Information:
Broader Perspectives

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First, a quick review…

The information went data way

The General Definition of Information

Information = Data + Meaning

Luciano Floridi, *Information: A Very Short Introduction*, Oxford 2010.

General Definition of a Datum

Dd $=_{def}$ x being distinct from y

where the x and y are two un-interpreted variables and the domain is left open to further interpretation.

Luciano Floridi, *Information: A Very Short Introduction*, Oxford 2010.

Common/Useful Representations of Data

- **Analog**

- **Discrete**
(digital)

- **Binary**
(y'all know what that is...)

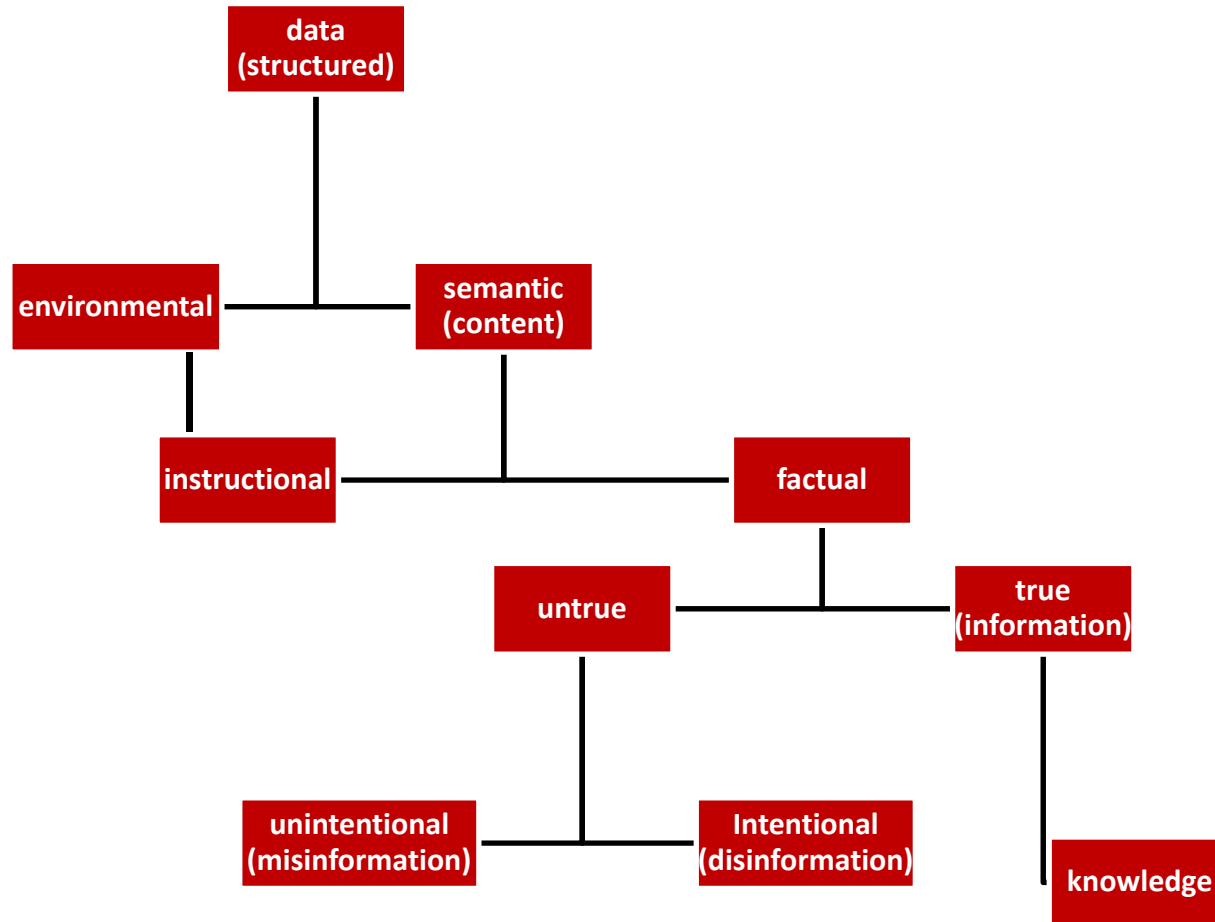Luciano Floridi, *Information: A Very Short Introduction*, Oxford 2010.

