WP4 : Software Sensor Development

CESAME

Objectives

- to provide on-line values of key process components that are not accessible for on-line measurement in presence of uncertainty in the kinetics.
- Since the operation time is intrinsically limited, one major challenge in the software sensor design is to able to act on the convergence rate of the observer so that estimates of the unmeasured variables can convergence fast enough

Case Study : Mexico process

- on-line estimation of substrate and biomass concentrations from the on-line measurements of dissolved oxygen
- poor knowledge of the kinetics parameters of the biomass growth (Haldane model)

Example #1

- combination of an asymptotic observer with an adaptive observer that provides both state and parameter on-line estimates.
- parameter uncertainty assumed to be concentrated on the parameter μ_0 of the Haldane model
- available on-line measurements : dissolved oxygen S_0 and $S_{0,in}$, inlet COD concentration $S_{C,in}$ and inlet flow rate q_{in}.

Asymptotic Observer

- Auxiliary variables : $z_1 = S_O + k_2 X$

$$z_2 = S_O - \frac{k_2}{k_1} S_C$$

- Mass balance equations for z_1 and z_2 :

$$\frac{dz_1}{dt} = \frac{b}{k_2} S_O - \frac{b}{k_2} z_1 + \frac{q_{in}}{V}(S_{O,in} - z_1) + k_L a(S_{Os} - S_O)$$

$$\frac{dz_2}{dt} = \frac{b}{k_2} S_O - \frac{b}{k_2} z_1 + \frac{q_{in}}{V}(S_{O,in} - \frac{k_2}{k_1} S_{C,in} - z_2) + k_L a(S_{Os} - S_O)$$

- Software sensor values : $X_e = \frac{z_1 - S_O}{k_2}$

$$S_{C,e} = S_O - \frac{k_1}{k_2}(S_O - z_2)$$

Adaptive Observer

$$\frac{d\hat{X}}{dt} = \bar{\mu}_0 \varphi(S_{Ce})\hat{X} + \Delta\mu_0 \ \varphi(S_{Ce})X_e - \frac{q_{in}}{V} X \ + \ C_1(S_O - \hat{S}_O)$$

$$\frac{d\hat{S}_O}{dt} = -k_2\bar{\mu}_0\varphi(S_{Ce})\hat{X} - k_2\Delta\mu_0 \ \varphi(S_{Ce})X_e - b\hat{X} + \frac{q_{in}}{V}(S_{O,\,in} - S_O)$$

$$+ k_L a(S_{Os} - S_O) + \ C_2(S_O - \hat{S}_O)$$

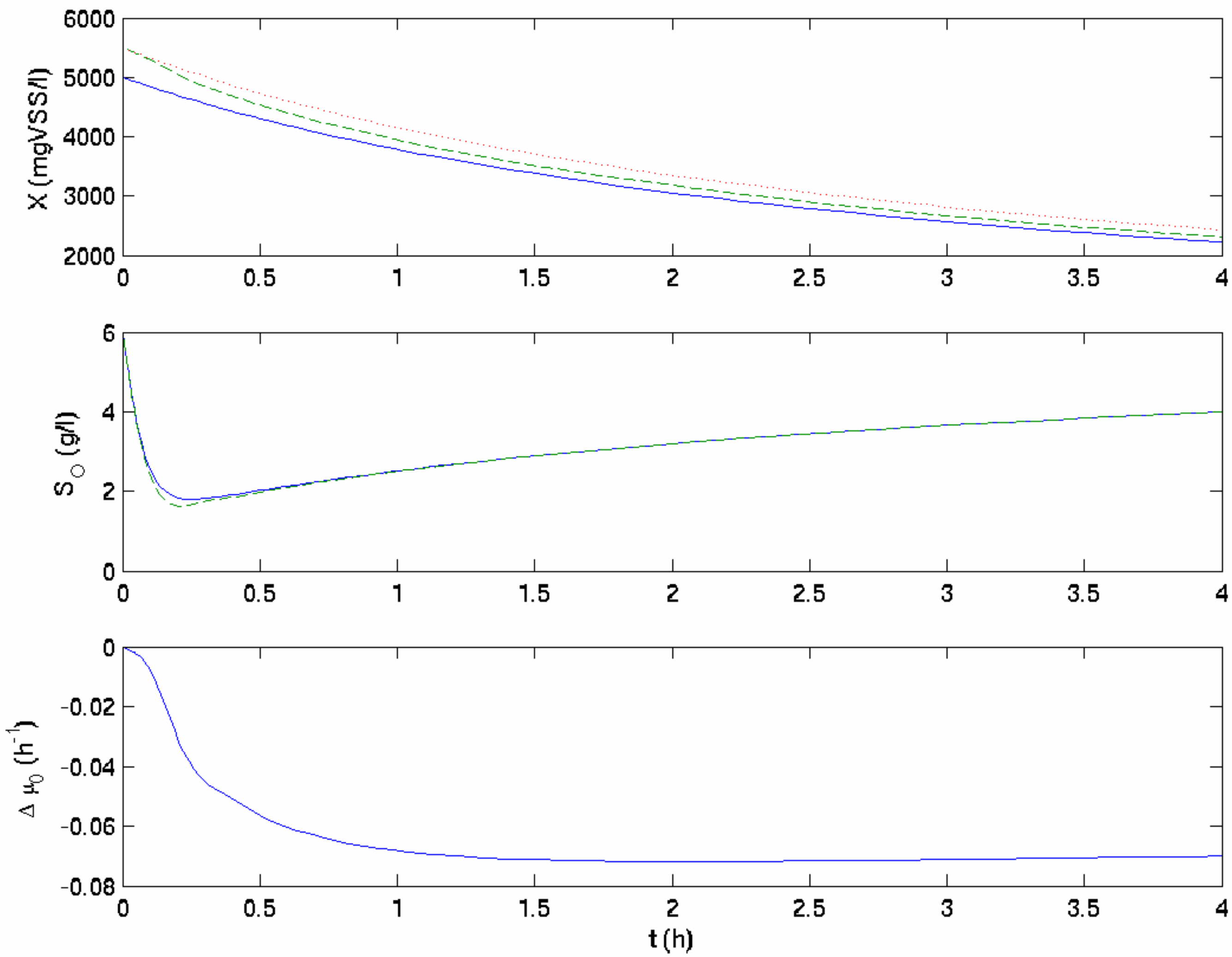
$$\frac{d(\Delta\mu_0)}{dt} = C_3(S_O - \hat{S}_O)$$

