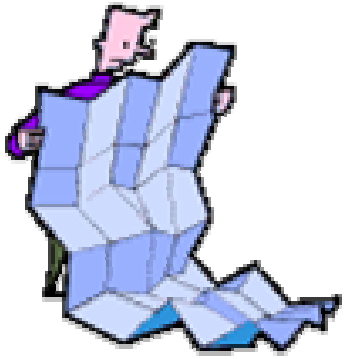
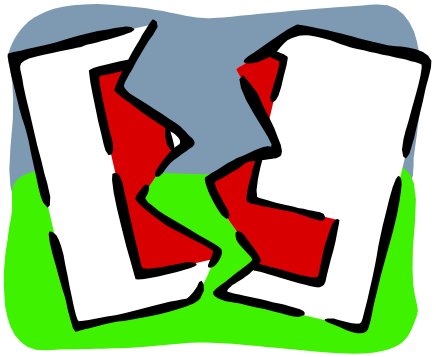
Research Roadmap



Existing Research Roadmap

- Is being discarded
- Start again



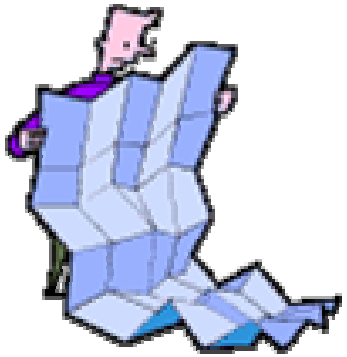
Goals of the Meeting

- everyone has a clear idea of what we are trying to achieve
- a consensus on the approach
- a structure for the roadmap
- a list of components that we've covered
- a list of gaps / things to do
- a corresponding list of people who will agree to fill those gaps.

Strawman Roadmap

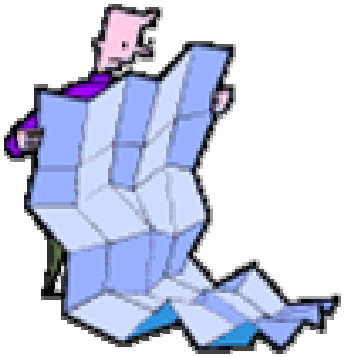
- Pull it apart
- Reconstruct it

Roadmap Objectives



Basic scientific techniques
System Engineering Methodologies
Application Requirements
Computational Architectures
Hardware Infrastructure

Roadmap Focus

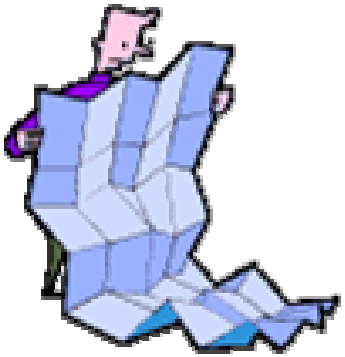


Key challenges

Priority Issues

Timescales

Roadmap Problems



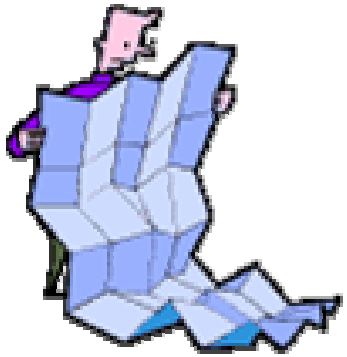
Cognitive Vision:

Vision++ ?
Vision + AI ?
Vision + Cognition ?
Vision $\subset$ Cognition ?

What brand of cognition?

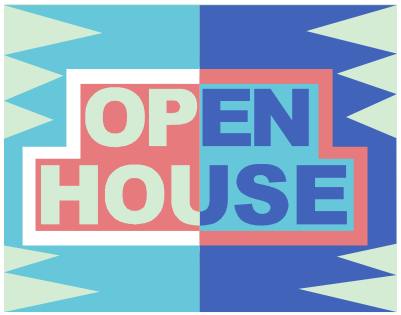
What makes computer vision cognitive?

Wanted …



Open research agenda

Encompassing all
Paradigms / Models

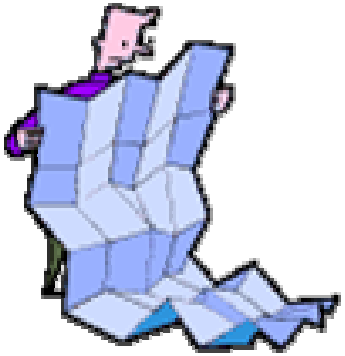


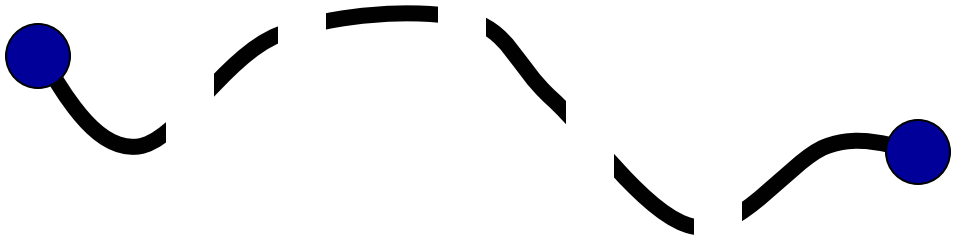
Wanted …

1. Inclusive research agenda
2. Neutral definition of cognitive vision
3. Delineate of the space of cognitive vision
4. Identify critical gaps in understanding
5. Strategy for filling these gaps
6. Identify competing approaches
7. Flag common research issues
8. Highlight contentious issues
    - embodiment
    - representations
    - nature of knowledge
    - role of language
    - inter-dependence of perception and action

