Challenges & Solutions in Artificial Cognitive Systems

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Outline

- Cognitive Systems?
- Challenges and Opportunities
- An approach to study of the problems
- "Appetizers"
- Wrap-up

Cognitive Systems

- Cognition: the process of acquiring knowledge and understanding through reasoning, experience and the senses
- Artifacts that have competencies for representation, reasoning, acquisition and acting on the external world

A few side axioms

- Cognitive systems only makes sense in an embodied context
- Passive sensing is inadequate for cognition

CoSy: Cog Sys for Cog Ass

- Studies of artificial embodied agents that interact with people in everyday environments

What we are trying not to do!

©[CMU / RI / CS - Thrun & Kiessler 2001]

This is not a singleton, there are lots of poor designs out there!

Key Input to the Challenge

- Good old fashioned artificial intelligence (GOFAI)
- Flexible Manipulation/Mobility/Grasping Systems
- "Robust" small scale language systems
- Statistical learning theory
- "small scale vision systems"
- Moore's Law!

Key issues for system design

- Representations & Architectures
- Perception-Action Integration
- Strategies for Learning
- Planning and Autonomy
- The role of Language
- Interaction Design
- Categorical Perception

Representations

- Types and roles of representations
- Open-ended representations
- The relation to language
- Integration across space, action and self-image ... while considering uncertainty, deliberation and facilitating communication

Architecture

- Organization of system
- Integration across reactive, deliberative and reflexive process across control, reasoning and communication
- Most attempts have been "religious"
- A need to integrate across disciplines
- Integration of self-observation and introspection

Perception-Action Integration

- Beyond Pre-Programmed Control
- Beyond a fixed motion vocabulary
- Adaptation to changes in embodiment
- Dynamic generation of "primitives"
- Is perception-action generation feed-forward driven? Or how dominant is feed-forward control?

Learning

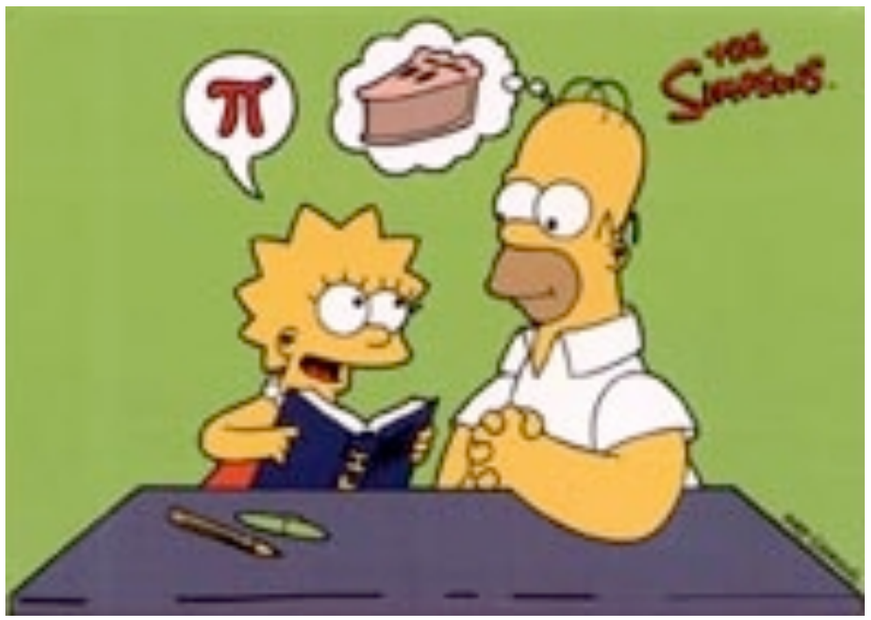
- Learning is multi-faceted:
  - life-long, open-ended, incremental
- The role and impact of learning at different stages
  - Tutor-driven vs exploratory learning
- Maintenance of consistency across modalities
- Distribution of learning and adaptation

