A Proof-of-Concept Energy Model for an Unmanned Agricultural Robot

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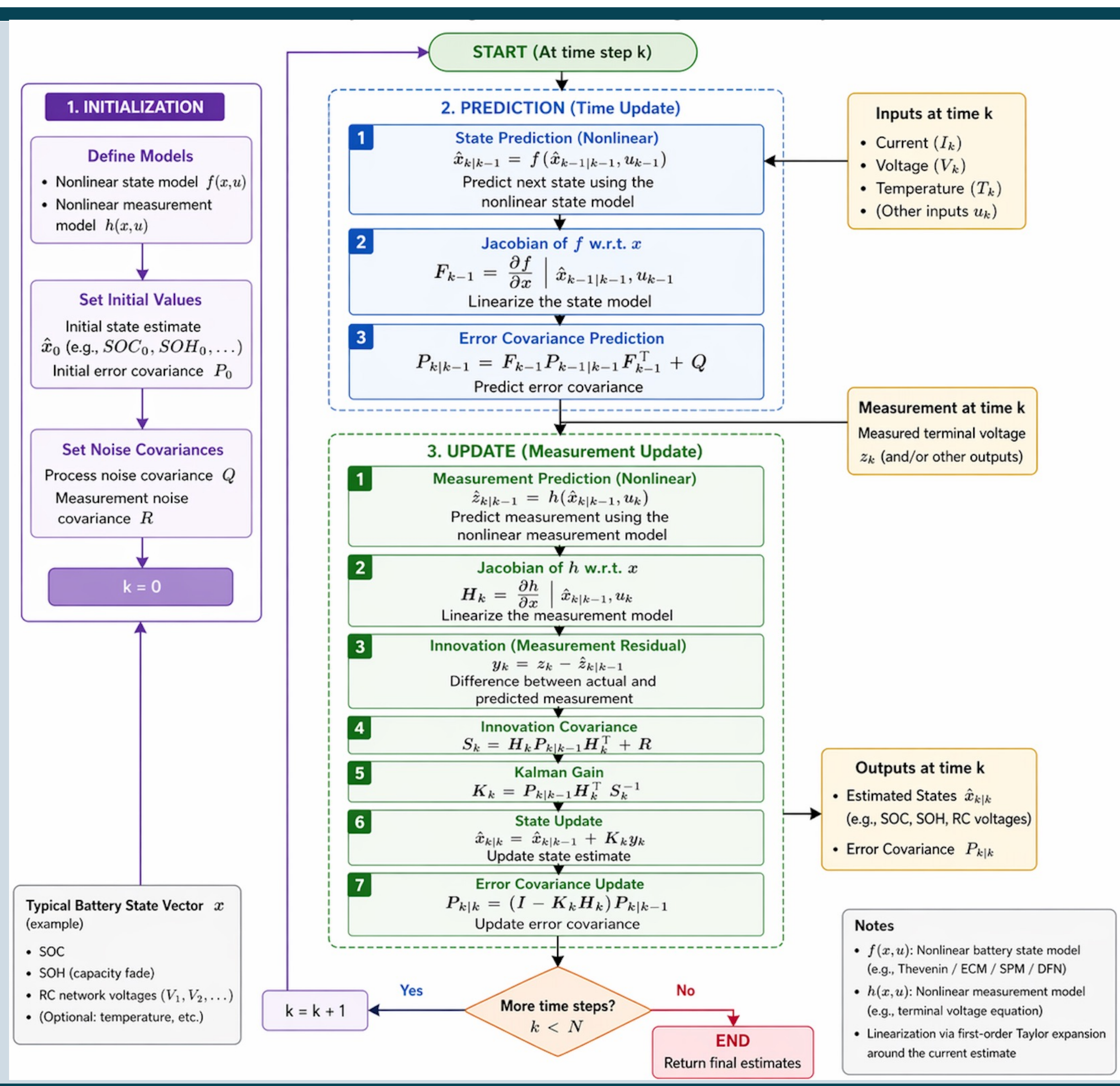
Battery-aware mission planning for unmanned off-grid robotics

Battery characterization is expensive and bound to laboratory conditions. With basic, lab-calibrated instrumentation, parameter extraction from specific battery packs is possible.
An equivalent circuit model enables the creation of a digital twin of the battery management system used on the robot.
This enables mission planning around energy use, the optimization of the use of renewables and reduced battery wear, extending total service life.



Introduction

UGVs in agriculture are limited by battery capacity and terrain-dependent losses. This work introduces a lightweight framework linking mission demand with battery state prediction.
Pulse testing is used to determine basic battery characteristics that are then used as the basis of a prediction model.
The goal of this work is to extend battery service life, optimise mission planning and enable battery powered vehicles to comply with the EU regulations relating to the battery passport framework (2023/1542 and 2023/1791).

Materials and methods

DUT is a 14-series, 48V nominal battery pack consisting of Samsung SDI 94Ah NMC cells.

The battery pack was subject to 20A pulses as per the 1kW average power draw of the platform.

The pulses were logged and analysed for immediate DCIR and slow relaxation dynamics over several minutes.

Logging devices are Raspberry Pi Pico2, logging speed was set to 350900 samples per second on both channels, data streamed over USB bulk endpoints.

Acquisition was synchronised using a GPIO trigger. Data remained synchronous over 100M+ samples.

Battery characteristic values were used to construct an EKF that estimates battery SOC based on measured current and terminal voltage.

Results and Discussion

A dominant DCIR of 4.6 mΩ was extracted with a standard deviation of 0.44.
Slow polarization dynamics were not visible at this resolution and pulse magnitude.
An ECM was constructed using a DCIR and R1 split of 60/40, which is consistent with data from literature.
Three drive cycles were defined at various power levels, mock data was generated and fed into the constructed EKF.
The resultant SOC drop of 2.8% over the 10 minute synthetic cycle is consistent with expectations.
This work serves as the framework for a battery estimator that is based on traction model, enabling battery-aware mission planning for off-grid robotics.
Future works include improved fidelity pulse testing and multi-point cycle verification.