With the gains computed as follows :

$$C_1 = -(\lambda_1 + \lambda_2 + \lambda_3) - \frac{q_{in}}{V} + \bar{\mu}_0\varphi(S_e)$$

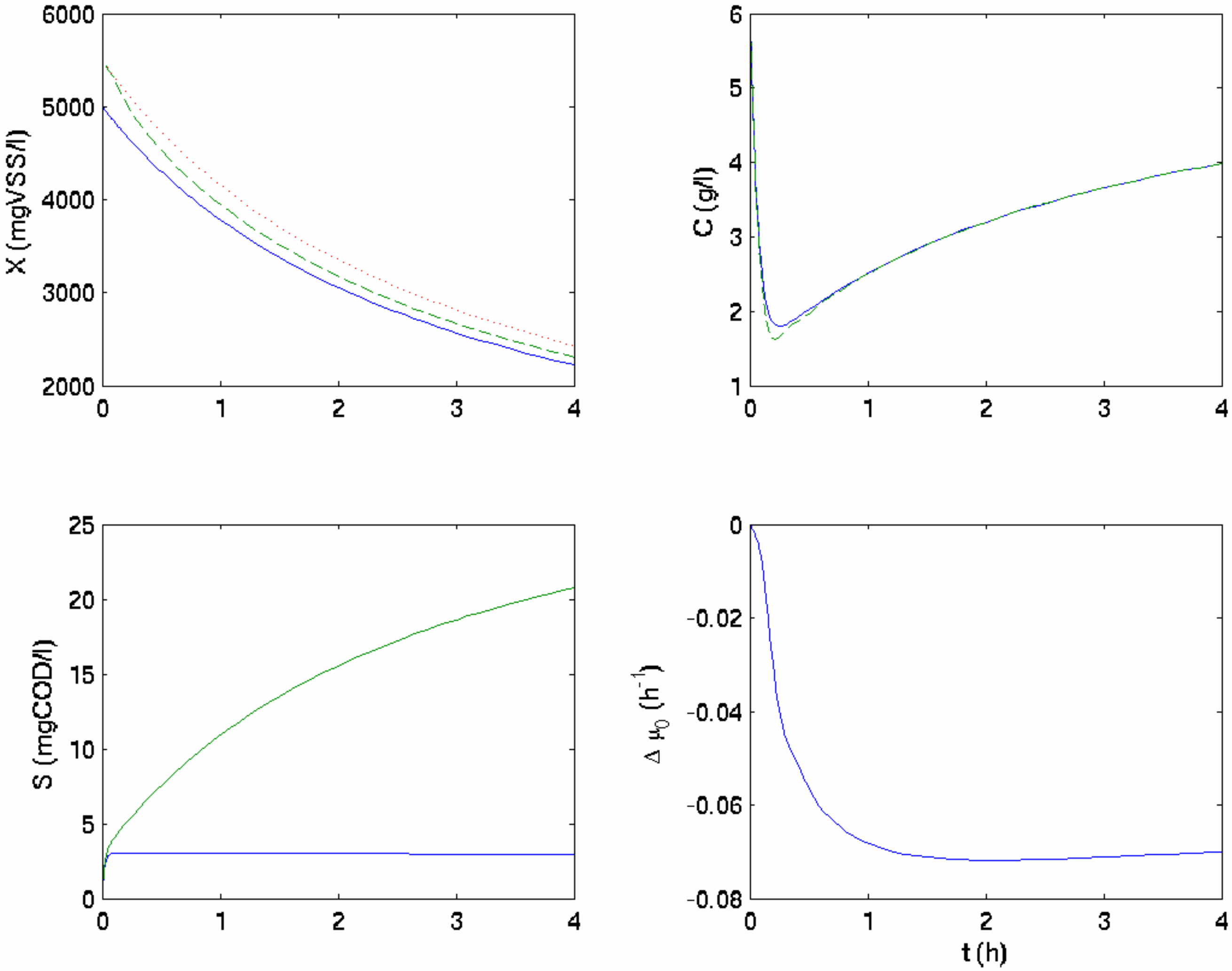
$$C_2 = \frac{\lambda_1\lambda_2\lambda_3}{\varphi(S_e)X_e(b + k_2 q_{in}/V)}$$

