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Sensorless Control of Brushed DC Motors: A Cost and Space Efficient Approach Using Sliding Mode and State Space Observers

Elias Baltazar Spilak[1], Pavol Makys[1], Alex Franko[1]

1 Department of Power Systems and Electric Drives, University of Zilina, Zilina 010 26, Slovakia

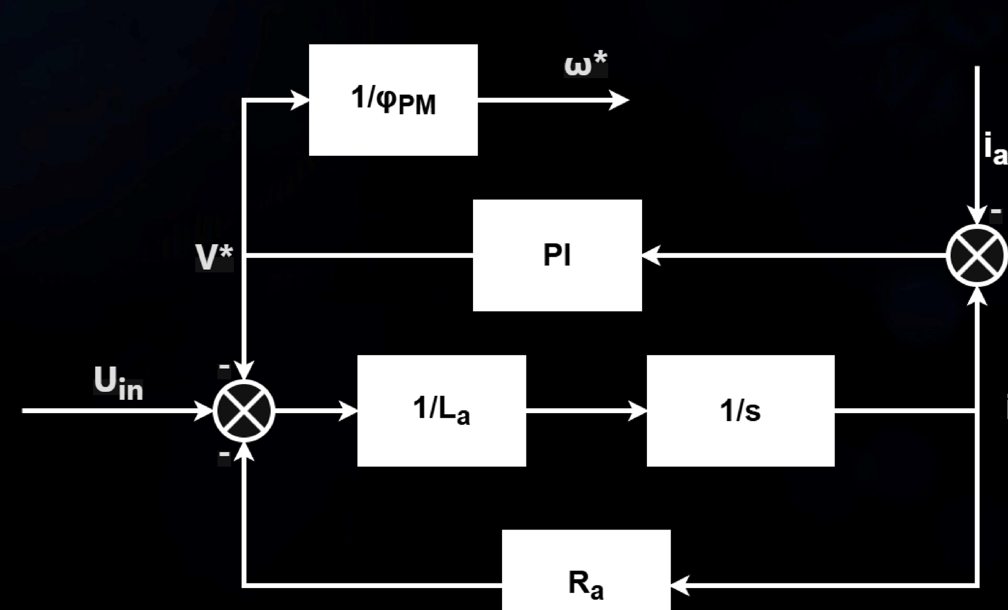
INTRODUCTION

A brushed DC motor is widely used in cost-sensitive applications such as automotive window lifters, seat actuators, wipers, and power mirrors due to its simplicity and low cost. Proper control typically requires position or speed data, often provided by sensors. However, these sensors significantly increase cost, making sensorless control a preferred alternative.

