University of Glasgow

Short-Circuit Fault Models Analysis for a Planetary Rover DC Motor Actuator Using a Kalman Filter Model-Based Fault Detection Approach

Salim Al Oufi, Euan McGookin, Kevin Worrall

WORLD CHANGING GLASGOW

A WORLD TOP 100 UNIVERSITY

Introduction

- In order for the Planetary Exploration Rover (PER) to be robust it has to be capable to detect, isolate and recover from faults which is essential for continued operation.
- Health monitoring and recovery systems can be achieved through simulation.
- Actuators are critical systems in the PER, where their failure led to severe consequences for the mission.
- DC Motor actuators of a PER could experience various types of faults, and short-circuit (SC) is one of the common DC motor faults.
- The effect of SC fault could be minor as a reduction in the efficiency going up to complete failure of the DC motor.
- Studying a physical system is expensive and time-consuming, and simulation is a solution to that.
- The contribution is comparing two SC fault models of PER actuators and investigating the PER model response and the health monitoring system to the fault.

Lynxmotion 4WD3

- **Rigid body dynamics:**

$$M\dot{\nu} + C(\nu)\nu = \tau - D(\nu) - g(\eta)$$

- **Kinematics**

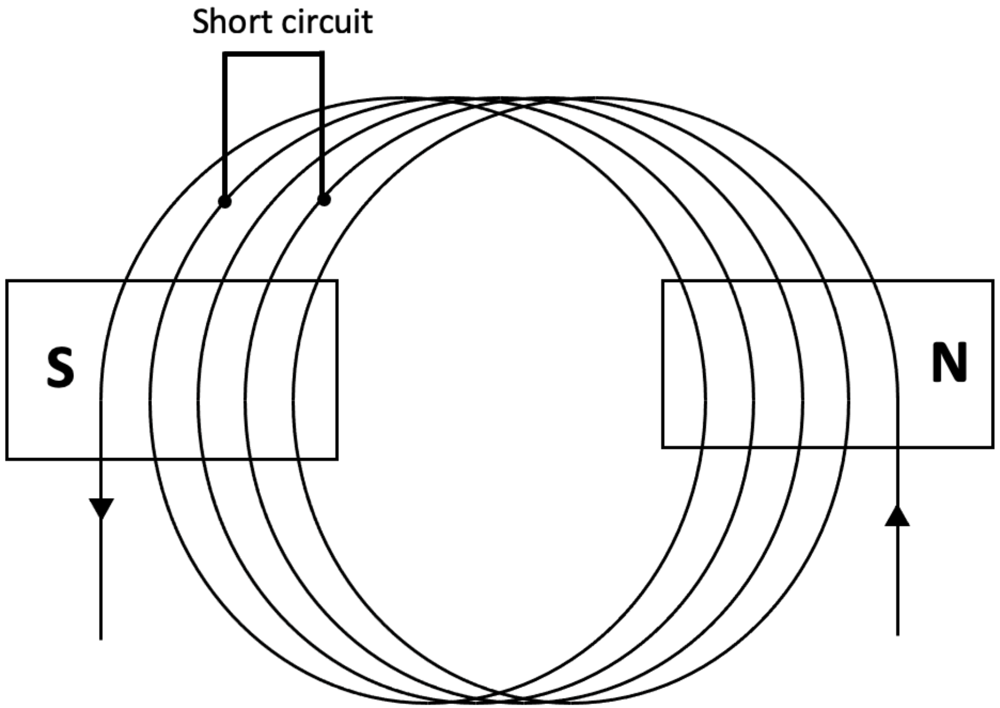
$$\dot{\eta} = J(\eta)\nu$$

- **DC Motor dynamic:**

$$V(t) = L\dot{I}(t) + RI(t) + K_e\omega(t)$$
$$J\dot{\omega}(t) = K_t I(t) - \mathrm{b}\omega(t) - \tau_L$$

- **Two PID controller for surge velocity and heading**
- **Line-of-Sight for Guidance and navigation**

