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The Environment as Theory: An Example Using the ACT-R/SOS Environment

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One of the most useful and clarifying ideas in cognitive modeling is Anderson's (1993) schema for understanding cognitive models in terms of *frameworks*, *theories* and *models*. In this paper we propose that this schema is equally valuable for describing the environment that a cognitive model acts within. Physics provides us with the correct models for representing the physical environment. However, the interaction between cognition and the physical environment is mediated by transduction processes, which are not fully understood. Thus you cannot simply slap a physics model onto a cognitive model. One way of dealing with this is to assume a transduction model that delivers what the cognitive model needs. Another approach is to drop physics and transduction completely and model the environment as it appears to the cognitive system after transduction.

This is the approach we took in creating SOS version 1.0 (Emond, West, 2003; West, Emond 2002; http://actr-sos.sourceforge.net/). SOS, which stands for Simple Object System, is a modeling system for creating low fidelity environments for ACT-R models to act on. It is meant to compliment ACT-R PM (Byrne & Anderson, 1998), which is a higher fidelity environment system for ACT-R, containing a much more detailed model of how we interact with the environment. The advantage of SOS is that it is easy to learn, quick to use, and very flexible (assuming you understand ACT-R).

SOS v 1.0 allows the modeler to build a chunked representation of the environment that functions according to its own rules, built in by the modeler. Changes occurring in the environment are represented the same way they would be in the ACT-R declarative memory system. That is, by making new chunks available or changing the slot values of existing chunks (new chunks are not actually created but toggled from visible to not visible). Both the perceptual and semantic properties of objects are encoded as slot values. SOS objects also contain a special slot for actions. The action slot specifies a target (i.e., another chunk representing some part of the environment) and an action (i.e., how to change the chunk structure of the target). It is also possible to insert lisp functions into the action sequence to create more complex effects. Thus SOS models how the environment works, but represents the environment as how we see it rather than how it is, physically.

SOS fits well into Anderson's (1993) schema of frameworks, theories, and models. SOS is based on the framework assumption that the end function of transduction is to create a mental model of the physical world in a format acceptable to declarative memory. The SOS code represents a computational theory about how the physical world is coded and how, once coded, it interacts with cognition. SOS assumes that cognition is described by ACT-R and also assumes that the coding of the physical environment results in a chunked representation that is highly similar to the way ACT-R chunks information in declarative memory. Consistent with the current ACT-R architecture, SOS interacts with ACT-R through the ACT-R buffer system. Also, although SOS does not embody a specific model of attention, because SOS focuses on objects it lends itself somewhat more naturally to creating models that use some form of object-orientated attention.

However, just as ACT-R does not specify how specific types of declarative memory content should be organized, SOS does not specify how specific environments should be organized. This must be specified as an SOS model. The important point in creating an SOS model is that chunking can occur based on abstract properties, as well as physical properties. This can be illustrated with a simple SOS model we built called SUE (simulated user environment). SUE is meant to model knowledge driven navigation in graphical computer interfaces such as Windows or OS X. To do this it was necessary to have chunks representing graphical elements such as icons, menu bars, dialogue boxes, etc. However, at a higher level, all objects in the environment are considered as either objects or containers. For example, an icon would be an object and an icon bar would be a container. This abstract structure is central to the process of navigating, modeled using ACT-R, but does not occur in the ACT-R model. Instead it is *delivered* from the environment through the transduction processes.

The SOS architecture makes this distinction very clear. All chunking that occurs in SOS occurs outside of cognition, in the perceptual systems. Note that this implies that the perceptual systems are capable of a certain level of semantic coding (e.g., seeing a bucket as a container). Being clear about this distinction, whatever modeling system you are using, is important because meaningful structure exists in the environment and is also added by the transduction process. What a cognitive model needs to do in order to complete a task is heavily dependent on the type of structure it is presented with. For example, the abstract structure presented by SUE allows the cognitive model to navigate much faster than it could if only low-level visual information were available. Problem solving can also be facilitated by structure from the environment and transduction (e.g., see Chalmers, French, & Hofstadter, 1995). Thus it is important to be clear about what is being coded where. We suggest that treating environmental simulations as models and using the frameworks, theories, models schema is a good way to do this.

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