Towards a formal modeling of affordances

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The Score 1:0 meeting

Affordances are interesting ...

- The term 'affordance' was coined by J. J. Gibson.
- "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill." (Gibson, 1979/2014, p. 119)
- E.g., a stair affords climbing when it is a certain proportion of a person's leg length.

... but also mysterious

▶ "An important fact about the affordances of the environment is that they are in a sense objective, real, and physical, unlike values and meanings, which are often supposed to be subjective, phenomenal, and mental. But, actually, *an affordance is neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy*. It is equally a fact of the environment and a fact of behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer." (Gibson, 1979/2014, p. 121, emphasis added)

Motivation/Goal/Method

▶ The notion of affordance has been since utilized in a number of different domains, including robotics.

▶ It would be valuable to formalize this cross-disciplinary notion in order to conceptualize the real world coherently.

▶ Goal: to take the first step towards a formal modeling of affordances

▶ Method: to base M. T. Turvey's (1992) dispositional theory of affordances upon the formal representation of dispositions that is elaborated in the existing ontology research

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What are dispositions?

- A disposition: an intrinsic property with a 'causal profile'

- A property of some object ('bearer') which brings about some state of affairs ('realization') when it is stimulated ('triggered') by some state of affairs under some specific circumstances ('background conditions')

- E.g., the flammability (disposition) of a match (bearer) is realized when it is struck against a suitable surface (trigger) in an oxygenated environment (background condition), thereby bringing about the production of fire (realization).

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Reciprocal dispositions

▶ Some dispositions are *reciprocal*: they are *mutually* realized when matched with their 'partner' dispositions.

▶ E.g., the disposition of salt to dissolve is realized when met with the disposition of solvent (e.g., water) to dissolve a solid.

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Turvey's motivation

- One of the key features of animal activity is its prospective control (PC): "control concerned with future events, usually interpretable as goals to be realized" (Turvey, 1992, p. 179)

- E.g., to walk across a cluttered room, an agent needs to know what (bodily movement) is *possible*.

- The ecological approach to PC requires that affordances be perceivable in such a way that they are closely linked with the possibilities of the environment with respect to which PC is conducted.

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Turvey's theory

- An affordance is the kind of disposition whose reciprocal disposition (what Turvey calls 'effectivity') has as bearer an organism

- E.g., the affordance of the stairs is their disposition to move up an organism.

- It is realized only when an organism that has the disposition (effectivity) to move up locates herself in the vicinity of the stairs.

- The affordance disposition of the stairs and the organism's effectivity disposition are mutually realized, thereby bringing about the organism's climbing the stairs.

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Pros and cons

▶ Comparatively straightforward interpretation of Gibsonian notion of affordance

▶ The concept of disposition has been extensively exploited in the ontology research (e.g., biomedicine)

▶ A formal (OWL-friendly) representation of dispositions has been investigated as well

▶ E.g., do gaps have the dispositions to afford organisms hiding?

▶ A cloud of suspicion hangs over dispositions in general in the ontology research

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Basic assumptions

- All the variables presented below should be read as particulars (at the instance level) rather than universals (at the class level).

- Concrete individuals fall into two types: continuants (aka endurants) (CONT) and occurrents (aka perdurants) (OCUR).

- One major subcategory of continuants is objects (OBJ).

- The participation-in relation $PC(x, y, t)$ where x is an object, y is an occurrent, and t is a time.

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Dispositions

- ▶ Röhl and Jansen's (2011) formalization of dispositions (DISP)
- ▶ A disposition is a property of (inheres_in) some object; it can be realized in (has_realization) some occurrent; and it is also triggered by (has_trigger$_D$) some occurrent

- ▶ I additionally introduce the relation (backcon_of) between a background condition of a disposition and the disposition.
- ▶ backcon_of$(x, y) \rightarrow (\text{CONT}(x) \lor \text{OCUR}(x)) \land \text{DISP}(y)$

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Agents and non-agents

- There exist an organism, or more generally an agent (AGE), and a non-agentive object (NAG) such as the stairs.

