Comments 15: \* Page (19) « measurement noise and process noise ». How are they

defined? How are they generated?

Reply:

Frist we should introduce the system’s state transition function and measurement function for better explanation. The functions can be denoted as:



In which the Xk being the state value at step K, Yk being the observer’s value at step K. Qk and Rk are process and measurement noise at step K.

In the context of the formula, Q represents the process noise, which is the deviation between the true state value at time k, denoted as Xk, and the predicted state, denoted as f(Xk-1). Given the true state at the previous time step, calculates the subsequent state using model.[1] The difference between the calculated state and the actual state represents the process noise, which serves as a measure of the inaccuracy of the state transition equation. This inaccuracy comes from two primary sources: first is the inherent simplifications within the model itself. Second, the real system is subject to unpredictable disturbances. These factors collectively signify that the model fails to fully capture the true dynamics of state changes. Similarly, the measurement noise R quantifies the deviation between the sensor-observed value Yk and the estimated observation h(Xk) calculated from the true state at time k. This discrepancy is influenced by two key aspects: the precision limitations of the sensors, and the accuracy of the measurement equation "h()".Both measurement and process noise were adding certain variance to existing values.

By adding the variance, we can provide an environment closer to real world environment. We referenced Bao’s research [2, 3, 4] to determine the value of variance, and apply the variance on observer’s measurement to create noise. The process noise is generated by applying variance of process noise on observer’s measurement. The measurement noise is generated by applying the variance of measurement noise on observer’s measurement, and determine the weight of model’s estimates against the observer’s value.

External disturbances and state transfer equation errors could cause the process noise. Sensor inaccuracies and measurement equation errors could cause measurement noise.

Ref:

[1] Bulut Y, Vines-Cavanaugh D, Bernal D. Process and Measurement Noise Estimation for Kalman Filtering. In: Proulx T, editor. Structural Dynamics, Volume 3, New York, NY: Springer New York; 2011, p. 375–86. <https://doi.org/10.1007/978-1-4419-9834-7_36>.

[2] C. Bao, M. Ouyang, B. Yi. Modeling and control of air stream and hydrogen flow with recirculation in a PEM fuel cell system — I. Control-oriented modeling. Int J Hydrogen Energy 2006; 31: 1879-96.

[3] C. Bao, W.G. Bessler. Two-dimensional modeling of a polymer electrolyte membrane fuel cell with long flow channel. Part I. Model development. J Power Sources 2015; 275: 922-34.

[4] C. Bao, W.G. Bessler. Two-dimensional modeling of a polymer electrolyte membrane fuel cell with long flow channel. Part II. Physics-based electrochemical impedance analysis