Project Title: CPS: Small: Control of Distributed Cyber-Physical Systems under Partial Information and Limited Communication

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The principal objective of this project is the development of novel control architectures and computationally efficient controller design algorithms for distributed cyber-physical systems with decentralized information infrastructures and limited communication capabilities. We are interested in distributed cyber-physical systems where the system components are able to communicate with one another. Cooperative active safety in Intelligent Transportation Systems is our focus cyber-physical application. Our methodology for design of communicating distributed hybrid controllers aims to integrate in a novel manner discrete-event controller design and hybrid controller design and optimization. Both safety and liveness specifications will be addressed. The methodology to be developed exploits problem decomposition and is aimed at cyber-physical systems that share features of modularity in system representation, partial information, and limited communication. The technical approach consists of the following steps: (i) abstraction of the essential features of the cyber-physical system as a formal discrete-event model; (ii) synthesis of a set of distributed discrete-event control laws as well as sensor activation and communication strategies for the system agents; (iii) incorporation of the underlying continuous dynamics of the cyber-physical system with the preceding distributed control logic for the purpose of hybrid controller design and quantitative performance optimization; (iv) iteration between steps (ii) and (iii) for performance improvement.

Due to the nature of control problems under partial observation, there does not exist in general a "supremal" (in the sense of minimally restrictive) solution in terms of language inclusion at the discrete-event level. We will couple the hybrid solver with the discrete-event solver in the following manner: The discrete-event solver will pass sets of solutions to the hybrid solver; one set of solutions refers to the control, sensor activation, and communication strategies of the set of agents. Based on the performance of the solutions obtained by the hybrid solver for a given input from the discrete-event solver, we may need to further guide the search for "good" (e.g., locally minimal) solutions in the discrete-event solver. Specifically, the results from the hybrid solver will generate a total order among the partially-ordered solutions of the discrete-event level.

The cyber-physical application that will serve as a platform for the validation of the results is that of cooperative active safety in Intelligent Transportation Systems. The essential features of collision avoidance scenarios (safety and liveness) will be retained from a roundabout test-bed, which will be implemented in PI Del Vecchio's laboratory.