Dealing with Hamiltonian Structure: Challenges and Successes

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Spectrum of an Alternating Pencil

+ + + + + + + +

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- Mackey/Mackey/Mehl/Mehrmann

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$$Hamiltonian matrix: (JH)^{T} = JH$$

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 $N = L^T J L$ $A - \lambda N \Rightarrow J^T L^{-T} A L^{-1} - \lambda I$ *Hamiltonian matrix*: $(JH)^T = JH$ Hamiltonian matrix \Leftrightarrow alternating pencil

$$\lambda \begin{bmatrix} G & M \\ -M & 0 \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} + \begin{bmatrix} K & 0 \\ 0 & M \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

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$$H^{-1} = \begin{bmatrix} I & 0 \\ \frac{1}{2}G & I \end{bmatrix} \begin{bmatrix} K^{-1} & 0 \\ 0 & M \end{bmatrix} \begin{bmatrix} I & -\frac{1}{2}G \\ 0 & I \end{bmatrix} J^{T}$$

LQG Control Problem

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LQG Control Problem • $\dot{x} = Ax + Bu$ • $I(x, u) = \int_0^\infty \left[\frac{1}{2}x^TQx + x^TSu + \frac{1}{2}u^TRu\right] dt$ • $L(x, u, \mu) = I(x, u) + \int_0^\infty \mu^T(\dot{x} - Ax - Bu) dt$

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skew-symmetric/symmetric

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- complete eigensystem

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Skew-Hamiltonian matrices ...

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$$H^2$$

• eigenvalues of H

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Benner/Mehrmann/Xu (199X)

Chu/Liu/Mehrmann (2004)

CLM Method • Chu/Liu/Mehrmann (2004) • $H \leftarrow U^T H U$

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- Deflate. (many details skipped)

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- Extract *k*-dimensional isotropic invariant subspace.
- This is more robust, more efficient, but we're still working on it.














