

# Improving Design of Measuring and Control Systems by Introducing Sensor Models into Dynamic WWTP Simulation

Americana

Montréal, Qc

17 03 2009

Estelle Lagacé,  
Lluís Corominas, Peter Vanrolleghem, Leiv Rieger



## Scope

- Introduction
- Sensor Modeling
- Control
- Results
- Conclusion



2



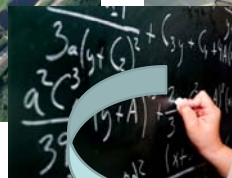
# Introduction



Need to improve/optimize system performance in WWTP  
Control is one approach



# Introduction



Process engineer

Control engineer

Operator



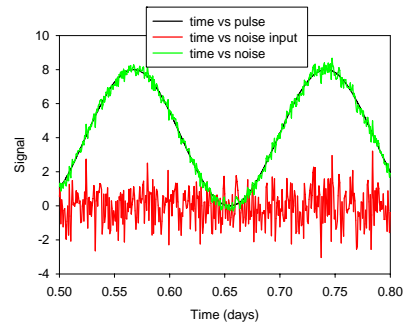
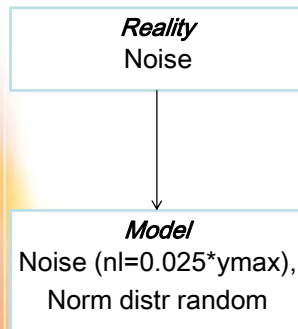
Dynamic models

Sensor models are generally not used

⇒ Need to include sensor models ?

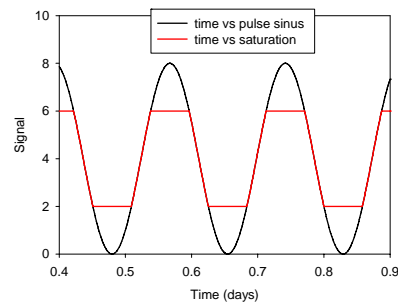
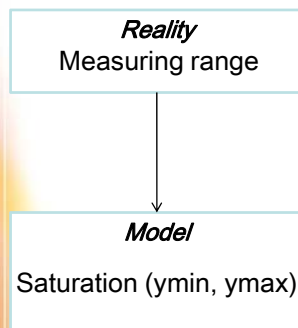
## 2. Sensor models

### From reality to the model (assumptions)



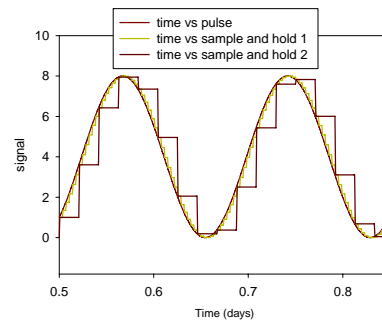
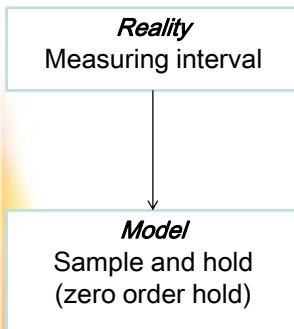
## 2. Sensor models

### From reality to the model (assumptions)



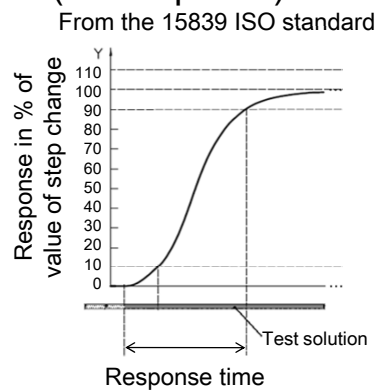
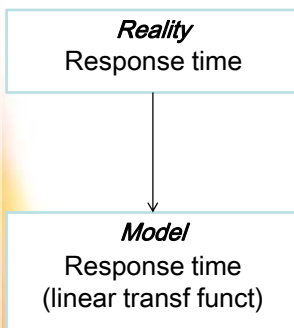
## 2. Sensor models

### From reality to the model (assumptions)



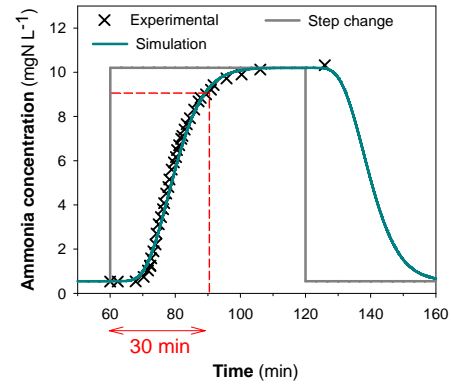
## 2. Sensor models

### From reality to the model (assumptions)



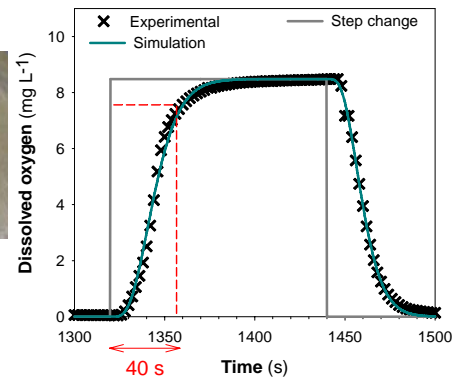
## Sensor modeling - characterisation

### Ammonia sensor



## Sensor modeling - characterisation

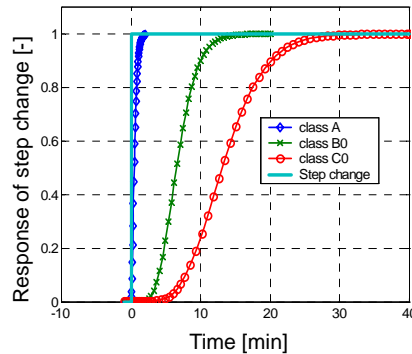
### DO sensor



## Sensor modeling - classification

According to Rieger et al. (2003)

