How Minds Work
Schema Mechanism

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Schema Mechanism

- Implements early stages of Piaget's theory of child development
- A mechanism of mind
- Controls a body in a micro world
- Learns about (creates?) objects
- Learns almost from scratch

Data structures

- Items — binary state holders
  – either on or off.
- Actions — produce state
  in the environment
- Schemas designate the effects of actions on states.
- Schemas don't perform any actions

Items

- Primitive items — sensory inputs.
- Synthetic items — autonomously constructed by the schema mechanism
- Synthetic items designate states at higher levels of abstractions.
- Concept of a table might be synthetically constructed
  - in an appropriate environment
  - with appropriate goals (values)

Actions

- Primitive actions
- Motor outputs
- Composite actions
  - Constructed autonomously by the mechanism
  - State transitions at higher levels of abstraction
  - Chains a sequence of less abstract actions, eventually backing down to primitive actions
  - Might reach an arm under a table and lift it

Recursive Definition

- Schemas defined in terms of items and actions
- Synthetic items and composite actions are defined in terms of schemas
- Start with items and actions, and define some schemas
- Schemas help define further items and actions, and hence also further schemas
- Schemas may have other schemas as elements, a recursive definition

Schema

- Context — a set of items
- Action — an action
- Result — a set of items
- The schema asserts that
  - if the context is satisfied (all its items are on)
  - and the action is taken
  - then the result becomes more likely
    (more likely that all its items are on)

Simple to Complex

- Spin-off schemas built when a relation between items and actions is discovered
- Composite actions (implemented by schemas) coordinated to achieve some goal
- Synthetic item — a state not expressible as some combination of current states
- Synthetic items permit the invention of radically new concepts, for example conservation

Schema vs Production Rule

- Production rule — if preconditions hold, perform the action
- Schema not a production rule
- Schema asserts that
  - its specified action
  - taken in its context
  - makes its result more likely to occur
- Context not a precondition —action may be done in another context or it not in this one

Reliable Schema & Plans

- Action of a *reliable* schema, in context, makes the result more likely than not.
- Schemas keep track of reliability statistically
- Plan—a set of schemas coordinated to achieve some specified result.
- Only reliable schemas can participate in a plan.

Finding Reliable Schema

- Unreliable schemas are stepping stones to finding reliable schemas
- Schema mechanism looks for results
  that follow from actions, reliably or not
- If a result follows unreliably, the mechanism looks for added context to improve reliability
- When successful, it spins off a new schema adding the newly discovered context
  to a copy of the old schema

Action Selection

- Schemas with satisfied contexts compete to have their action performed
- Schemas on compete on how well their results contribute to some goal
- Mechanism chooses at random among the more qualified schemas.
- Schemas compete via their exploratory value
- Recent schemas likely to be reactivated
- Schemas leading to undesirable results can be suppressed

Schema Mechanism's Microworld

- Populated by objects that can be seen, felt, grasped and moved
- Schema mechanism controls
  - a hand which can feel, grasp and move
  - an eye that can see

Primitive Items and Actions

- Primitive items
  - visual (input from various places)
  - tactile (input from around the hand)
  - visual proprioceptive (direction the eye is looking)
  - tactile proprioceptive (how far hand is reaching and in what direction)
- Primitive actions
  - hand can move forward, back, left and right
  - Four actions change the visual field
  - hand can open and close

Primitive Schema

- Begin with one primitive schema for each primitive action
- A primitive schema has an empty context and an empty result
- Is a point of departure for building schemas *with* context and result
- New schemas are spun off by adding new items of context and/or result to copies of existing schema
- The original schema remains

Extended Context & Result

- Each schema has an extended context and an extended result
- Each extended context or result includes a slot for every item
- Every time a new item is created, a slot for it is added to each extended context and extended result

Schema with Extensions

Context	Action	Result
Extended Context		Extended Result

Extended Result Slot

- Keeps track of whether its item turns on more often if the schema has just executed
- If so, spin off a new schema
  with that item added to its result.
- If its item is more likely to turn off,
  the spin-off schema is created
  with the negative of the item in its result
- A schema may be arbitrarily unreliable

Extended Context Slot

- Keeps track of whether the schema
  is more reliable when its item is on
- If so, a new schema spins off
  with that item as part of its context
- If more reliable with it's item off,
  put the negative of the item
  in the spin-off schema’s context

Synthetic Items

- Based on some schema
- Objects and other concepts
  can be constructed
- Object permanence—synthetic item reifies recoverability
- the ontology of the system changes

Locally Consistent Schema

- Objects tend to stay put for a while
- If an action reaches out, touches an object, draws back, and reaches out again,
  it's likely to touch something again
- Schema mechanism tracks
  the local consistency of each schema
- If a schema is locally consistent,
  the mechanism builds a synthetic item for it.
- New item represents whatever condition governs the schema's success or failure

Schema for Synthetic Items

- Build host schema
  from the locally consistent schema with synthetic item as context
- When the synthetic item is on, the host schema is reliable,
  at least for a while
- When is the new synthetic item on?

Synthetic Items at Work

- Successful activation of host schema
  turns the synthetic item on
- Unsuccessful turns it off
- Synthetic item turns off
  after its time period of local consistency
- A synthetic item turns on or off
  together with any strongly correlated item
- schema mechanism must track of all this

Readings

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