Semantic Models and Ontologies in Modelling Policy-making –A Position Paper–

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Abstract. In modelling policy-making, we propose the use of formal semantic models and ontologies to structure the analysis of informal policy statements, specify the domain, generate the logical space of arguments and counter-arguments about a policy proposal, and underpin tools for automated policy-making.

Keywords. policy-modelling, semantics, ontologies

Introduction

In this position paper, we discuss the role of semantic models and ontologies in modelling policy-making. Policy making can be viewed as a cyclical, multi-stage process [1,2] with several stages: evaluation, agenda setting, policy formulation, decision, implementation. We focus on the policy formulation stage, where the policy proposal is set and critiqued.

While current approaches make some use of IT, e.g. e-petitions to get feedback on a policy proposal, these tend to be too *coarse-grained* to identify what, in particular, citizens agree or disagree with. Moreover, there is a lack of *structure* to the proposal in the sense that the components and their relationships have to be identified. Consequently, it is difficult to apply automated techniques and tools to support policy formulation, which would make it more efficient, transparent, and accessible.

In recent work [3,4], formal semantic models are introduced to represent knowledge about the policy domain and to provide components that are used in forming practical reasoning arguments about policy proposals. Such arguments are extracted from comments on policy proposals, formalised, then presented to users in a web-based policy consultation tool, where users are queried about their opinions about particular components of the policy proposal [5].

In our view, formal semantic models are advantageous in that they provide a precise basis for organising, distinguishing, and reconciling the diverse opinions

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from the original documents, for constructing initial arguments based on this collective understanding, for evaluating these arguments by identifying conflict and inconsistency, and for assimilating additional information. It disciplines the policy analysts' analysis of the source material by providing a clear, specific structure into which the arguments from the source must be cast, thereby clarifying alternatives and making implicit information explicit. Furthermore, the model, once given, can be used to generate the logical space of arguments found in the source materials along with their systematic inter-relationships. The semantic model also supports and makes transparent the policy analysts' evaluation of given arguments in light of the responses to the survey, which may endorse, oppose, or introduce further particular elements of the arguments. A formal model specifies a computer program that can generate arguments and their relationships, allowing in-depth representation and automated reasoning. In sum, the semantic model helps us to have a greater understanding of the meaning and implications of the policy as well as how they might specifically critique or contribute to it.

Aligned with the semantic model, we propose to present an ontology for the domain, where the ontology is systematically derived from the semantic model. The ontology has been used to generate arguments using the *Legal Knowledge Interchange Format* (LKIF) [6], an XML specification for the representation of legal rules, and Carneades [7], a tool which supports argument representation and evaluation. The role of the ontology is to act as a bridge between the formal model and the executable code. This bridge could also be realised in other ways, such as a database or even directly in code, e.g. Prolog.

While we have some understanding of the semantic models and ontologies, we intend to deepen and broaden it, elaborating on the derivations, relationships, and applications of the models and ontologies as well as extending our current representations to incorporate models and ontologies for related aspects of policy-making such as supporting arguments concerning credible sources of information and causation. In the following sections, we outline elements of our current understanding of the formal semantic model and ontology, while at the workshop, we propose to present elaborated and extended analyses.

1. Practical Reasoning and a Semantic Structure

In public policy discussions, participants recommend and justify what should be done. We can represent such arguments with the practical reasoning argumentation scheme (PRAS) [8,9], wherein the proponent justifies an action:

> **PRAS**: In the current circumstances (R), action Ac should be performed, since this will bring about a new set of circumstances, the consequences (S), in which some goal (g) is realised. Goal g is desirable as it promotes a particular social value (v).

To give a formal semantic basis to the scheme, we make use of a computational model based on the Action-Based Alternating Transition System with Values (AATS+V) [10,9,3]. Here we provide an informal statement of the AATS+V and its association with the PRAS (see [3] for a full, formal specification and a range of examples), where main elements of the structure are:

- Q, a set of *states*, where a state is a consistent conjunction of literals. Current circumstances S and consequences R in the PRAS are states.
- Ag is a set of *agents*, Ac_i is the set of *actions* available to a particular agent, ag_i, and J is the set of *joint actions*, assuming agents execute actions jointly. In the PRAS, agents appear as part of Ac.
- The *state transition function* defines the state that results from the execution of each joint action in a given state. Transitions are implied in the PRAS by the change from circumstances to consequences.
- A *goal* is a literal that holds after execution of a joint action, where the negation of the literal holds in a circumstance before execution.
- V is the set of *values* relevant to the scenario.
- The *valuation function* defines the status (promoted +, demoted -, or neutral =) that labels the transition between the two states. The values and function are given in the PRAS.