Planning and Autonomy

- Operation is always in a dynamic environment
- Re-planning will be required
- Paradigms for error detection and recovery across system and tasks
- Coupling between architecture and autonomy

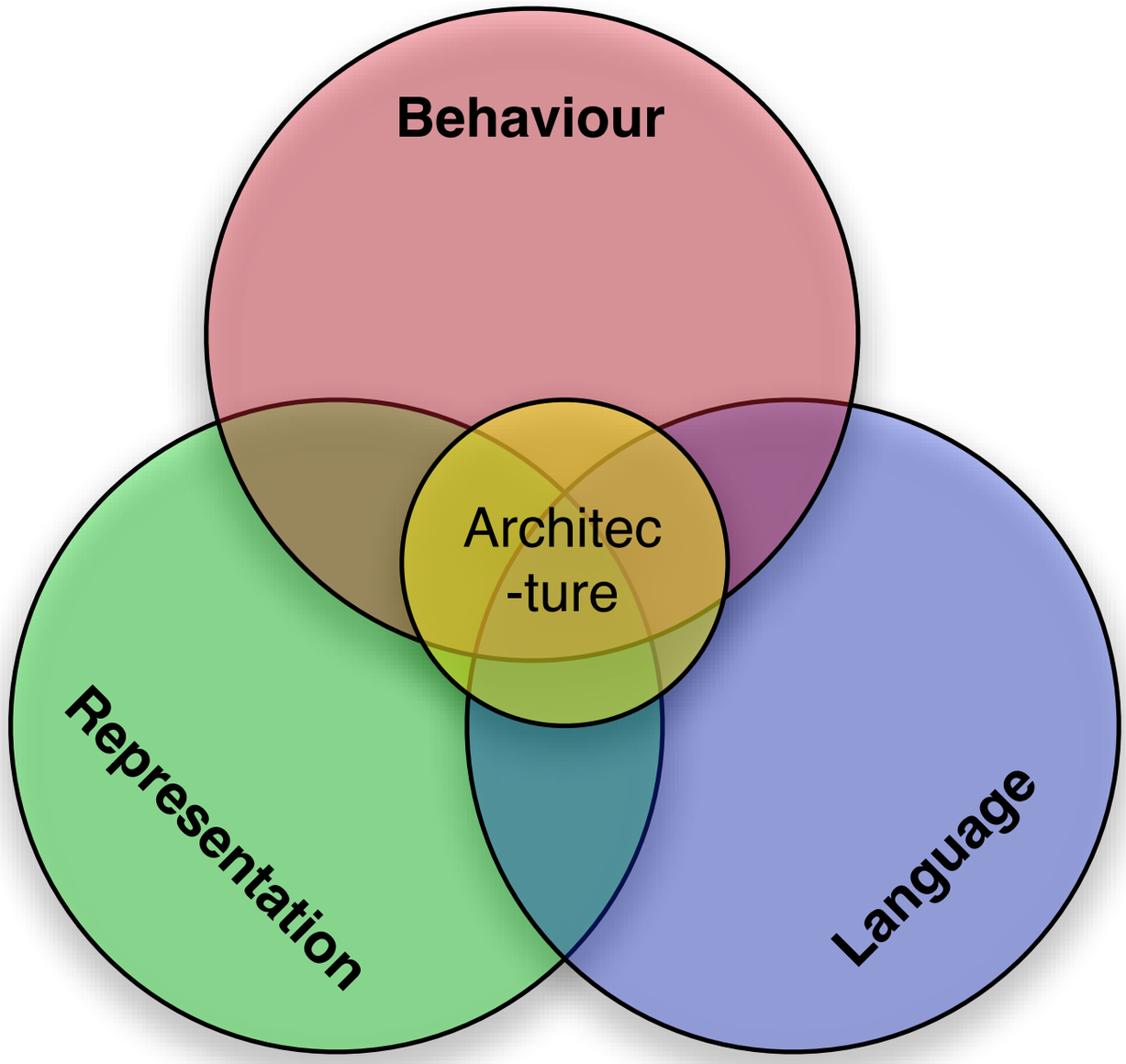
Language and Interaction

- Communication is key to a cognitive system
- Communication >> Language
- Integration of Body, Speech, Motion/Context
- Co-operation poses interesting challenges
  - Dialog Design, Resolution, Gaze, Attention, ...



