Ontologies for Behavior

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ABSTRACT

Summary: Although dozens of biological ontologies have been created and deployed, relatively little attention has been given to using ontologies to represent behavior. Ontologies for two different behavior systems are described here. One ontology was a translation of a published ethogram, and the second was coded from video clips in a comparative study of jumping spider courtship.

Availability: http://mesquiteproject.org/ontology/
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MOTIVATION

Although dozens of biological ontologies have been created and deployed, relatively little attention has been given to using ontologies to represent behavior. One exception has been the small portion (0.6%) of terms in the February 2004 release of Gene Ontology categorized under the term ‘behavior’. Two ontologies, described here, were constructed to explore ontologies as representations for behavior. The first ontology was constructed from a traditional ethogram (behavior catalog). The second was constructed from video clips for a comparative study of courtship in a group of jumping spiders. Both were built on variants of a core ontology that could be expanded for describing and functionally annotating behavior data.

IMPLEMENTATION

The ethogram-based ontology was constructed from a published (Hailman and Elowson’s, 1992) ethogram of loggerhead sea turtle (Caretta caretta) nesting. The second ontology was developed from video clips of male courtship behavior in the jumping spider Habronattus californicus, which were made available by Wayne Maddison (unpublished data). Protégé data files for both ontologies have been posted, as have HTML renderings of the term hierarchies. The sea turtle ontology has been translated to the Gene Ontology flat file format (Gene Ontology Consortium, 2000).

Sea turtle nesting

Hailman and Elowson’s (1992) ethogram of sea turtle nesting consisted of detailed descriptions of 10 stages in the nesting process and their component action patterns. The ethogram included 57 terms for behavior patterns (actions) and three terms for body postures. The ontology contained 240 behavior terms, including mirror images of terms from Hailman and Elowson, and larger behavior groups and events resulting from actions. The ontology also included supporting terms, both explicit physical terms (e.g. ‘sand’) and abstractions (e.g. ‘local coordinate system’) used to define behavior terms.

Because this ontology was based on an ethogram, which summarized multiple observations of full and partial behavior, this ontology embodied the notion of ontology as controlled vocabulary. Although most terms were represented using classes, they could have easily been represented as individuals of a small number of term classes. The Gene Ontology translation demonstrated the feasibility of this alternate representation.

Jumping spider courtship

The second ontology was built to describe courtship behavior in a male jumping spider (H. californicus). The courtship ontology contained 53 action terms and six body position terms. This ontology differed from the Loggerhead ontology in two ways. First, this ontology was built directly from the analysis of video clips. To link the video clips to the ontology, individuals that represented 7 spiders, 194 behavior events and 93 video records were added. Second, the ontology was explicitly designed for a comparative study of courtship in a clade of Habronattus spiders.

Design

Both ontologies were designed to facilitate comparative studies. This comparative focus was reflected in several features of the ontologies. A shared, base ontology defined terms for basic physical, temporal and behavioral concepts. The base ontology was included in a set of ontologies, one per species, which contained homologous, anatomical terms that were used to define behavior terms. The lowest level of ontologies contained the focal behavior terms for each species.
Fig. 1. Taxonomy of behavior terms used in the ontologies. The highest level of the taxonomy for primitive actions split them according to the effect of actions on the animal's surface: change in connectivity (e.g. open/close); shape change, properties of the surface material (e.g. color change). Lower levels were organized by body part involved and context (membership in larger action patterns). This taxonomy deliberately ignored the function of actions.

Most taxonomies of behavior are organized by function, at least near the top of hierarchy. However, use in comparative studies recommended categorization by topography (physical form) of primitive actions. Figure 1 shows the taxonomy used for behavior terms. Most body motions involved changes in the spatial relations of body parts and were classed as shape changes. Actions that involved opening and closing of body orifices were classed as topological changes. Below this level, terms were classified by the body part involved. At the lowest level, behavior terms were categorized by context, the larger pattern that contained the unit.

The next step to allow the comparative use of these ontologies will be the development of a tool. The design for the tool has begun. The tool will perform analysis in two phases: alignment and scoring. The alignment phase will group behavior and anatomy terms based on the hierarchy of part-of relations, rather than is-a relations. The scoring phase could calculate similarity, from tree distances in the is-a hierarchy and other properties of the terms. The (external) phylogenetic tree would enter the analysis at the scoring stage.

**DISCUSSION AND CONCLUSION**

Ontologies for behavior will tend to take one of two forms: either general vocabularies of behavior terms with minimal species specificity, or detailed, species-specific descriptions that are equivalent to ethograms. The ontology as ethogram approach suggests, appropriately, that one way to construct species-specific ontologies is as ethograms—collections and descriptions of behavior patterns. The turtle and spider ontologies also illustrate how species-specific ontologies can build on general purpose ontologies, both to facilitate vocabulary sharing, and to aid automated 'alignment' in comparative tools. The core of these ontologies, EKB, could serve as a base for a larger general behavior ontology. The layout of EKB includes separate term hierarchies for function and form and that the latter hierarchy might be organized by movement topography and grounded in biomechanics. Such a hierarchy of movement patterns is an attractive base for comparative studies. General behavior ontologies will also draw terms from anatomy, physics, time and theories of social interaction, among other fields.

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**REFERENCES**
