

Abstraction and problem reformulation

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In work done jointly with Toby Walsh, the author has provided a sound theoretical foundation to the process of reasoning with abstraction [GW90c; GW89; GW90b; GW90a]. The notion of abstraction formalized in this work can be informally described as:

[property 1] the process of mapping a representation of a problem, called (following historical convention [Sac74]) the "*ground*" representation, onto a new representation, called the "*abstract*" representation, which:

[property 2] helps deal with the problem in the original search space by preserving certain desirable properties and

[property 3] is simpler to handle as it is constructed from the ground representation by "throwing away details".

One desirable property preserved by an abstraction is provability; often there is a relationship between provability in the ground representation and provability in the abstract representation. Another can be deduction or, possibly inconsistency. By "throwing away details" we usually mean that the problem is described in a language with a smaller search space (for instance a propositional language or a language without variables) in which formulae of the abstract representation are obtained from the formulae of the ground representation by the use of some terminating rewriting technique. Often we require that the use of abstraction results in more efficient reasoning. However, it might simply increase the number of facts asserted (*eg.* by allowing, in practice, the exploration of deeper search spaces or by implementing some form of learning).

Among all abstractions, three very important classes have been identified. They relate the set of facts provable in the ground space to those provable in the abstract space. We call:

- TI abstractions all those abstractions where the abstractions of all the provable facts of the ground space are provable in the abstract space;
- TD abstractions all those abstractions where the

"unabstractions" of all the provable facts of the abstract space are provable in the ground space;

- TC abstractions all those abstractions where a fact is provable in the ground space if and only if its abstraction is provable in the abstract space.

Historically the word abstraction has been mainly used with a much more restricted meaning which captures its use in problem solving and planning (for instance in Abstrips or Soar). Our notion of abstraction (and in particular the three classes defined above) turns out to capture and provide a unifying framework for describing work done in the definition of decision procedures (see for instance [DG79; Giu91]), in planning and problem solving (see for instance [Sac73; Ell90; MH91; Kno89]), explanation (see for instance [Doy86]), common sense reasoning (see for instance [Hob85]), qualitative and model based reasoning (see for instance [Moz90; Wel91]), approximate reasoning [Imi87]), analogy (see for instance [Ble90]) and reasoning with very large data bases (see for instance [Lev92]).

At a close look abstraction seems also very related to problem reformulation. In particular it seems that problem reformulation can be characterized as using some of the subclasses of TC and TD abstractions introduced in [GW90c]. A positive feedback on this intuition would allow to use the framework described in [GW90c; GW89] to put the work on problem reformulation on a more solid ground and, at the same time, to study and compare the techniques used in problem reformulation with the techniques used in all the other areas captured by the framework.

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