Software State Observability in CPS: Tools for Modeling CPS Software

by Chinwendu Enyioha
PIs: Jason Rife, Sam Guyer

Challenge: Significant potential exists to introduce flexible models of CPS software, independent of programming language and software architecture, and unencumbered by rigid modeling considerations such as those imposed by hybrid-system modeling and formal methods. Ideally, new tools would automatically convert raw code into an accurate reduced-order model of arbitrary CPS software, thereby enabling streamlined verification and performance analyses.

Solution: At a high level, our approach decomposes a program into disjoint sets of commands (lines of code) such that elements in each set receive and process inputs concurrently. We call each such set a Temporal Segment (TS). The TS models a set of commands as an algebraic delay equation, which has the form $y(t + \Delta t) = f\,(u(t))$.

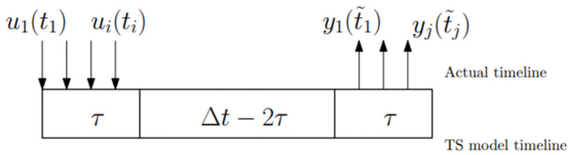

Fig. 1 Timeline of TS for $\Delta t > 2\tau$

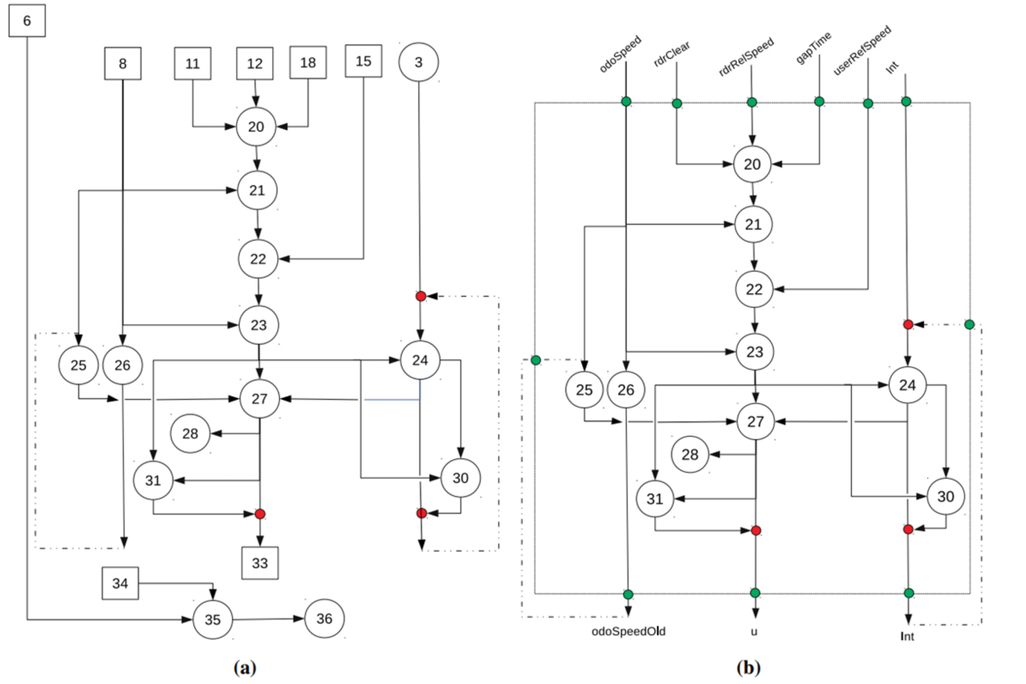

Fig. 2 Figure 2a shows graph model for the ACC Algorithm 1, and Figure 2b shows entry and exit points of the main TS of ACC graph model in Algorithm 1. The red dots are 'mux' points, in which one of multiple incoming signals to that point is active or selected; and the green dots are interconnect nodes, indicating signal entry or exit points into the TS.

Impact: By applying graph-based methods to analyze a representative Adaptive Cruise Control (ACC) code, we determined the minimal set of probes needed to provide full coverage for the main subgraph within the ACC. In concept, these tools could be automated to apply to much larger CPS software programs, by decomposing those programs into temporal segments (TS) similar to the one analyzed here and by optimizing probe selection for each TS.

Broader Impact: Our proposed approach will permit software engineers greater latitude in developing new software, paving the way for more flexible and effective integrated CPS systems and for fast verification, which will help spark emerging markets for low-cost unmanned aerial vehicles and automated ground transport. Our educational impact includes training graduate students and creating a new collaborative robotics class concerning safety assurance for human-robot teams.

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