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Situatedness/Embeddedness

The situated movement—situated language, SITUATED COGNITION AND LEARNING, situated behavior—views intelligent human behavior as engaged, socially and materially embodied activity, arising within the specific concrete details of particular (natural) settings, rather than as an abstract, detached, general-purpose process of logical or formal ratiocination.

Situatedness arose in the 1980s as a reaction against the then-dominant classical view of mind. The classical approach, inherited from the logical and metamathematical traditions (dubbed "GOFAI" by Haugeland 1997, for "good old fashioned artificial intelligence"), views cognition as: *individual,* in the sense that the essential locus of intelligence is taken to be the solitary person; *rational,* in that deliberative, conceptual thought is viewed as the primary exemplar of cognition; *abstract,* in the sense that implementation and the nature of the physical environment are treated as of secondary importance (if relevant at all); *detached,* in the sense that thinking is treated separately from perception and action; and *general,* in the sense that cognitive science is taken to be a search for universal principles of general intellection, true of all individuals and applicable in all circumstances.

Situated approaches reject one or more of these assumptions, arguing instead that cognition (indeed all human activity) is: *social,* in the sense of being located in humanly constructed settings among human communities; *embodied,* in that material aspects of agents' bodies are taken to be both pragmatically and theoretically significant; *concrete,* in the sense that physical constraints of realization and circumstance are viewed as of the utmost importance; *located,* implying that context-dependence is a central and enabling feature of all human endeavor; *engaged,* in that ongoing interaction with the surrounding environment is recognized as primary; and *specific,* in that what people do is seen as varying, dramatically, depending on contingent facts about their particular circumstances.

Within these broad outlines, situated approaches vary widely, from incremental proposals incorporating a degree of context-dependence within largely classical frameworks to more radical suggestions with substantial methodological and metaphysical commitments.

Closest to traditional models are "situated language" proposals for treating INDEXICALS, tense, and other context-dependent linguistic constructs (Barwise and Perry 1983). Terms such as *here, I,* and *now* are used on different occasions, by different individuals, to refer to different people and places, in ways that depend systematically on the circumstances of use. Formally, treating such context-dependence requires a two-stage SEMANTICS, distinguishing the MEANING of a word or sentence (the stable "rule" or pattern that the child learns, such as that "I" is used to refer to the speaker) from the *interpretation* of any particular utterance. Thus when two people shout "I'm right! You're wrong!" their utterances are said to coincide in meaning, but to differ in interpretation. Similarly, "4:00 p.m." can be assigned a single, constant meaning, mapping utterance situations onto times, depending on the date and time zone.

This general strategy of treating meaning as a function from context to interpretation (λ context . interpretation) has been applied to other forms of circumstantially determined interpretation, including anaphora and ambiguity (Gawron and Peters 1991). Methodologically, it requires a shift in focus from sentence types to individual utterances, and a generalization of inference from truth-preservation to reference-preservation (e.g., to understand why tomorrow we use "yesterday" to refer to what today we refer to with "today"). Nevertheless, such treatments remain largely compatible with classical views of cognition as individualistic, deductive, even relatively abstract (see INDIVIDUALISM).

Many, however, feel that situated intuitions run deeper. A further step, embodied in research on COGNITIVE ARTIFACTS, recognizes that an agent's embedding situation is not only a semantical resource for determining REFERENCE, but also a material resource for simplifying thought itself. Agents need not remember what remains in their visual fields, nor measure what they can directly compare. More generally, as captured in Brooks's (1997) slogan that "the world is its own best model," it is more efficient for an agent to let the world do the computing, and determine the result by inspection, than to attempt to shoulder the full load deductively. Moreover (see, e.g., Kirsh 1995), if the world happens not to provide exactly what one wants, one can sometimes rearrange it a bit so that it does. Lave, Murtaugh, and de la Rocha (1984) cite a near-mythic example of someone who, when asked to make 3/4 of a recipe that called for 2/3 of a cup of cottage cheese, measured out 2/3 of a cup, smooshed it into a flattened circle, and cut away 1/4 of the resulting patty.

