

Process Algebras & Network Motifs

section 1

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Trento Seminar

1

Process algebras and network motifs 1

- **Introduction**
 - **Goals**
 - **Methods**
 - **Motivations**
- Review of π -calculus
 - Syntax
 - Structural Equivalence
 - Semantics
 - Stochastics
- Review of Kinetic Proofreading
 - Origins
 - Dynamics
 - Examples
 - Modeling in π -calculus
- Introduction of reflective calculi
 - Syntax
 - Structural Equivalence
 - Semantics
 - A New Approach to Stochastics
 - Modeling in a reflective calculus

Introduction – Goals

- Conducting original research
 - The Questions are more important than the answers
 - Sizing problems
 - Decomposing problems
- Working as a team
 - 'Symmetry of ignorance'
 - Division of labor
 - Communication
- Facility with the analytic tools
 - Process algebras
 - Dynamical systems
- Exposure to the domain
 - Transcription networks
 - Signaling networks

Introduction – Goals

- Conducting original research
 - The Questions are more important than the answers
 - Sizing problems
 - Decomposition
- Working as a team
 - ‘Symmetry’
 - Division of labor
 - Communication
- Facility with mathematics
 - Process analysis
 - Dynamical systems
- Exposure to the domain
 - Transcription networks
 - Signaling networks



Ex.1: i am **not** a biologist;
i don't even know
how much i don't know.

Ex.2: it's been 30 years since
i practiced continuous mathematics
at the heart of dynamical systems

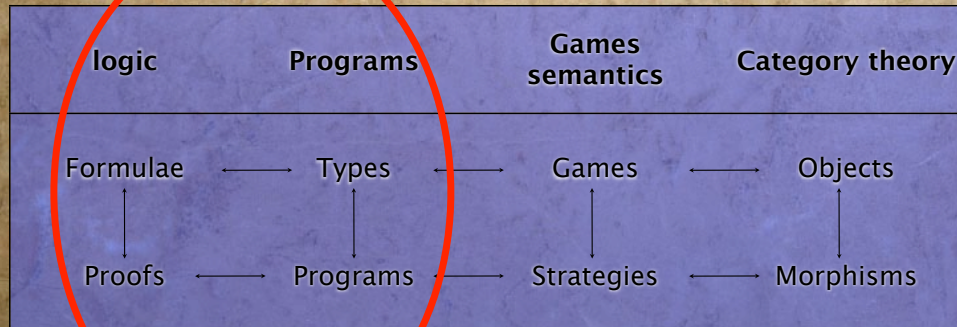
Introduction – methods

- Work together on a hard problem
 - For which the answer is not yet worked out
- Everyone is a peer
 - We will teach each other
- Get our hands dirty
 - Do the math
 - Build executable models
- Set ambitious goals
 - Drive with concrete deliverables

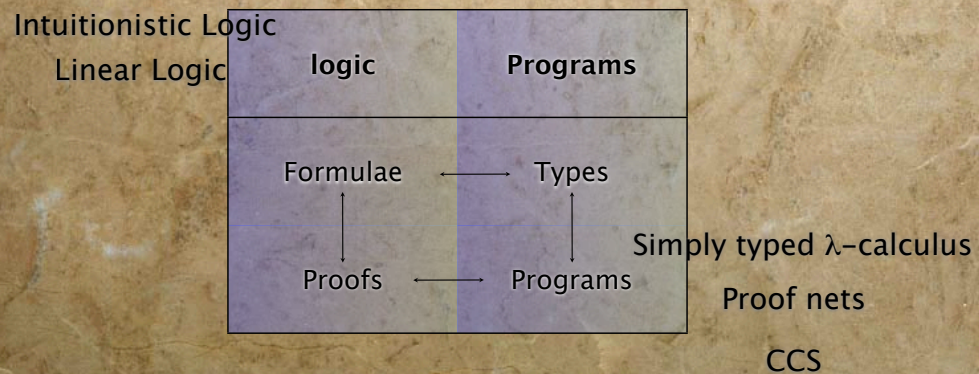
Introduction – motivations

- Biology is transforming itself into a computational science
 - Has yet to absorb the deep messages of computing
- Computing is a young field with some profound things to say to the physical sciences
 - Scale-invariance
 - Proposition-as-types paradigm
- Why network motifs?
- Why kinetic proofreading?

Propositions-as-types paradigm



Propositions-as-types paradigm



Propositions-as-types paradigm

- Deep organizing principle of equality

$$P \approx Q \Leftrightarrow \forall E. P:E \Leftrightarrow Q:E$$

P is effectively the same as Q iff no experiment can distinguish them

- Process algebras refine this notion by 'extending in time'

$$P \approx Q$$

$$\Leftrightarrow$$

$$\forall e. P \rightarrow^e P' \Rightarrow \exists Q'. Q \rightarrow^e Q' \ \& \ P' \approx Q'$$

$$\forall e. Q \rightarrow^e Q' \Rightarrow \exists P'. P \rightarrow^e P' \ \& \ P' \approx Q'$$

- These notions coincide exactly when the experiments E are Hennessy-Milner formulae...

Propositions-as-types paradigm

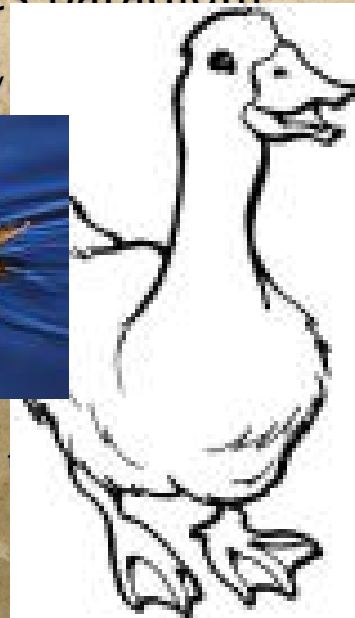
- Deep organizing principle of equality

P is effective
distinguish



$P \rightarrow^e P' \text{ \& } P' \approx Q'$

ide exactly when
r formulae...



Propositions-as-types paradigm

But this is a scientific principle!

The analytic tools currently brought to bear on the physical sciences are remarkably silent on such matters and yet they have practical implication for a broad range of scientific concerns

Why these biological investigations?

- Why network motifs?
 - Understand the search for organizing principles (and principles of organization) from the eyes of biologists
 - Additionally, there ongoing efforts to find evidence of statistically significant over (and under) representation of certain kinds of networks
- Why kinetic proofreading?
 - Well-understood from a dynamical systems point of view
 - Lots of literature
 - Significant evidence of the occurrence of this phenomena in a wide range of networks

Why these biological investigations?

- A radical proposition:
network motifs : types :: networks : programs
- We don't seek individual motifs
 - We seek ensembles of motifs that cohere
 - What is the measure of that coherence?
 - It gives rise to an interesting and useful observation-based equality
 - Where the motifs are the observations
 - And 'interesting' and 'useful' have to do with separation of classes of networks
- Kinetic proofreading is not a single motif -- it is a scheme of motifs -- a set of observations

Propositions-as-types paradigm

