ARC '16

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Robust Controller and Fault Diagnoser Design for Linear Systems with Event-based Communication

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In order to improve the effectiveness and safety of control systems, the problem of integrated fault diagnosis and control (IFDC) design has attracted significant attention in the recent years, both in the research and in the application domains. The integrated design unifies the control and diagnosis units into a single unit which leads to less complexity as compared to the case of separate designs. Nowadays, the IFDC modules are implemented on digital platforms. However, in almost all of these implementations, the IFDC task is executed periodically with a constant sampling period, which is called "time-triggering" sampling. However, the time-triggering sampling scheme produces many useless messages if the current sampled signal has not significantly changed in contrast to the previous sampled signal, which leads to a conservative usage of the communication bandwidth. This is especially disadvantageous in applications where the measured outputs and/or the actuator signals have to be transmitted over a shared (and possibly wireless) communication network, where the bandwidth of the network (and power consumption of the wireless radios) should be constrained. To mitigate the unnecessary waste of computation and communication resources in conventional time-triggered IFDC design, the problem of event-triggered integrated fault diagnosis and control (E-IFDC) for discrete-time linear systems is considered in this paper. A single E-IFDC module based on a dynamic filter is proposed which produces two signals, namely the residual and the control signals. The parameters of the E-IFDC module should be designed such that the effects of disturbances on the residual signals are minimized (for accomplishing the fault detection objective) subject to the constraint that the mapping matrix function from the faults to the residuals is equal to a pre- assigned diagonal mapping matrix (for accomplishing the fault isolation objective), while the effects of disturbances and faults on the specified control output are minimized (for accomplishing the fault-tolerant control objective). Two event-triggered conditions are proposed and designed to reduce the transmissions from the sensor to the E- IFDC module and from the E-IFDC module to the actuator. These event-triggered conditions determine whether the newly measured data or control output, respectively, should

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be transmitted or not. Indeed, the sensor measurement (controller output) is sent to the E-IFDC module (actuator) only when the difference between the latest transmitted sensor (controller) value and the current sensor measurement (controller output) is sufficiently large as compared to the current sensor (controller) value. This property reduces the burden on the network communication and saves the communication bandwidth in the network. Consequently, it is possible to significantly reduce the usage of communication resources for diagnosis and control tasks as compared to a conventional time-triggered IFDC approach. A multi-objective formulation of the problem is presented based on the $H\infty$ and H- performance indices. The sufficient conditions for solvability of the problem are obtained in terms of linear matrix inequality (LMI) feasibility conditions. Indeed, the filter parameters and the event-triggered conditions are simultaneously obtained using strict LMI conditions. The main advantage of the proposed LMI formulation is that it is convex, and is therefore solved effectively using interior-point methods. Application of our methodology to a linearized model of the Subzero III ROV is presented to illustrate the effectiveness and capabilities of our proposed methodology. Remotely operated vehicles (ROVs) are underwater robotic platforms that have become increasingly important tools in a wide range of applications including offshore oil operations, fisheries research, dam inspection, salvage operations, military applications, among others. Since transmission resources are limited under water, using an event-triggered scheme for communication is more efficient. Therefore, the results of this paper are applied for designing an event-triggered IFDC module for the Subzero III ROV.