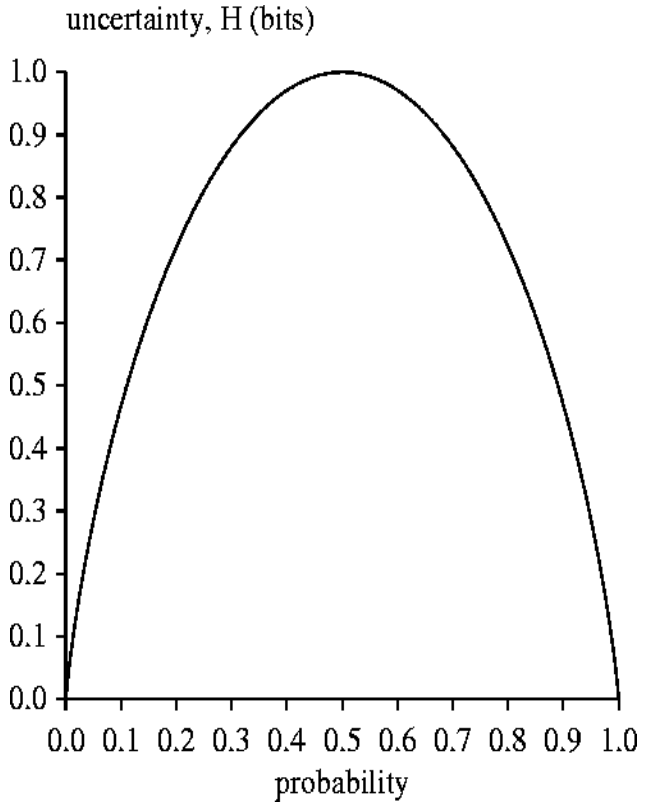
https://www.youtube.com/watch?v=R4OlXb9aTvQ



Entropy?

- No, you are not in a physics class

- Information is always a measure of the decrease of uncertainty at a receiver.



Not a perfect story

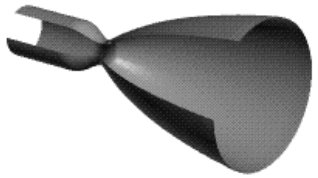
- Many authors criticize the use of the term entropy, and physics of information

That's not going to stop us!

- However the *idea* is very relevant to
  - modeling (sometimes equations)
  - design (variables)
  - architecture (how they are put together)
  - as well as how we "condition the system"

- We'll revisit the components of information soon but first let's take some examples

Equations!



S = Entropy
T = Temperature
V = Volume
E = Internal Energy
C_p = Heat Capacity (constant pressure)

p = Pressure
H = Enthalpy
Q = Heat Transfer
R = Gas Constant
C_v = Heat Capacity (constant volume)

2nd Law of Thermodynamics: $S_2 - S_1 = \frac{\Delta Q}{T}$ differential form: $dS = \frac{dQ}{T}$

1st Law for a Gas: $dQ = dE + p\,dV$ or $dQ = dH - V\,dp$

Ideal Gas: $pV = RT$ $dE = C_v\,dT$ $dH = C_p\,dT$

Substitute: $dQ = C_v\,dT + \frac{RT}{V}\,dV$ $dQ = C_p\,dT - \frac{RT}{p}\,dp$

Substitute: $dS = C_v\frac{dT}{T} + R\frac{dV}{V}$ $dS = C_p\frac{dT}{T} - R\frac{dp}{p}$

Integrate: $S_2 - S_1 = C_v \ln\frac{T_2}{T_1} + R\ln\frac{V_2}{V_1}$ $S_2 - S_1 = C_p \ln\frac{T_2}{T_1} - R\ln\frac{p_2}{p_1}$

specific form: $s_2 - s_1 = c_v \ln\frac{T_2}{T_1} + R\ln\frac{v_2}{v_1}$ $s_2 - s_1 = c_p \ln\frac{T_2}{T_1} - R\ln\frac{p_2}{p_1}$

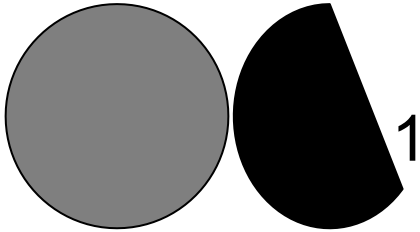
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0$$

Navier–Stokes equations *(general)*

$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v}\cdot\nabla\mathbf{v}\right) = -\nabla p + \nabla\cdot\mathbf{T} + \mathbf{f},$$

For information systems?

- 88767?
- (98) 8767
- 998-8767
- (857)-998-8767
- +1(857)-998-8767
- 518 –xxx- xxxx ?(Troy!)



