Introduction to Cognitive Science: Notes

IV: How Animals and Humans Actually Make Plans

- Readings for this section: *Shanahan 2001.

IV: How Animals and Humans Actually Make Plans

- Some animals can make plans of this kind, involving tools (Köhler 1925).

Figure 1: From Köhler 1925

Figure 2: From Köhler 1925

The Monkey and the Bananas in LDEC

- The monkey and bananas, again simplified: grabbing something gets you to the state of having it, and if you were 6 ft higher than where you are you could grab the bananas (hack avoids axiomatizing arithmetic):

  (1) a. $\{\mathit{affords}(\mathit{grab}(x))\} \multimap [\mathit{grab}(x)]\mathit{have}(x)$
  b. $\mathit{at}((\mathit{here}+3)+3) \Rightarrow \mathit{affords}(\mathit{grab}(\mathit{bananas}))$

- If something is a box you can climb on it:

  (2) $\mathit{box}(b) \Rightarrow \mathit{affords}(\mathit{climb\text{-}on}(b))$

- —and if you are at a place and you climb on a box you are at a place that is higher by 3ft:

  (3) $\{\mathit{affords}(\mathit{climb\text{-}on}(b))\} \wedge \mathit{at}(p) \multimap [\mathit{climb\text{-}on}(b)]\mathit{at}(p+3)$

- Axioms for *puton* are as before.

The Monkey and the Bananas, (Contd.)

- If the initial state of the world is as follows:

  (4) $at(here) \wedge box(b1) \wedge box(b2) \wedge clear(b1) \wedge clear(b2)$

- —then the goal (5a) gives rise to (5b) as one possible plan that the situation affords and which results in having the bananas

  (5) a. $goal(affords(\alpha) \wedge [\alpha]have(bananas)$

  b. $\alpha = [puton(b1, here); climb\text{-}on(b1);$
  $puton(b2, b1); climb\text{-}on(b2); grab(bananas)]$

- However, we have said nothing yet about the problem of *Search* implicit in identifying such plans.

LDEC and Human Cognition

- The dynamic axioms of LDEC can be viewed as a representation of Miller et al's **TOTE units**, Piaget (1936)'s **Circular Reactions** , or of the Behaviorists' notion of **operant**.
- The "Test-Operate/Test-Exit" loop of TOTE units is necessary for the execution of the plan in the world, and is also represented in the dynamic logic.
- For example the following LDEC rules represent what a 1-4 month infant has learned about the breast (simplifying somewhat). First, a breast "affords" suckling, in Gibson's sense, where $\Rightarrow$ is standard implication:

  (6) $\mathit{breast} \Rightarrow \mathit{affords}(\mathit{suckle})$

  And the following rule represents the effects of suckling using Kleene $+$ iteration of a test and an elementary action:

  (7) $\{\mathit{affords}(\mathit{suckle})\} \wedge \mathit{hungry} \multimap [(\mathit{hungry}?;\mathit{suckle})^{+}]\neg \mathit{hungry}$

- Later: wanting to be somewhere affords crawling towards it, and if you crawl you stop not being there and start being there:

  (8) $want(there) \Rightarrow affords(crawl)$

  (9) $\{affords(crawl)\} \wedge \neg there \multimap [(\neg there?; crawl)^{+}]there$

- Rather than computing with possible worlds, the child may associate probabilities with rules like (7) and (9), based on counts of outcomes over those same encountered situations, to guide planning.

- The qualification problem can then be dealt with reactively in such a framework, much as by the Mars Rover, via rules like the following

  (10) $affords(bawl)$

  (11) $\{affords(bawl)\} \wedge \neg happy \multimap [(\neg happy?; bawl)^{+}]happy$

How Animals and Humans Make Plans (contd.)

- Such search seems to be *reactive* to the presence of the tool and *forward-chaining*, rather than backward-chaining (working from goal to tool). That is, the animal can make a plan in the presence of the tool, but has difficulty with plans that require subgoals of finding tools.
- It implies that actions are accessed via perception of the objects that mediate them—in other words that actions are represented as the *affordances* of objects, in Gibson's (1966) terms.
- This seems a good way for an animal to plan. If there *is* a short plan using available resources, forward chaining will find it.
- Backward chaining requires the evolution of tools with very general affordances, like credit cards and mobile phones.

Formalizing Affordance in LDEC

- We can define the affordances of objects directly in terms of LDEC preconditions like Notes IV (6)
- Thus the affordances of doors are *pushing* and *going through*:

(12) $$affordances(door) = \left\{ \begin{array}{l} push \\ go\text{-}through \end{array} \right\}$$

- This provides the basis for Reactive, Affordance-based, Forward-Chaining plan construction that is characteristic of primate planning.

