Co-evolution in Epistemic Networks

Reconstructing Social Complex Systems

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The Reconstruction Problem

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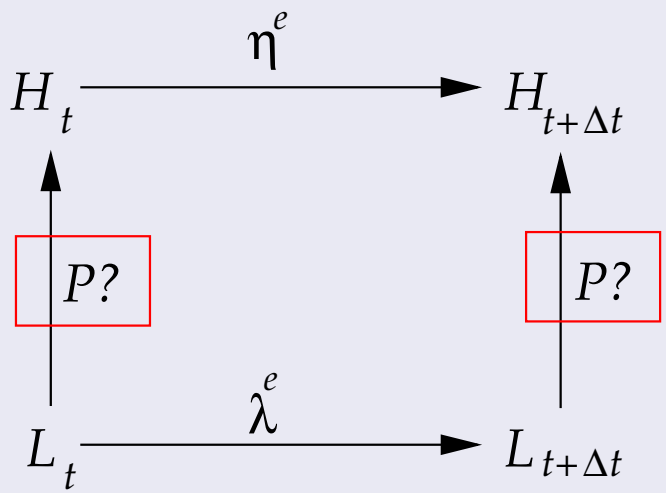
(i) Find P in order to deduce high-level observations H from strictly low-level phenomena L.

(ii) Find a low-level dynamics λ that rebuilds high-level evolution η^e.



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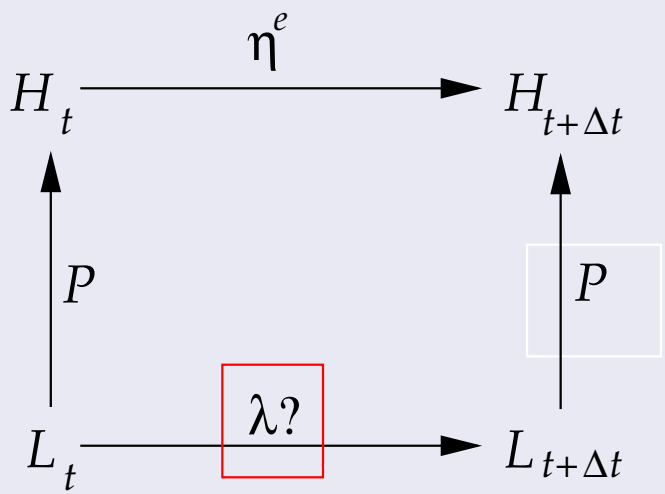

Objectives

A socio-semantic complex system

1. Reproduce a hierarchic epistemic hypergraph of a knowledge community that fits a high-level expert-based description
2. Provide a low-level dynamics and a morphogenesis model that rebuilds the empirically observed high-level structure

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The structure of a knowledge community, and in particular its epistemic hypergraph, is primarily produced by the co-evolution of agents and concepts.

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Outline

1. **Epistemic communities**
   - Rationale & definitions
   - Epistemic community taxonomy and Galois lattices
   - Partial taxonomies: rebuilding history
2. **Micro-foundations of epistemic networks**
   - Networks
   - Towards a rebuilding model
   - Reconstruction of epistemic communities

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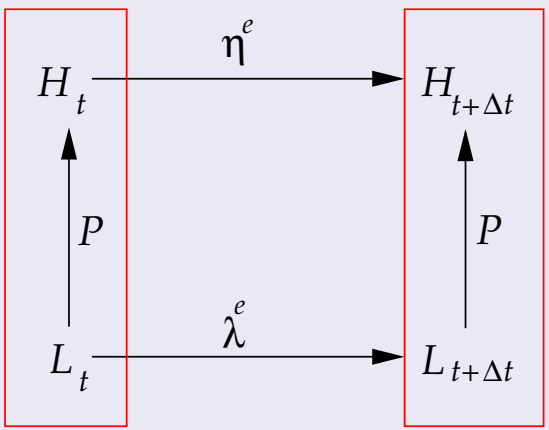
Building taxonomies

Rationale

Describe the taxonomy of a knowledge community, in particular scientific communities, that matches high-level descriptions.



Building taxonomies

Epistemic communities

- Epistemic Community: group of agents sharing a common set of subjects, concepts, issues; sharing a common goal of knowledge creation — Haas (1992), Cowan et al. (2000)
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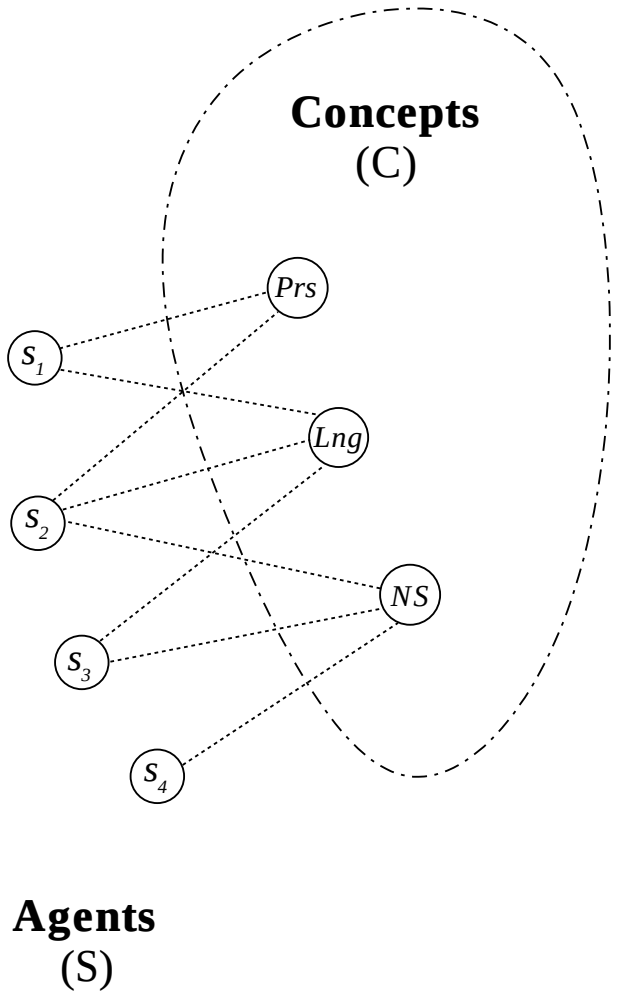
Building taxonomies