$$C_3 = \frac{\lambda_1\lambda_2\lambda_3}{b + \bar{\mu}_0\varphi(S_e)}\left[-(\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_1\lambda_3) + C_2\left(\frac{q_{in}}{V} - \bar{\mu}_0\varphi(S_e)\right) - C_3 k_2 \varphi(S_e)X_e\right]$$

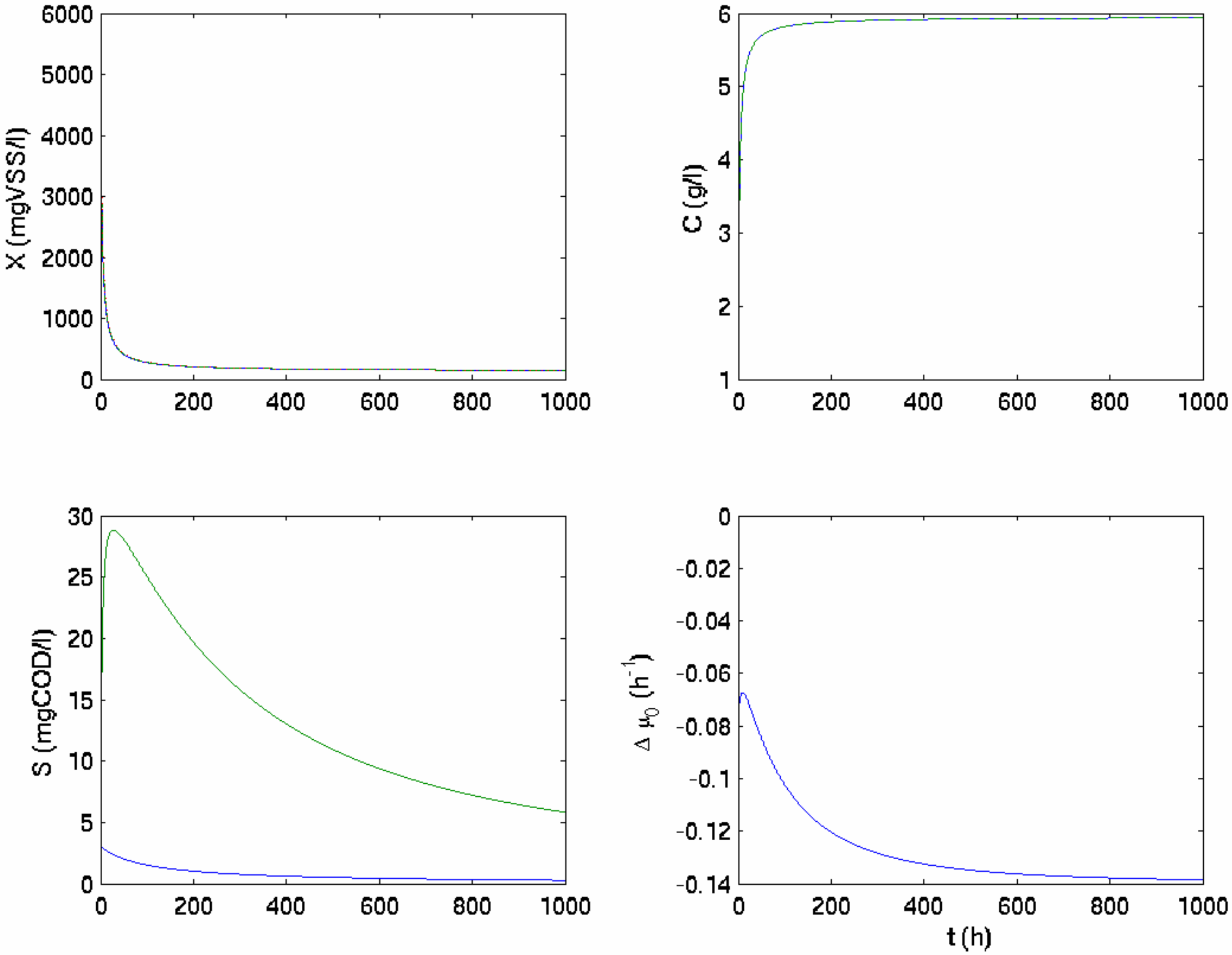