Short-Circuit Implementation



- Reduction ration δ
- Armature's number of turns N
- Length of conductor l

$$\boldsymbol{V(t) = L\dot{I}(t) + RI(t) + K_e\omega(t)}$$
$$\boldsymbol{J\dot{\omega}(t) = K_tI(t) - \mathbf{b}\omega(t) - \tau_L}$$

$$L = \mu\frac{N^2A}{l}$$
$$R = \rho\frac{l}{A}$$
$$K_e = K_t = 2BNlr_a$$

Short-Circuit Models

Model A

- Proposed by Zhang J [1]
- The SC ratio δ applied on R and L

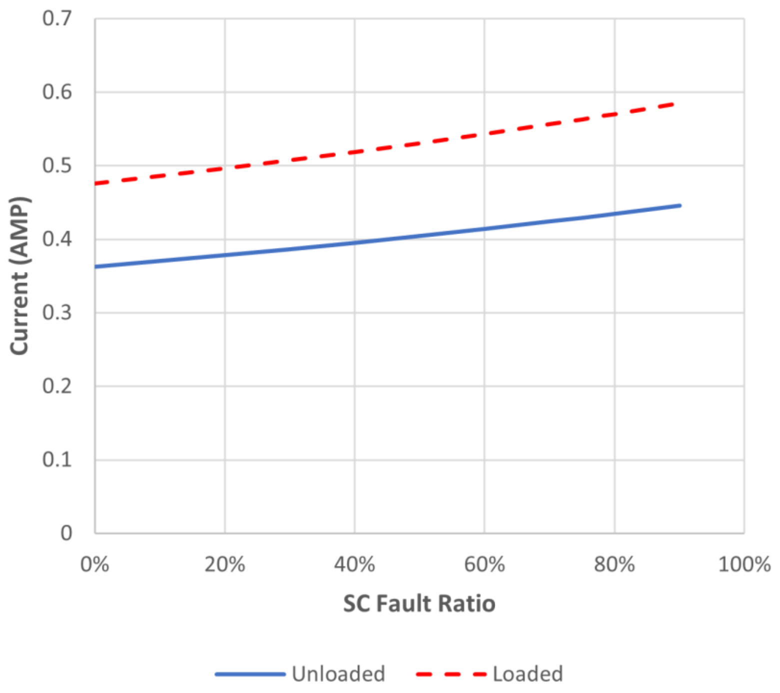
Model B

- Proposed by Farooq JA [2]
- The SC ratio δ applied on R, L and (K_e, K_t)

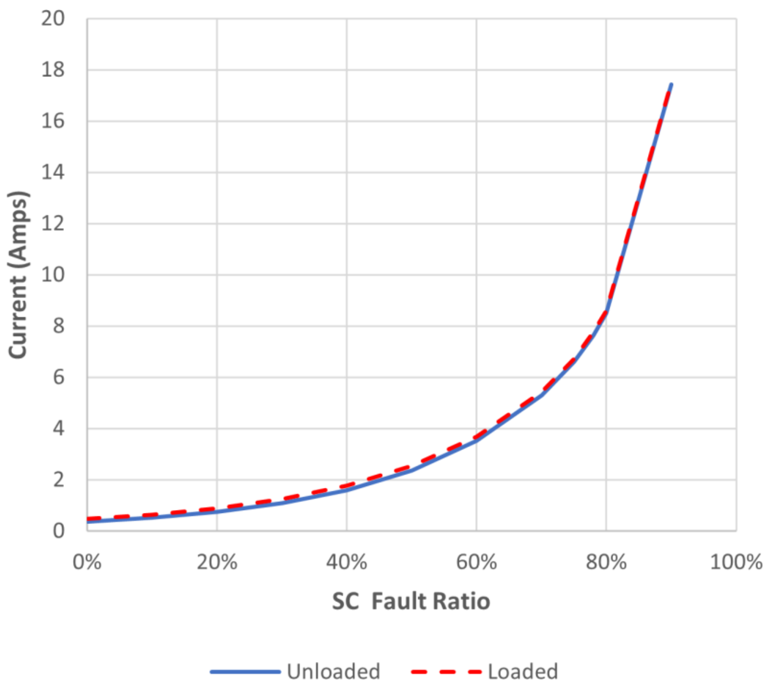
[1]. Zhang J, Zhan W, Ehsani M. On-line diagnosis of inter-turn short circuit fault for DC brushed motor. ISA transactions. 2018;77:179-87
[2]. Farooq JA, Raminosoa T, Djerdir A, Miraoui A. Modelling and simulation of stator winding inter-turn faults in permanent magnet synchronous motors. COMPEL-The international journal for computation and mathematics in electrical and electronic engineering. 2008;27(4):887-96.

