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Machine Learning for Automated Synthesis of Complex Software

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The automated construction of computer programs from formal behavioral specifications [1] has been a subject of active interest in the software engineering community for the last forty years. Several approaches for constructing programs from variants of temporal logics have been studied, and practical tools for generating programs from high-level specification languages such as UML have been implemented. However, little effort has been directed towards the automated synthesis of correct-by-construction software by leveraging complementary strengths of formal verification and modern machine learning techniques.

Machine learning methods are quite adept at learning linear and nonlinear relations between two or more variables of interest to a data scientist. While these methods are scalable and can learn models with millions of data points with ease, they suffer from learning errors and may not necessarily learn the concept class being taught. On the other hand, *formal verification* methods can algorithmically decide if a candidate program satisfies the specifications that constraint the set of behaviors expected from the program. However, formal verification cannot generate the correct program from the specification itself. By combining the strengths of machine learning and formal verification, it is feasible to algorithmically synthesize programs from various flavors of formal and informal specifications, including logics, input-output examples, and a library of program templates. Conceptually, the synthesis technique [2] leverages inductive learning techniques as a student generalizing from sets of behaviors to candidate programs while deductive formal methods serve as a teacher rectifying generalizations to slowly guide the automated synthesis technique towards provably correct programs.

In practice, software engineering problems are too complex for a human expert to resolve on her own; these include the design of optimal control algorithms for cyber-physical systems and the optimization of software for upcoming SoC and embedded computing platforms. A prototypical example of the former class of problems is the automated synthesis of controllers for biomedical devices such as artificial pancreata. Unlike traditional control problems, such software has no scope for error and must quickly adapt to both inter-patient variations and possible failures in the hardware itself. Another challenging problem is the ability to port IEEE floating-point compliant numerical software from traditional x86 architecture to modern SoC platforms, GPGPU hardware, or fixed-point ECUs. These complex tasks provide exciting opportunities for the automated synthesis of complex correct-by-construction software.

The algorithmic synthesis of complex and evolving software that can replace error-prone aspects of software engineering is an exciting area of research that will greatly benefit from cross-pollination between machine learning and formal verification.

References

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