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A Comparison of Inverse Simulation-Based Fault Detection in a Simple Robotic Rover with a Traditional Model-Based Method

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Abstract : Robotic rovers which are designed to work in extra-terrestrial environments present a unique challenge in terms of the reliability and availability of systems throughout the mission. Should some fault occur, with the nearest human potentially millions of kilometres away, detection and identification of the fault must be performed solely by the robot and its subsystems. Faults in the system sensors are relatively straightforward to detect, through the residuals produced by comparison of the system output with that of a simple model. However, faults in the input, that is, the actuators of the system, are harder to detect. A step change in the input signal, caused potentially by the loss of an actuator, can propagate through the system, resulting in complex residuals in multiple outputs. These residuals can be difficult to isolate or distinguish from residuals caused by environmental disturbances. While a more complex fault detection method or additional sensors could be used to solve these issues, an alternative is presented here. Using inverse simulation (InvSim), the inputs and outputs of the mathematical model of the rover system are reversed. Thus, for a desired trajectory, the corresponding actuator inputs are obtained. A step fault near the input then manifests itself as a step change in the residual between the system inputs and the input trajectory obtained through inverse simulation. This approach avoids the need for additional hardware on a mass- and power-critical system such as the rover. The InvSim fault detection method is applied to a simple four-wheeled rover in simulation. Additive system faults and an external disturbance force and are applied to the vehicle in turn, such that the dynamic response and sensor output of the rover are impacted. Basic model-based fault detection is then employed to provide output residuals which may be analysed to provide information on the fault/disturbance. InvSim-based fault detection is then employed, similarly providing input residuals which provide further information on the fault/disturbance. The input residuals are shown to provide clearer information on the location and magnitude of an input fault than the output residuals. Additionally, they can allow faults to be more clearly discriminated from environmental disturbances.

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