The AATS+V is an abstract semantic structure that we have instantiated [5]. However, to operationalise and automatically reason with the arguments generated from the semantic representation, we must represent the instantiated semantic model in a machine readable form.

2. The Ontology

We have represented our instantiated semantic model in an OWL ontology using the *Protege* ontology editor and knowledge acquisition system. For the purposes of this position paper, we do not give a full presentation of the ontology, but indicate the elements of the semantic model (given in *italics*) followed by ontological classes with data and object properties (indicated in **bold**), briefly discussing the relationship between elements of the semantic model and the ontology.

- Q - class **State** of individuals such as q_0,...,q_6. Every element of Q is an individual in **State**.
- q_0 - class **CurrentState** with a single individual. The class has **hasTime** data property with range to type **string** set to value 0 and an object property **stateRelation** with domain **CurrentState** and range **State**. The object property associates the **CurrentState** individual with a **State** individual, thus indicating the time of the **State** individual.
- Ag - For each agent in Ag, we have an object property with domain **JointAction** and range **Action**, for each of the available action subclasses, e.g. j_0 **jointActionGovernment governmentAction1**.
- Ac_i - **Action** with disjoint subclasses for each agent in Ag, e.g. **Government**, and given individuals. These subclasses have a data property **hasAction** with domain **Action** and range of type **string**.
- *System transition function* τ - a class **Transition** with object properties **transitionJointAction** with range **JointAction**, **transitionSource** with range **State**, and **transitionTarget** with range **State**.
- *Action pre-condition function* ρ - this is expressed derivatively in the ontology as individuals of **Action** do not themselves have preconditions. The

class **Transition** has an object property **transitionJointAction**, which gives the joint actions associated with individuals in **Transition**. **JointAction** has an object property that identifies the actions associated with the **JointAction**, e.g. **jointActionNature natureAction1**. In addition, the class **Transition** has object property **transitionSource**, which gives an individual of **State** as source of an individual in **Transition**. Thus, individuals of **Action** implicitly are associated with a source state in virtue of object properties to transitions.

- *Atomic propositions* - a data property with range **State** and range type **boolean**. For each atomic proposition of ϕ, there is a separate data property, e.g. **hasPropertyP**.
- *Interpretation function* π - this is given by assignment of a boolean value to each of the data properties associated with each proposition with respect to a state, where **hasPropertyP** is a data property with domain **State** and range **boolean**. For example, q_1, an individual from **State**, has the **hasPropertyP** data property set to **false**.
- *Joint actions* - a class **JointAction** with several joint action object properties, one for each of the **Action** subclasses associated with an agent, e.g. **jointActionGovernment governmentAction1**.
- V - a class **Value** that has individuals such as **Budget**, **Freedom**, etc.
- *Valuation functions* δ - demotes and promotes object properties from **Transition** to **Value**.

One of the key differences between the AATS+V semantic model and the OWL ontology is that the ontology can only be expressed within the constraints of Description Logics, while the AATS+V is expressed in First-order Logic and functions. In addition, not every aspect of the semantic model is translated directly into the ontology, e.g. the Action pre-condition function has no direct correlate in the ontology. As well, though the semantic model represents propositions and their interpretation (truth-value) as is standard in logic, there are alternative ways to achieve the same representation in the ontology. These (and other) issues remain to be explored further.

Here we have presented the ontological realisation of the semantic model. Other operational representations are possible in a database or in a Prolog program, offering different *views* on the semantic information and supporting different *functionalities* relative to purpose.

3. Conclusion

In this position paper, we have outlined some of our motivations and uses for a semantic model and ontology for policy-making. Some of the formal elements are sketched. In future work, we deepen and broaden our understanding of representations of policy-making, for example, by adding argumentation schemes for causation or credible source along with supporting semantic models and ontologies.

Acknowledgements

This work was partially supported by the FP7-ICT-2009-4 Programme, IMPACT Project, Grant Agreement Number 247228. The views expressed are those of the authors and are not necessarily representative of the project.

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