

Deploying Robots in Everyday Environments: Towards Dependable and Practical Robotic Systems

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Platform and Environment

Some preliminary results of our fault detection, diagnosis, and remote monitoring concept in a real hospital environment on a prototype of the ROPOD platform are presented here

Smart Wheel:

- **Differential drive wheel pair** with communication via EtherCAT
- Provides **40 state variables** including voltage, current, encoder positions and velocities, temperature, and IMU data
- Prototype platform has **four Smart Wheels** and can transport carts

Environment:

- **Highly dynamic hospital environment:** moving people, carts, elevator
- **Safety-critical requirements** including no stoppage near fire doors

Relevance:

- **Fully-autonomous** and **newly developed** fleet of robots in a real environment - hence **high risk of failures**
- Hospital staff will require support in case of failures: **quick remote diagnosis of failures** is a critical requirement
- **Black box logs data** for remote analysis and diagnosis
- **Component monitoring** provides a means to quickly **isolate faults**
- **Dashboard and remote monitoring** ensures support even if no technical staff is present on-site



Failure Mode Effects Analysis (FMEA)

Our initial FMEA primarily addressed the Smart Wheel; the failure networks generated through this process form the basis of our fault diagnosis concept. A sample output of the FMEA is illustrated in the figure on the right: in case of a short circuit in the emergency stop cables, issuing an emergency stop signal is not possible since this is a normally-closed circuit.

S=10	Low energy channels (Slip rings for EtherCAT (4x) and Emergency (2x))	Ensure dust & water protection
SMART-Wheel Design-FMEA	Emergency slip rings: Ensure reliable conductivity	Ensure dust & water protection
Fulfill requirement for SMART-Wheel 1.3.1.3.1.a.5	1.3.1.3.1.1.3.3.b.2	1.3.1.3.1.1.3.3.1.a.1
Emergency stop does not work (1)	Short cut (Emergency slip rings) (1)	Water entry (Slip rings not protected against water) (2)
		Slip rings (Emergency) are positioned...
		has to be discussed with supplier Ket... [Deadline? (in progress) Responsible?]
		Function test with dust and water inf... [Deadline? (in progress) Responsible?]