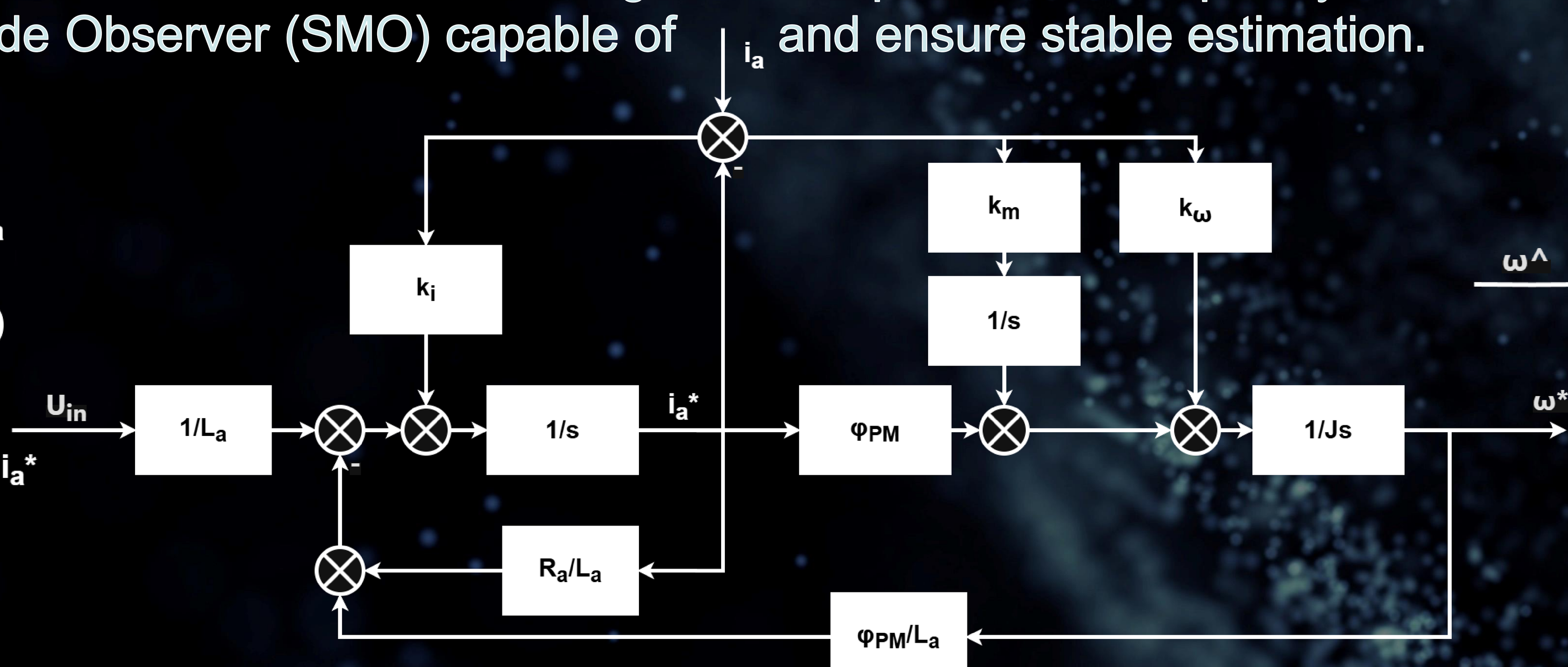
Sensorless control methods are classified into two groups. One relying on a mathematical DC motor model, using Back EMF measurements to estimate speed. These methods are sensitive to parameter variations and perform poorly at low speeds. The second approach measures motor current ripple, relying on harmonics caused by rotor slotting to calculate speed and position. It is parameter-independent and works well at low speeds.

METHODS & IMPLEMENTATION

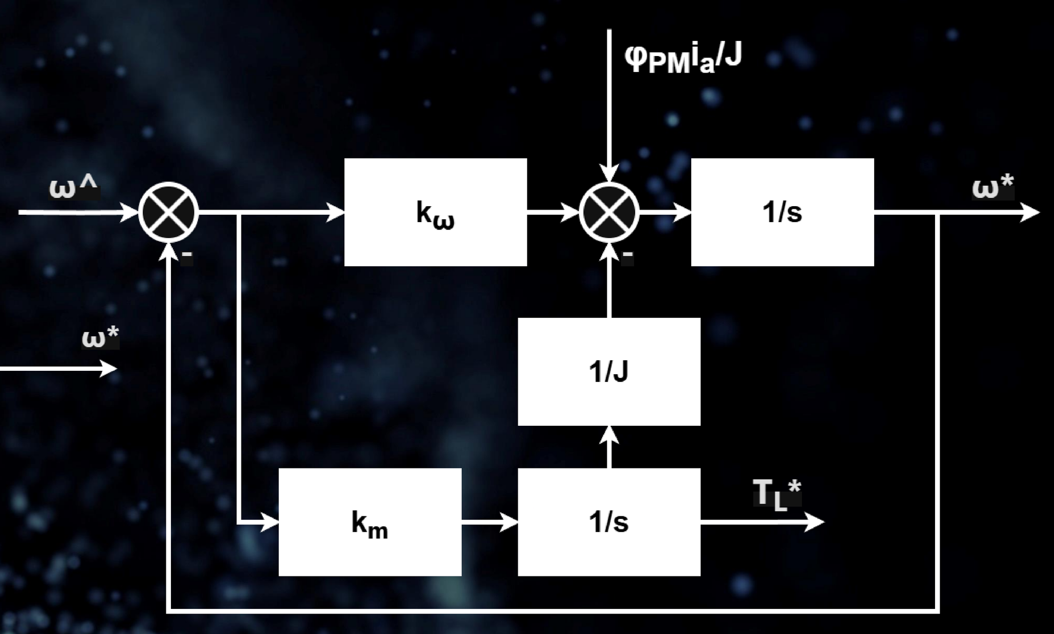
This study presents two model-based methods and a supporting third for estimating angular velocity in cost-constrained high-speed brushed DC motor applications. Both rely on Back-EMF for information at high speeds. The first uses a robust Sliding Mode Observer (SMO) capable of handling parameter variations and disturbances, while the second, a State Space Observer, offering high accuracy but with greater computational complexity. A Filtering Observer is added to reduce noise and ensure stable estimation.



