Real-time Robot and Spacecraft Actuators Fault Diagnosis and Motion Estimation

In recent years, the fault diagnosis of electro-mechanical robotic systems has been performed in widespread applications, including grand vehicles, unmanned aerial vehicles, and spacecraft. According to the IFAC SAFEPROCESS Technical Committee defined terminology, there is an absolute necessity to identify unexpected changes (faults) in a system before they lead to a complete breakdown (failure) [1]. It is also worth noting that actuator fault detection is particularly important in space applications, as thruster faults occurred in 12% of 129 searched spacecraft launched between 1980 and 2005 [2]. The functionality to supply computational redundancy for a robotics system to be sustained is fault diagnosis – the computational utilization of mathematical relations between measured or estimated variables to detect possible malfunctions that we want to realize with few extra conventional motion estimation procedures.

We propose improved particle filtering-based approaches, adaptive resampling for the fault states, and state-segmentation. The ordinal approaches such as State Observer and Kalman Filtering can *detect* faults but *diagnose*. This means it can detect something is wrong, but cannot find which component has been failed and how. Particle Filtering is an excellent frame work for modeling faults so it may diagnose faults. However, the ordinal Particle Filter requires tremendous amount of “particles,” each of which represent dynamics and fault mode. The goal of this research is to reduce amount of particles (or computation). The adaptive resampling involves resampling timing as well as the use of a reward-punishment function constructed from the actuator input information. As another novel approach to particle filtering, both a continuous state vector and fault states are segmented. For each segmented space, an attempt is made to construct a corresponding posterior distribution independently, resulting in a reduction in particles.

Keywords: Fault Diagnosis, Particle Filtering, Failure Detection and Recovery, Redundant Robots, Space Robotics

Reference

[1] R. Isermann and P. Balle, Trends in the application of model-based fault detection and diagnosis of technical processes, Control Engineering Practice, vol. 5, no. 5, 709/719, 1997.
[2] M. Tafazoli, A study of on-orbit spacecraft failures, Acta Astronautica, vol. 64, no. 2-3, 195/205, 2009.

HTV approach

Method #	#1: State Observer	#2: Kalman Filter	#3: Ordinal Particle Filter	#4: Improved Particle Filter
Noise tolerability	Sensitive to sensor noise & modeling error	Robust to noise	Robust to noise	Robust to noise
Can fault detect?	Yes	Yes	Yes	Yes
Can fault diagnosis?	No	No	Yes	Yes
Is computable?			No	Yes

Fig. 1 Comparison of Actuator Fault Detection/Diagnosis Methods