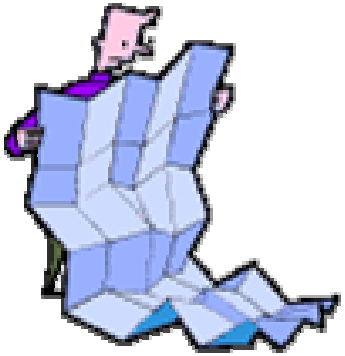
Roadmap Problems

Not One Point of Departure
And One Destination

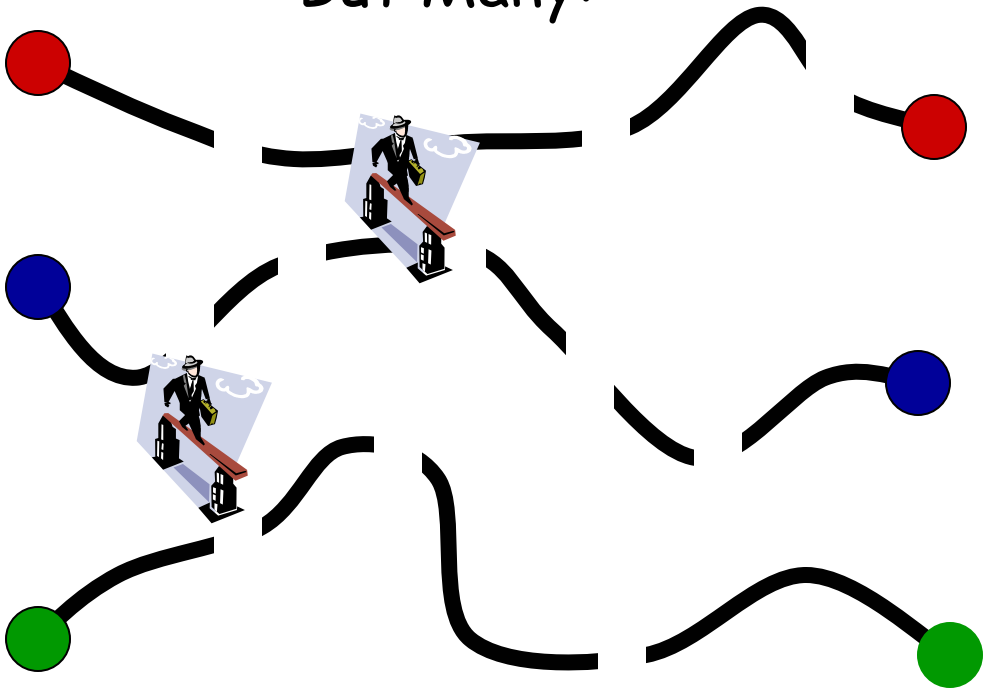




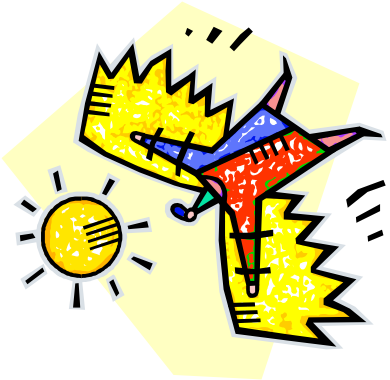
Roadmap Problems

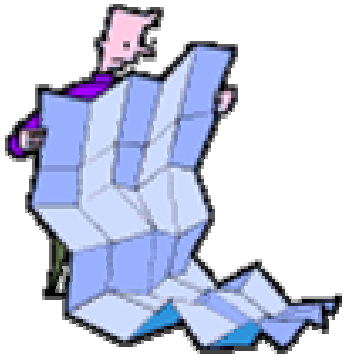


But Many:



Dangers





Lose initial focus

Alienate computer vision actors

Alienate KBS AI actors

Definition of Cognitive Vision

'Cognitive computer vision is concerned with integration and control of vision systems using explicit but not necessarily symbolic models of context, situation and goal-directed behaviour. Cognitive vision implies functionalities for knowledge representation, learning, reasoning about events & structures, recognition and categorization, and goal specification, all of which are concerned with the semantics of the relationship between the visual agent and its environment.'

ECVision

Definition of Cognitive Vision

'Cognitive computer vision is concerned with integration and control of vision systems using explicit but not necessarily symbolic models of context, situation and goal-directed behaviour. Cognitive vision implies functionalities for knowledge representation, learning, reasoning about events & structures, recognition and categorization, and goal specification, all of which are concerned with the semantics of the relationship between the visual agent and its environment.'

ECVision

Definition Problems

'How' rather than 'What'

Very architecture focussed

Not neutral to underlying paradigm

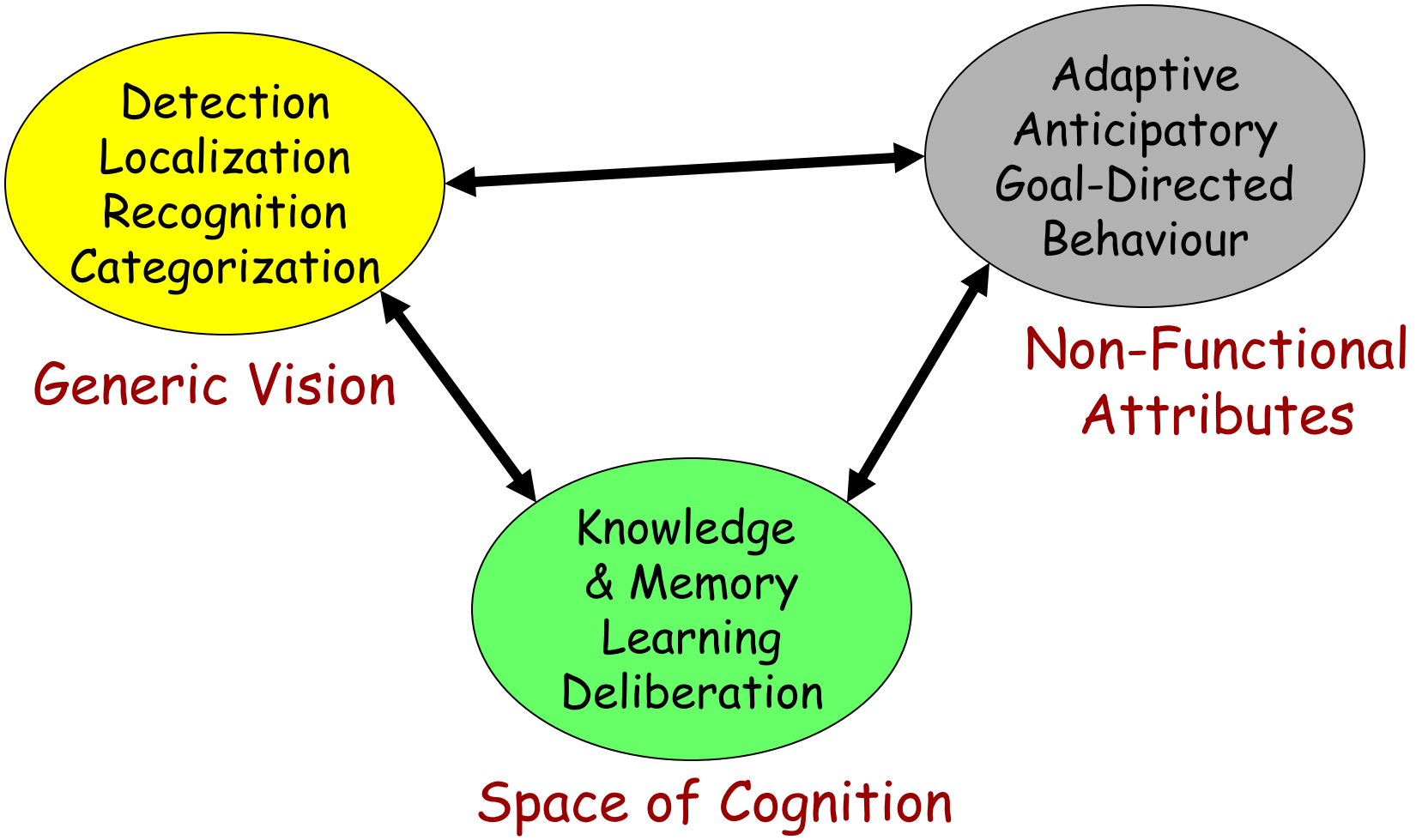
Definition of Cognitive Vision

A. Can achieve the four levels of generic visual functionality
    1. Detection
    2. Localization
    3. Recognition
    4. Understanding (role, context, purpose)

