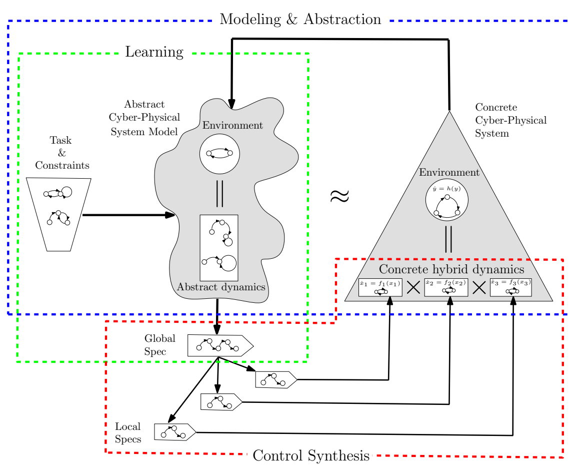
Efficient Control Synthesis and Learning in Distributed Cyber-Physical Systems

This project is on coordinating groups of heterogeneous autonomous cyber-physical systems for the purpose of satisfying general control specifications that involve temporal as well as scheduling constraints, in an environment that is partially unknown and dynamically changing. Solutions to a problem of this kind offer initial coordination strategies for effective response to time-critical challenges that require orchestrated actions between interdependent individual assets. Examples include emergency response and search and rescue scenarios.

The hypothesis is that when the interdependent agents are modeled as a special type of hybrid dynamical systems, it is possible to obtain resolution-independent discrete abstractions of them that give rise to computation models associated with a proper subclass of regular formal languages. The significance of this is that there is sufficient mathematical structure in this class for operations between its members to become computationally efficient, mathematical representations to become compact, and for these objects to naturally lend themselves to efficient identification in the limit, a type of learning, which is being explored in the context of computational linguistics.

The objective therefore is first to identify the right discrete abstractions, and then define the operations that would enable one to obtain collective models of these interacting cyber-physical systems, which can learn their environment through observation. Given that these collective models have enough structure to permit efficient planning and control computations, the control plans can be then refined on-line, based on the increasingly more accurate description of the environment dynamics.



To achieve this goal we need to determine the appropriate class of hybrid systems, specify the abstraction process, characterize the expressiveness of the derived abstract models, find out what computational tools and techniques can be applied, and then use them for cooperative control design and planning. At the core of this approach is the idea of building increasingly complex discrete dynamical models based on simple factors, and developing new algebraic tools for composing them efficiently. So far, the algebraic approach to automata theory has proven an effective framework for characterizing the class of discrete abstractions obtained from stable hybrid dynamical systems, and developing algorithmic tools that contribute in the analysis and synthesis of control strategies, which have guaranteed implementation on the concrete underlying dynamical systems.