Constraint Satisfaction Problems and Knowledge Representation

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Abstract

The Constraint Satisfaction Problem framework is used as a knowledge representation framework for artificial intelligence tasks. As such it can be judged by adequacy criteria proposed for knowledge representation schemes (Mackworth, 1988). For example, as an aspect of descriptive adequacy, we want to know how a CSP arises from a task specification. Under procedural adequacy, we can ask if there are computational advantages to the CSP representation over, say, a propositional logic representation.

These questions can be posed in a formal setting for depiction described with Reiter (Reiter and Mackworth, 1988). There we propose a logical framework for depiction and interpretation that formalizes image domain knowledge, scene domain knowledge and the depiction mapping between the image and scene domains. This framework requires three sets of axioms: image axioms, scene axioms and depiction axioms. An interpretation of an image is defined to be a logical model of these axioms. For a simple map world we show how the task level specification may be refined to a provably correct implementation by applying model-preserving transformations to the initial logical representation to produce a set of propositional formulas. The implementation may use known constraint satisfaction techniques to find the set of models of these propositional formulas. This approach provides a formal framework for analyzing and going beyond existing systems such as Mapsee, and for understanding the use of constraint satisfaction techniques.

In that framework, there are two ways to encode the SAT problem as a CSP. The first encoding uses the propositional variables as CSP variables. The second encoding uses the natural domain variables as CSP variables. This approach gives a more efficient

and natural encoding than the first. For an arbitrary SAT problem only the first encoding is available, but for the restricted class of SAT problems which arise in the depiction framework the second encoding is appropriate.

Finally, an encoding of every CSP problem as a SAT problem is also available, but it is not a compact representation of the problem since it does not explicitly use the structure inherent in the CSP framework.

By investigating these connections between the CSP approach and other approaches based on first order and propositional logic we can understand how CSP's arise from a formal specification and learn how the structure inherent in the CSP framework can be exploited, using, for example, efficient approximation algorithms.

References

1. Mackworth, A.K. "Adequacy Criteria for Visual Knowledge Representation", in Z. Pylyshyn (ed.) *Computational Processes in Human Vision*, Norwood, N.J.: Ablex Publishers, pp. 464–476, 1988.

2. Reiter, R. and Mackworth, A.K. "A logical framework for depiction and image interpretation", UBC Department of Computer Science, TR88–17, 1988 (to appear in *Artificial Intelligence*).