A Luenberger observer for an infinite dimensional system with disturbances at the boundary: a UV disinfection example

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Abstract - Inspired by a convection-diffusion process in industry, we design an asymptotic strong Luenberger-like observer which is dependent on boundary observations. The observer is constructed using the theory of boundary control systems [2], instead of following the route of Bounit and Hammouri [1]. A disinfection process in an annular reactor is used as an inspiring example and further worked out. In this example, it is also shown that the performance of the boundary observer is very sensitive to the change of the diffusion-convection ratio.

1 Case Study: a UV disinfection process

In greenhouse drain water infestation and disinfection of fluid food products, *annular* tube reactors are the most commonly applied reactor types to reduce pathogenic bacteria or viruses by UV light disinfection. In annular photoreactors the lamp tube is placed along the flow direction. We take an annular reactor as our model system, with output boundary observations $y(t)$ of the active biomass concentration $w(x,t)$, as input the fluence intensity of the lamp and a measured boundary disturbance $u_d(t) = w(0,t)$. We consider (i) the modeling of dispersion phenomena by diffusion–advection laws and (ii) biomass deactivation by ultraviolet irradiation obeying first order kinetics with constant lamp input. This, along with some other (simplifying) assumptions lead to,

$$\Sigma_M := \begin{cases} \frac{\partial}{\partial t} w(x,t) = \alpha \frac{\partial^2}{\partial x^2} w(x,t) - v \frac{\partial}{\partial x} w(x,t) \ldots \\ \quad -\beta w(x,t), \quad w(x,0) = w_0(x) \\ w(0,t) = \bar{u}_d(t), \quad \frac{\partial w}{\partial x}\big|_{x=1} = 0 \\ y(t) = w(1,t) \end{cases} \tag{1}$$

with α the diffusion constant, v the convective flow velocity and β the degree of inactivation.

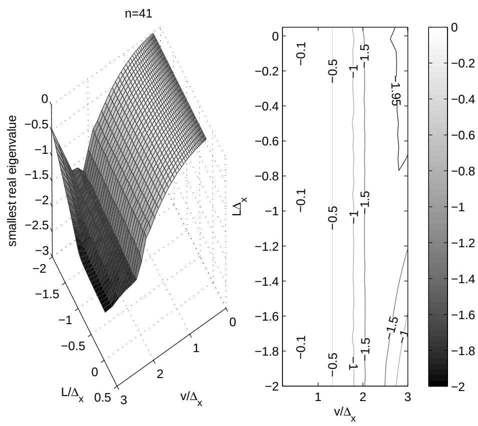
2 Theory and Results

We propose the following observer with asymptotic decreasing error $\varepsilon = w - \hat{w}$ as $t \to 0$,

$$\begin{aligned} \dot{\hat{w}}(t) &= A\hat{w}(t) \\ \mathfrak{B}_1^{obs}\hat{z}(t) &= \mathfrak{B}_1\hat{w}(t) \\ \mathfrak{B}_2^{obs}\hat{z}(t) &= \mathfrak{B}_2\hat{w}(t) + L\left(\hat{y}(t) - y(t)\right) \\ \mathfrak{C}\hat{w}(t) &= \hat{y}(t) \end{aligned} \tag{2}$$

where $(A,\ D(A))$ is an infinitesimal generator of a contraction C_0-semigroup on a Hilbert space Z, $\mathfrak{B}_i^{obs},\ i = 1,2$ and $\mathfrak{C}$ are boundary operators.

With finite differences, the influence of the observer gain on the system matrix is inspected and depicted in the following figure ($\alpha = 1$, $\beta = 1$):



For low Peclet numbers (low velocity - diffusion ratio) and mild inactivation, the sensitivity of the smallest real eigenvalue of the error dynamics of the observer system to the gain L is strongest.

3 Future work

Currently, system (1) in connection with a boundary observer is investigated in the bilinear setting, *i.e.*, where the lamp fluence rate is considered as a control variable, hence $\beta(t) := k_1 u(t)$, with k_1 a susceptibility constant.

References

[1] H. Bounit and H. Hammouri. Observers for infinite dimensional bilinear systems. *European Journal of Control*, 3(1):325–339, 1997.

[2] R.F. Curtain and H. Zwart. *An Introduction to Infinite Dimensional Linear Systems Theory*. Springer-Verlag, New York, 1995.