As these examples suggest, situated approaches tend to shift theoretical focus from abstract deduction onto concrete activity: cooking dinner, making one's way across a crowded subway platform, negotiating turn-taking in a conversation. Situated theorists take these activities not only to be nontrivial achievements, but also to be paradigmatic of human intelligence. With respect to action, furthermore, several writers advocate a shift in emphasis from (rational) advance planning to on-the-fly improvisation. Thus Brooks (1997), Agre and Chapman (1987), and Rosenschein (1995) argue that embodied agents can inventively exploit facts about their physical circumstances to avoid explicit representation and reasoning. Suchman (1987) claims that most human activity, rather than implementing preconceptualized plans, consists of incessant, creative, improvisational mobilization and appropriation of the vast array of resources that environments regularly make available. Not only do people rarely "figure it all out in advance," she argues, but their stories should be understood not as veridical reports of how activity comes to be, but as after-the-fact reconstructions whose role is to retrospectively render activity intelligible (and perhaps accountable).

These shifts in focus have substantial methodological implications. In part, they involve the rejection of longstanding Cartesian intuitions that although movement, sensation, and adaptive reaction to the physical world lie within the province of "mere brutes," high-level conceptualization is challenging and paradigmatic of what it is to be human. They also reflect a change in disciplinary affiliation, from LOGIC, mathematics, computer science, and (individual) psychology, toward sociology, anthropology, science studies, general epistemology, and philosophy of science. More concretely, they involve a shift in methods from *in vitro* toward *in vivo* studies, and from both statistical surveys and laboratory experiments toward "thick descriptions" of real people acting in real-life situations.

Such methodological and epistemological considerations lead to even more radical situated positions. In the situated language proposal discussed earlier, meanings were considered stable, but interpretation varied. But some writers argue that circumstance can affect *meaning*, too. Winograd (1985) argues that what *water* means in the question "Is there any water in the refrigerator?" depends on whether the questioner is thirsty, worried about humidity and condensation, or testing a child's understanding of the constitution of eggplants. Smith (1996: 328–329) considers a case where two friends, in late-night conversation, shape the meanings of their words (such as when describing a friend as "skewed"), rather in the way that blues players bend notes on a guitar. Such examples are theoretically challenging because they raise the ontological question of what properties such utterances designate. It is not obvious "bendable" predicates can be accommodated on the model of ambiguity, with contextual factors selecting from a fixed (pregiven) stock of external properties.

Pressed by such challenges, the strongest variants of situatedness bite the bullet and take ontology itself to be context-dependent. On such a view, not only is what we do, what we say, and how we get at the world viewed as dependent on facts about our circumstances, but also *how the world is*—the very objects and properties in the world we therein talk about and live in and get at—are also taken to depend on (interpretive) context (Cussins 1992; Smith 1996). Taken to its logical extreme, that is, situatedness leads to a view of an ontologically plastic (though perhaps still highly constrained) world that, in contrast with the naive realism implicit in the classical picture, is at least partially socially constructed. Not surprisingly, such views reflect back onto our understanding of the nature of science itself (see, e.g., Haraway 1991). This is situatedness with a vengeance.

At the broadest level, the basic tenet of the situated movement has been accepted. That language, cognition, and activity are fundamentally context-dependent is by now a theoretical truism. What remains a matter of debate is how far this situated intuition should be taken. Everyone agrees that language is indexical, a smaller number are prepared to dethrone ratiocination as the hallmark of the mental, and those who are prepared to take context-dependence through to metaphysics remain a distinct minority. How the issues are resolved may depend on the extent to which the various communities advocating a situated approach—linguistics, cognitive science, AI, sociology, philosophy, feminism, science studies, and so on—collaborate in following out the consequences of this transformation to our traditional self-conception.