Types of Data

- **Primary**
(raw data in a database, or a table, …)
- **Secondary**
(converse of primary data, stuff that is missing…)
- **Metadata**
(data about data, location, format, copyright,…)
- **Operational**
(data about the operation of a data system…)
- **Derivative**
(data extracted from other data, as in mining…)

Luciano Floridi, *Information: A Very Short Introduction*, Oxford 2010.

The General Definition of Information

Definition: σ is in instance of information,
understood as semantic content,
if and only if:

1) σ consists of *n data*, for $n \geq 1$;

2) The data are *well-formed*;

3) The well-formed data are *meaningful*.

Luciano Floridi, *Information: A Very Short Introduction*, Oxford 2010.

Information: A Taxonomy

Luciano Floridi, *Information: A Very Short Introduction*, Oxford 2010.

Three Types of Information

- **Syntactic Information**
  Related to symbols from which messages are formed, and to their interrelations (structural)

- **Semantic Information**
  related to the meaning of messages...

- **Pragmatic Information**
  Related to the usage and effect of messages

Jan C. A. van der Lubbe, Information Theory, Cambridge 1997.

Example

I. John was brought to the railway station by taxi.

II. The taxi brought John to the railway station.

III. There is a traffic jam on highway A3, between Nuremberg and Munich in Germany.

IV. There is a traffic jam on highway A3 in Germany.

Jan C. A. van der Lubbe, Information Theory, Cambridge 1997.

Example

I.   John was brought to the railway station by taxi.

II. The taxi brought John to the railway station.

Syntactically different, but semantically and pragmatically identical.

Same meaning and equally informative.

Jan C. A. van der Lubbe, Information Theory, Cambridge 1997.

Example

I.   John was brought to the railway station by taxi.

II.   The taxi brought John to the railway station.

III.   There is a traffic jam on highway A3, between Nuremberg and Munich in Germany.

IV.   There is a traffic jam on highway A3 in Germany.

Differ in syntax.

Also semantics: III gives more precise information than IV.

Pragmatic aspect of information depends on context.

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INFORMATION = MESSAGE?

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Two Traditions...

- Concerned primarily with semantic & pragmatic aspects of information.

- Concerned with syntactic aspects of information:
  - How do you measure syntactic information?
  - Limits on the amount of information which can be transmitted?
  - Limits on compression of information?
  - How to build information processing systems approaching these limits?

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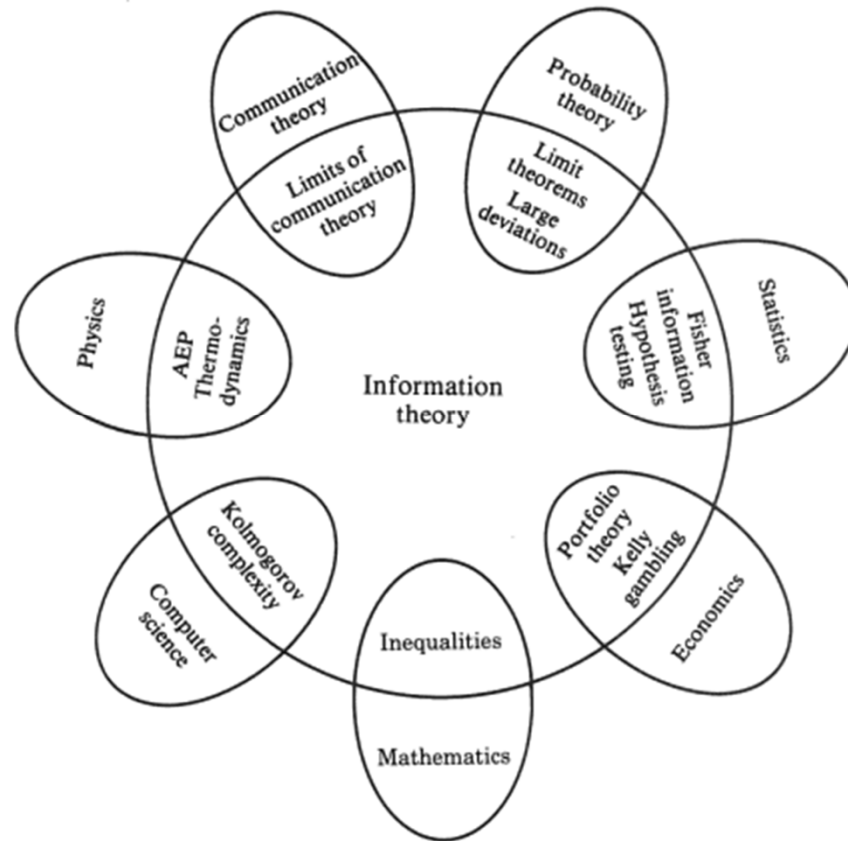
Classical Information Theory

