

Embodied Machines

- Artificial vs. Embodied Intelligence
 - Artificial Intelligence (AI)
 - Natural Language Processing (NLP)
 - Goal: write programs that understand and identify grammatical patterns
 - Assign conventional meanings to words
 - Context (word environment) can be looked at to some extent to disambiguate meaning
 - Meanings are lists of associations and relations
 - Associations are human programmed ontologies

Embodied Machines

- Embodied Intelligence
- Artificial life
- Self organizing intelligence
 - Meaning is situated in experience:
 - Organisms structure world to suit their needs
 - Organisms perceive the world via a body
 - Language emerges through self-organization out of local interactions of language users.
 - Living ecology better metaphor for cognitive system than computer program
 - Artificial systems need human-like cognitive capabilities to be effective users of human language

Embodied Machines

- Self organization
 - Bootstrapping
 - Means of learning
 - Drives/goals/tasks
 - Experience in world
 - Interaction with others
 - Intelligence
 - Language evolves both in the individual and in the community through negotiation

Embodied Machines

- Talking Heads Experiments (Luc Steels)
 - Create simple robots with
 - Perceptual systems
 - Language production and listening capabilities
 - Learning capability
 - Put robots in environments containing objects of interest and other robots to talk to
 - Give robots a task requiring speaker/hearer interaction:
Guessing Game
 - Goal: Observe how learning takes place
 - Potential to modify environment in various ways
 - Change participants, stimuli, etc.

Embodied Machines

- “Building colonies of physical autonomous robots roaming the world in search of stimulating environments and rich interactions with other robots is not feasible today. So how can we ever test seriously situated and socially embedded approaches to cognition?”
- Teleporting
 - Human hardware and software are not distinct
 - Talking heads have distinct heads and bodies
 - ‘heads’ can be loaded into different bodies
 - Physical bodies can be located anywhere in the world

Embodied Machines

- Robot bodies
 - Physical bodies located somewhere in the world in real space
- Virtual agent
 - Software structure (memory, lexicon, grammar)
- Real agent
 - Exists when virtual agent is loaded in a physical robot body
 - Real agents can only interact when they are instantiated in the same physical environment
 - No long distance communication

Embodied Machines



Robot body

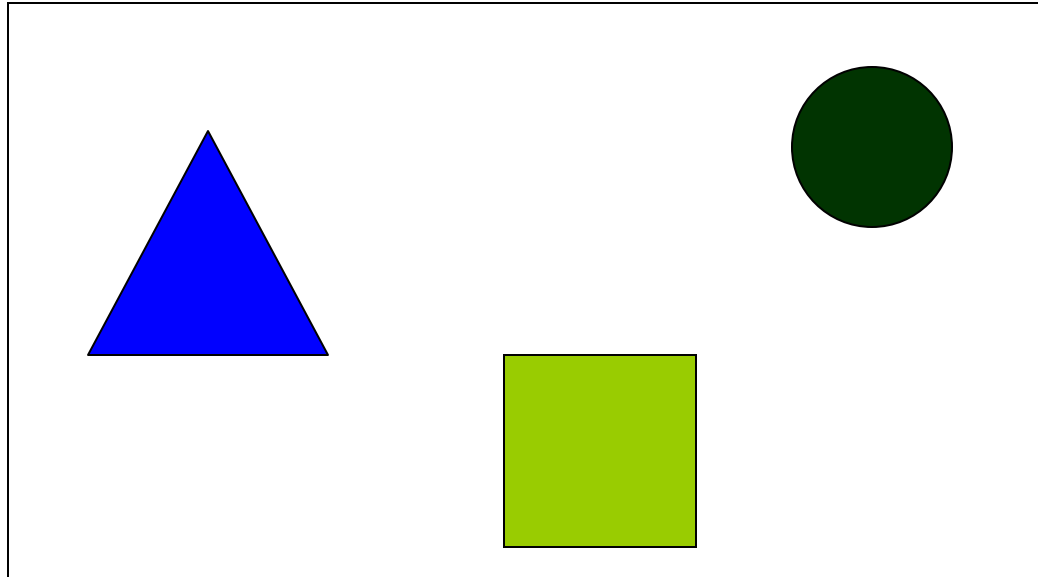
- Camera on pan/tilt motors
- Loudspeaker for output
- Microphone for input
- Computer