B. Purposive goal-directed behaviour
   Adaptive to unforseen changes
   Anticipate the occurrence of objects/events

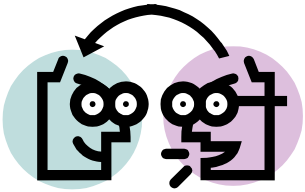
C. Achieved through:
    1. Learning semantic knowledge (form, function, & behaviours)
    2. Retention of knowledge (agent/environment)
    3. Deliberation about objects/events, including the cognitive system itself.

Definition of Cognitive Vision

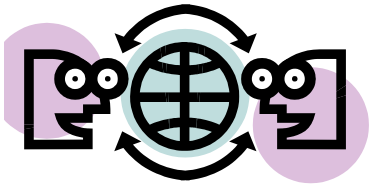


Approaches to Cognition

Cognitivist



Emergent



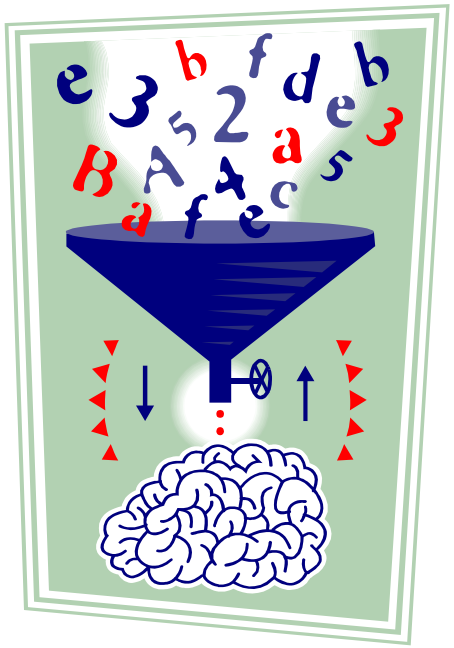
Perceptual capacities are based on models of external designer

Perceptual capacities are a consequence of historic embodied enactive development

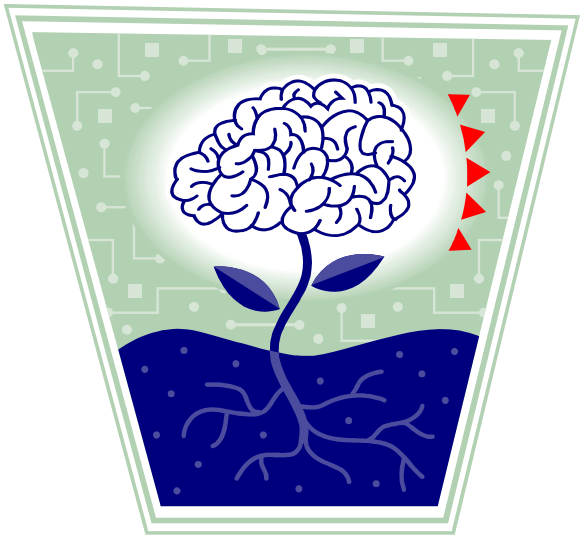
Information Processing / Symbolic Representational Systems

Connectionist Systems/ Dynamical Systems / Enactive Systems

The Kernel of the Problem



OR



Cognitivist Hybrid Connectionist Dynamical Enactive

Cognitivist Hybrid Connectionist Dynamical Enactive

- Knowledge provided by human designers
- Possibly refined through learning
- Symbols refer to objects that are external to the system
- Often brittle

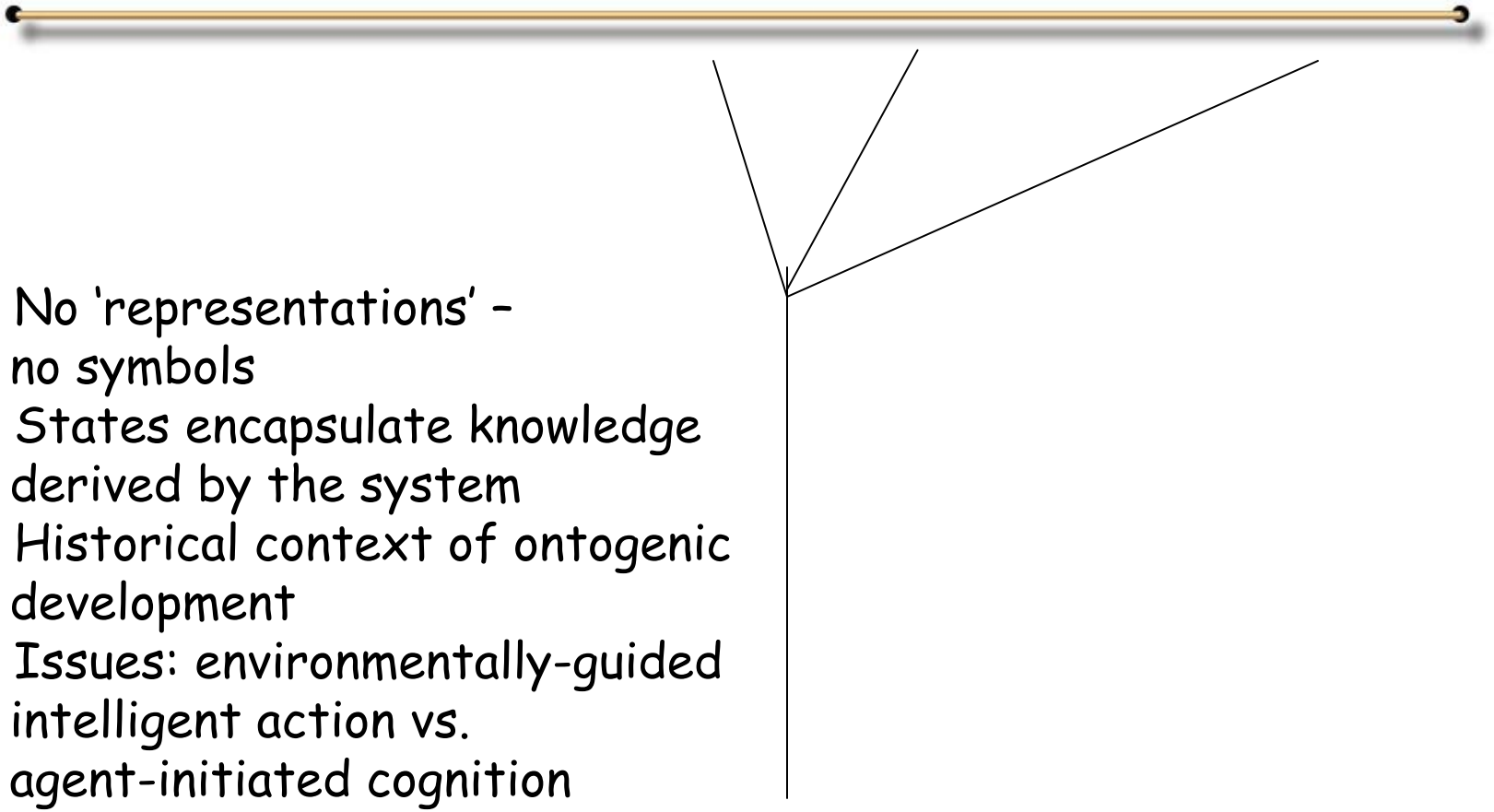
  Representations based on axioms & assumptions of an external designer
- Fail when they stray far from the domain for which they were designed

