Modeling Affordances with Dispositions

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Abstract. Affordance remains obscure conceptually and formally notwithstanding its paramountcy to the ecological approach to perception, cognition, and action. This paper aims to offer a preliminary work to a full-fledged formal modeling of affordance. Characteristic of the approach of the paper is to base M. T. Turvey's dispositional theory of affordance upon the formal representation of dispositions that is elaborated in the existing ontology research. This work will contribute to the research to which the agent-environment interaction is integral.

Keywords. affordance, disposition, environment, perception, formal modeling

1. Introduction

The term 'affordance' was coined by Gibson [1] to pin down precisely the interaction between animals and the environment: "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill" [1, p. 119]. For instance, a gap affords hiding when it is of a certain size relative to the size of a person and a stair affords climbing when it is a certain proportion of a person's leg length.

The notion of affordance has been since utilized in a number of different domains, ranging from philosophy and cognitive science to engineering fields such as robotics [2,3]. It would be therefore valuable to axiomatize this cross-disciplinary notion in order to conceptualize the real world coherently. This would help to provide a general framework for enhancing the integration of empirical data on agents' cognition. The ontological nature of affordance is nonetheless such a highly controversial subject that one can nowadays find numerous theories of affordance (e.g., [4,5,6,7]).

In this paper I offer a preliminary formalization of the notion of affordance so that its full-fledged version will be implementable and available in information systems. I begin by presenting Turvey's [8] dispositional account of affordance, which would fit well with the formal ontological conception of affordance (Section 2). Then I attempt a formal characterization of the affordance concept (Section 3) and provide a brief, opinionated survey of related work (Section 4). I conclude the paper with some brief remarks on future directions of research (Section 5).

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2. Affordances and Dispositions

Turvey [8] offers a dispositional theory of affordance. Here I detail the notion of disposition for the sake of my future argument. A disposition is an intrinsic property with a 'causal profile' [9,10].[2] In more detail, it is 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'). It is additionally based on some non-dispositional (categorical) property ('base') [12].[3]

Examples include the flammability of a match. The flammability disposition of the 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). It is also based on a particular molecule structure (base) of the match. Moreover, some dispositions are *reciprocal*: they are *mutually* realized when matched with their 'partner' dispositions [14]. For instance, the disposition of salt to dissolve is realized when met with the disposition of solvent (e.g., water) to dissolve a solid.

Turvey's fundamental presumption is that 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" [8, p. 174]. To walk across a cluttered room, for instance, an agent needs to know what (bodily movement) is *possible*. The ecological approach to PC therefore 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.

Granted that dispositions essentially carry inside them potency, all these considerations lead to the idea that an affordance is the kind of disposition whose reciprocal disposition (what Turvey calls 'effectivity') has as bearer an organism.[4] For instance, the affordance of the stairs is their disposition to move an organism upward. It is based on the physical structure (i.e. a set of steps) of the stairs and it is realized only when an organism that has the disposition (effectivity) to move upward locates itself 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.

A dispositional theory of affordance would mesh well with the formal ontological treatment of affordance in some respects, although its theoretical validity is a contentious matter (but see Section 4). First, the concept of disposition has been so extensively exploited in the ontology research (e.g., in the biomedical [15] and engineering [16] domains) that it would be more acceptable to employ dispositions than to introduce some new concept.[5] Second, a formal representation of dispositions has been investigated [13,18] well enough to enable us to have a rich formalization of affordances as dispositions in the long run.

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[2]As the standard account goes, a property is intrinsic if an entity's having that property depends on what the entity is like and not on anything else outside the object. See e.g., Francescotti [11] for detailed discussions on intrinsic properties.

[3]I follow Röhl and Jansen's [13] terminology for dispositions because it is widely used in formal ontology, although I myself prefer to use the terms 'power' and 'manifestation' instead of 'disposition' and 'realization', respectively.

[4]Strictly speaking, there is a subtle but non-trivial difference between Turvey's [8] own claim that affordances and effectivities are *complementary* and my reinterpretation of his dispositional view of affordances based on the notion of reciprocal dispositions. While leaving a close analysis of this point for future work, I would say that I am making his theory more defensible by softening the claim under consideration.

[5]Note the noticeable skepticism over dispositions in the context of formal ontology, however (e.g., [17]).

3. Preliminary Formalization

3.1. Basic Assumptions

I provide a preliminary first-order formalization of the dispositional conception of affordance along Turvey's [8] line of argument. All the variables presented below should be read as particulars (at the instance level) rather than universals (at the class level).