Formal framework

- Consider a binary relation $\mathcal{R}$ between agents & concepts
- *Intent* $S^{\wedge}$ of an agent set S: all concepts used by every agent in S
- *Extent* $C^{\star}$ of a concept set C
- *Epistemic community*: the extent of a concept set C
- "$\wedge\star$" is a *closure operation*:
  1. (idempotent) $(S^{\wedge\star})^{\wedge\star} = S^{\wedge\star}$
  2. (extensive) $S \subseteq S^{\wedge\star}$
  3. (increasing) $S \subseteq S' \Rightarrow S^{\wedge\star} \subseteq S'^{\wedge\star}$
- (S, C) is closed *iff* $C = S^{\wedge}$ and $S = C^{\star}$



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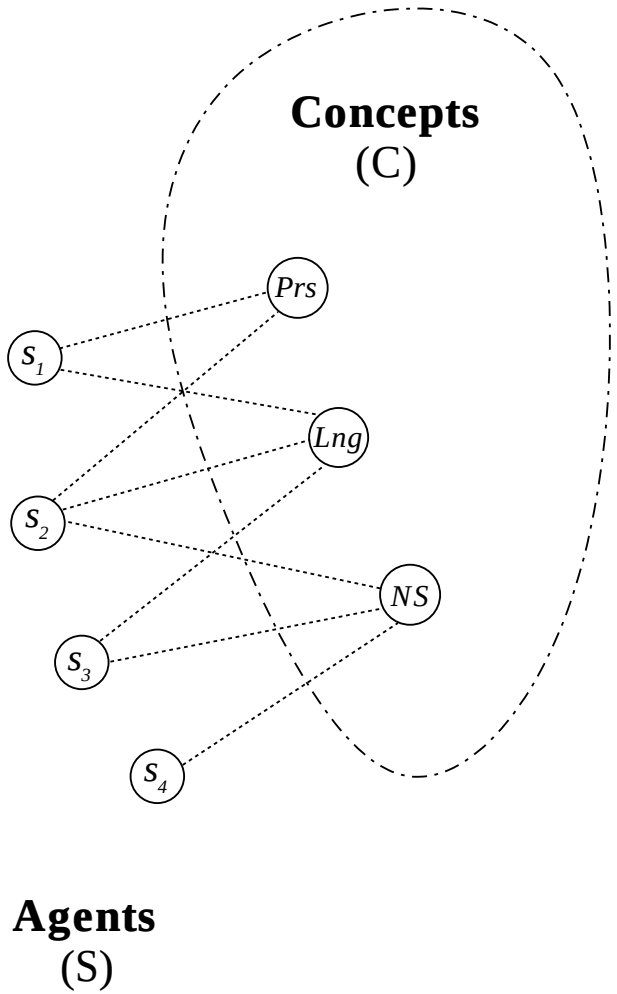

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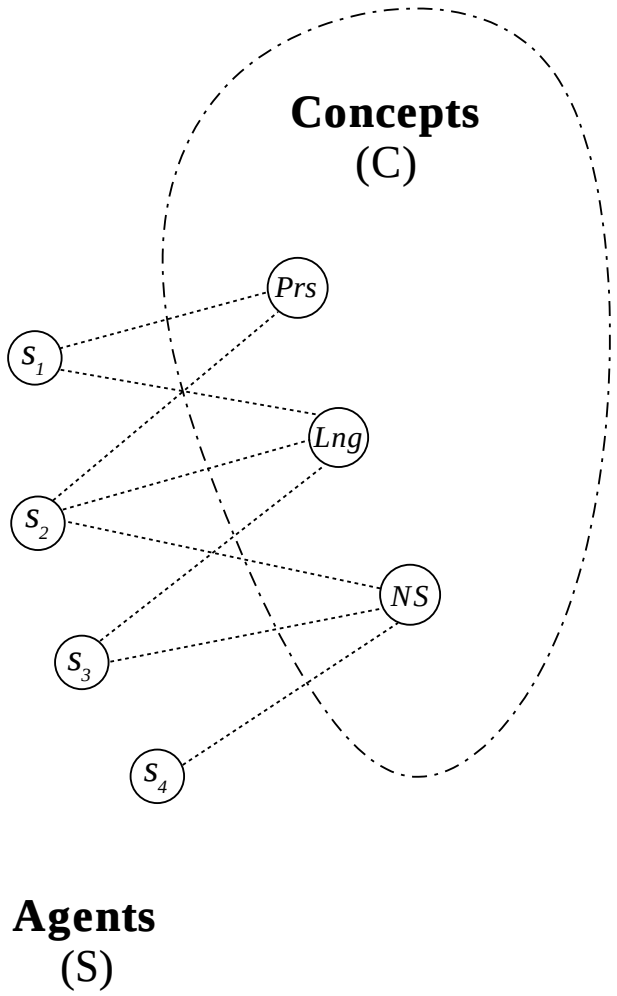

Building taxonomies

Representing epistemic communities

1. structured into fields, with common concerns,
2. hierarchically: generalization / specialization,
3. overlapping.