Cognitivist Hybrid Connectionist Dynamical Enactive

- Generic representational schemes
- Populated entirely by the agent
- Incremental unsupervised learning
- Deliberative behaviour designed in

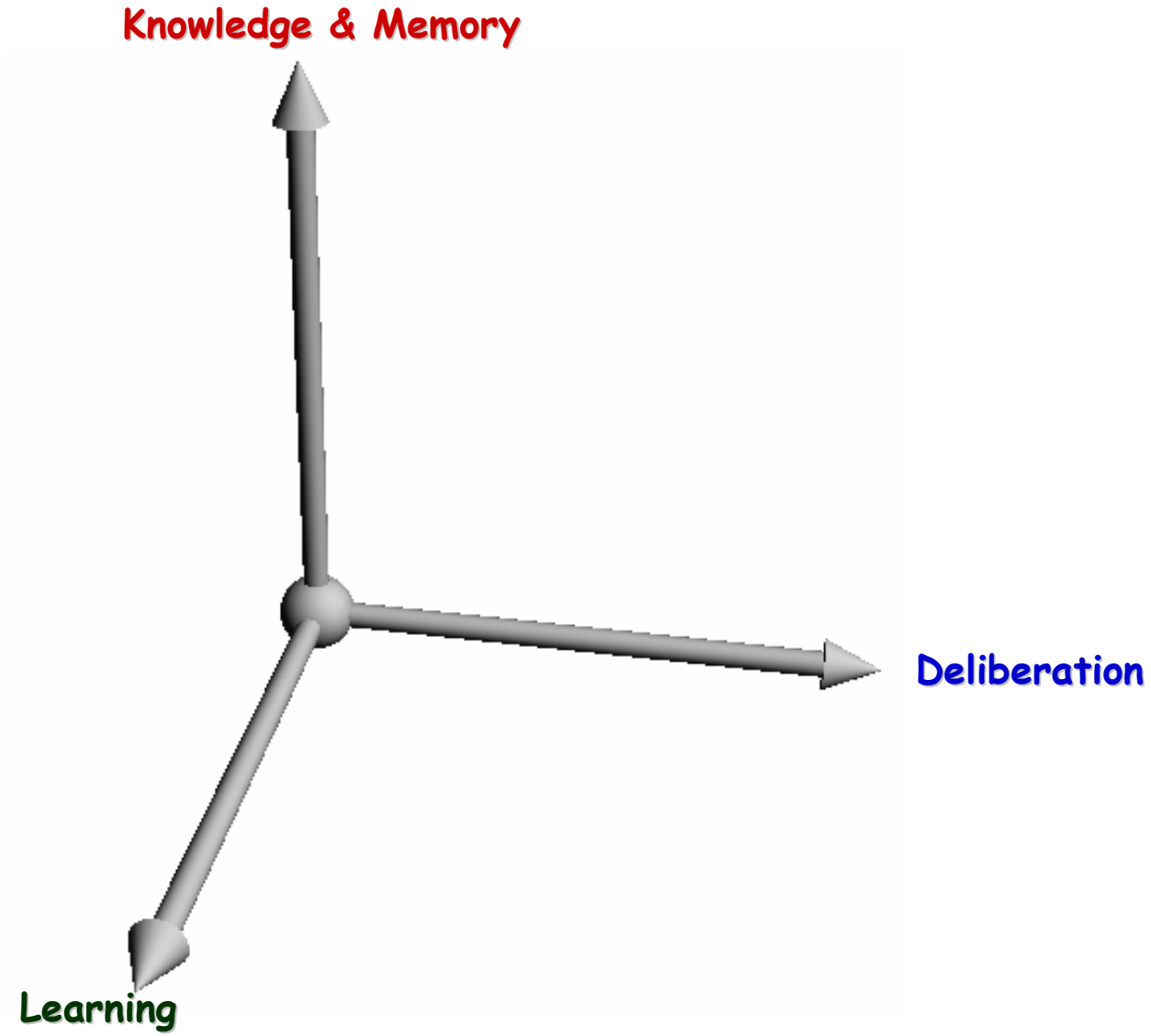
(link between perceptual-motor skill and knowledge representation controlled by designer)