I commence with the basic categories and relations that are comparatively widespread in upper ontologies. Concrete individuals fall into two types: continuants (aka endurants) (CONT) and occurrents (aka perdurants) (OCUR). Generally speaking, continuants exist in time, whereas occurrents extend through time. One major subcategory of continuants is objects (OBJ). As for the relations, I introduce the participation-in relation $participates\_in(x,y,t)$ where x is an object, y is an occurrent, and t is a time.

As for dispositions (DISP), I use Röhl and Jansen's [13] formal relations and assume their axioms (which I omit to present owing to spatial limitations). That is to say, 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. I leave open whether the former is a continuant or an occurrent, partly because of its general conceptual underdevelopment[6]:

$$backcon\_of(x,y) \rightarrow (CONT(x) \vee OCUR(x)) \wedge DISP(y) \tag{1}$$

3.2. Formal Characterization

First of all, there exist an organism, or more generally an agent (AGE), and a non-agentive object such as the stairs. Agents are objects. For the sake of simplicity I introduce the predicate NAG for a non-agentive object, which is straightforwardly defined as follows:

$$AGE(x) \rightarrow OBJ(x) \tag{2}$$

$$NAG(x) \leftrightarrow OBJ(x) \wedge \neg AGE(x) \tag{3}$$

Most importantly, affordances (AFOD) are dispositions that inhere in non-agentive objects and effectivities (EFEC) are dispositions that inhere in agents:

$$AFOD(x) \rightarrow DISP(x) \wedge \exists y(NAG(y) \wedge inheres\_in(x,y)) \tag{4}$$

$$EFEC(x) \rightarrow DISP(x) \wedge \exists y(AGE(y) \wedge inheres\_in(x,y)) \tag{5}$$

Since Turvey focuses mainly on affordances for actions (ACT), which would be interpreted as occurrents in which an agent participates, a realization of an affordance is an action and so is a realization of an effectivity:

$$ACT(x) \rightarrow \exists y(AGE(y) \wedge participates\_in(y,x)) \tag{6}$$

$$AFOD(x) \wedge has\_realization(x,y) \rightarrow ACT(y) \tag{7}$$

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[6]See e.g., Barton, Rovetto and Mizoguchi [19] for some thoughts on a background condition of a disposition.

$$\text{EFEC}(x) \wedge \text{has\_realization}(x,y) \rightarrow \text{ACT}(y) \tag{8}$$

It is rather difficult to specify the reciprocal relationship between affordances and effectivities within the present framework.[7] Here I impose the following constraints on the relationship between them. The triggering occurrent of an affordance has as participant a bearer of some effectivity and vice versa. In addition, a realization of an affordance is also a realization of some effectivity and vice versa:

$$\text{AFOD}(x) \wedge \text{has\_trigger}_\text{D}(x,y) \rightarrow \exists z, w(\text{EFEC}(z) \wedge \text{inheres\_in}(z,w)$$
$$\wedge \text{ participates\_in}(w,y)) \tag{9}$$

$$\text{EFEC}(x) \wedge \text{has\_trigger}_\text{D}(x,y) \rightarrow \exists z, w(\text{AFOD}(z) \wedge \text{inheres\_in}(z,w)$$
$$\wedge \text{ participates\_in}(w,y)) \tag{10}$$

$$\text{AFOD}(x) \wedge \text{has\_realization}(x,y) \rightarrow \exists z(\text{EFEC}(z) \wedge \text{has\_realization}(z,y)) \tag{11}$$

$$\text{EFEC}(x) \wedge \text{has\_realization}(x,y) \rightarrow \exists z(\text{AFOD}(z) \wedge \text{has\_realization}(z,y)) \tag{12}$$

I finally consider the environment (ENV). From the current perspective, the environment would be seen as a continuant that is a background condition of an effectivity disposition:

$$\text{ENV}(x) \rightarrow \text{CONT}(x) \tag{13}$$

$$\text{ENV}(x) \rightarrow \exists y(\text{EFEC}(y) \wedge \text{backcon\_of}(x,y)) \tag{14}$$

When Mary is about to climb the stairs, for instance, her environment contains the available space between the stairs and her, but not the surface of the planet Mars. This is, on the present interpretation, because the former (but not the latter) is part of the background condition of Mary's effectivity disposition to climb the stairs. Given the systematicity of a background condition of a disposition, this view of the environment matches the intuition that the environment is something systematic.[8]

4. Related Work

As for conceptual work, Reed [4] considers affordances as the resources of the environment that are encountered by animals.[9] His theory would however imply the primacy

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[7]It would be necessary to introduce, for instance, the reciprocal relation between dispositions [20, p. 104], but a full discussion of this topic is beyond the scope of my investigation.