$1\frac{3}{4}$

- What helps reduce entropy / uncertainty?
- Notice: ‘signs’ as information representations

AIM = Information integrity

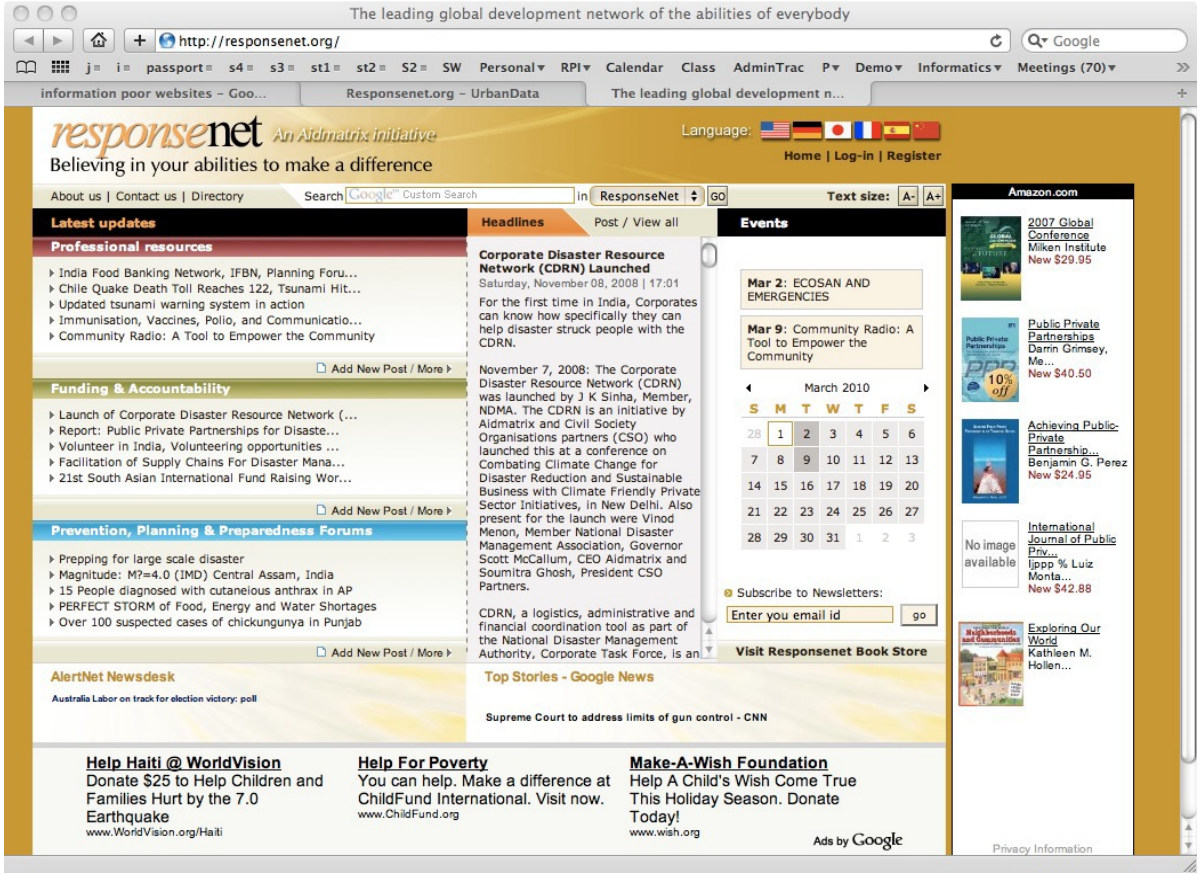
- In later classes we cover cognitive and social factors in increasing the conditional entropy and *thus* reducing the uncertainty and *thus* increasing information content and value

- We will also cover semiotics (signs) as a prelude to visualization as a presentation mechanism for information

Think of web pages – what is H here?