Cognitivist **Hybrid** **Connectionist** **Dynamical** **Enactive**



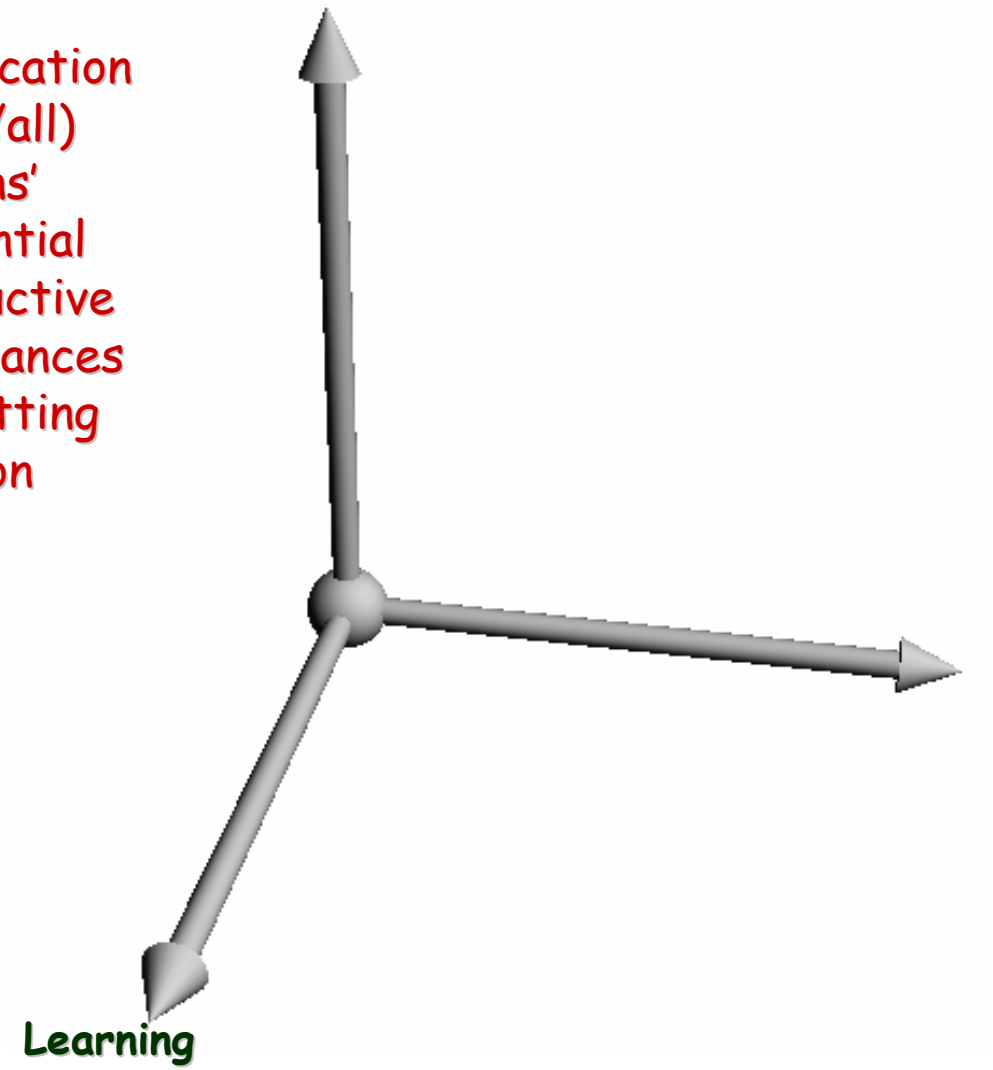
- No 'representations' – no symbols
- States encapsulate knowledge derived by the system
- Historical context of ontogenic development
- Issues: environmentally-guided intelligent action vs. agent-initiated cognition

The Space of Cognitive Vision

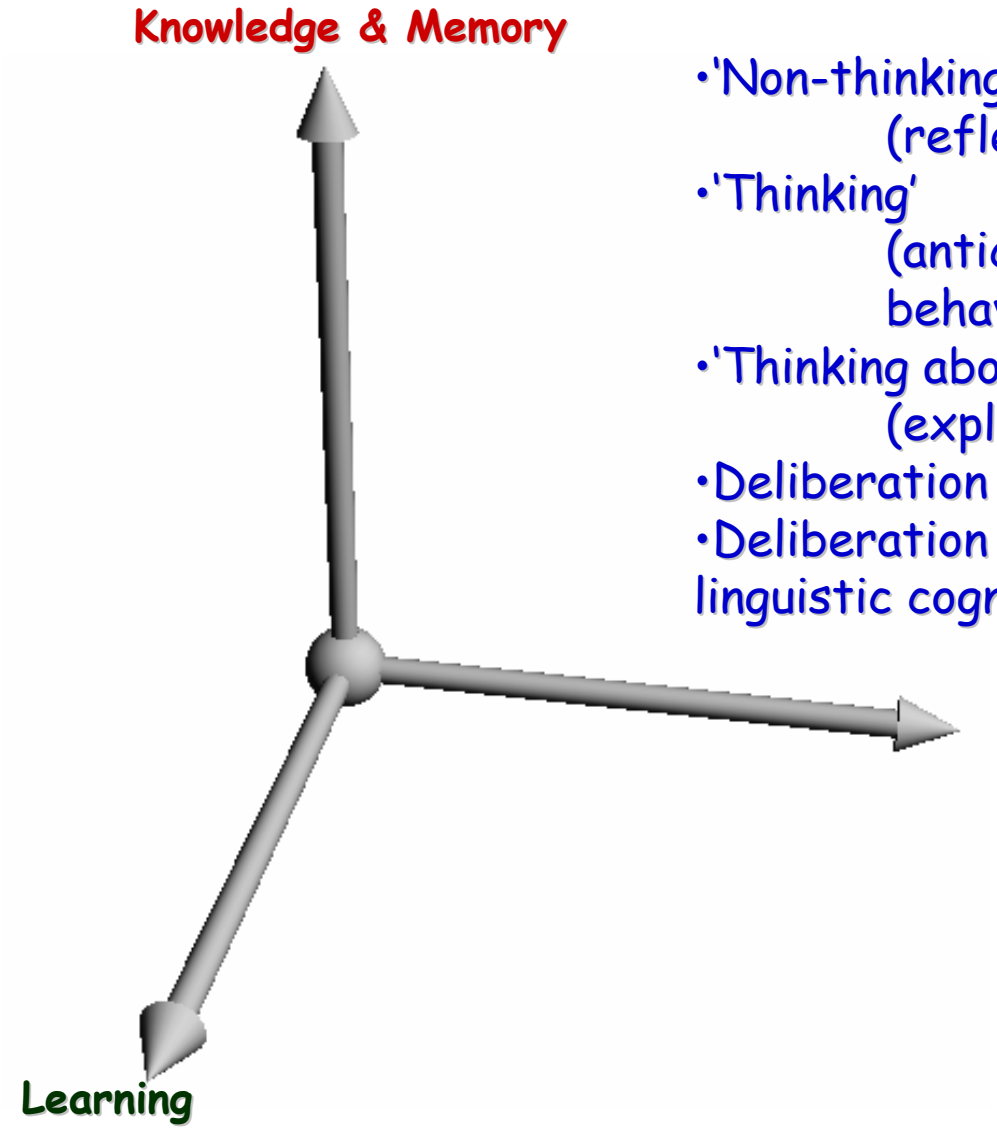


The Space of Cognitive Vision

- A priori specification
- Learned (some/all)
- 'Representations'
  - Referential
  - Constructive
- Requisite invariances
- Graceful forgetting
- Form vs function
- Adaptiveness
- Anticipation
- Time

