AISB'99 CONVENTION

PROCEEDINGS OF THE 6TH WORKSHOP ON AUTOMATED REASONING

BRIDGING THE GAP BETWEEN THEORY AND PRACTICE

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EDINBURGH COLLEGE OF ART &
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AISB Convention 1999

Sixth Automated Reasoning Workshop: Bridging the Gap between Theory and Practice

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Combining Reasoning Systems

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Why Combine Logics?

Combining logics for modeling purposes has become a rapidly expanding enterprise that is inspired mainly by concerns about modularity and the wish to join together different kinds of information. As any interesting real world system is a complex composite entity, decomposing its descriptive requirements (for design, verification, or maintenance purposes) into simpler, more restricted reasoning tasks is appealing as it is often the only plausible way forward. It would be an exaggeration to claim that we have a thorough understanding of 'combined methods.' Nevertheless, a core body of notions, questions and results has emerged for an important class of combined logics, and we are beginning to understand how this core theory behaves when we try to apply it outside this particular class.

Does the idea of combining logics actually offer anything new? Some of the possible objections can be justified. Logical combination is a relatively new idea: it has been not yet systematically explored, and there is no established body of the results or techniques. Nonetheless, there is a growing body of logic-oriented work in the field, and there are explorations of their uses in AI, computational linguistics, automated deduction, and computer science. An overly critical reaction seems misguided.

The plan of this abstract is as follows. We start with a discussion of a class of problems typically considered in the are. We then take a brief look at actual implementations of combined logics.

Transfer Problems

Let $\mathbf{L}_1$ and $\mathbf{L}_2$ be two logics—typically, these are special purpose logics with limited expressive power, as it often does not make sense to put together logics with universal expressive power. Let P be a property that logics may have, say decidability, or axiomatic completeness. The *transfer problem* is this: if $\mathbf{L}_1$ and $\mathbf{L}_2$ enjoy the property P, does their combination $\mathbf{L}_1 \oplus \mathbf{L}_1$ have P as well? Transfer problems belong to the main mathematical questions that logicians have been concerned with in the area of combining logics.

When, and for which properties do we have transfer or failure of transfer? As a rule of thumb, in the absence of interaction between the component logics, we do have transfer; here, absence of interaction means that the component languages do not share any symbols, except maybe the booleans and atomic symbols. Properties that do transfer in this restricted case include the finite model property, decidability, and (under suitable restrictions on the classes of models and the complexity class) of complexity upper bounds.

The positive proofs in the area are usually based on two key intuitions: *divide and conquer* and *hide and unpack*. That is: try to split problems and delegate sub-problems to the component logics; and when working inside one of the component logics view information relating to other component logics as alien information and 'hide' it—don't unpack the hidden information until we have reduced a given problem to a sub-problem in the relevant component logic. Neither of these key intuitions continue to work in the presence of interaction. For instance, consider two modal languages $\mathcal{L}_1$ and $\mathcal{L}_2$ with modal operators $\Box$ and $\blacksquare$, respectively; there are logics $\mathbf{L}_1$ and $\mathbf{L}_2$ in $\mathcal{L}_1$ and $\mathcal{L}_2$ whose satisfiability problem is in NP, while the satisfiability problem for the combined language *plus* the interaction principle $\Box p \to \blacksquare p$ is undecidable.

Combinations at Work

Does combining logics work for actual reasoning systems? That is: can existing tools for component logic be put together to get tools for combined logics? Obviously, the *re-use* of tools and procedures is one of the key motivations underlying the field. Now, one cannot put together any proof procedures for two logics in a uniform way. First, 'proving' can have different meanings in different logics: (semi-)deciding satisfiability or validity, computing an instantiation, or generating a model. Second, it is not clear where to "plug in" the proof procedure for a logic $\mathbf{L}_1$ into that for a second logic $\mathbf{L}_2$; a proof procedure may have different notions of valuations, or of proof goals.

So what can one do? One way out is to impose special conditions on the calculi that one wants to combine [BG98]. Another possibility, in the case of modal logics, is to use a translation-based approach to theorem proving, by mapping all component logics into a common background logic. [GS96] provide an interesting example by combining efficient propositional decision procedures into a decision procedure for the modal logic **K**.

There are quite a few successful particular instances of combined logics, where we have no problems whatsoever in putting together tools; see [AAdR99, KdR99]. By and large, however, we don't have a good understanding of how to proceed. Further experimentations are needed, both locally, and network based, so that at some stage we will be able to plug together tools without having to be the designer or engineer of the systems.

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