SOLUTION OF STATE EQUATIONS

CASE STUDY: MULTISTAGE PRINTING PRESS

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Robust control of multistage printing systems

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ABSTRACT

Printing errors (e.g. doubling) in multistage printing machines are mainly caused by web tension fluctuations, which arise from excessive rotation non-synchronization errors among the driven rollers in different stages (units). Therefore, the critical task in printing quality control is to attenuate web tension variations. In this paper, a robust H_∞ control strategy is proposed to attenuate tension fluctuations when the system is subject to disturbances and variations in speed or other operating conditions. Three system robustness properties are analyzed by using structured singular value analysis (μ-analysis). A systematic investigation is taken to analyze the impacts of different parameter variations on system robustness, with a purpose of providing a reference for achieving robust stability in a multistage printing system. The effectiveness of the proposed robust H_∞ controller is evaluated by both simulation and experimental tests.

A MULTISTAGE PRINTING PRESS TYPICALLY CONSISTS OF >5 STAGES

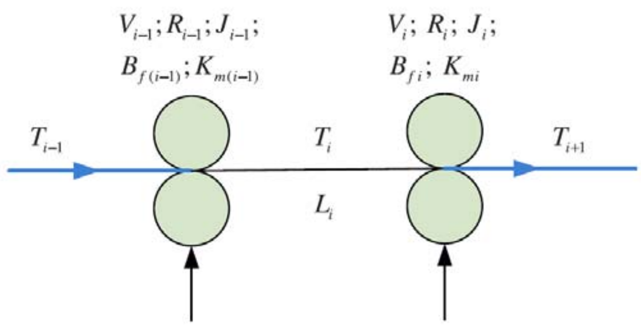
- Paper (called the web) is fed from an unwinding roll and accumulated on a winding roll
- Press value depends upon printed image quality, speed, and cost

DOUBLING (OR BLURRING) IS A PRINT QUALITY DEFECT CAUSED BY MISSYNCHRONIZTION OF STAGES

An Example of
Doubling Print Errors

- Causes: vibration, machinery imperfections (wear and damage), and web tension fluctuation
- Goal: Improve web tension control

MODEL THE WEB MOVING BETWEEN TWO DRIVEN ROLLERS



- States: web tension (T_2) and roller velocity (V_1 and V_2)
- Inputs: motor current (I_1 and I_2)
- Disturbances: surrounding web tension (T_1 and T_3)
- Outputs: web tension (T_2) and roller velocity (V_1)

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MODEL THE WEB MOVING BETWEEN TWO DRIVEN ROLLERS

$$\begin{cases} \dot{x}_p = A_n x_p + B_{n1} d + B_{n2} u \\ y = C_n x_p \end{cases}$$

$$x_p = [x_1\ \ x_2\ \ x_3]^T = [T_2\ \ V_1\ \ V_2]^T, u = [u_1\ \ u_2]^T = [I_1\ \ I_2]^T, y$$
$$= [y_1\ \ y_2]^T = [T_2\ \ V_1]^T, d = [d_1\ \ d_2]^T = [T_1\ \ T_3]^T$$

$$A_n = \begin{bmatrix} -\frac{v_{20}}{L_2} & -\frac{aE}{L_2} & \frac{aE}{L_2} \\ \frac{R^2}{J} & -\frac{B_f}{J} & 0 \\ -\frac{R^2}{J} & 0 & -\frac{B_f}{J} \end{bmatrix}, B_{n1} = \begin{bmatrix} \frac{v_{10}}{L_2} & 0 \\ -\frac{R^2}{J} & 0 \\ 0 & \frac{R^2}{J} \end{bmatrix},$$

$$B_{n2} = \begin{bmatrix} 0 & 0 \\ \frac{RK_m}{J} & 0 \\ 0 & \frac{RK_m}{J} \end{bmatrix}, C_n = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}.$$

- State-space matrices provided in MATLAB

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SYSTEM ANALYSIS

1. Is the system stable? Determine the eigenvalues of A.
2. Determine the state transition matrix.
3. Calculate the response of the web tension (T_2) to a step change in upstream web tension (T_1).