INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title:

Event-triggered Adaptive Control of Networked Nonlinear Systems with Application to Mobile Robots

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Thesis Submitted to the Department/ Center	:	**EEE**
Date of completion of Thesis Viva-Voce Exam	:	**01.02.2022**
Key words for description of Thesis Work	:	**Adaptive control, Backstepping, Event-triggered, Mobile robots, PatrolBot, State predictor, Uncertainties, Time-delays**

SHORT ABSTRACT

Over the past few years, networked control systems (NCSs) have been very popular in terms of research as well as industrial applications. Such systems enjoy the merits of low cost, flexibility, reliability, and ease of maintenance. However, due to the network-induced constraints, design and implementation of controller communicating with the system over a network is indeed challenging. These constraints, including but not limited to induced delays and band-limited channels, may result in data loss consequently leading to degraded system performance or even instability. In addition to network constraints, the presence of unknown parametric uncertainties poses another challenge to the problem of an effective NCS design. Therefore, this thesis is aimed at designing a suitable controller that is capable of eliminating the network effects without affecting the system performance and stability. The emphasis of the design algorithm is laid on compensating for network delays (induced in the sensor-to-controller and controller-to-actuator channels) and reducing the resource utilizations (quantified in terms of number of transmissions and control updates), while still guaranteeing the system stability with acceptable performance.

This thesis can be divided into two major parts. In the first part, an event-triggered adaptive backstepping control scheme is proposed for a class of uncertain nonlinear systems in the presence of network-induced delays. Then, in the second part, the developed control scheme is applied on a nonholonomic mobile robot and further extended to multiple mobile robots. To overcome the limitation of channel bandwidth in NCSs, an event-triggered control scheme is proposed in this work. As compared to the traditional time-triggered paradigm, the proposed scheme significantly reduces the computational and communication burden which is highly desirable for NCSs. Unlike conventional fixed and relative thresholds, an improved triggering condition is proposed, grounded on a Lyapunov analysis based threshold. The proposed triggering condition is directly obtained from the derivative of Lyapunov function by ensuring its negative semi-definiteness property. It leads to a substantially reduced number of transmissions and exhibits more efficiency in resource utilization. To deal with the network-induced delays, an auxiliary compensation system is incorporated to handle the input delay induced in the controller-to-actuator channel. Further, a state-predictor is designed to handle the situation when both state and input delays are induced in the network channels. The convergence of the predicted states to the actual states is proved using the Lyapunov-Razumikhin theorem. Using graph theory concepts, the developed control scheme is further extended to a leader-follower network with multiple mobile robots.

In addition to simulation and comparison results, the proposed control scheme is validated experimentally on a real mobile robot (PatrolBot). Unlike other studies where only kinematic model of the robot is considered, the dynamic model of the robot is incorporated in this study which is a more practical consideration. To handle the hardware restrictions, the dynamic model is modified to admit direct velocity commands as control input which is desirable for commercial mobile robots. The obtained results guarantee faithful trajectory tracking in the presence of both state and input delays with a substantial saving of channel bandwidth and computational resources. These results also substantiate the suitability of the theoretical propositions for practical network-based applications.