DC Motor Current Response with SC Fault Models

Model A

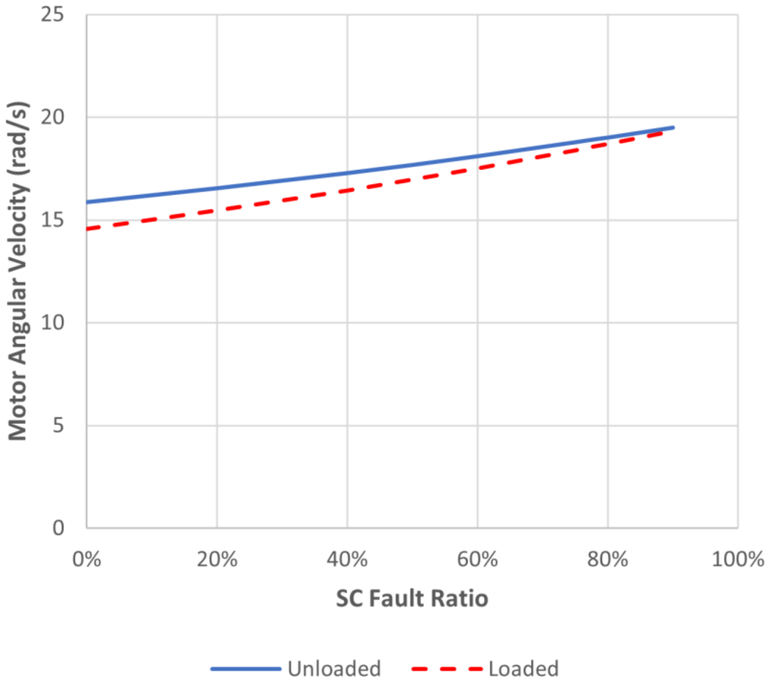


Model B

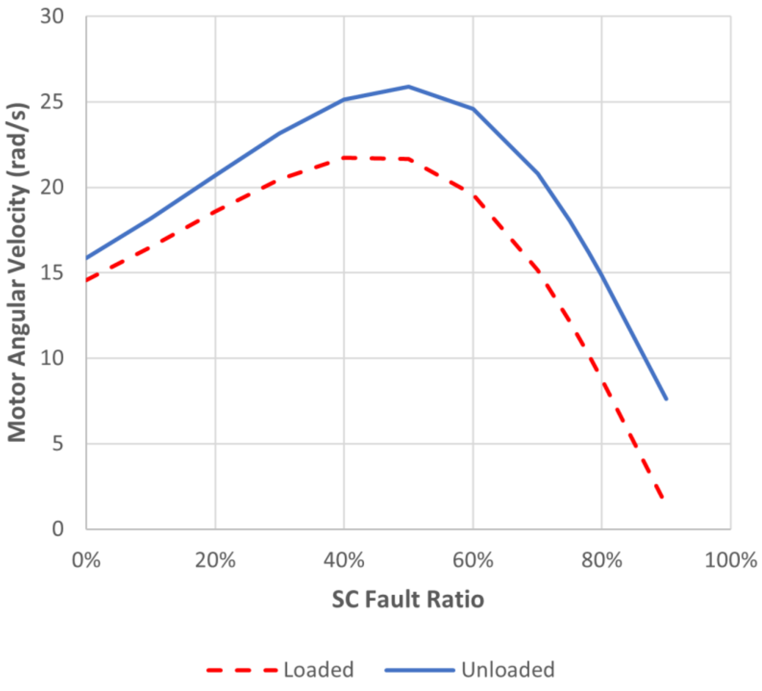