From trees to lattices

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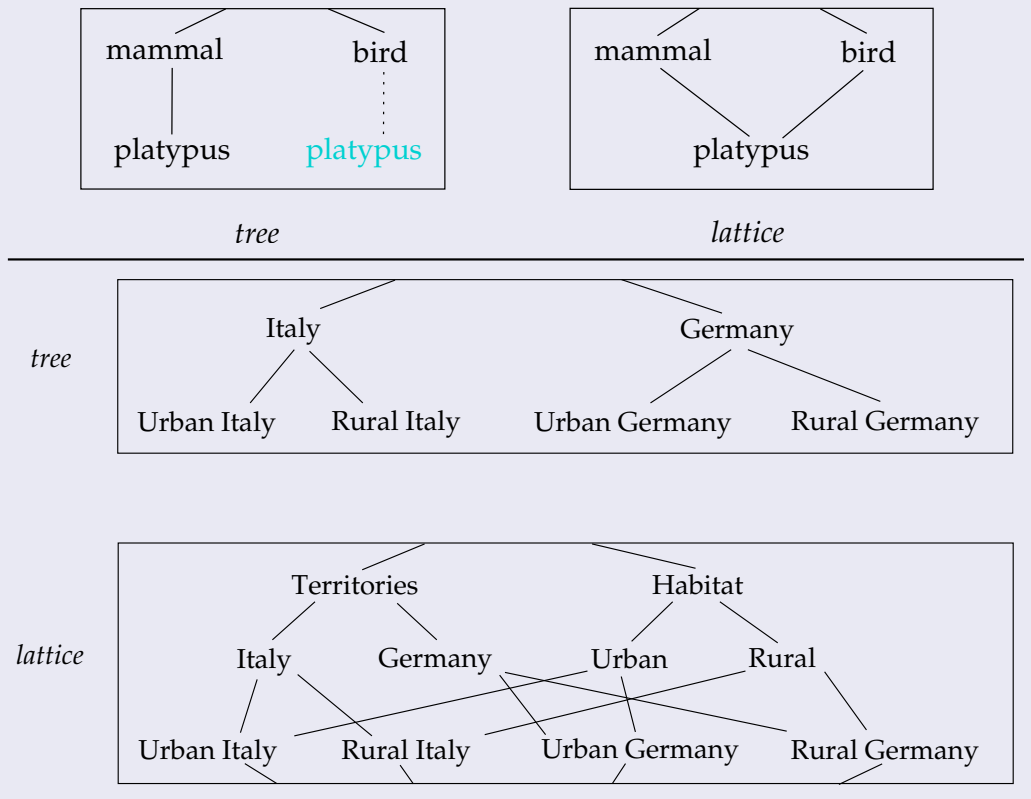
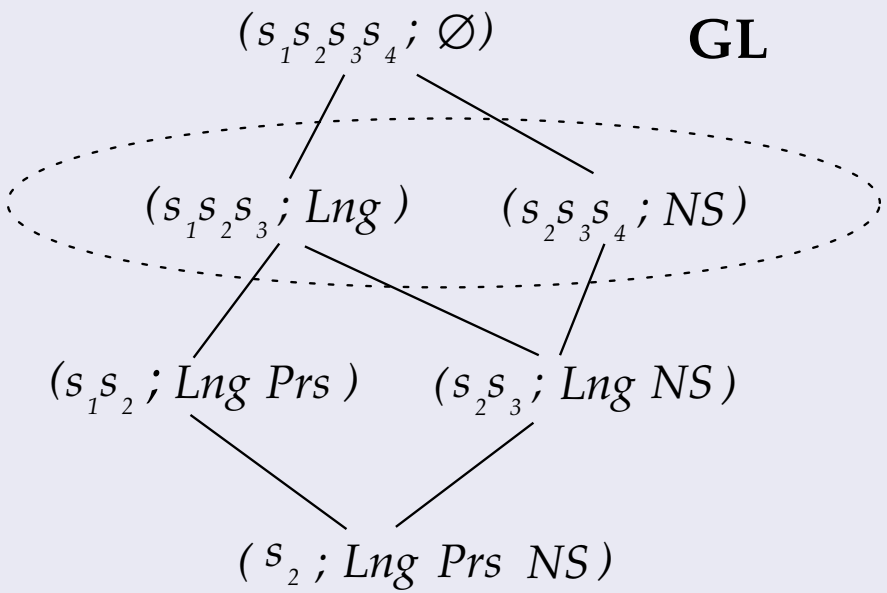


Building taxonomies

Galois lattices

GL=$\{(S^{\wedge\star}, S) | S \subseteq \mathbf{S}\}$ is the partially-ordered set of all epistemic communities, with the partial order:

$$(X, X^{\wedge}) < (X', X'^{\wedge}) \Leftrightarrow X \subset X'$$



Managing taxonomies

Taxonomy selection & extraction

- Which ECs should we extract from the lattice?
- *Given the assumptions*, a first criterion is agent set size — Small isolated ECs could be interesting too.
- In order to create a partial taxonomy, with *selection heuristics*: partially-ordered set overlaying the lattice: "epistemic hypergraph"