[8]Built in alignment with the upper ontology Basic Formal Ontology (BFO) [20], for instance, the environmental ontology [21,22] defines the class *environmental system* (which is synonymous with the environment) as a 'system which has the disposition to environ one or more material entities' where a system is a 'material entity (note: the BFO category) consisting of multiple components that are causally integrated'.

[9]"The fundamental hypothesis of ecological psychology (...) is that *affordances and only the relative availability (or nonavailability) of affordances create selection pressure on the behavior of individual organisms; hence, behavior is regulated with respect to the affordances of the environment for a given animal.*" [4, p. 18]

of the environment over animals in tension with the ecological approach to the animal-environment interaction. Sanders [5] maintains that "affordances are ideal primitives for general ontology" [5, p. 103], but this claim is too extreme to fit well with my aim to give a formal-ontological modeling of affordance. Stoffregen [6] argues that affordances are properties of the animal-environment system: they are *emergent properties* that do not inhere in either the environment or the animal.[10] The ontological nature or even the existence of emergent properties is nonetheless highly debatable (see e.g., [23]).[11]

As for formal work, Steedman [24] formalizes affordances using the Linear Dynamic Event Calculus: a formalism for reasoning about causal relations over events. My proposal may be said to underlie his model because the triggering occurrent of the affordance disposition bears a causal relation to its realization occurrent (cf. [25]). Galton [26] formally addresses the question of where a given surface layout of an object determines and possesses a particular group of affordances. My formalization could be harmonized with Galton's in such a way that he investigates the relation between the affordance disposition and its physical base from the viewpoint of knowledge representation.

Şahin et al. [27] formalize affordances based on three perspectives on them (the second of which they take to be central to Turvey's account): *agent perspective*, *environmental perspective*, and *observer perspective*. Capturing the first perspective in terms of Turvey's original idea of the effectivity disposition (which tends to be neglected in the literature), my formal modeling can be coherently enlarged to accommodate the third one, together with the auxiliary claim that the *capacity disposition* (e.g., [28]) of the observer is necessary for the mutual realization of the affordance and effectivity dispositions.

Ortmann and Kuhn's [29] extension of their ontology of observations to include Turvey's view of affordance is fairly close to, but nevertheless differs relevantly from my approach in the sense of focusing more on the agentive and perceptual facet of affordances than their ontological (dispositional) one. This may be partly due to their compliance with the DOLCE [30] upper ontology, which purports to represent the categories with a clear cognitive bias and which does not explicitly have the disposition category.

5. Conclusion

I have proposed a preliminary formalization of the affordance concept based on Turvey's dispositional account of affordances, borrowing a formal representation of dispositions from the existing ontology research. In the future I will deepen the formal modeling of affordances, e.g., by having a more expressive formalization of dispositions. Once the (full) formalization is available, I will apply it to, e.g., the implementation of the robot's dynamic interaction with its environment and other agents (including humans) [2,3,27].

References

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

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[10]Chemero [7] similarly proposes that affordances be relations between the abilities of animals and features of the environment.

[11]Moreover, the emergent properties of the animal-environment system may be, if any, better explicable in terms of its *collective disposition* [15]: the disposition of the animal-environment system in virtue of the affordance disposition of the environment and the effectivity disposition of the animal.

[2] A. Chemero and M. T. Turvey. Gibsonian Affordances for Roboticists. *Adaptive Behavior* 15(4): 473–480, 2007.

[3] H. Min, C. Yi, R. Luo, J. Zhu, and S. Bi. Affordance Research in Developmental Robotics: A Survey. *IEEE Transactions on Cognitive and Developmental Systems* 8(4): 237–255, 2016.

[4] E. S. Reed. *Encountering the World: Toward an Ecological Psychology*. Oxford University Press, 1996.

[5] J. T. Sanders. An Ontology of Affordances. *Ecological Psychology* 9(1): 97–112, 1997.

[6] T. A. Stoffregen. Affordances as Properties of the Animal-Environment System. *Ecological Psychology* 15(2): 115–134, 2003.

[7] A. Chemero. An Outline of a Theory of Affordances. *Ecological Psychology* 15(2): 181–195, 2003.