- $AGE(x) \rightarrow OBJ(x)$
- $NAG(x) \leftrightarrow OBJ(x) \wedge \neg AGE(x)$

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Affordances and effectivities

- Affordances (AFOD) are the dispositions that inhere in non-agentive objects and effectivities (EFEC) are the disposition that inhere in agents

- $\mathsf{AFOD}(x) \to \mathsf{DISP}(x) \land \exists y(\mathsf{NAG}(y) \land \mathsf{inheres\_in}(x, y))$
- $\mathsf{EFEC}(x) \to \mathsf{DISP}(x) \land \exists y(\mathsf{AGE}(y) \land \mathsf{inheres\_in}(x, y))$

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Affordances for actions

- ▶ Turvey focuses mainly on affodances for actions (ACT): occurrents in which an agent participates
- ▶ A realization of an affordance is an action and so is a realization of an effectivity

- ▶ $ACT(x) \rightarrow \exists y(AGE(y) \land PC(y, x))$
- ▶ $AFOD(x) \land \text{has\_realization}(x, y) \rightarrow ACT(y)$
- ▶ $EFEC(x) \land \text{has\_realization}(x, y) \rightarrow ACT(y)$

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Reciprocal relationship

▶ The triggering occurrent of an affordance has as participant a bearer of some effectivity and vice versa

▶ A realization of an affordance is also a realization of some effectivity and vice versa

▶ $\text{AFOD}(x) \wedge \text{has\_trigger}_D(x, y) \rightarrow$
$\exists z, w(\text{EFEC}(z) \wedge \text{inheres\_in}(z, w) \wedge \text{PC}(w, y))$

▶ $\text{EFEC}(x) \wedge \text{has\_trigger}_D(x, y) \rightarrow$
$\exists z, w(\text{AFOD}(z) \wedge \text{inheres\_in}(z, w) \wedge \text{PC}(w, y))$

▶ $\text{AFOD}(x) \wedge \text{has\_realization}(x, y) \rightarrow$
$\exists z(\text{EFEC}(z) \wedge \text{has\_realization}(z, y))$

▶ $\text{EFEC}(x) \wedge \text{has\_realization}(x, y) \rightarrow$
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Environment

- The environment (ENV) would be seen as a continuant that is a background condition of an effectivity disposition

- $ENV(x) \rightarrow CONT(x)$
- $ENV(x) \rightarrow \exists y(EFEC(y) \land backcon\_of(x, y))$

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Related work

- ▶ Reed (1996): the resources of the environment that are encountered by animals

- ▶ Sanders (1997): primitives

- ▶ Stoffregen (2003): the emergent properties of the animal-environment system
- ▶ Chemero (2003): relations between the abilities of animals and features of the environment

Conclusion and future work

- Proposed a preliminary formalization of the affordance concept based on Turvey's dispositional account of affordances

- To deepen the formal modeling of affordances
- To apply the (full) formalization to the domains in which which the agent-environment interaction plays a vital role
- Possibly in a collaborative project with some domain experts (e.g., cognitive scientists and roboticists)

References

- J. J. Gibson. *The Ecological Approach to Visual Perception* (Classic Edition). Routledge, 2014. Originally published in 1979 from Houghton Mifflin.

- M. T. Turvey. Affordances and Prospective Control: An Outline of the Ontology. *Ecological Psychology* 4(3): 173–187, 1992.

- J. Röhl and L. Jansen. Representing dispositions. *Journal of Biomedical Semantics* 2(Suppl 4), S4, 2011.

References

- ▶ E. S. Reed. *Encountering the World: Toward an Ecological Psychology*. Oxford University Press, 1996.
- ▶ J. T. Sanders. An Ontology of Affordances. *Ecological Psychology* 9(1): 97–112, 1997.
- ▶ T. A. Stoffregen. Affordances as Properties of the Animal-Environment System. *Ecological Psychology* 15(2): 115–134, 2003.
- ▶ A. Chemero. An Outline of a Theory of Affordances. *Ecological Psychology* 15(2): 181–195, 2003.