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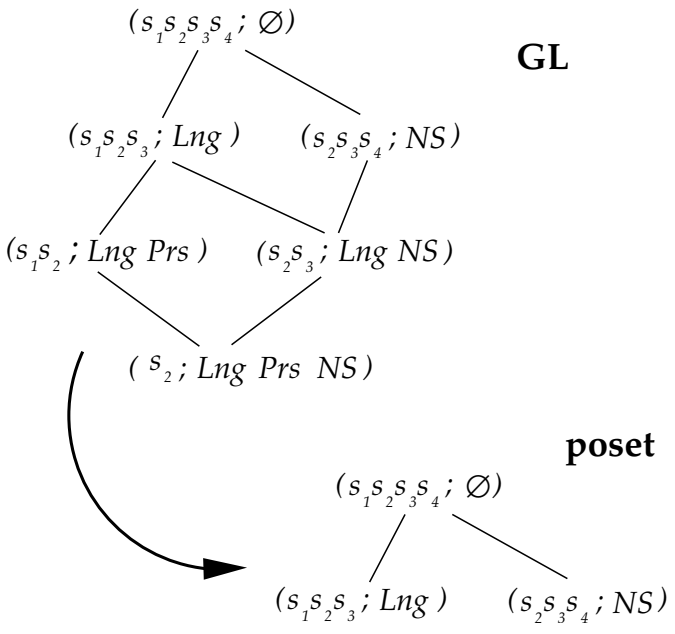
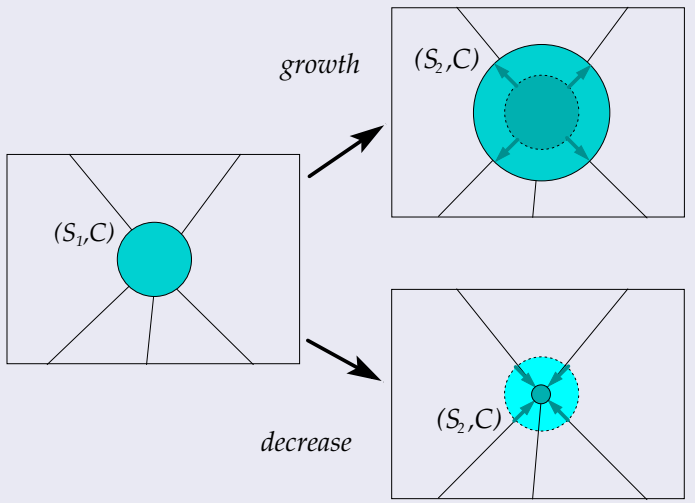