For experimenters

- Television screen < camera
- Computer screen < computer

Embodied Machines

- Environment
 - White board containing basic shapes of various sizes and colors

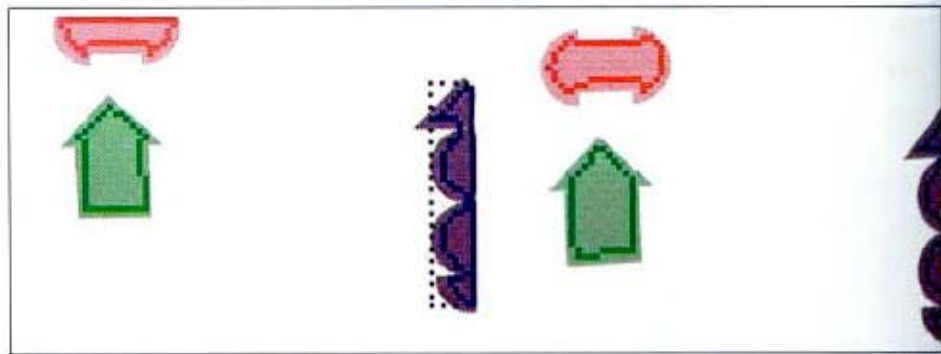
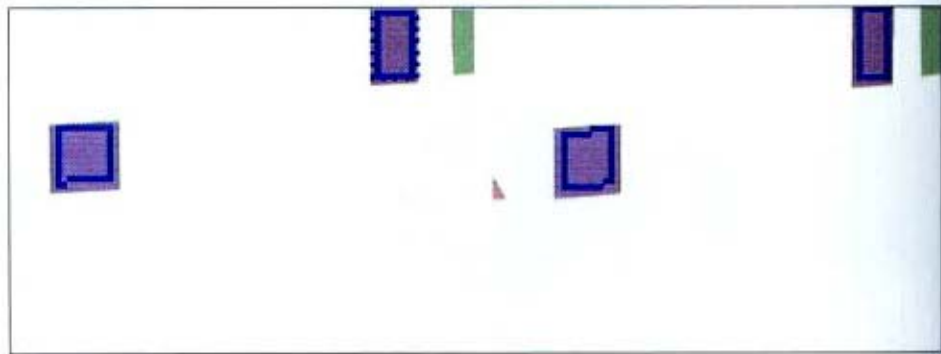
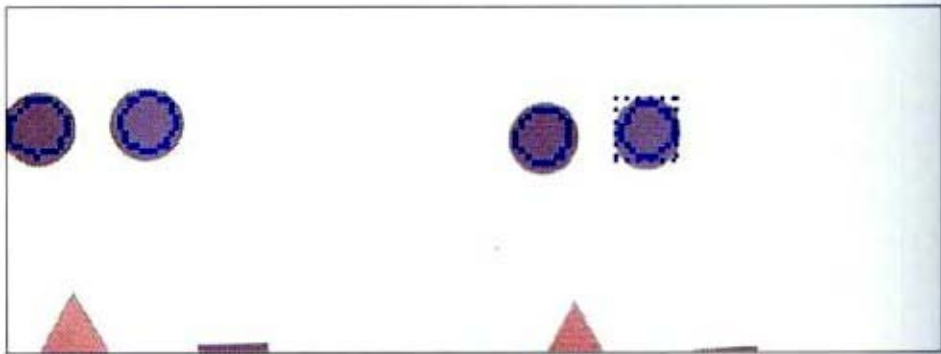


Embodied Machines

- Agent's Brain Architecture
 - Perceptual layer
 - Sensory system visual & auditory
 - Conceptual layer
 - Categorization/ontology - no initial values
 - Lexical layer
 - Words – no initial values
 - Syntactic layer
 - Word order – no initial values
 - Pragmatic layer
 - Scripts for language games

Embodied Machines

- Perceptual layer
 - Visual system
 - Camera
 - Segmentation programs
 - Easy environment: basic shapes, clear boundaries
 - Auditory system
 - Microphone
 - Auditory signal processing



Embodied Machines

- Conceptual layer
 - Categorization/ontology - no initial values
 - World is a collection of objects (shapes on whiteboard)
 - Robots want to build a set of meanings
 - Meaning is a region represented by a **prototype**
 - A particular color, area and location
 - The **category** of every object is the region represented by its nearest prototype
 - An object is **discriminated** if its category is different from all the others in the context

Embodied Machines

CONTEXT:

A=(0.1, 0.3)

B=(0.3, 0.3)

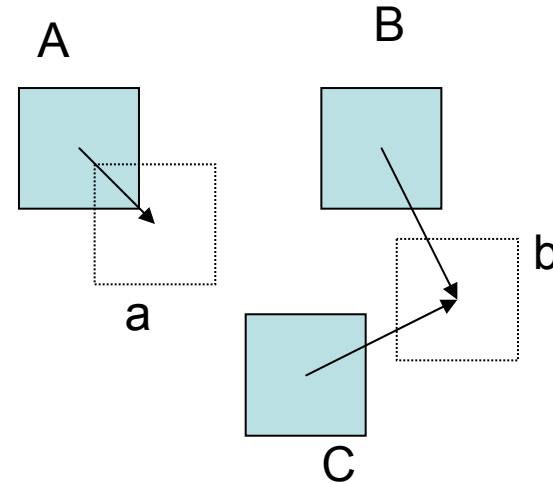
C=(0.25, 0.15)

