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Fault Tolerant Control of Multiple Mobile Robots

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Recently, usage of autonomous wheeled mobile robots (WMRs) is significantly increased in different industries such as manufacturing, health care and military and there exist stringent requirements for their safe and reliable operation in industrial/commercial environments. In addition, autonomous multi-agent mobile robot systems in which specific numbers of robots are cooperating with each other to accomplish a task is becoming more demanding in different industries in the age of technology enhancement. Consequently, development of fault tolerant controller (FTC) for WMRs is a vital research problem to be addressed in order to enhance the safety and reliability of mobile robots. The main aim of this paper is to develop an actuator fault tolerant controller for both single and multiple-mobile robot applications with the main focus on differential derive mobile robots. Initially, a fault tolerant controller is developed for loss of effectiveness actuator faults in differential drive mobile robots while tracking a desired trajectory. The heading and position of the differential drive mobile robot is controlled through angular velocity of left and right wheels. The actuator loss of effectiveness fault is modeled on the kinematic equation of the robot as a multiplicative gain in the left and right wheels angular velocity. Accordingly, the aim is to estimate the described gains using joint parameter and state estimation framework. Toward this goal, the augmented discrete time nonlinear model of the robot is considered. Based on the extended Kalman filter technique, a joint parameter and state estimation method is used to estimate the actuator loss of effectiveness gains as the parameters of the system, as well as the states of the system. The estimated gains are then used in the controller to compensate the effect of actuator faults on the performance of mobile robots. In addition, the proposed FTC method is extended for the leader-follower formation control of mobile robots in the presence of fault in either leader or followers. Multi agent mobile robot system is designed to track a

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trajectory while keeping a desired formation in the presence of actuator loss of effectiveness faults. It is assumed that the leader controller is independent from the followers and is designed based on the FTC frame work developed earlier in this document. Also, the fault is modeled in the kinematic equation of the robot as a multiplicative gain and augmented discrete-time nonlinear model is used to estimate the loss of effectiveness gains. The follower controller is designed based on feedback linearization approach with respect to the coordinates of the leader robot. An extended Kalman filter is used for each robot to estimate parameters and states of the system and as the fault is detected in any of the followers, the corresponding controller compensates the fault. Finally, the efficacy of the proposed FTC framework for both single and multiple mobile robots is demonstrated by experimental results using Qbot-2 from Quanser. To sum up, a fault tolerant controller scheme is proposed for differential drive mobile robots in the presence of loss of effectiveness actuator faults. A joint parameter and state estimation scheme is utilized based on EKF approach to estimate parameters (actuator loss of effectiveness) and the system states. The effect of the estimated fault is compensated in the controller for both single robot and formation control of multiple mobile robots. The proposed schemes are experimentally validated on Qbot-2 robots.