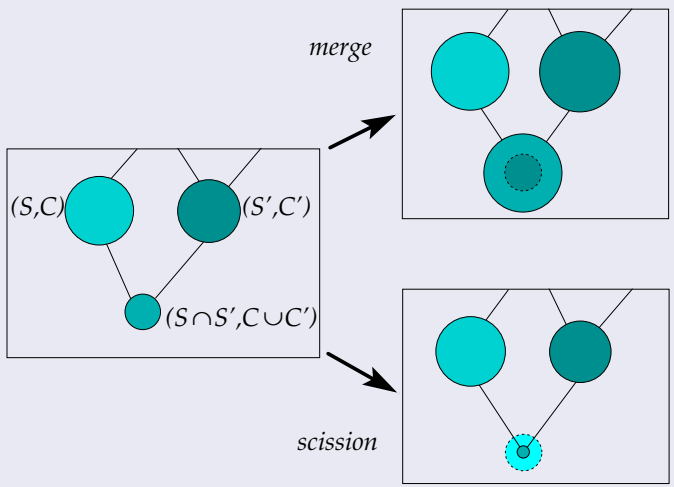
Managing taxonomies

Taxonomy evolution

1. Progress or decline of a field

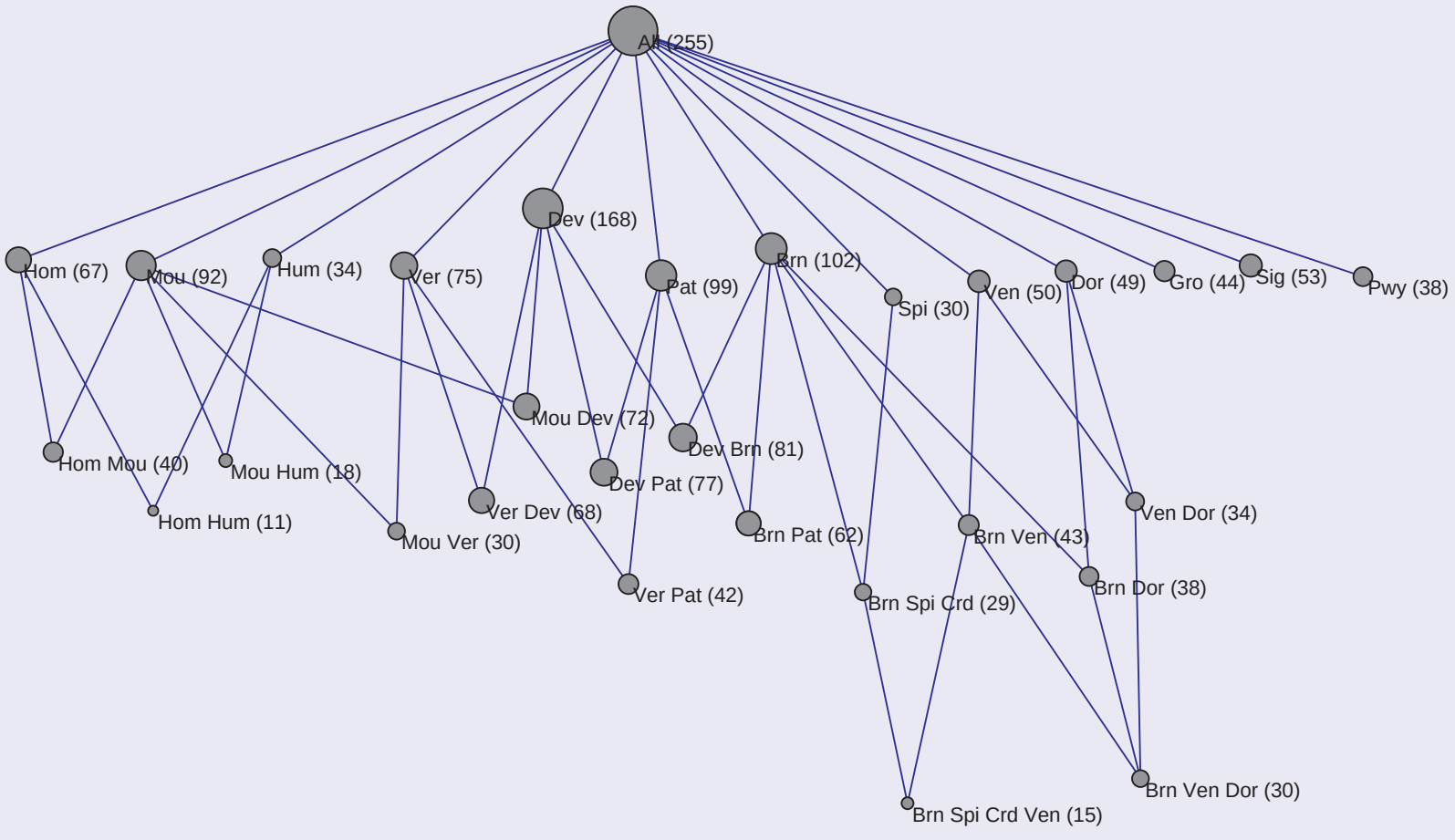


2. Merging or scission of a field



Empirical results

Hierarchical epistemic hypergraph 1990-1995



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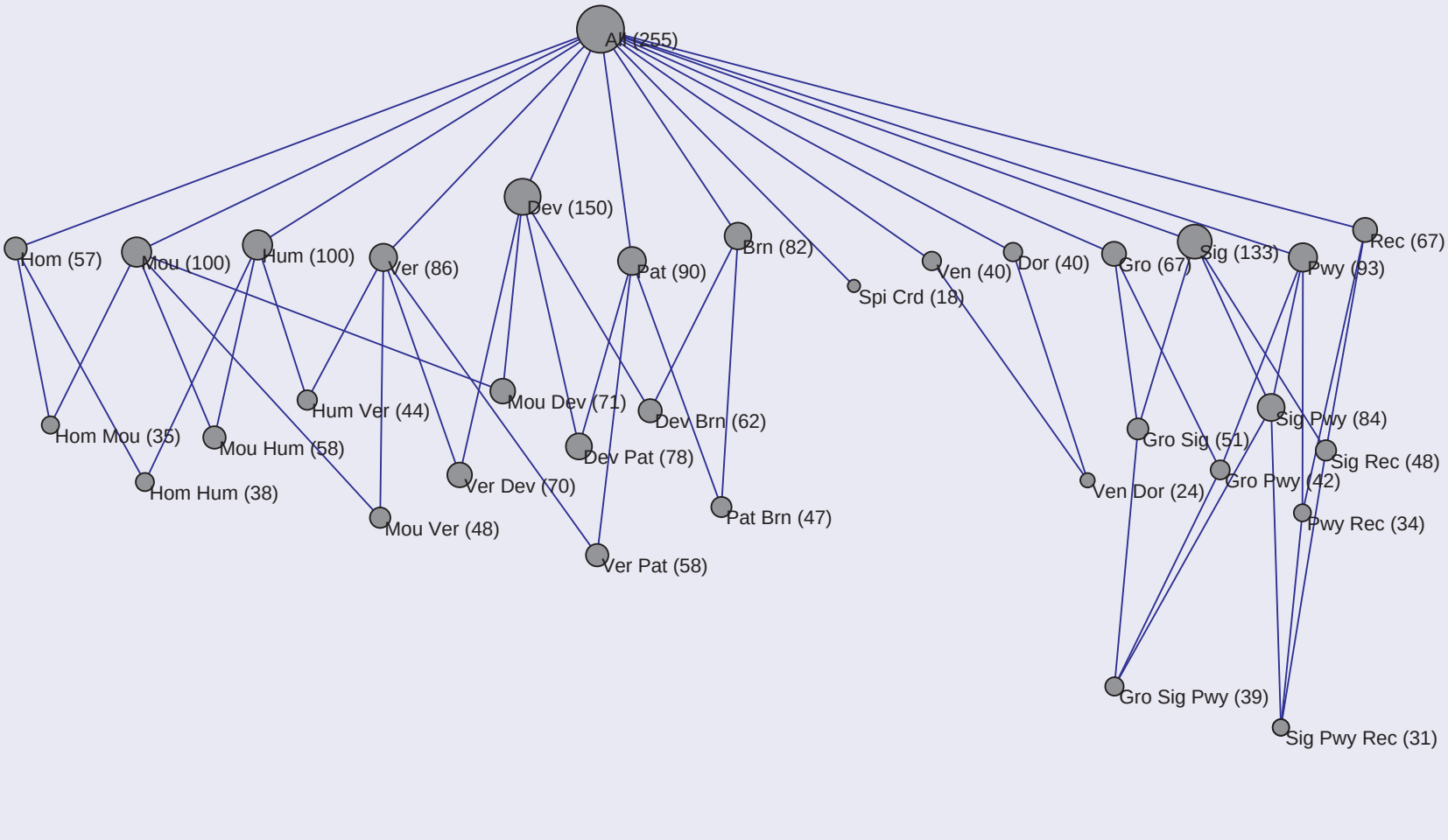

Empirical results

Historical description

1. Research on brain and spinal cord depreciated,
2. The community started to enquire relationships between signal, pathway, and receptors,
3. Mouse-related research is stable, yet significant stress on human-related topics & new relationship to homologous genes and vertebrates: growing focus on differential studies.