ROBOT'S PROTOTYPES:

a=(0.15, 0.25)

b=(0.35, 0.3)

A is discriminated
B and **C** are not



A is categorised as **a**
B is categorised as **b**
C is categorised as **b**

Embodied Machines

– Lexical layer

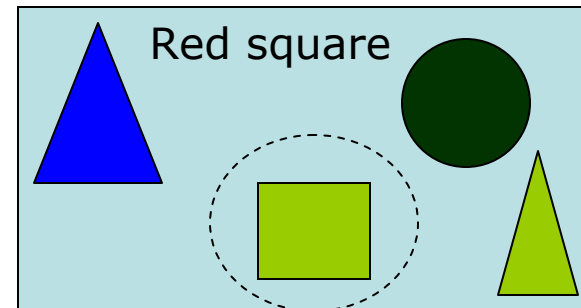
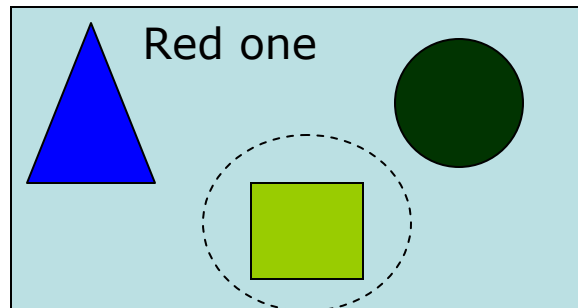
- Words initially created randomly
- Associated with categories
- Word-category association strengthened through use

– Pragmatic layer

- Scripts for guessing game
- Provides robot's *raison d'être*
- Drive module

Embodied Machines

- The Guessing Game
 - Speakers role:
 - Speaker agent randomly searches environment, locates an area of interest (context)
 - Focuses hearer's attention on same context
 - Chooses an object in context (topic)
 - Describes object to hearer



Embodied Machines

- The Guessing Game
 - Hearer's role:
 - Hearer tries to guess what speaker is referring to
 - Indicates guess by pointing at topic (focusing)
 - Game succeeds if hearer guesses right
 - Associations between word and category strengthened
 - If hearer guesses wrong
 - Speaker points to topic as well
 - Speaker and hearer adjust strength of association between lexical item and category

Embodied Machines

- Why Guessing Game can fail:
 - Speaker has no word for object of interest
 - Hearer does not have word
 - Hearer has word but has assigned it to some other concept
 - Speaker and Hearer have different vantage points

Embodied Machines

- If speaker has no word for object of interest.
 - Speaker creates word
 - Speaker and hearer strengthen association between new word and target

Embodied Machines

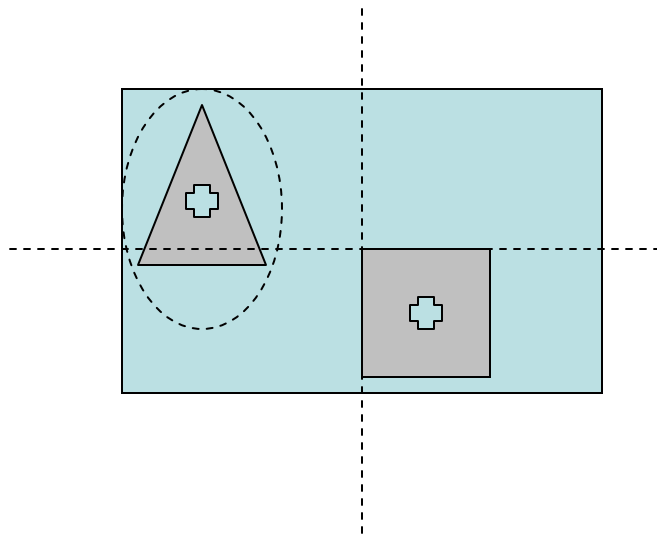
- If hearer doesn't have word,
 - Speaker points to target
 - Hearer creates association between new word and target
 - Speaker reduces strength of association between word and target

Embodied Machines

- If hearer has word, but it refers to a different concept
 - Hearer points to (wrong) target
 - Game fails
 - Speaker points to correct target
 - Hearer creates association between word and new target

Embodied Machines

- Carving up reality
 - No *a priori* categories are given to agents
 - Agents can perceive edges → contours → shapes, color, luminance, location of centers



Possible categorization strategies:

High thing
Left thing

Embodied Machines

– Correlates in biological Cognition

- Cotton, thistle, flax
 - Human: clothing source (cotton,flax)/ weed (thistle)
 - Boll Weevil: food (cotton)/weeds (thistle & flax)
- Absolute vs. relative reckoning systems
- Young woman/old woman