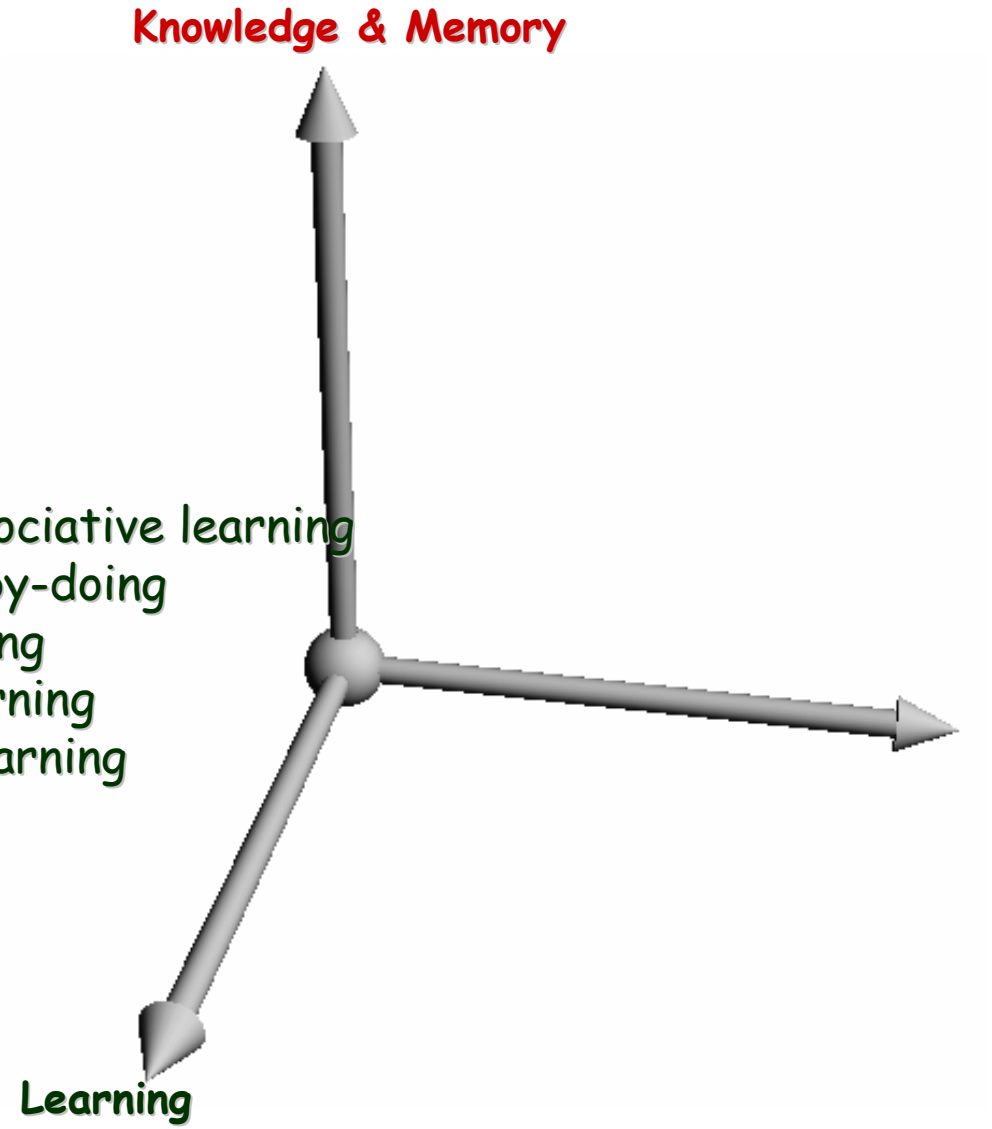


The Space of Cognitive Vision



- 'Non-thinking (reflexive behaviour)
- 'Thinking' (anticipatory adaptive behaviour)
- 'Thinking about Thinking' (explicit reflection)
- Deliberation as symbolic reasoning
- Deliberation as re-entrant linguistic cognitive co-development

The Space of Cognitive Vision



- Unsupervised associative learning
  learning-by-doing
- Supervised learning
- Unsupervised learning
- Reinforcement learning
- On-line
- Off-line

Research Agenda Structure

For Each Paradigm: Cognitivist / Hybrid / Emergent

1. **Generic Vision Capabilities**
   - (a) Detection
     - State of the art
     - Key issues
     - Desirable capabilities
     - Possible approaches
   - (b) Localization
   - (c) Recognition
   - (d) Understanding
2. **Learning**
   - State of the art
   - Key issues
   - Desirable capabilities
   - Possible approaches
3. **Knowledge & Memory**
4. **Deliberation**
5. **Interdependencies**

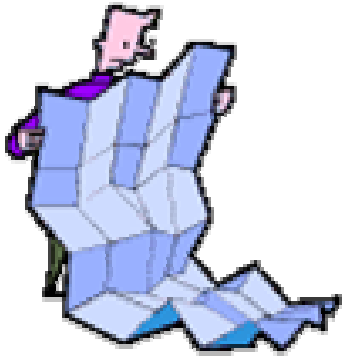
   Vision-Learning / Vision-Memory / Vision-Deliberation / Learning-Memory / Learning-Deliberation / Memory-Deliberation

Some Challenges

- Categorization by Function
- Integration/ Emergence of Language
- Deliberation: Symbolic Reasoning vs Linguistic Trophyllaxis
- Time: Anticipation & Projection
- Configuration of Visual Capabilities
- Plastic Memory: Graceful Forgetting

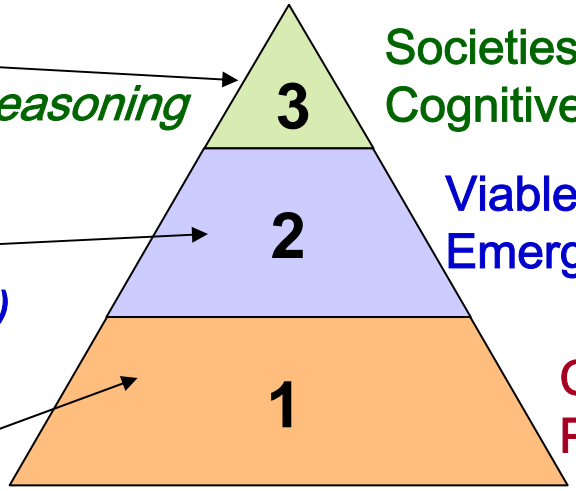
Embodiment
(Interactive physical exploration of environment)