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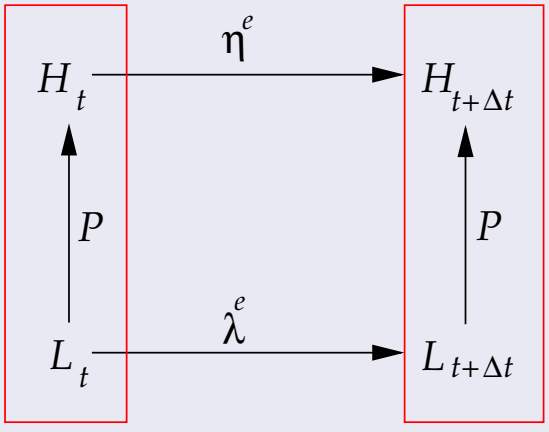

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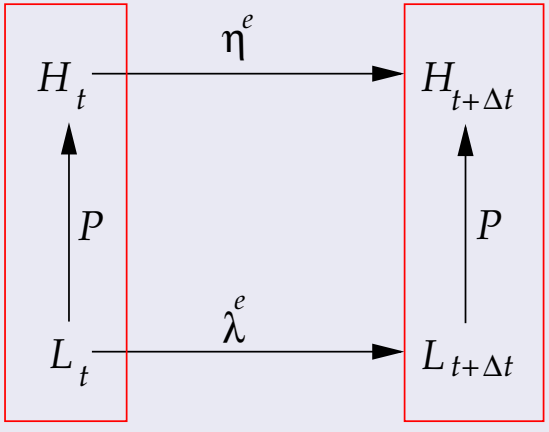

Micro-foundation

Reconstructing high-level structure from low-level dynamics:
— reverse problem: find λ such that $P \circ \lambda = \eta^e \circ P$.

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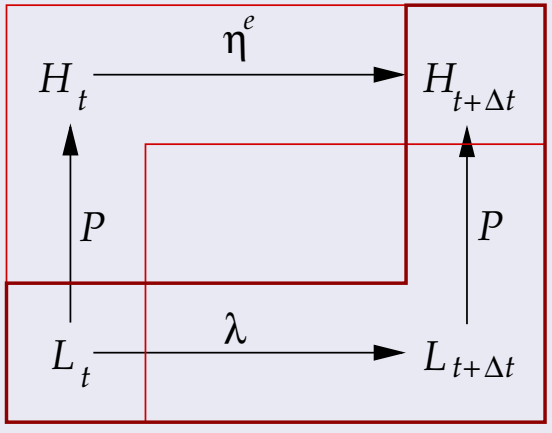

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Epistemic networks

Definitions

What is an epistemic network?

- A network of agents: $\mathcal{S}$=($\mathbf{S}$, $E_{\mathbf{S}}$), evolving with time: $\mathcal{S}(t)$
- Semantic network: network of concepts, $\mathcal{C}$=($\mathbf{C}$, $E_{\mathbf{C}}$)
- Agents are linked to concepts they use, through $\mathcal{R}$.
- Three kinds of relations: $\mathcal{R}^{\mathbf{S}}$, $\mathcal{R}^{\mathbf{C}}$ and $\mathcal{R}$:

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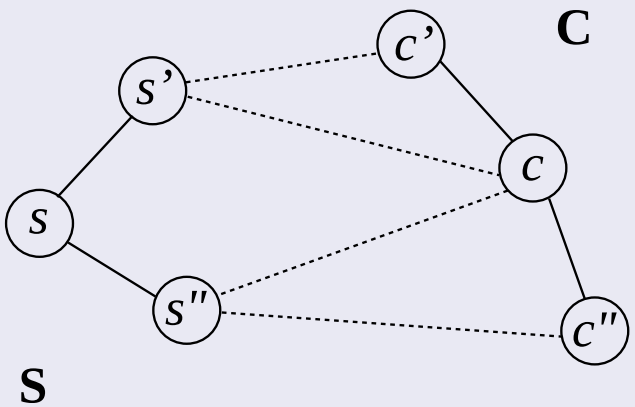

Network morphogenesis

A brief survey

1. *Early times*: Erdos-Renyi, until unsatisfying power-law degree distribution and other statistical parameters
2. Pioneering models rebuild clustering, and degree distribution (preferential attachment (PA), network growth)
3. Since then and until now: models introducing various kinds of PA to rebuild diverse statistical parameters
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High-level features

Degree distributions

- Four degree distributions: social, semantic, socio-semantic (from agents, from concepts)
- Power-law tail, log-normal fit

Clustering structure

High clustering both for monopartite coefficients and bipartite coefficients

Epistemic community structure

Many large ECs, particular distribution of EC sizes.