Structure?

- The basic components



CoSy Consortium

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CNRS	K. O'Regan
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Approach

- Study of problems centered on three demonstrator scenarios
- The scenarios are important focal points for the design of studies
- The physical implementation is secondary
- The scenarios are "mental integrators"

Scenarios / Demonstrators

- Explorer
- PlayMate
- Philosopher

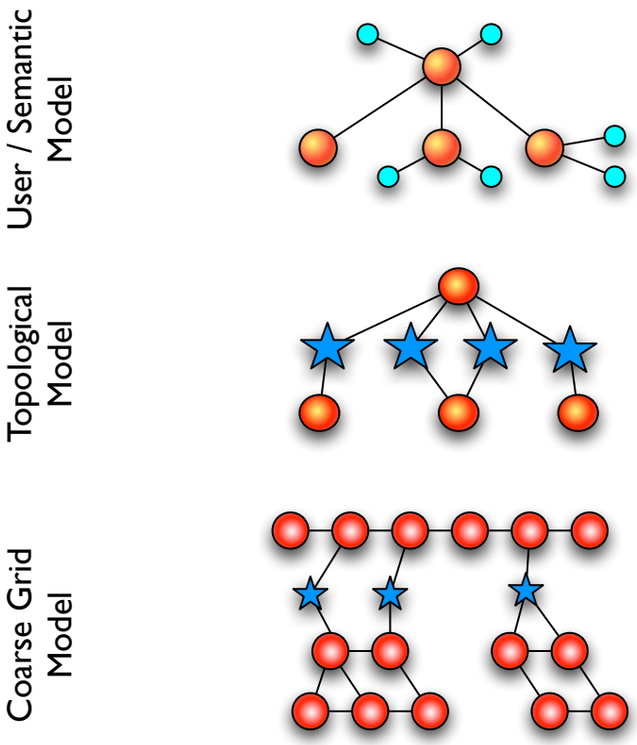
Explorer

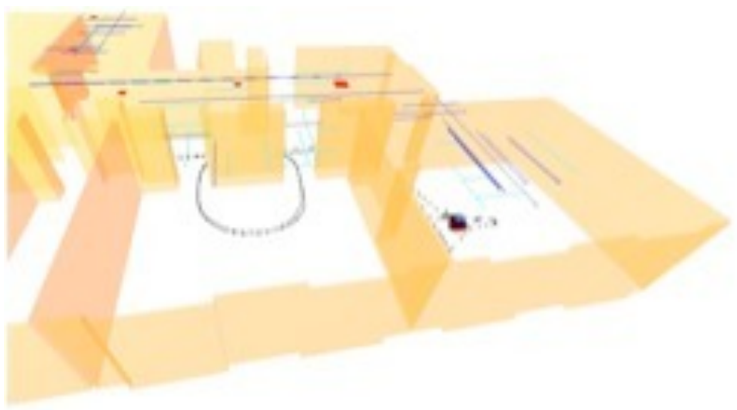
- Spatial Exploration
  - Generation of Semantic Spatial Hierarchies
- Reasoning about Space
  - Is Raja's office next to Rachid's?
- Communicating about space?
  - Relation between space models and dialog/lang

The "Easy" Fix

"Now! …. That should clear up a few things around here!"