Pseudo-Sliding Mode Observer



State Space Observer

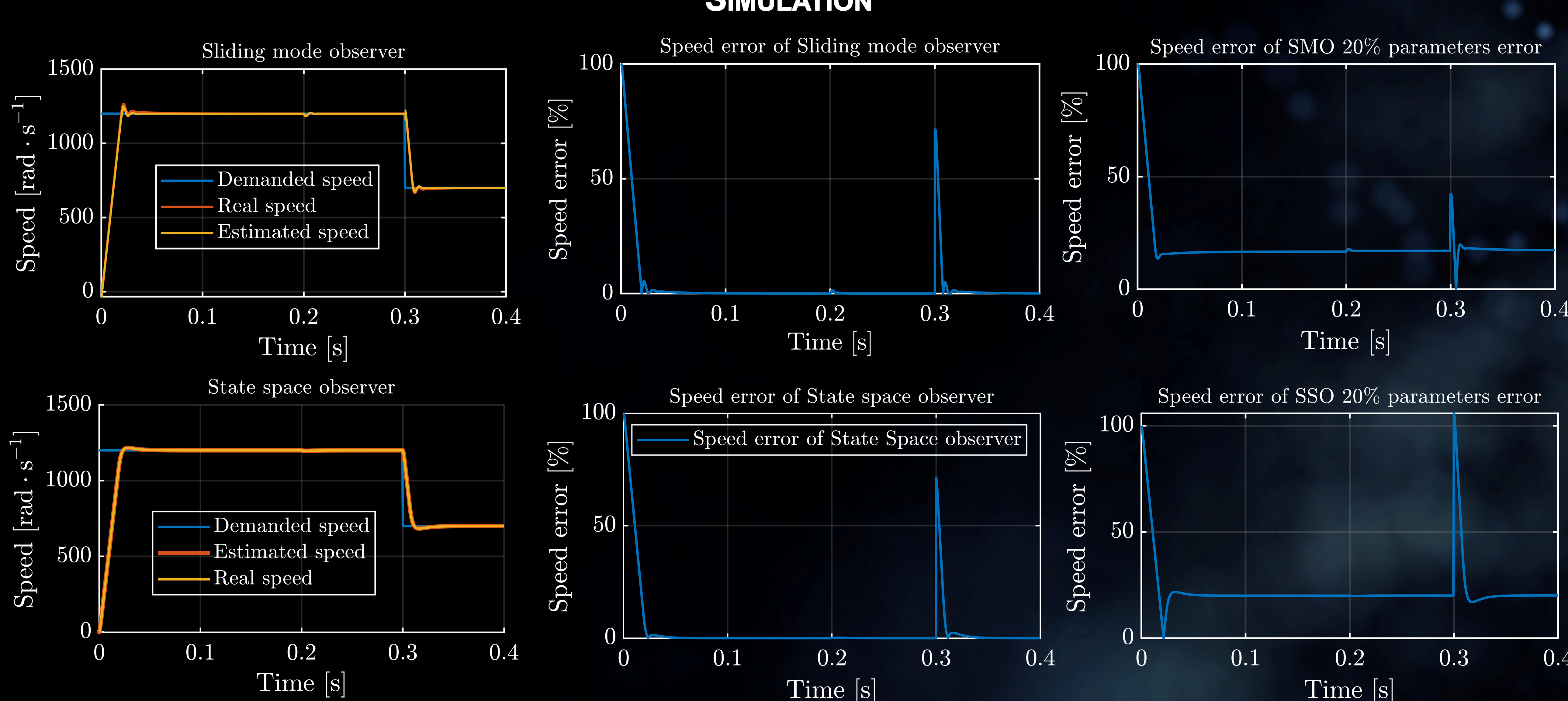


Filtering Observer

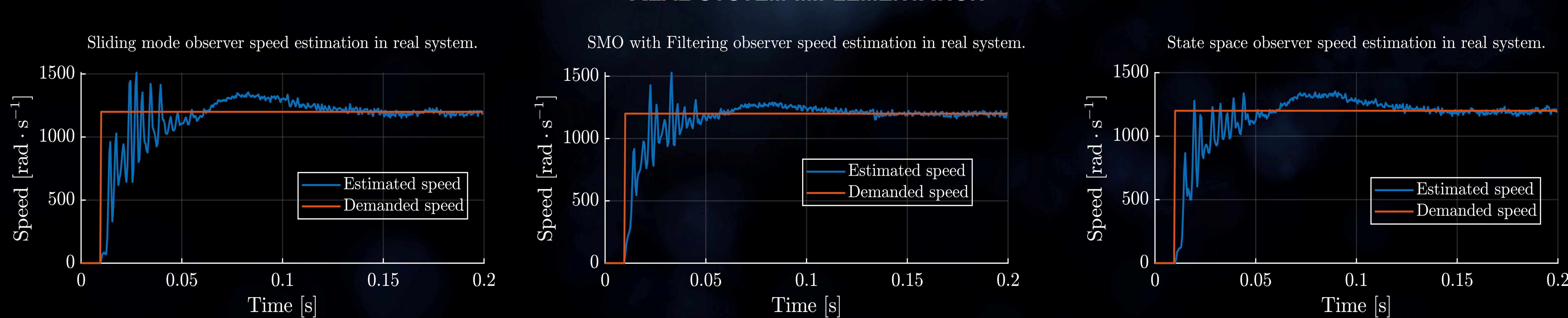
We tested the proposed estimation methods using MATLAB /Simulink. The simulation included an initial no-load startup, the application of a load torque, and a change in the demanded speed. To evaluate accuracy, an error in motor parameters was introduced. The Speed filtering observer was not used in the simulation, but it was applied in real hardware tests. The real hardware tests were conducted on a small self-driving car model. The car was controlled using the S32K144-Q100 general-purpose evaluation board from NXP. This board managed two motors. The control and observer algorithms operated at a frequency of 20 kHz, which was sufficient for the control loop and observers to function effectively. The PWM module was also configured to 20 kHz, as this was the maximum frequency at which the PWM could be updated.

RESULTS

Simulation



Real system implementation



CONCLUSION

The State Space Observer (SSO) achieved higher accuracy but required more computation, making it ideal for precision-focused applications. The Sliding Mode Observer (SMO) showed strong robustness to parameter variations and improved noise resistance when combined with a Filtering Speed Observer.

Experimental validation on a self-driving car confirmed both methods as viable for cost-effective high-speed motor control. These findings underscore the potential of sensorless control for automotive and robotic applications. Future work will focus on reducing computational overhead, enhancing real-time performance, and extending these methods to other motor types and domains.