Suggest empirically credible low-level dynamics

Measuring interaction behavior

- Measure the interaction behavior of agents
- Have an essential preference f for nodes of kind m: $P(\mathrm{L}|m)$
  $\rightarrow$ we may estimate f through $\hat{f}(m) = \frac{\nu(m)}{P(m)}$
- Check correlations between parameters: $\hat{c}_{m'}(m) = \frac{P(m|m')}{P(m)}$

Event-based modeling

Distinguish activity from attractivity: rich-get-richer or rich-work-harder?
Activity and interactivity: $f(m) = a(m)\iota(m)$

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Measuring low-level dynamics

Network growth

Event-based low-level dynamics

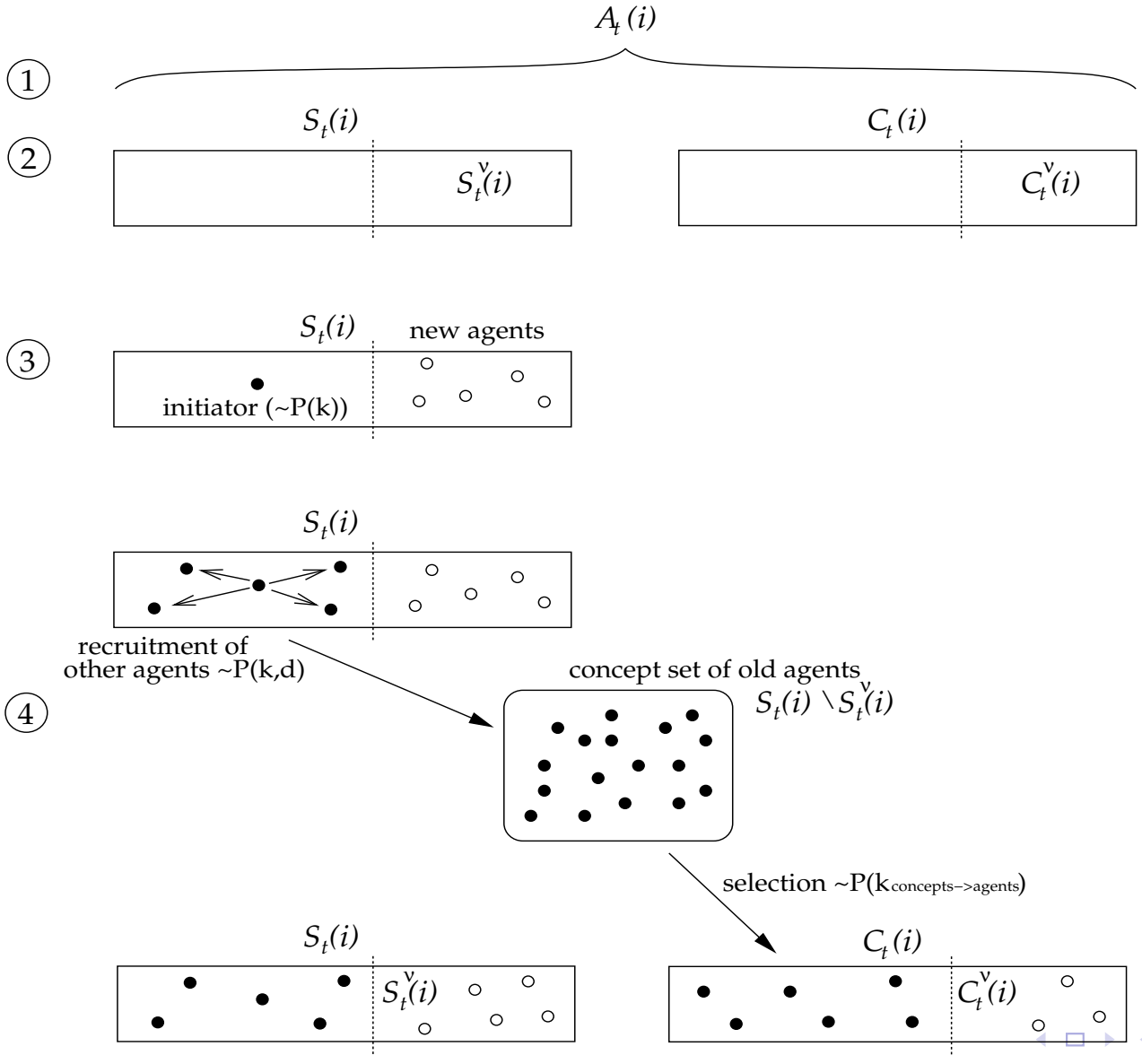
Choice of agents

Geometric distribution of agents, tri-modal distribution for newbies

Choice of concepts

Geometric distribution of concepts, uni-modal distribution of novel concepts

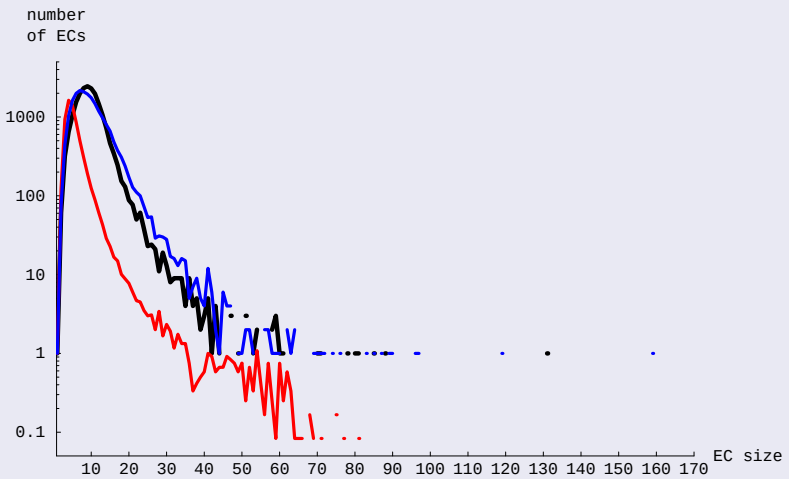
Model design



Reconstruction

Epistemic communities are produced by the co-evolution of agents and concepts

Degree distributions, clustering structure, epistemic structure are reconstructed.