Not worst but poor

One more


The leading global development network of the abilities of everybody
http://responsenet.org/
Google
information poor websites – Goo...
Responsenet.org – UrbanData
The leading global development n...
responsenet
An Aidmatrix initiative
Believing in your abilities to make a difference
Language:
Home | Log-in | Register
About us | Contact us | Directory
Search
Google Custom Search
in
ResponseNet
GO
Text size:
A-
A+
Latest updates
Professional resources
India Food Banking Network, IFBN, Planning Foru...
Chile Quake Death Toll Reaches 122, Tsunami Hit...
Updated tsunami warning system in action
Immunisation, Vaccines, Polio, and Communicatio...
Community Radio: A Tool to Empower the Community
Add New Post / More
Funding & Accountability
Launch of Corporate Disaster Resource Network (...
Report: Public Private Partnerships for Disaste...
Volunteer in India, Volunteering opportunities ...
Facilitation of Supply Chains For Disaster Mana...
21st South Asian International Fund Raising Wor...
Add New Post / More
Prevention, Planning & Preparedness Forums
Prepping for large scale disaster
Magnitude: M?=4.0 (IMD) Central Assam, India
15 People diagnosed with cutaneious anthrax in AP
PERFECT STORM of Food, Energy and Water Shortages
Over 100 suspected cases of chickungunya in Punjab
Add New Post / More
Headlines
Post / View all
Corporate Disaster Resource Network (CDRN) Launched
Saturday, November 08, 2008 | 17:01
For the first time in India, Corporates can know how specifically they can help disaster struck people with the CDRN.
November 7, 2008: The Corporate Disaster Resource Network (CDRN) was launched by J K Sinha, Member, NDMA. The CDRN is an initiative by Aidmatrix and Civil Society Organisations partners (CSO) who launched this at a conference on Combating Climate Change for Disaster Reduction and Sustainable Business with Climate Friendly Private Sector Initiatives, in New Delhi. Also present for the launch were Vinod Menon, Member National Disaster Management Association, Governor Scott McCallum, CEO Aidmatrix and Soumitra Ghosh, President CSO Partners.
CDRN, a logistics, administrative and financial coordination tool as part of the National Disaster Management Authority, Corporate Task Force, is an
Events
Mar 2: ECOSAN AND EMERGENCIES
Mar 9: Community Radio: A Tool to Empower the Community
March 2010
S M T W T F S
28 1 2 3 4 5 6
7 8 9 10 11 12 13
14 15 16 17 18 19 20
21 22 23 24 25 26 27
28 29 30 31 1 2 3
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Top Stories - Google News
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Milken Institute
New $29.95
Public Private Partnerships
Darrin Grimsey, Me...
New $40.50
Achieving Public-Private Partnership...
Benjamin G. Perez
New $24.95
No image available
International Journal of Public Priv...
Ijppp % Luiz Monta...
New $42.88
Exploring Our World
Kathleen M. Hollen...
Help Haiti @ WorldVision
Donate $25 to Help Children and Families Hurt by the 7.0 Earthquake
www.WorldVision.org/Haiti
Help For Poverty
You can help. Make a difference at ChildFund International. Visit now.
www.ChildFund.org
Make-A-Wish Foundation
Help A Child's Wish Come True This Holiday Season. Donate Today!
www.wish.org
Ads by Google
Privacy Information

Information gain/loss

- In probabilistic terms, the entropy decreases by conditioning on the distribution.
  - The mutual information of two variables defines how much information one variable contains about the other.
  - It is therefore defined as the decrease of the uncertainty of one variable by knowing the other.
- What does this mean for an information *system?* E.g. a website or web service?

More on this later …

In-Class Exercise

- Break into groups of 3 – 4 persons
- Each explain your “Use Case” in Assignment 1 to others in your group (elevator speech no more than two minutes per person).
- Discuss the information and information uncertainty in your “Use Case”.
- In groups, come up with means of reducing the uncertainty in your “Use Case”.
- Some number (about 10) students will be randomly selected from class to explain the Information and Information Uncertainty in your “Use Case”.

Summary

- About systems
- Information systems
- The elements of theory so far
  - Entropy/ uncertainty
- Content, context, structure
- Presentation, organization

Class 4: Reading Assignment: Semiotics/ CogSci / social science

Submit summaries of ONLY 2 readings by email.

•Wikipedia entry for Semiotics: [https://en.wikipedia.org/wiki/Semiotics]
• Cognitive Science: [https://plato.stanford.edu/entries/cognitive-science/]
• Informatics Research Agenda and people: [http://www.ncbi.nlm.nih.gov/pmc/articles/PMC131031/]
• Abductive Reasoning: [http://en.wikipedia.org/wiki/Abductive_reasoning]

Optional Reading

• Shannon's 1948 paper: [https://people.math.harvard.edu/~ctm/home/text/others/shannon/entropy/entropy.pdf]
• GUI ICON Sets [http://www.hongkiat.com/blog/40-free-and-useful-gui-icon-sets-for-web-designers/]
• Cognitive Science (reference): [http://cogsci.uwaterloo.ca/courses/phil256.html]
• Peirce [https://plato.stanford.edu/entries/peirce/]

What is next

- Week 4 – Foundations; semiotics, library, cognitive and social science and class exercise - information modeling

- Assignment 2

Assignment 1 DUE: Wednesday, February 5th 2025 8:00 pm ET on LMS or by email

Thanks!

Work on Assignment 1!!