DC Motor Velocity Response with SC Fault Models

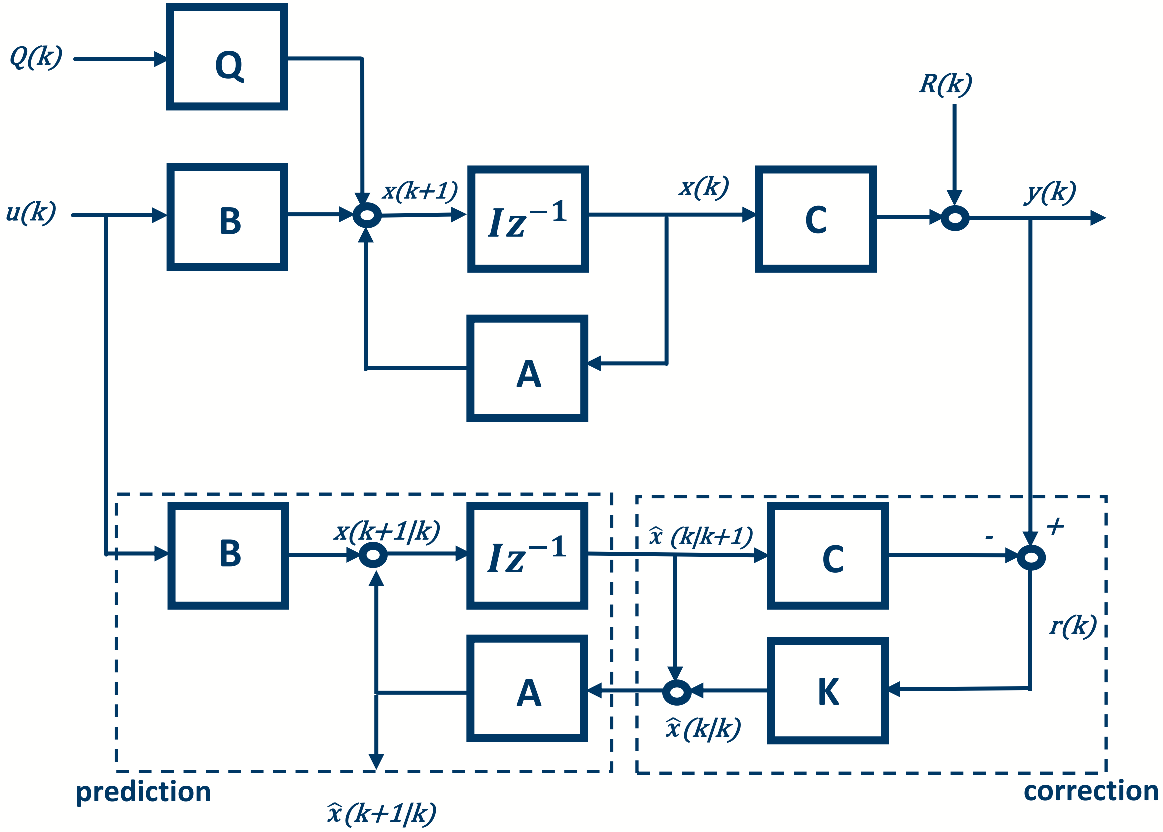
Model A



Model B



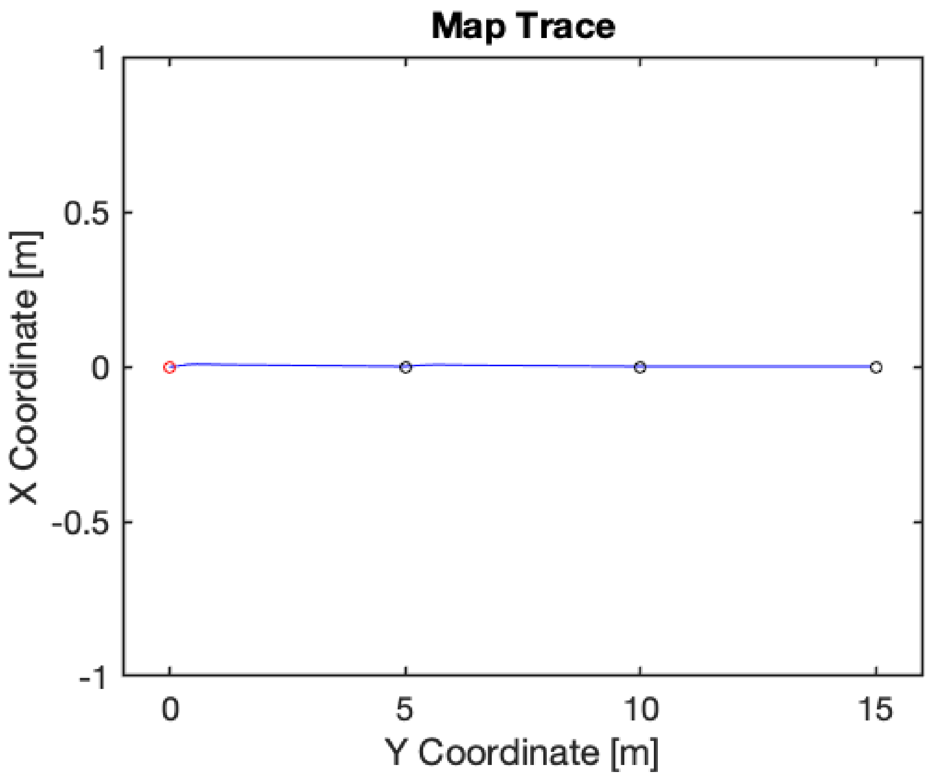
Kalman Filter Fault detection and isolation



