Beyond Shannon:
The Meaning & Structure of Information

Workshop
Institute for Advanced Study
University of Amsterdam
6-8 May 2019
Amsterdam

Organizers: Peter Sloot, Rick Quax, Ryan James,
Jeff Emenheiser, JPC.

Agenda

- The Problem
- Workshop Format
- Workshop Output

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The Challenge

- What is a complex system?

The signature of a complex system is how it *generates, stores, & transforms information*.

50+ year research program:
Norbert Wiener 1948 & Andrei Kolmogorov 1958

The more sophisticated these are the more complex the system.

The Problems

- Shannon multivariate informations (all!) miss **Statistical Dependencies**
- Worse, they give answers that **Mislead**
- Shared information: **Redundant, Synergistic, Unique decomposition** (PID) **inconsistent** for N > 2 variables
- No consistent measure of **Information Flow**
- No consistent measure of **Causality**
- Discrete $\Longrightarrow$ Continuous: Singular limit, Information diverges & negative

The Consequences

- We do not know what **Correlation** is.
- We do not know what **Statistical dependency** is.
- We do not know what **Structure** is.
- We do not know what **Randomness** is.

- **Fraudulent white noise**:

  Processes with N-way dependencies, but no n-way, $0 \leq n < N$.

- Finite Processes $\Longrightarrow$ **Uncountable set of predictive features**
- Classical & Quantum Physics Inconsistent:

Ambiguity of simplicity

Nature's Challenge

If we study the history of science we see happen two inverse phenomena **...** Sometimes **simplicity hides under complex appearances**; sometimes it is the simplicity which is apparent, and which **disguises extremely complicated realities**.

… No doubt, if our means of investigation should become more and more penetrating, we should discover the simple under the complex, then the complex under the simple, then again the simple under the complex, and so on, without our being able to foresee what will be the last term. We must stop somewhere, and that science may be possible, **we must stop when we have found simplicity**. This is the only ground on which we can rear the edifice of our generalizations.

Henri Poincaré, "Hypotheses in Physics", in **Science and Hypothesis**,
tr. George Bruce Halsted, Walter Scott Publishing (London, 1905)
Ch. IX, 140-159.

Discovery?

It is by logic that we prove, but by intuition that we discover.

Henri Poincaré, **Mathematical Definitions in Education**,
Georges Carré, Paris (1904) Part II. Ch. 2 p. 129.

Our Problem

- Statistical dependencies that **no** multivariate Shannon information can detect and represent.*

- Half a century after Kolmogorov ported information theory to physics, we now know information theory is deeply incomplete.

- We do not even know what correlation is.

- Perhaps, it is understandable that our training was inadequate.

- What is unforgivable is that it was (and is) misleading.

*Subsumes mathematical statistics, which uses linear models.

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	Monday, 6 May 2019	***Tuesday, 7 May 2019***	***Wednesday, 8 May 2019***
	University of Amsterdam	*University of Amsterdam*	*University of Amsterdam*
	Venue: Institute for Advanced Study	*Venue: Institute for Advanced Study*	*Venue: Institute for Advanced Study*
8:30 AM	**Continental breakfast**	**Continental breakfast**	**Continental breakfast**
9:00 AM	Organizers: ***Welcome***	**Technical Contexts**	**Structure of Information Processing**
	What's the Problem?	Information theory frameworks, roadblocks?	How can information be processed by a system?
	Introductions all around	**Kristian Lindgren**: Information in Statistical Physics	**Sarah Marzen**: Information in the Brain
	Charge to participants:	**Hector Zenil**: Algorithmic Information Theory	**Jeff Emenheiser**: Directionality of Interpretations
	What questions are in need of answers?		
10:30 AM	**Coffee break**	**Coffee break**	**Coffee break**
11:00 AM	**Jim Crutchfield**: Nouveau Cybernetics?	**Jeff Emenheiser**: Partial Information Decomposition	**Others**/Open discussion
	Ryan James: Road to Multivariate Information Theory	**Ryan James**: Mapping the Simplex	
Noon	**Lunch**	**Lunch**	**Lunch**
1:00 PM	**Contexts**	**Structure of Information Storage**	**Contexts (reprise)**
	Uses of an interpretable theory of multivariate information?	How can information be stored by a system?	Reflections on workshop (Up to half hour each)
	Randy Beer: A Brief History of Partial Information	**Rick Quax**: Synergy	**Randy Beer**
			Jan de Boer
	Peter Sloot	**Fernando Rosas**:	**Peter Sloot**
		ΨID: Decomposing integrated information	**Alfons Hoekstra**
3:00 PM	**Coffee break**	**Coffee break**	**Coffee break**
	Alfons Hoekstra	**Greg ver Steeg**: Applications in Machine Learning	**Wrapping Up**
3:30 PM			**Jeff Emenheiser**: Summary
		Others/Open discussion	Discussion
4:00 PM	**IAS Causality Competition?**		**Looking forward:**
			Planning
4:30 PM	Discussion	Discussion	Collaborations?
			Journal special issue?
5:00 PM	**Adjourn**	**Adjourn**	**Adjourn**
6:30 PM	**Group Dinner**	**Dinner: Own recognizance**	**Dinner: Own recognizance**
	In de Waag, Nieuwmarkt 4, 1012 CR Amsterdam		***Day Four: Collaborations, spontaneously structured***

Attendees	**Institution**	**Email**
Co-Organizers		
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Competitions?

- Challenge community to address
  - Information Flow
  - Causality

- Recall SFI Prediction Competition (1991)

Onwards!