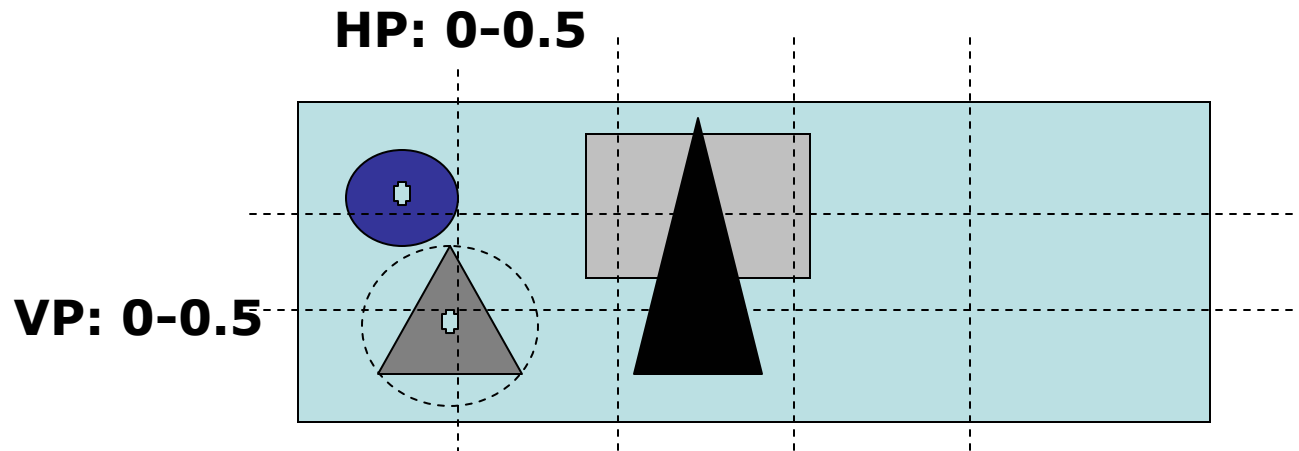
Embodied Machines

Speaker: categorizes topic as VPOS 0-0.5
says 'lu'

Hearer: categorizes 'lu' as HPOS 0-0.5
says 'lu?' (which *lu* are you talking about?)

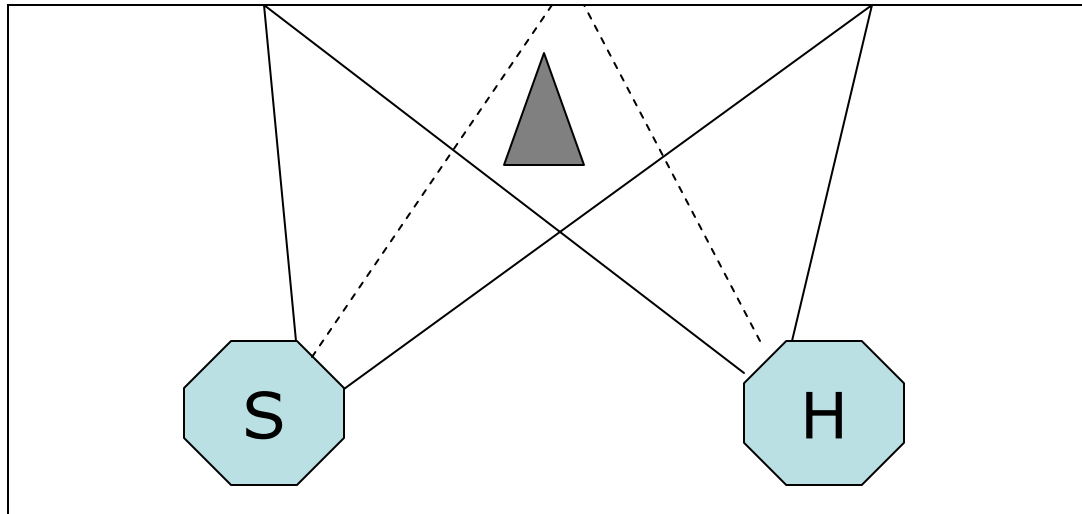
Speaker: points to target

Hearer: categorizes topic as VPOS 0-0.5



Embodied Machines

- Speaker and hearer have different vantage points
 - Assume agents both have Left/Right distinction
 - Left and Right have body based vantage point



Embodied Machines

- Correlates with metaphorical vantage points
 - Sandwich in a garbage can
 - Food or garbage?
 - Depends on life circumstances, personal tolerances, etc.
 - 16 year old murderer
 - Child or adult?
 - Depends on purposes of categorizer

Embodied Machines

– Ambiguity in the system

- Arises when agent has already associated a category with a word
- Speaker introduces new word for same category
- Negotiation takes place
- Across population, forms become strengthened or pruned
- Ambiguity can be maintained