Introduction to Cognitive Robotics

Module 6: Artificial Cognitive Systems

Lecture 3: Learning and development

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Learning

1. Supervised

Teaching data in the form of required behaviour provide directional error signals

2. Reinforcement

Teaching signals are scalar reward or reinforcement signals

(maximize the cumulative sum of rewards over time)

3. Unsupervised

No teaching signals

(uncover statistical regularities)

Learning

- Supervised: Cerebellum

  Internal models of the environment
  Short-cut models of input-output associations learned elsewhere

- Reinforcement: Basal Ganglia

  Evaluate given state;
  Select action

- Unsupervised: Cerebral Cortex

  Represent external state & internal context;
  Provide common representational framework for Cerebellum and BG

(Doya 1999)

Learning

- Hippocampus–Cortex Complementary Learning
- Hippocampus: rapid auto- and hetero-associative learning
- Hippocampus reinstates neo-cortex memories

[McClelland et al. 1995]

Cognitive Development

Cognition

- Anticipating the need for action
- Formulating the motor commands required to act successfully (effective action)
- Predicting the outcome of those actions
- Adaptively and prospectively carrying out those actions

Cognitive Development

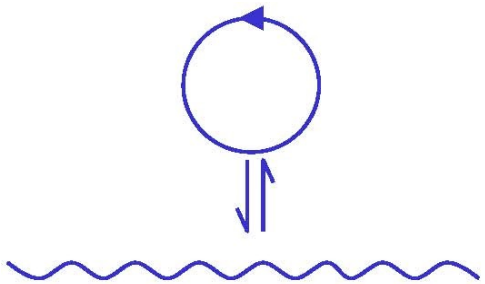
Cognitive development is a process which an agent undergoes to

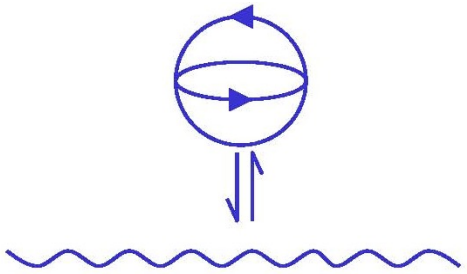
Expand its repertoire of possible actions

Extend the time horizon of its capacity for prospection:

the ability to anticipate (a) events and (b) the need to act

Cognitive Development





Anticipation / Planning / Explanation / Prediction

Cognitive Development

Development arises due to changes in the central nervous system as a result of dynamic interaction with the environment

- Emergence of new forms of action
- Acquisition of predictive control of these actions

Mastery of action relies critically on prospection

- Inference of upcoming events
- Inference of outcome of actions

Cognitive Development

Discover new ways of doing things

- May need to inhibit existing abilities (i.e. it. may be a non-monotonic process)
- May need to allow for (or cause) changes in the physical structure of the agent

Cognitive Development

Discover new ways of doing things

- Typically make use of scaffolding
- The progressive development of innate skills or skills that are learned early on
- Development is phased

Cognitive Development

Developing the ability to help others and be helped by others

- 14 to 18 months: **instrumental helping behaviour**
- 2 years: start to solve **simple cooperation** tasks with adults
- 2-3 years: ability to **cooperate** with peers
- 3 years: complex **collaboration**
  - Sharing of intentions
  - Joint coordination of complementary actions
- 3 ½ years: Roles in the task can be reversed; & can teach new partners

Cognitive Development

The prospective aspect of development is accelerated by internal simulation

- Mentally rehearsing — consciously or subconsciously — the execution of actions
- Inferring the likely outcome of those actions

Cognitive Development

Exploratory motives

- Discovery of novelty and regularities in the world
- Discovery of the potential of the agent's own actions

Cognitive Development

Social motives

- Need to belong
- Self-preservation
- Cognitive consistency with others
- Expressed from birth through tendency to
  - Fixate on social stimuli
  - Imitate basic gestures
  - Engage in social interaction

Jean Piaget (1896–1980)

Lev Vygotsky (1896–1934)

Learning vs. Development

Learning

A process for improving the performance of a system

A process for estimating or improving the parameter values that govern the behaviour of a known model

Development

Remark: unsupervised learning and reinforcement learning do this to an extent

A process for generating or discovering the model itself

Requires two-way interaction between agent and world

Requires scaffolding on existing capabilities