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Classical Information Theory

- Concerned with syntactic aspects of information:
    - How do you measure syntactic information?
      Answer: Entropy, H.
    - Limits on the amount of information which can be transmitted?
      Answer: Channel Capacity, C
    - Limits on compression of information?
      Answer: Entropy, H.
    - How to build information processing systems approaching these limits?
      Answer: Fo' real!

Thomas M. Cover & Joy A. Thomas, *Elements of Information Theory*, Second Edition, Wiley 1990.

Relationship with Other Fields

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Floridi's Roadmap

- ## Mathematical Information
  Information Theory

- ## Semantic Information

- ## Physical Information
  Universe is fundamentally composed of data, instead of matter or energy, with material objects as a complex secondary manifestation.

- ## Biological Information
  Genetic Information, Neural Information, Computational Neuroscience, …

- ## Economic Information
  Commoditization of information, value of information, game theory, …

- ## Ethics of Information

Luciano Floridi, *Information: A Very Short Introduction*, Oxford 2010.

Five Fundamentals of Information

- ## Entropy
  Information Theory, bits, bandwidth, codes,…

- ## Economics
  Strategies for value: how information is produced, priced, and distributed, …

- ## Encryption
  Secure transmission, digital signatures, digital cash, …

- ## Extraction
  Data organization, storage, extraction, etc…

- ## Emission
  Frequency, modulation, radio, TV, phones, networks, …

David G. Luenberger, *Information Science*, Princeton 2006.

Towards a Science of Information

- Information Theory needs to meet new challenges of current applications in *biology, communication, knowledge extraction, economics, ...*

- Understand new aspects of information in **structure, time, space, and semantics**.

- PLUS...dynamic information, limited resources, complexity, representation-invariant information, and cooperation & dependency

Some Challenges...

- ## Structure

    Measures are needed for quantifying information embodied in structures (e.g., information in material structures, nanostructures, biomolecules, gene regulatory networks, protein networks, social networks, financial transactions).