X (mgVSS/l)
6000
5000
4000
3000
2000
0
0.5
1
1.5
2
2.5
3
3.5
4
S_O (g/l)
6
4
2
0
Δ μ_0 (h^-1)
0
-0.02
-0.04
-0.06
-0.08
t (h)

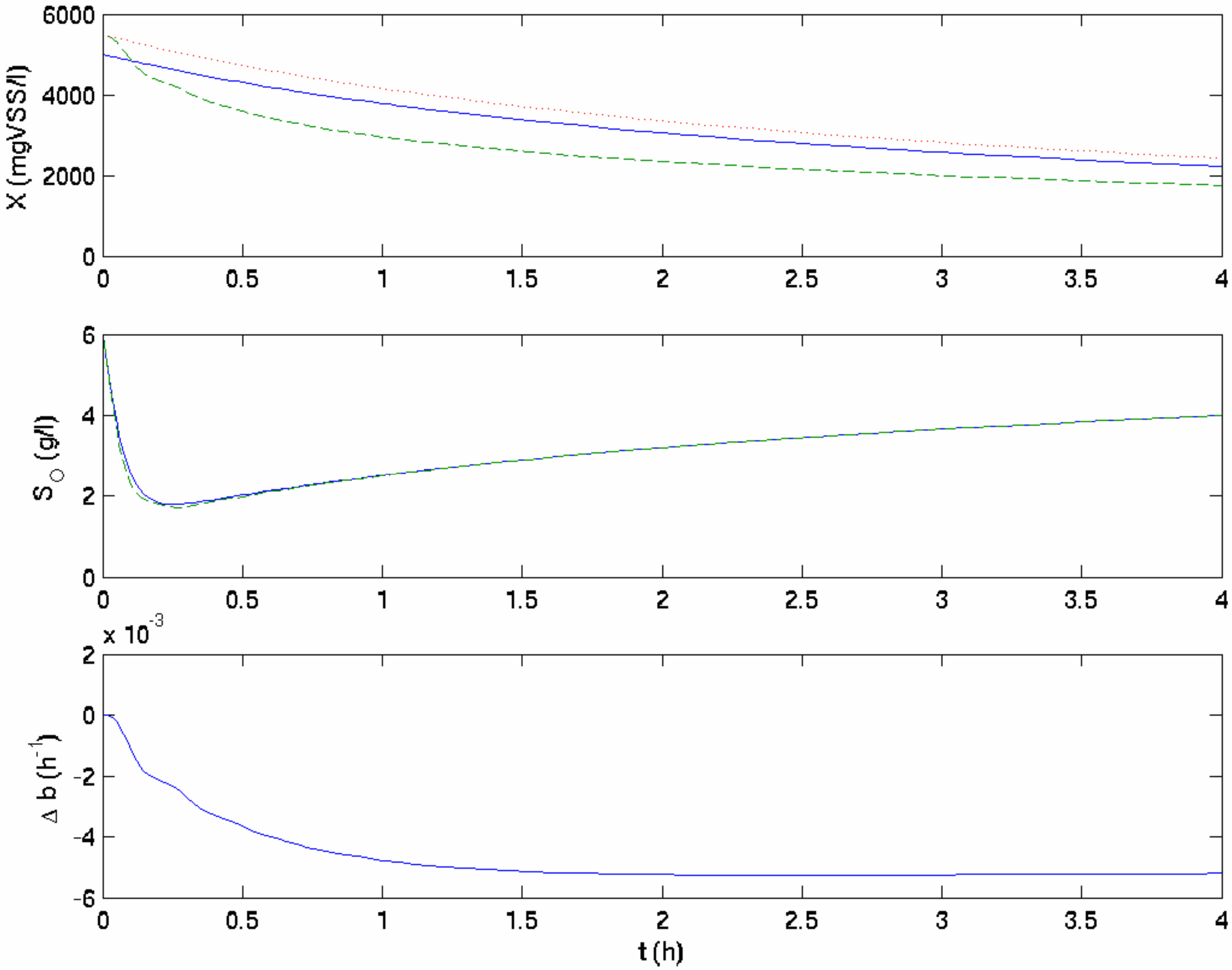
+ estimation of S_c



…after a longer time…



Assumption : b uncertain



Extended Luenberger Observer

- work on robustness?