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MJCG

Specification and Verification II 2003

HV1: Solution Notes

This question pertains to the "Property specification and checking" part of the course.

(a) Describe the semantics of formulas in *linear temporal logic* (LTL) and *computation tree logic* (CTL). Illustrate your answer by contrasting the meanings of $\mathtt{G}\,P$ in LTL with $\mathtt{AG}\,P$ (where P is a property of states) in CTL in LTL and CTL.

> LTL formulas express properties of executions of a system. Semantically they are predicates on sequences of states or paths.
>
> The meaning of $\mathtt{G}\,P$ is the predicate that is true of a path π if P is true for every element of π.
>
> CTL formulas are properties of the transition graph of a system. If a system is non-deterministic, so that some states have more than one successor, then the transition graph will be a tree. Thus, in general, CTL formulas are properties of trees.
>
> The meaning of $\mathtt{AG}\,P$ is the predicate that is true if P is true for every state on every R-path starting from s. Alternatively, P is true at every node of the the tree (R, s), where R is a transition relation giving the edges of the tree and s is the root. Thus $\mathtt{AG}\,P$ means P is true of all R-reachable states.

(b) Give an LTL property that cannot be expressed in CTL.

> The property "on every path there is a point after which P is always true" is expressible as $\mathtt{F(G}\,P\mathtt{)}$ in LTL, but cannot be expressed in CTL.

(c) Give a CTL property that cannot be expressed in LTL.

> The property "from every state it is possible to get to a state in which P holds" is expressible as $\mathtt{AG(EF}\,P\mathtt{)}$ in CTL, but cannot be expressed in LTL.

(d) Describe briefly the kinds of properties that can be expressed using Sugar Extended Regular Expressions (SEREs), Foundation Language (FL) formulas and Optional Branching Extension (OBE) formulas of the *Sugar 2.0* property language. [4 marks]

> SEREs are regular expressions that specify properties of finite sequences of states. FL formulas are an extension of LTL for expressing properties of computation paths (finite or infinite). OBE formulas are CTL properties.

(e) Consider the property: "whenever a, b and c occur on successive cycles, then on the cycle that c occurs, d must occur also, followed on the next cycle by e" (where a, b, c, d and e are boolean expressions). Use this property to illustrate how SEREs can sometimes help specify properties more compactly than pure LTL.

> The pure LTL representation of the property would be
> $\texttt{G(a} \Rightarrow \texttt{X(b} \Rightarrow \texttt{X(c} \Rightarrow \texttt{(d} \wedge \texttt{X e))))}$,
> but using Sugar SEREs this is
> `{a;b;c}|->{d;e}`.