Automatic Learning of Proof Methods in Proof Planning*

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Abstract

We present a framework for automated learning within mathematical reasoning systems. In particular, this framework enables proof planning systems to automatically learn new proof methods from well chosen examples of proofs which use a similar reasoning pattern to prove related theorems. Our framework consists of a representation formalism for methods and a machine learning technique which can learn methods using this representation formalism. We briefly present how to learn methods in the ΩMEGA proof planner. The approach is a two-stage one, first to learn method outlines and second to build complete methods from method outlines.

Proof planning [Bun88] is an approach to theorem proving which uses proof methods rather than low level logical inference rules to find a proof of a theorem at hand. A proof method specifies a general reasoning pattern that can be used in a proof, and typically represents a number of individual inference rules. Proof planners search for a proof plan of a theorem which consists of applications of several methods. One of the ways to extend the power of a proof planning system is to enlarge the set of available proof methods. This is particularly beneficial when a class of theorems can be proved in a similar way, hence a new proof method can encapsulate the general reasoning pattern of a proof for such theorems. A difficulty in applying

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a proof pattern to many domains is that in the current proof planning systems new methods have to be implemented and added by the developer of a system. We devised a framework within which a proof planning system can learn frequently occurring patterns of reasoning automatically from a number of typical examples, and then use them in proving new theorems [JKB01]. The availability of such patterns, captured as proof methods in a proof planning system, reduces search and proof length. We implemented this learning framework for the proof planner ΩMEGA [BCF+97], and – we call our system LEARNΩMATIC. LEARNΩMATIC consists of, first, a learning mechanism, which learns so-called *method outlines* from proof traces of typical examples. Method outlines are essentially names of methods, sequences, disjunctions, repetitions (arbitrary or fixed number), and branching points (as list of branches). For instance, from the outlines $e_1 = [a, a, a, a, b, c]$ and $e_2 = [a, a, a, b, c]$ the system would generalise to $[[a]^*, [b, c]]$.

The second part of LEARNΩMATIC consists of a mechanism which enables ΩMEGA to use these method outlines as fully fleshed proof methods by adding to them additional information and performing search for information that cannot be reconstructed.

Further information about the project and links to publications can be found on `www.cs.bham.ac.uk/~mmk/projects/MethodFormation/`.

References

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