Explorer





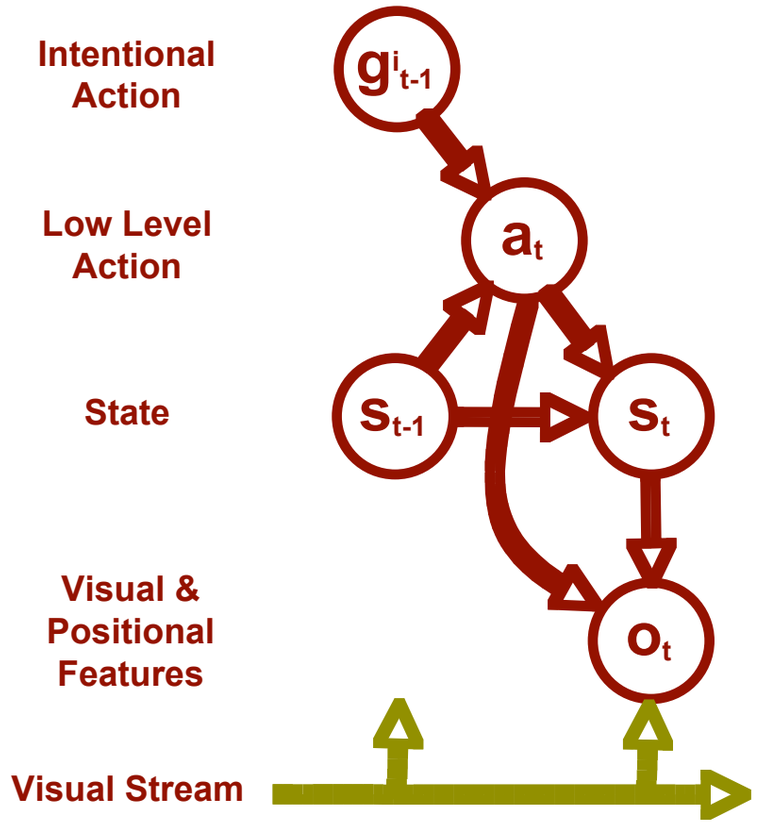
- Anchoring between human mental models and human models
- From semantics to metric geometry

PlayMate

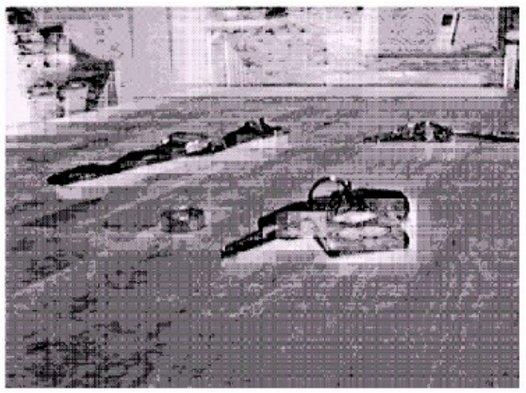
- Manipulative acts to construct an artifact
  - Observe actions
  - Generate internal representation(s)
  - Replicate artifacts (not blind action replication)
    - This is not learning by direct imitation
- Example construction of a bridge / house
- Recognition of key objects/action properties and use of these to generate actions

PlayMate

- Fundamental Challenges
  - Object affordances (what are they are how are they recognized?)
  - Action modelling
  - Dynamic Planning
    - Error / Success diagnostics
    - Dynamic Recovery