Formalizing Affordance in LDEC (Contd.)

- The Gibsonian affordance-based door-schema can then in turn be defined as a function mapping doors into (second-order) functions from their affordances like pushing and going-through to their results:

  (13) $door' = \lambda x_{door}.\lambda p_{affordances(door)}.px$

- The operation of turning an object of a given type into a function over those functions that apply to objects of that type is another primitive combinator called **T** or *type raising*, so (13) can be rewritten $door' = \lambda x_{door}.\mathbf{T}x$, where

  (14) $\mathbf{T}a \equiv \lambda p.p(a)$

- The type-raising combinator **T** is related to the notions of *Object-Orientation* and *Continuation Passing* in the theory of programming languages.

Type-Raising and Natural Language

- Such a concept of doors is useful for reactive planning, and one can add more affordances to $affordances(door)$ as one's experience increases.
- However, it is a somewhat stultifying representation in human terms, One would like to have the advantages in terms of efficiency of planning that thinking of objects in terms of their affordances allows, while also being able envisage novel uses for doors—for example, using one as a table, or as a raft—when circumstances demand it.
- It would be improved if objects were classified as flat, less dense than water etc. represented as attribute-value pairs
- One of the few sources of information about the natural classifications of objects that permit limited generalization comes from linguistics.

Navaho Classifiers (Wikipedia)

Classifier+Stem	Label	Explanation	Examples
-’ą	SRO	Solid Roundish Object	bottle, ball, boot, box, etc.
-yí	LPB	Load, Pack, Burden	backpack, bundle, sack, saddle, etc.
-ł-jool	NCM	Non-Compact Matter	bunch of hair or grass, cloud, fog, etc.
-lá	SFO	Slender Flexible Object	rope, mittens, socks, pile of fried onions, etc.
-tą	SSO	Slender Stiff Object	arrow, bracelet, skillet, saw, etc.
-ł-tsooz	FFO	Flat Flexible Object	blanket, coat, sack of groceries, etc.
-tłéé’	MM	Mushy Matter	ice cream, mud, slumped-over drunken person, e
-nil	PLO1	Plural Objects 1	eggs, balls, animals, coins, etc.
-jaa’	PLO2	Plural Objects 2	marbles, seeds, sugar, bugs, etc.
-ḱą	OC	Open Container	glass of milk, spoonful of food, handful of flour,
-ł-ţí	ANO	Animate Object	microbe, person, corpse, doll, etc.

Languages that Lexicalize Affordance

- As a consequence, the English verb “give” is expressed by 11 different forms in Navajo, depending on the charateristics of the object given, including *níłjool* (give-NCM), used in “give me some hay” and *nítįįh* (give-SSO), used in “give me a cigarette”.
- The appearance of such pronominal classifiers on the verb is an example of a “head marking” system of *case*, inasfar as the final position of such classifiers “structurally” marks the fact that they are patients of the action (cf. Blake 2001:13).

Languages that Lexicalize Affordance

- The interest of such classifiers and their reflex in Navajo nominalizations as a form of case marking agreement is twofold.
- First, if these classifiers appear explicitly in Navajo, one might expect that they reflect a universal ontology of entities.
  - The advantage of such ontologies is that they allow an agent to generalize the notion of affordances of doors to other actions applying to objects of that class.
  - The extension to a system of case allows even further generalization to the full range of transitive actions.
- Second, the type-raising nature of case shows up very directly in the theory of grammar (see below).

Languages that Lexicalize Affordance

- Many North American Indian languages, such as the Athabascan group that includes Navaho, are also comparatively poorly off for nouns. Many nouns for artefacts are morphological derivatives of verbs.
- For example, “towel” is *bee ’ádít’oodí*, glossed as “one wipes oneself with it”, and “towelrack” is *bee ’ádít’oodí bąąh dah náhidiiltsos*—roughly “one wipes oneself with it is repeatedly hung on it”.
- Such languages appear to lexicalize nouns as a *default affordance* (**T**), and to *compose* such affordances (**B**).

Languages that Lexicalize Affordance

Of course, we should avoid crassly Whorfean inferences about Navaho-speakers abilities to reason about objects. Though productive, these lexicalizations are as conventional as our own.

- Navaho-speakers probably think English is totally weird in allowing denominal verbs, like “shelve” and “pocket” with equal productivity. (We shall return to this question.)
- Navaho nouns are also implicitly classified by animacy, shape, and consistency.
- However, rather than being realized via a rich gender system, as in some other Athabaskan languages such as Koyukon, this classification is reflected in verbal morphology. For example, the classifier *-iltsos* on the verb “hung,” *náhidiiltsos* marks it as predicated of flat, flexible things like towels. A belt-rack would have a different classifier.

References

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