See also ANIMAL NAVIGATION; ECOLOGICAL PSYCHOLOGY; FRAME PROBLEM; INTELLIGENT AGENT ARCHITECTURE; MOBILE ROBOTS; PLANNING

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Situation Calculus

The situation calculus is a language of predicate logic for representing and reasoning about *action* and *change.* This KNOWLEDGE REPRESENTATION language was originally developed by John McCarthy (McCarthy 1963; McCarthy and Hayes 1969) and is commonly used in artificial intelligence for purposes such as predicting the effects of actions on a system's state, PLANNING actions to achieve given goals (Green 1969), diagnosing what events might explain some observations, and analyzing the operation of programs that perform such tasks. Other formalisms used for the same purposes include modal logics such as dynamic logic and various logics for TEMPORAL REASONING (Goldblatt 1987), as well as the event calculus (Kowalski and Sergot 1986).

In the situation calculus, the initial situation of the world or system under consideration is represented by the constant S_0; this is simply understood as a situation where no actions of interest have yet occurred. The situation that results from an action *a* being performed in a situation *s* is represented by the term *do(a,s).* For example, $do(pickup(Rob,Package_1),S_0)$ might represent the situation where the robot *Rob* has performed the action of picking up the object $Package_1$ in the initial situation S_0; similarly, $do(goTo(Rob, MailRoom), do(pickup(Rob,Package_1), S_0))$ might represent the situation where *Rob* subsequently moved to the *MailRoom.* Thus, a situation is essentially a possible world history, viewed as a sequence of actions.

The situation calculus provides a way of specifying what the effects of an action are. For example, the axiom

$$\forall o \forall x \forall s (\neg Heavy(o, s) \\ \rightarrow Holding(x, o, do(pickup(x, o), s)))$$

could be used to state that an agent *x* will be holding an object *o* in the situation that results from *x* performing the action of picking up *o* in situation *s* provided that *o* is not heavy. Note that relations whose truth value depends on the situation, such as *Heavy* and *Holding*, take a situation argument; such relations are called *fluents*. From the above axiom and the assumption $\neg Heavy(Package_1, S_0)$, that is, that $Package_1$ is not heavy initially, one could conclude that $Holding(Rob, Package_1, do(pickup(Rob, Package_1), S_0))$, that is, that *Rob* would be holding $Package_1$ after picking it up in the initial situation. One can also use the situation calculus to represent the preconditions of actions, that is, the conditions under which it is possible to perform the action. Note that a situation calculus model of a system is just a theory in classical first-order logic and thus an ordinary theorem proving system can be used to infer consequences from it. This may be an advantage over the alternative modal logic formalisms.

Some of the most problematic features of commonsense reasoning manifest themselves in reasoning about action. For instance, although it seems reasonable that a model of a system should include an effect axiom for every action affecting a fluent (actions typically affect very few fluents), one should not have to include an axiom for every fluent that remains unchanged by an action (e.g., that going to a location does not change the color of objects). Yet this is just what is required by a straightforward application of logic to such reasoning. Dealing with the resulting mass of axioms is error-prone and computationally costly. This problem of representing succinctly and computing effectively with the "invariants" of actions has been called the FRAME PROBLEM by McCarthy and Hayes (1969) and has been the subject of much recent research (Elkan 1992; Hanks and McDermott 1986; Pylyshyn 1987; Reiter 1991; Sandewall 1994; Shanahan 1997). It has been one of the major motivations for research on nonmonotonic logics where a conclusion may be invalidated by additional assumptions (Reiter 1987). A nonmonotonic logic might attempt to solve the frame problem by representing the "persistence" assumption that says that fluents remain unaffected by actions unless it is known to be otherwise.

Note that some approaches to reasoning about action or processes such as STRIPS-based planning (Fikes and Nilsson 1971) and most work in process control and software