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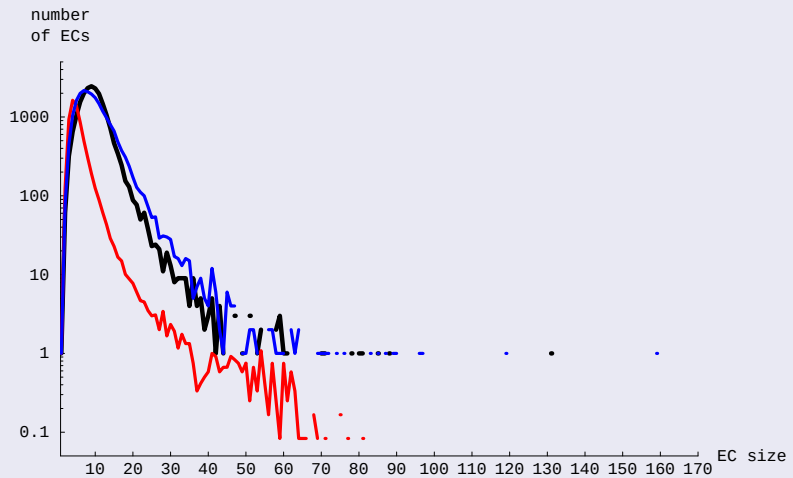

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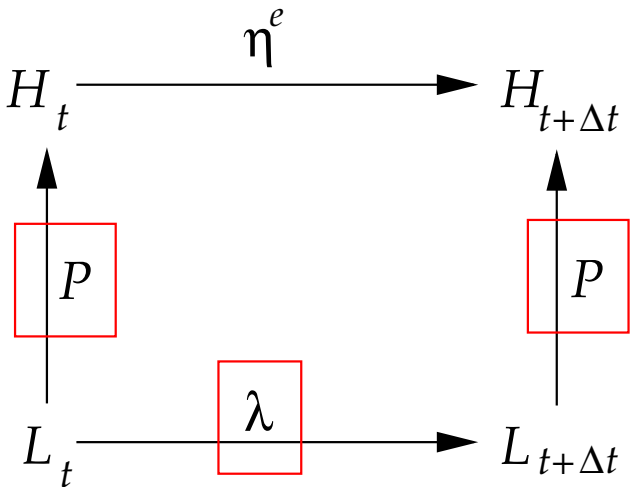

Integrated example of reconstruction in social science preliminary to studying knowledge diffusion and, eventually, naturalizing cultural anthropology

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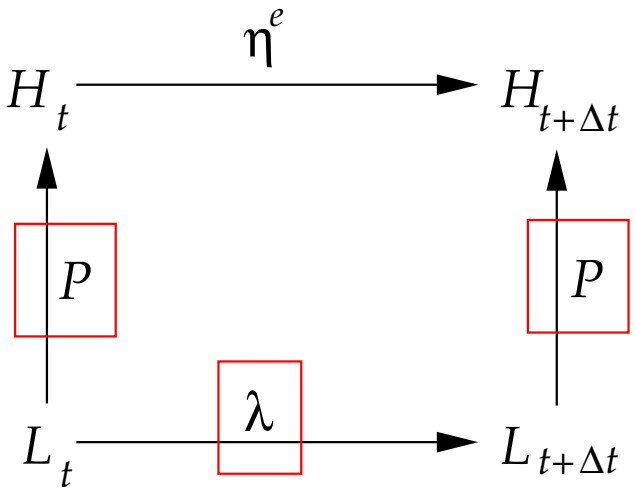

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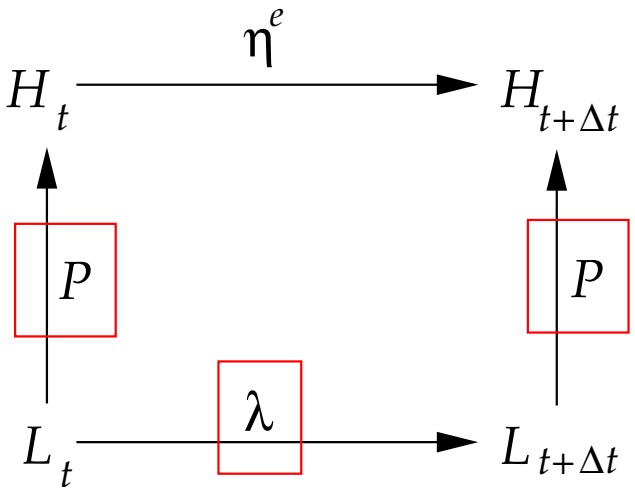

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Appraising levels

Relationships between different levels

- Dualism, reductionism ?
- Emergentism: low-level phenomena cause high-level phenomena, yet in turn not necessarily reduceable to low-level phenomena.

- Is it ok that a lower level creates a higher level, then the higher level in turn influences the lower level?
- Rather, different modes of access to a same process: dual-mode of operational access.
  "There may be emergence without emergent properties. Not asymmetric emergence of high-level properties out of basic properties, but symmetrical co-emergence of microscopic low-level features and high-level behavior" (Bitbol, 2005)

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"Observationism"

1. no substantial reality of levels
2. no reciprocal causation, but informational links
3. some phenomena cannot be rebuild from some given lower-level decriptions

Modeling links between levels

Reconstruction

- "Observationism" induces simply informational dependence between both levels: $\lambda(L|H)$, $\eta(L|H)$
- Thus, reconstruction failure may also come from ill-defined levels: not yielding enough information about the given phenomenon (e.g. learning & glial cells; concepts in addition to simple social interactions between agents)
- Reductionism only works when H is *fully deduceable*, not reduceable, from L.

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Co-evolutionary framework

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- No downward causation either, simply influence of already existing environmental artifacts
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