PlayMate



Philosopher

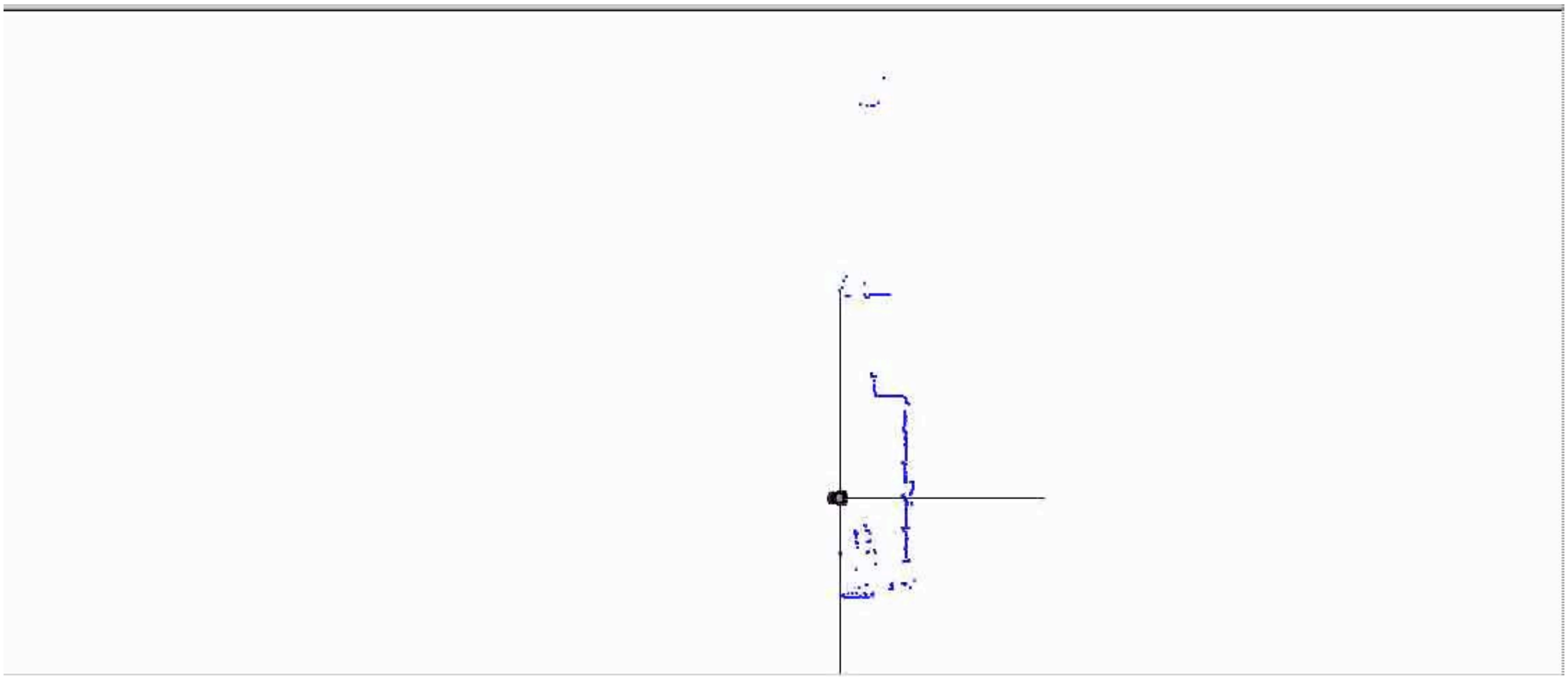
- Discovery of new facts / hypotheses about the world entirely based on reflexive processing / reasoning

- "this must be a coffee maker" or
- "given where we have been this must be Aarons office"

Status

- Explorer
  - Generation of models of the environment and basic "human" annotation
- PlayMate
  - Primarily visual scene modelling and early manipulative acts
  - Manipulation is picking up speed!
- Philosopher
  - Has not been studied in much detail, yet!

Explorer Example 1



Explorer Example 2

PlayMate

- Building spatial exo-centric models
- Spoken dialog to interact with system
- First spatial planning systems
- Basic Manipulation Skills

- The emphasis is on cognitive skills rather than manipulative skills

PlayMate

Key issues for system design

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Summary

- Cognitive systems might be the next step in "intelligent" systems
- The problems are truly hard and require interdisciplinary collaboration
- Reductionistic vs holistic approach
- Aim is science rather than engineering!

Summary

- Collaborative approach to design of systems
  - The system requirements
  - The human model of the world
    - Cognitive systems - building a bridge
- Building systems for everyday people in everyday setting is hard.
  - Real Systems for Real People in the Real World!