- ## Time

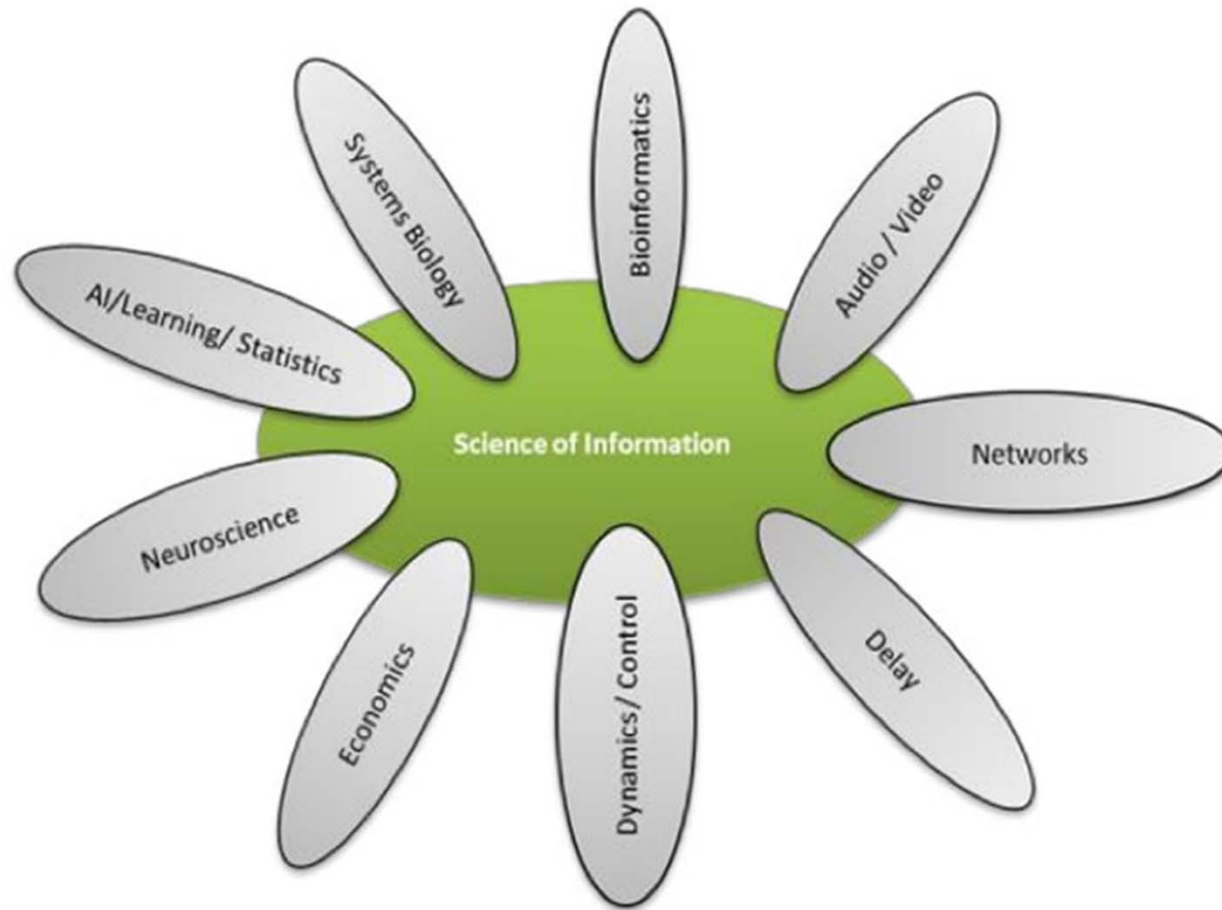   Delay (e.g., information arriving late may be useless or has less value).

- ## Semantics

    Is there a way to account for the meaning or semantics of information?

- ## Knowledge Extraction

    Data driven science focuses on extracting information from data. How much information can actually be extracted from a given data repository? How?

Science of Information

Center for Science of Information (soihub.org->Research Overview), 2012.

Emerging Frontiers of SoI

	Information Theory & Communications		Biology		Knowledge Extraction		Economics	
	Traditional	Quantum	Molecular	Neuroscience	Big Data	Semantics	Theory	Applications
Fundamentals								
Structure								
Time								
Space								
Semantics								

Our SoI Roadmap

- ## Foundations of Information Theory
  Entropy, codes, compression, channels, …

- ## Communications
  Voice, data, …

- ## Biological Information
  Bioinformatics, proteomics, epidemiology, neuroscience,…

- ## Information Extraction
  Big data, storage, processing, IR, indexing, search engines, visualization,…

- ## Economic Information
  Dynamic economic theory, behavior of continuously optimizing agents in markets, …

- ## Quantum Information

How "dirty" do we want to get?

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Next,

Fundamentals of Information Theory