Research Roadmap



Enactive Systems

IP Representational — Hybrid — Connectionist — Dynamical



Emergence of Language:
Explicit deliberative self-reflective reasoning

Societies of
Cognitive Entities

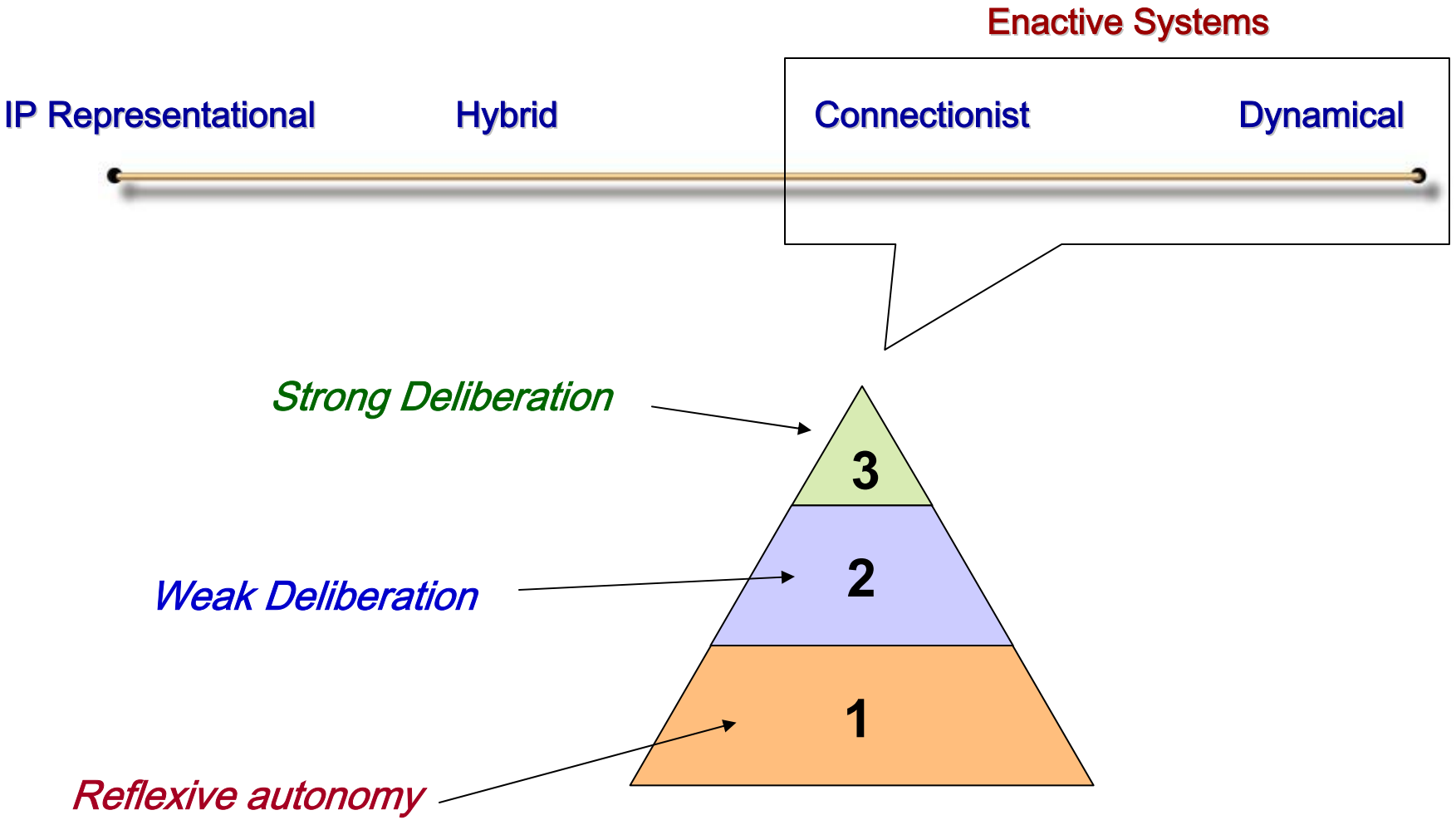
Rationalization of
interactions & perceptions:
Intelligent (adaptive & anticipatory)
behaviour

Viable Organisms
Emergence of Cognition

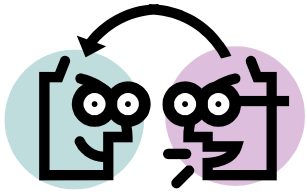
Cellular Organization
Physical Instantiation

Structural coupling with
the environment

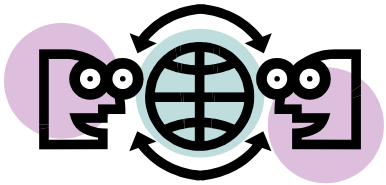
Same approach: operational closure

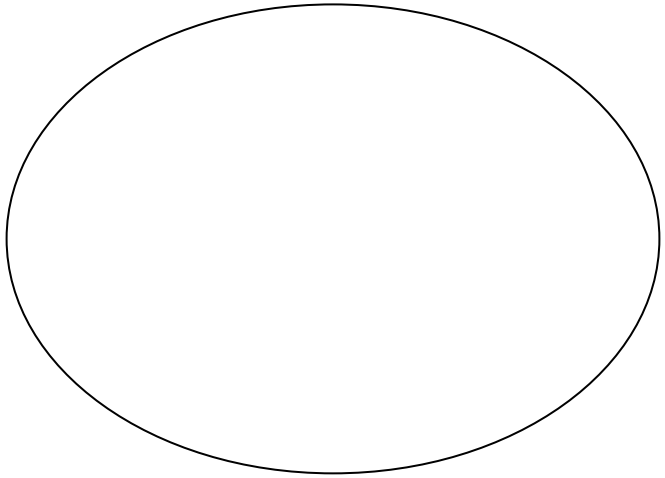

Enactive Systems
IP Representational
Hybrid
Connectionist
Dynamical
Strong Deliberation
Weak Deliberation
Reflexive autonomy
3
2
1

