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Designing Parameters of Hybrid System

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A hybrid system is a dynamical system with both discrete and continuous state change. Therefore, it is useful for the analysis and design of distributed, embedded control systems. Hybrid systems have been used as mathematical models for many important applications, such as automated highway systems, air-traffic management systems, manufacturing systems, chemical processes, robotics, real-time communication networks, and real-time circuits. Their wide applicability has inspired a great deal of research from both control theory and theoretical computer science. In hybrid systems, it is known that complex phenomena that cannot be observed both in continuous-state systems and in discrete-state systems sometimes occur. Therefore, development of methodologies for designing highly reliable hybrid systems is demanded.
Most of the previous researches on hybrid systems are those for the verification, i.e., to check whether the design satisfies a given specification or not. However, the parameter design problem, which is the problem of deciding values of parameters so that the system fulfills the given behavioral specification as the inverse problem of verification, is not well discovered. By developing a technique of calculating optimal parameters in an algorithmic manner, we can make design processes of hybrid systems to be done more efficiently, comparing with the usual method by trial and error. In this research, the parameter design problem of hybrid systems is formulated

as a problem of deciding values of variables so that constraints described as formulas of first-order predicate logic with continuous and the discrete variables become true. We focus on Constraint Logic Programming (CLP), which is a processing system for solving constraint satisfaction problems with both logical constraints and numerical constraints. Using CLP, we develop a method to calculate values of parameters that fulfills a given behavioral specification described by temporal logic formulas.

CLP is a processing system based on logic programming such as Prolog. In addition, it is equipped with solvers for various kinds of constraint satisfaction problems. There are three advantages of using CLP. The first one is that there are similarities in operation semantics between CLP and hybrid automata. However, there are only a few previous researches on the analysis of hybrid systems using CLP. The second one is that CLP enables symbolic simulation of the behavior of hybrid automata. The third one is that we may only pay attention to relationship and constraints which exist on objects in the problem. In other words, we do not have to describe procedures to solve the constraints in CLP programs and we may describe only relations on objects as constraints. In this research, Keyed CLP, that is a CLP language with a solver for linear inequalities on the real number field, is used.

Temporal logic is used for describing various properties on state transitions in discrete systems. Temporal logics were first proposed by Pnueli in 1977, for the purpose of describing specification in the verification of concurrent programs, and there are various versions of them. In this research, we used a modified version of CTL (Computation Tree logic), where CTL is often used in the model checking etc. We associate with each temporal operator a maximum time by which the formula becomes true. This is necessary for the CLP execution to terminate within a finite number of steps. In this research, we formulate a parameter design problem of hybrid systems, and propose a method to solve it by using CLP. Any computation by the proposing method halts within a finite number of steps provided that the number of discrete state transitions that can occur in a given maximum time is bounded. Therefore, for linear hybrid automata, values of parameters fulfilling the behavioral specification can always be obtained under the assumption that every temporal operator has a maximum time. In the proposing method, we adopt a technique to approximate the negation of a region of parameters. It is to compute the negation of a convex polyhedron surrounded by the maximum and the minimum values of each variable. This is a restriction arising from the limitation of solvers in Keyed CLP. We need improve this problem in the future.