CPS: Small: Efficient Monitoring Techniques for Safety Critical Cyber-Physical Systems

Correct functioning of cyber-physical systems is of critical importance. This is more so in the case of safety critical systems such as in medical, automotive and many other applications. Since verification of correctness, in general, is infeasible and testing is not exhaustive, it is of critical importance to monitor such system during their operation and detect erroneous behaviors to be acted on.

This project proposes monitoring techniques, for checking the correctness of system behavior during it's operation, and raising an alarm when the system seems to exhibit erroneous behavior, which can be acted on. The proposed approach employs hybrid automata both for specifying the property to be monitored and for modeling the system behavior. The system behavior is probabilistic in it's evolution due to uncertainties introduced by noise and other factors. The property automaton is specified on system behaviors. Monitoring such systems is a challenging problem as the monitor can not observe the system state, but can only observe the outputs generated by it.

Intellectual Merit: The project proposes techniques for estimating the probability that the system behavior is erroneous based on observed outputs. Fundamental research on defining and detecting whether a system is monitorable with respect to a property are proposed. Various accuracy measures and cost based metrics for optimal monitoring are proposed. Techniques, based on prod- uct automata and Partially Observable Markov Decision Processes, for developing efficient and effective monitoring systems are proposed. The project proposes approaches for monitoring both safety and liveness properties. The proposed techniques will be experimentally evaluated.

The project proposes fundamental work in monitoring hybrid systems that arise in cyber-physical systems. It also plans to develop methods and tools for monitoring such systems. The scope of the project is cross cutting as it involves work in Computer Science and Electrical Engineering. If successful the results of the project can be transformative in ensuring the correct operation of systems.

Broader Impact: The proposed research will have broader impact in many areas such as healthcare, nursing/rehabilitation, automotive, safe usage home devices, etc. The benefits in nursing and rehabilitation emanate from the deployment of robots that assist or ultimately replace caregivers and nursing personnel in various care settings (e.g., at home, hospitals, long-term care facilities, rehabilitation and convalescent facilities). This has enormous implications for improved health outcomes and quality of life for older patients while minimizing care-giving and nursing workloads and costs.

The proposed work can be beneficial for friends and family members providing assistance to older people, as it will greatly reduce the burden of caring for older people. From an economic point of view, the results of the project can lead safer of cyber-physical systems.

The project includes education and outreach in the form of K-12 outreach, involvement of undergraduate as well as graduate students in research. The project is committed to involving women and minority students in education and research.