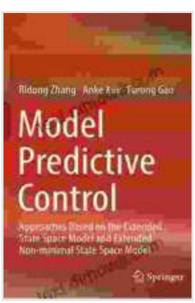
Unlocking the Power of State Estimation: Approaches Based on Extended State Space Model and Extended Non-minimal State Space Model

State estimation is a critical aspect of modern engineering systems, providing real-time information about the internal state of a system based on its observable outputs. This information is essential for control, diagnostics, and fault detection.

In this article, we delve into two powerful state estimation techniques: Extended State Space Model (ESSM) and Extended Non-minimal State Space Model (ENSSM). We will explore the foundations, applications, and advantages of these methods, providing a comprehensive guide for engineers and researchers.



Model Predictive Control: Approaches Based on the Extended State Space Model and Extended Non-minimal State Space Model by Mark Kreidler

★★★★★ 5 out of 5

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Extended State Space Model

The Extended State Space Model (ESSM) is a generalization of the classical linear state space model that incorporates nonlinear dynamics into the system representation. It is expressed as follows:

$$\begin{align}\dot{x}&= f(x, u) + w \\ y &= g(x) + v \end{align}$$

- x is the state vector.
- u is the input vector.
- y is the output vector.
- f is the nonlinear state transition function.
- g is the nonlinear output function.
- w is the process noise.
- v is the measurement noise.

The key advantage of ESSM is its ability to handle nonlinear systems, which are prevalent in many real-world applications. However, the nonlinearity of the system introduces challenges in state estimation.

Extended Non-minimal State Space Model

The Extended Non-minimal State Space Model (ENSSM) is a further generalization of ESSM that introduces non-minimal states into the system representation. Non-minimal states are additional states that are not directly observable from the system's outputs.

The ENSSM is expressed as follows:

$$\begin{align}\dot{x}&= f(x, z, u) + w \\ \dot{z}&= h(x, z, u) \\ y &= g(x, z) + v \end{align}$$

- x is the minimal state vector.
- z is the non-minimal state vector.
- u is the input vector.
- y is the output vector.
- f is the nonlinear minimal state transition function.
- h is the nonlinear non-minimal state transition function.
- g is the nonlinear output function.
- w is the process noise.
- v is the measurement noise.

ENSSM provides several advantages over ESSM:

- It can represent systems with non-observable states.
- It improves the accuracy of state estimation, especially in the presence of unmeasured disturbances.
- It allows for the estimation of system parameters that are difficult to identify using other methods.

Applications of ESSM and ENSSM

ESSM and ENSSM have a wide range of applications in various engineering domains, including:

- Aerospace systems (e.g., aircraft, spacecraft)
- Automotive systems (e.g., engine control, suspension control)
- Industrial systems (e.g., process control, robotics)
- Power systems (e.g., state estimation, fault detection)
- Biomedical systems (e.g., patient monitoring, disease diagnosis)

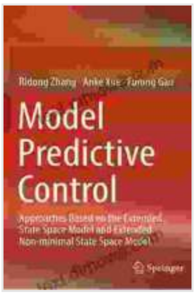
These methods are particularly useful for systems that exhibit nonlinear dynamics, unmeasured disturbances, or non-observable states.

Advantages of ESSM and ENSSM

Compared to other state estimation techniques, ESSM and ENSSM offer several advantages:

- **Nonlinearity Handling:** They can handle nonlinear systems effectively.
- **Non-minimal State Estimation:** ENSSM allows for the estimation of non-observable states.
- **Improved Accuracy:** They provide more accurate state estimates compared to linear methods.
- **Robustness:** They are less sensitive to model uncertainties and disturbances.
- **Flexibility:** They can be easily extended to incorporate additional system information.

Extended State Space Model (ESSM) and Extended Non-minimal State Space Model (ENSSM) are powerful state estimation techniques that provide accurate and reliable state estimates for nonlinear systems. Their ability to handle non-observable states and nonlinear dynamics makes them a valuable tool for a wide range of engineering applications.



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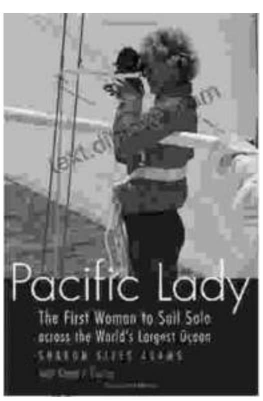

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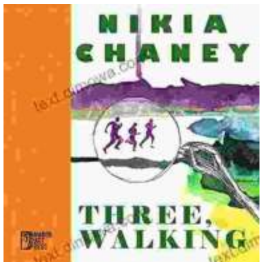

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