INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Achieving consensus is a major problem in multi-agent systems(MASs). Analysis, design and implementation of consensus in MASs is the main focus of this thesis. Motivated by recent surge in distributed control applications with networked mobile robots and sensor networks which are MASs, consensus problems in autonomous mobile robots and a sensor network are researched. In particular, faults in communication like complete loss and time-delay effects on consensus are studied. Complete loss of communication will prevent the multi-agent system in reaching consensus. Time-delay within certain limit deteriorate the performance of system by increasing the convergence time. Beyond the limit, the system never reaches consensus.

Two novel algorithms, namely “back-tracking” and “history following”, to reach consensus in case of communication loss for a multi-agent system(MAS) with switching topologies are proposed for mobile agents. A strongly connected topology is considered to make decision on usage of “back-tracking” algorithm whenever an agent loses communication. It ensures the mobile multi-agent consensus with intermittent communication loss by changing path of the agents to maintain a strongly connected topology. In the case of “history following” algorithm, the agents store past data and continue with most recent target position even after the loss of communication. Since the communication loss that we have considered is intermittent at few places, the agents regain communication after some displacement. Then the data is updated with new calculation of target position and stored for further usage that might arise. A simple obstacle avoidance algorithm also used while simulating a network of six mobile agents with intermittent communication loss and static obstacles. The pros and cons of both algorithms are discussed. Hardware implementation is performed for a three robot system without obstacles along with corresponding simulation to demonstrate the effectiveness of the algorithms.

In the case of sensor network application, necessary and sufficient conditions are derived for consensus with saturated agents, asynchronous input and communication time-delays, which are sometimes practically unavoidable. A multi-agent system of linear second order agents with saturation is considered. The distributed system is connected under fixed directed graph coupled with input and communication time-delays. Describing function analysis is used to approximate each nonlinear agent into cascade of linear and nonlinear elements. Nyquist stability criterion is used for analysing stability of the linear element, thereby estimating the existence of limit cycles. Explicit necessary and sufficient conditions are derived for stability of the linear element. Instability of limit cycles is estimated using those conditions, implying the consensus.

Further, stability analysis is performed using Lyapunov-Krasovskii functions instead of Nyquist stability criterion with multiple control laws. A set of linear matrix inequalities (LMIs) are derived to prove the stability of linear element. The stability range of time-delays are obtained using expressions derived from both Nyquist stability criterion and Lyapunov-Krasovskii approaches. A comparison of pros and cons with respect to time-delay ranges, applicability and computational complexity is presented. Simulations and corresponding hardware implementation are performed on a network of four agents and five agents to support the theoretical results with multiple control laws. Furthermore, a general nonlinear input is considered as input to a multi-agent system that is connected by an undirected network. It has been proved that, consensus can be achieved with any nonlinear function g that is symmetric to origin and $xg(x)>0$. Simulations and implementations are performed on a network of five agents.