Using Formal Meta-Data Descriptions for Automated Ecological Modeling

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System dynamics is a mathematical modeling approach widely used in environmental studies for representing and simulating ecological systems, giving support to prediction and decision making. The knowledge sources for model design are, essentially, human expertise and ecological data at various levels of abstraction. We observe that property descriptions of ecological data (ecological meta-data), such as functional, temporal and spatial relations between variables, seem to be cognitively close to the concepts and reasoning used by model designers. Can the process of linking ecological meta-data to model design be automated?

We aim to answer this question by: *(1)* developing a formal language for expressing ecological meta-data; *(2)* building a logic-based formalisation of connections between the meta-data descriptions and model design; and *(3)* semi-automating model design endorsed by meta-data descriptions.

Logic-based approaches for ecological modeling have been proposed in (Robertson *et al.* 1991). Emphasis is placed on the use of domain knowledge to support modeling automation, making model assumptions explicit to enable more informed model analysis. Our work evolves from these ideas, adding to them by investigating how ecological meta-data (which play a part in domain knowledge) can be conducive to model construction.

Automated modeling based on meta-data can only be attractive if the mechanisms supporting it are not restrictive to specific datasets. Pre-defining a detailed knowledge representation system still general enough to express properties of every ecological dataset is infeasible. Thus, what is needed is a general framework for meta-data description which can be instantiated to specific datasets and model purposes. We have a prototype ontology, named *Ecolingua*, for such a framework, providing a vocabulary and axioms for ecological meta-data description.

Ecolingua has been designed by trying and describing a diverse dataset generated by a tropical forest logging experiment in the Amazon, Brazil (Biot 1995). As design tool we have been using the www-based Ontolingua Server (Farquhar, Fikes, & Rice 1996) for ontology construction and sharing, which provides an extensive library of sharable ontologies. Ontolingua, the representation language used by the server, was created as an attempt to solve the ontologies' portability problem. It provides a standard representation with translations to the syntax of specific target languages. Our target language is Prolog, which we use to connect meta-data descriptions to endorsements of model structure. The server automatically translates *Ecolingua* plus all the ontologies it refers to, into a file containing a very large (5.3Mb) ill-structured knowledge base in a Prolog-readable version of the Ontolingua syntax. To extract a manageable knowledge base from this file we built tools for syntactic correction, consistency checking, pruning and mapping of logical sentences into more elegantly constructed Horn clauses. The outcome is a knowledge base providing a logical foundation for inference connecting meta-data descriptions to model design. This includes definitions inherited from the other ontologies used to build *Ecolingua* on the Ontolingua server.

Features of the meta-data description (instantiated to a particular dataset) are used to reconstruct semi-automatically steps taken in performing parameter estimation, a basic task of model construction. The ultimate goal is to build a system that semi-automates a range of system dynamics modeling tasks (parameter estimation, model structuring, equation design) and is able to furnish the user with the underlying meta-data support rationale. The system will infer prototypical models (or parts of them) to be interactively further refined by human modelers.

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