Sample FMEA for e-stop cable

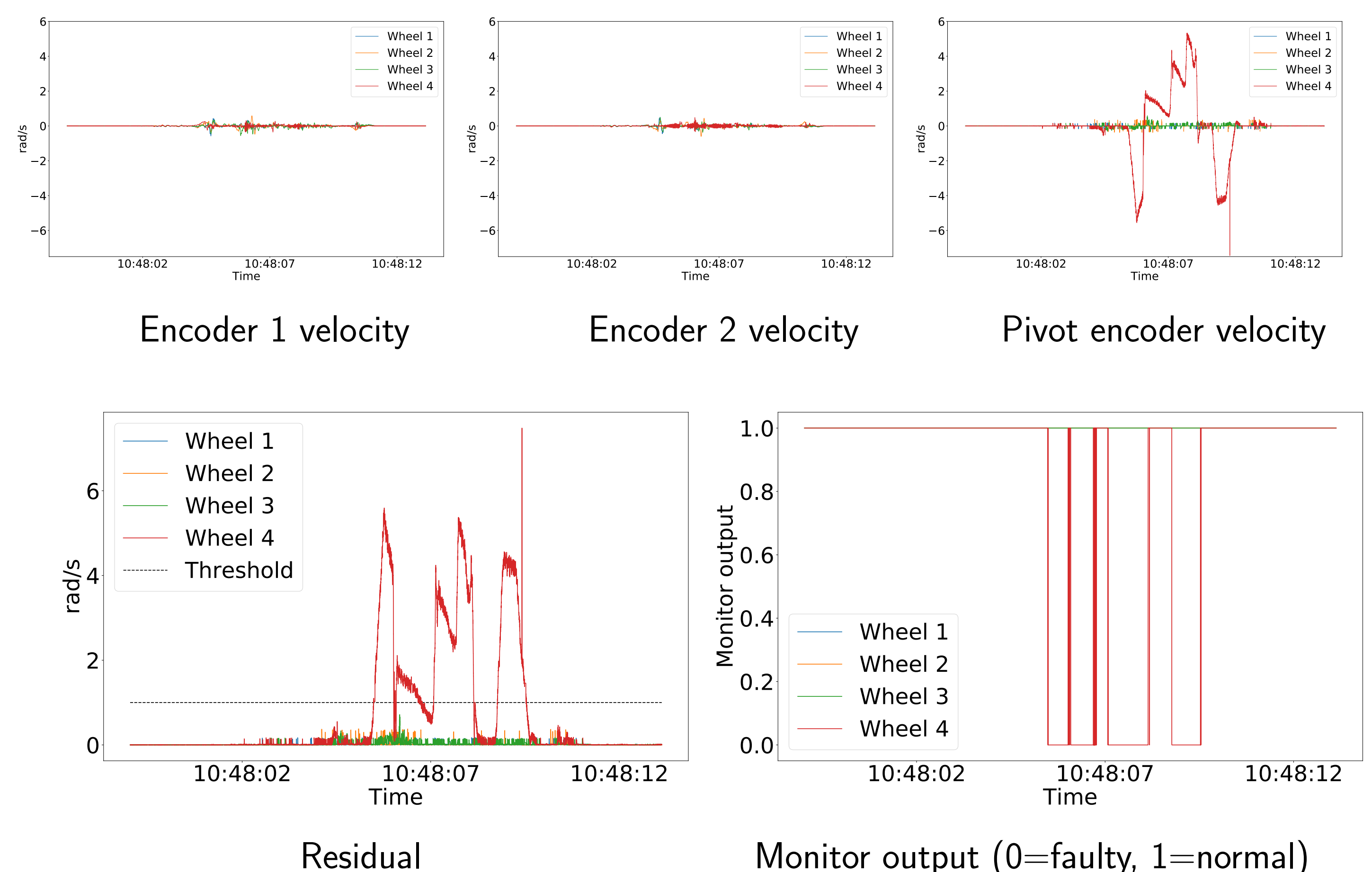
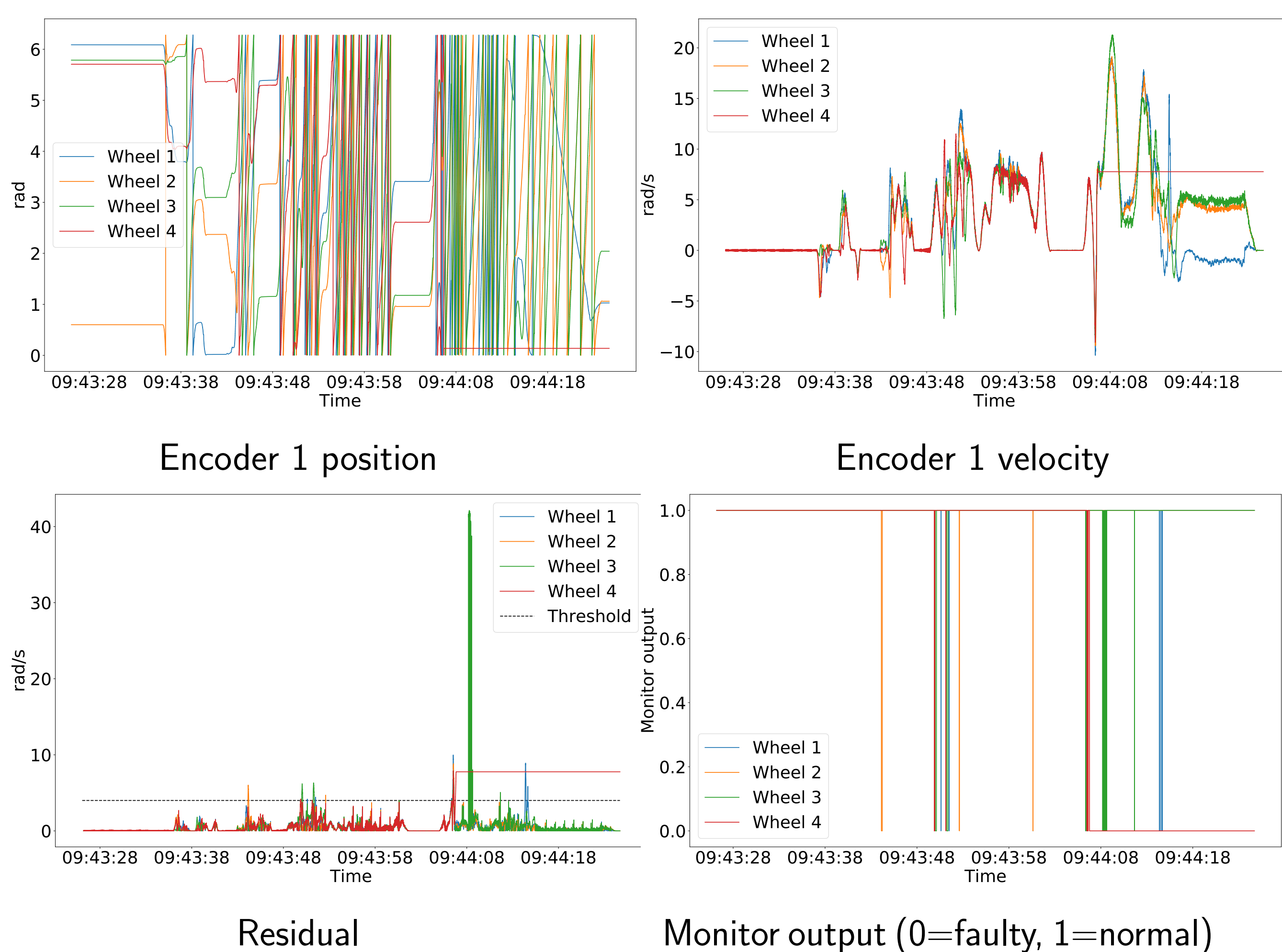
Use Case: Encoder Monitor

Position vs. Velocity Mode

- The Smart Wheel provides encoder positions and velocities for three encoders (wheel 1, wheel 2, and pivot)
- Our encoder monitor specification checks the consistency between the reported position and velocity for each encoder (the residual is obtained by comparing the sensed encoder velocity and the differential of the sensed encoder position)
- When the residual is above a predefined threshold, the encoder monitor returns a faulty status

Differential Drive Kinematics Mode

- A safety requirement of the ROPOD platform is that it does not get stuck near fire doors in the hospital; it is thus essential to detect states in which the ropod might be stuck, such as when one or more wheels are off the ground in free-wheeling mode
- The residual between the calculated pivot velocity (using differential drive kinematics) and the sensed pivot velocity gives an indication of such a state
- Our second encoder monitor mode reports a fault when this residual is above a threshold



Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N^o731848 ROPOD.

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