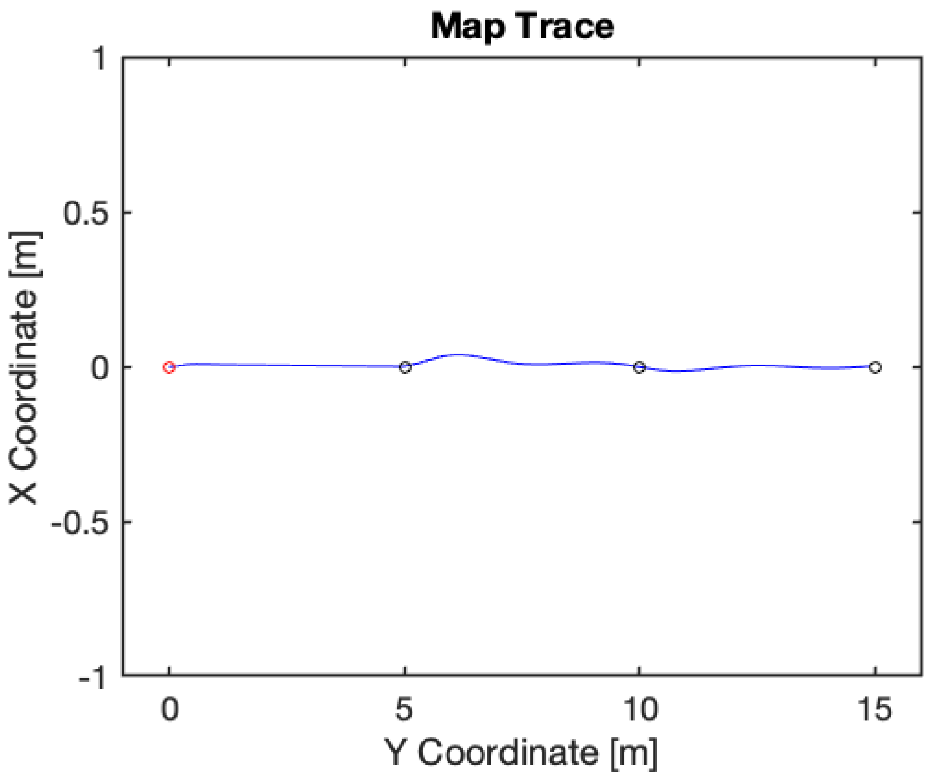
$$r(k) = y(k) - \hat{y}(k)$$

2D Closed Loop Straight-Line

Model A

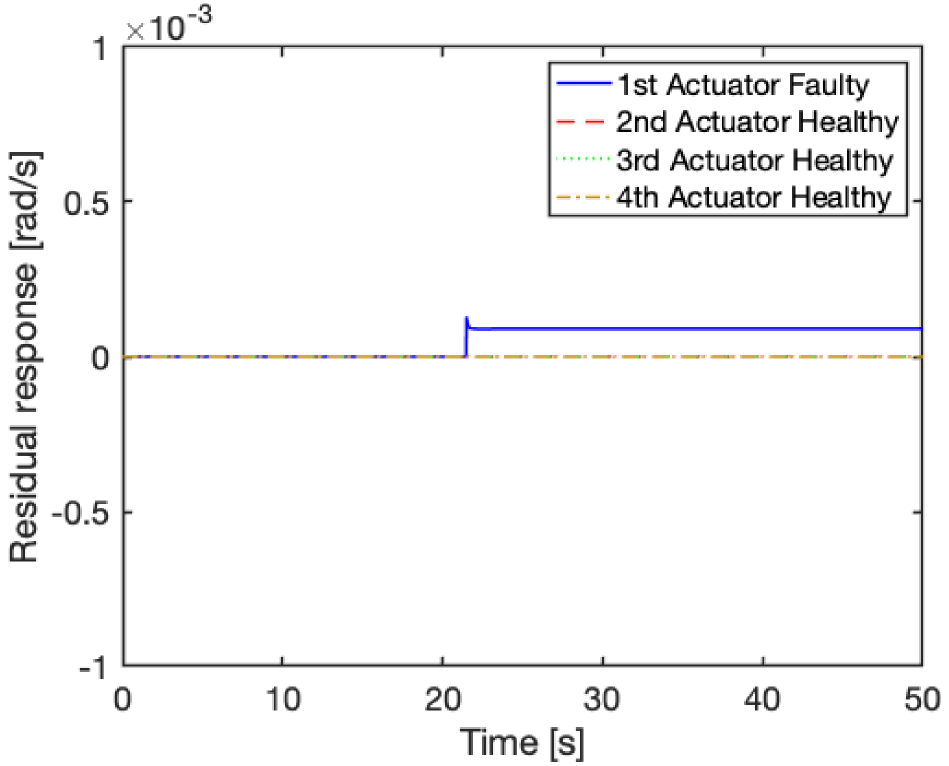


Model B

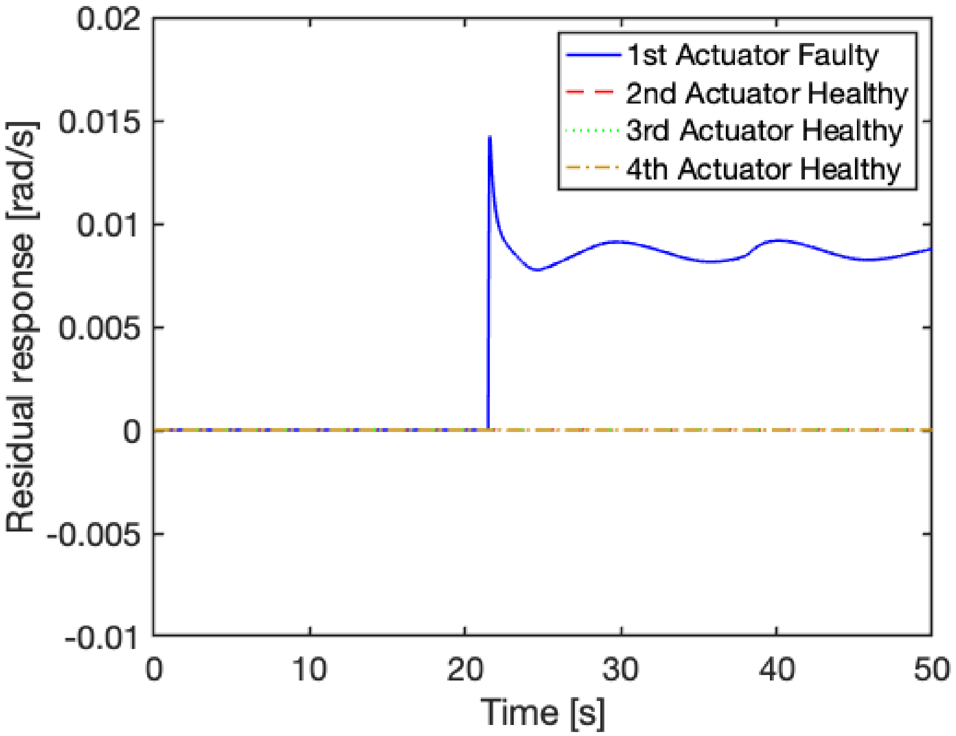


Residuals

Model A



Model B



Residual Analysis

δ	10%	20%	30%	40%	50%	60%	70%	80%	90%
SC Model A r(rad/s)	0.00003	0.00006	0.00009	0.00012	0.00015	0.00019	0.00022	0.00025	0.00029
SC Model B r(rad/s)	0.0016	0.004	0.008	0.013	0.02	0.04	0.08	0.17	0.38

Conclusions

- Two models of SC fault (Model A and Model B) are implemented to PER actuator’s DC motor model
- Fault was introduced to the DC motor with several ratios to analyse the current and angular velocity responding to each SC fault models. The impact of the SC fault Model A on the DC motor responses is small compared to the effect of Model B.
- The PER model presented here has been simulated in 2D closed-loop scenarios while introducing the SC fault models. The results show that the rover model performance is affected by fault Model B in the rover’s path following process
- The KF-based fault detection algorithm was able to detect the SC fault of Model B better than Model A
- Model B provides a SC fault representation that has an impact on the rover’s model and is easily detectable by using the KF-based fault detection method

Thank you for your attention

s.al-oufi.1@research.gla.ac.uk

#UofGWorldChangers

@UofGlasgow