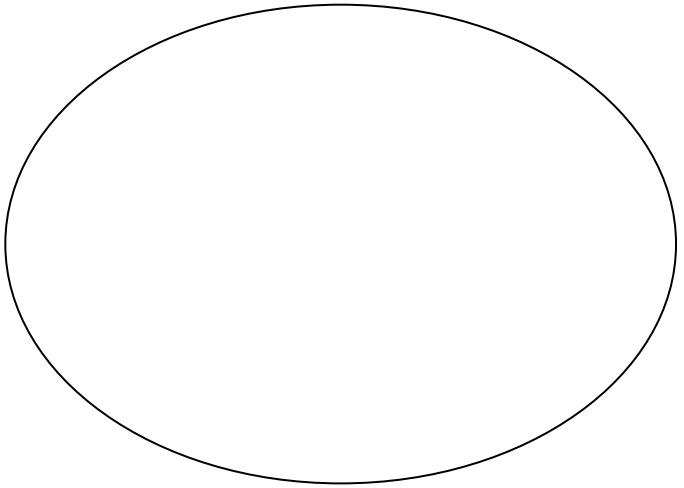
Cognitivist



Emergent



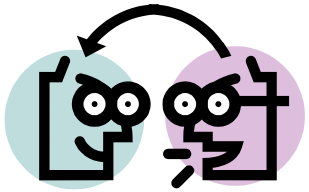




Information Processing /
Physical Symbol /
Representational Systems

Connectionist Systems/
Dynamical Systems /
Enactive Systems

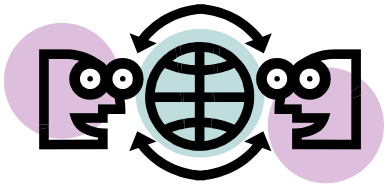
Cognitivist



Physical symbols refer to objects that are external to the systems

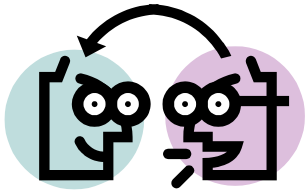
Information Processing / Physical Symbol / Representational Systems

Emergent



Connectionist Systems/ Dynamical Systems / Enactive Systems

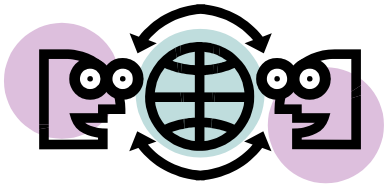
Cognitivist



Reasoning processes operate on perceptually-derived representations

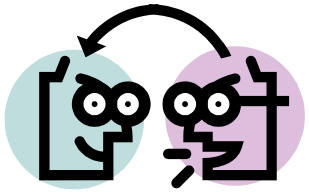
Information Processing / Physical Symbol / Representational Systems

Emergent



Connectionist Systems/ Dynamical Systems / Enactive Systems

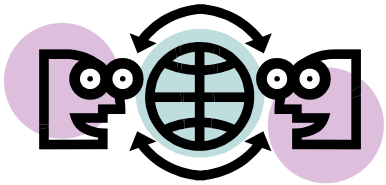
Cognitivist



Plans actions to achieve goals: Perception-Reason-Action cycle

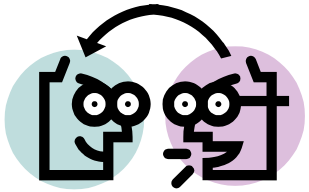
Information Processing / Physical Symbol / Representational Systems

Emergent



Connectionist Systems/ Dynamical Systems / Enactive Systems

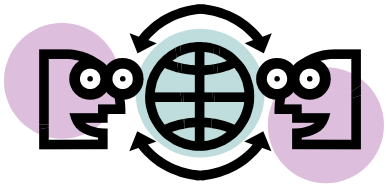
Cognitivist



Exploit user-models to render the problem tractable

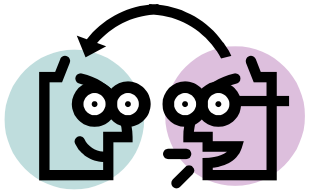
Information Processing / Physical Symbol / Representational Systems

Emergent



Connectionist Systems/ Dynamical Systems / Enactive Systems

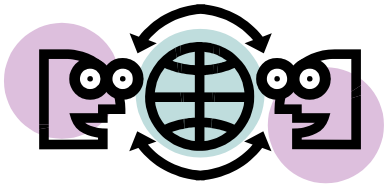
Cognitivist



Exploit user-models to render the problem tractable

Information Processing / Physical Symbol / Representational Systems

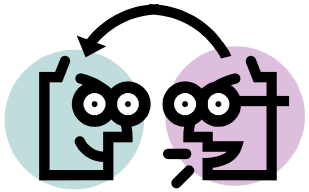
Emergent



Process view of knowledge: Collection of abilities 'How to Do' things

Connectionist Systems/ Dynamical Systems / Enactive Systems

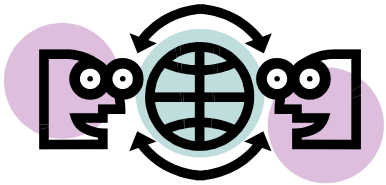
Cognitivist



Exploit user-models to render the problem tractable

Information Processing / Physical Symbol / Representational Systems

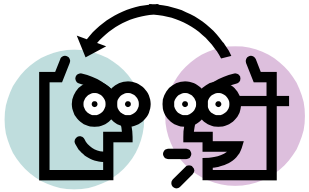
Emergent



Knowledge is dependent on the agent and its environmental context

Connectionist Systems/ Dynamical Systems / Enactive Systems

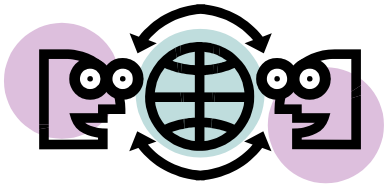
Cognitivist



Exploit user-models to render the problem tractable

Information Processing / Physical Symbol / Representational Systems

Emergent

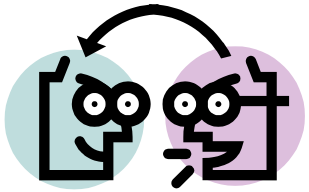


Reflexive & adaptive behaviours

Deliberative & cognitive behaviours

Connectionist Systems/ Dynamical Systems / Enactive Systems

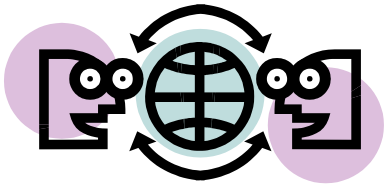
Cognitivist



Exploit user-models to render the problem tractable

Information Processing / Physical Symbol / Representational Systems

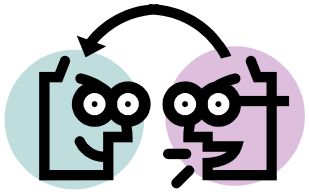
Emergent



Emergence of cognition: co-development of gent and its environment in real-time

Connectionist Systems/ Dynamical Systems / Enactive Systems

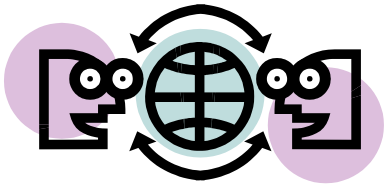
Cognitivist



Exploit user-models to render the problem tractable

Information Processing / Physical Symbol / Representational Systems

Emergent



System builds its own understanding: cognition emerges by exploratory learning & development

Connectionist Systems/ Dynamical Systems / Enactive Systems