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

[9] S. Mumford. *Dispositions*. Oxford University Press, 1998.

[10] G. Molnar. *Powers: A Study in Metaphysics*. Oxford University Press, 2003.

[11] R. Francescotti (ed.) *Companion to Intrinsic Properties*. De Gruyter, 2014.

[12] E. Prior, R. Pargetter and F. Jackson. Three Theses about Dispositions. *American Philosophical Quarterly* 19(3): 251–257, 1982.

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

[14] C. B. Martin. *The Mind in Nature*. Oxford University Press, 2007.

[15] A. Goldfain, B. Smith and L. G. Cowell. Dispositions and the Infectious Disease Ontology. In A. Galton and R. Mizoguchi (eds.), *Proceedings of the 6th International Conference of Formal Ontology in Information Systems (FOIS 2010)*, Toronto, Canada, May 11-14, 400–413, 2010.

[16] G. Guizzardi and G. Wagner. Dispositions and Causal Laws as the Ontological Foundation of Transition Rules in Simulation Models. In *Proceedings of the 2013 Winter Simulation Conference*, Washington DC, USA, December 8–11, 2013.

[17] N. Guarino. BFO and DOLCE: So Far, So Close.... In L. Zaibert (ed.), *The Theory and Practice of Ontology - Festschrift for Barry Smith*, Palgrave / Macmillan, 2016, 10–18.

[18] A. Barton, L. Jansen and J.-F. Ehier. A taxonomy of disposition-parthood. In A. Galton and F. Neuhaus (eds), *Proceedings of the 3rd Joint Ontology Workshops (JOWO 2017)*, CEUR Workshop proceedings, vol.2050, 2017.

[19] A. Barton, R. Rovetto and R. Mizoguchi. Newtonian Forces and Causation: A Dispositional Account. In P. Garbacz and O. Kutz (eds.), *Proceedings of the 8th International Conference of Formal Ontology in Information Systems (FOIS 2014)*, Rio de Janerio, Brazil, September 22–25, 2014, 157–170.

[20] R. Arp, B. Smith and A. D. Spear. *Building Ontologies with Basic Formal Ontology*. MIT Press, 2015.

[21] P. L. Buttigieg, N. Morrison, B. Smith, C. J. Mungall, S. E. Lewis and the ENVO Consortium. The environment ontology: contextualising biological and biomedical entities. *Journal of Biomedical Semantics* **4**:43, 2013.

[22] P. L. Buttigieg, E. Pafilis, S. E. Lewis, M. P. Schildhauer, R. L. Walls and C. J. Mungall. The environment ontology in 2016: bridging domains with increased scope, semantic density, and interoperation. *Journal of Biomedical Semantics* **7**:57, 2016.

[23] B. A. Bedau and P. Humphreys (eds.). *Emergence*. MIT Press, 2008.

[24] M. Steedman. Formalizing affordance. In *Proceedings of the 24th Annual Meeting of the Cognitive Science Society*, George Mason University, August 7–10, 2002, 834–839.

[25] S. Mumford and R. L. Anjum. *Getting Causes From Powers*. Oxford University Press, 2011.

[26] A. Galton. The Formalities of Affordance. In M. Bhatt, H. W. Guesgen and S. M. Hazarika (eds.), *Spatio-Temporal Dynamics: 19th European Conference on Artificial Intelligence (ECAI 2010) Workshop Proceedings*, Lisbon, Portugal, August 16–20, 2010, 1–6.

[27] E. Şahin, M. Çakmak, M. R. Dŏgar, E. Uğur, and G. Üçoluk. To afford or not to afford: A new formalization of affordances toward affordance-based robot control. *Adaptive Behavior* 15(4): 447–472, 2007.

[28] B. Smith. [Barry Smith]. (2017, 09, 12). Are there Capabilities on Mars? Retrieved from: `https://www.youtube.com/watch?v=lIPg2bGJSzE` (Last accessed on July 27, 2018).

[29] J. Ortmann and W. Kuhn. Affordances as Qualities. In A. Galton and R. Mizoguchi (eds.), *Proceedings of the 6th International Conference on Formal Ontology in Information Systems (FOIS 2010)*, Toronto, Canada, May 11–14, 2010, 117–130.

[30] S. Borgo and C. Masolo. Ontological Foundations of DOLCE. In R. Poli, M. Healy and A. Kameas (eds.), *Theory and Applications of Ontology: Computer Applications*, Springer, 2010, 279–295.