Sensor classes	Response time [min]	Measuring interval [min]
Class A	1	0
Class B <sub>0</sub>	10	0
Class B <sub>1</sub>	10	5
Class C <sub>0</sub>	20	0
Class C <sub>1</sub>	20	5
Class D	-	30



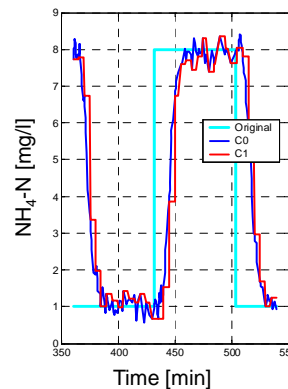
Rieger, L., Alex, J., Winkler, S., Boehler, M., Thomann, M., & Siegrist, H. (2003). Progress in sensor technology - progress in process control? Part I: Sensor property investigation and classification. *Water Science and Technology*, 47(2), 103-112. 11



## Sensor modeling - classification

According to Rieger et al. (2003)

Sensor classes	Response time [min]	Measuring interval [min]
Class A	1	0
Class B <sub>0</sub>	10	0
Class B <sub>1</sub>	10	5
Class C <sub>0</sub>	20	0
Class C <sub>1</sub>	20	5
Class D	-	30



Rieger, L., Alex, J., Winkler, S., Boehler, M., Thomann, M., & Siegrist, H. (2003). Progress in sensor technology - progress in process control? Part I: Sensor property investigation and classification. *Water Science and Technology*, 47(2), 103-112. 12



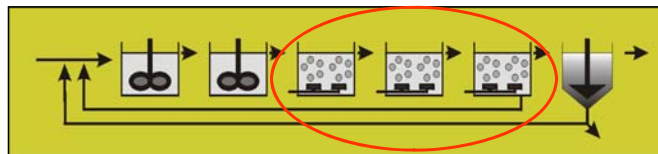
## Control - problem statement

- Control needs measured variables and acts on manipulated variables
- Sensors are used to measure the variables
- Sensor characteristics affect controller performance (e.g. response time, delay)
- Example : temperature control in room

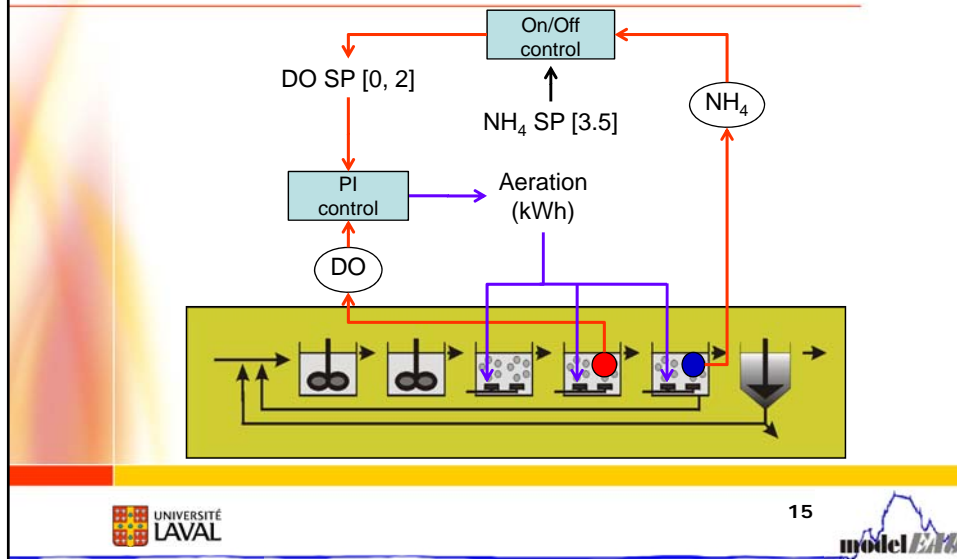


## Control - strategy

- Benchmark Simulation Model No1 (BSM1), IWA Task Group on Benchmarking control strategies
  - Control type: intermittent aeration
  - Objectives of control
    - Improve effluent quality (focus on nitrogen)
    - Decrease operational cost



## Control - strategy



## Control - Definition of scenarios

- Simulations done using different DO and ammonia sensor classes and the characterized sensors

Scenario	DO	NH <sub>4</sub> <sup>+</sup>
1	Idéal	Idéal
2	A	A
3	A (T90=5min)	B0
4	A	B0
5	A	B1
6	A	C0
7	A	C1
8	A	C1 (T90=30min)
9	A (T90=5min)	C1 (T90=30min)

Increase  
in sensor  
response  
time



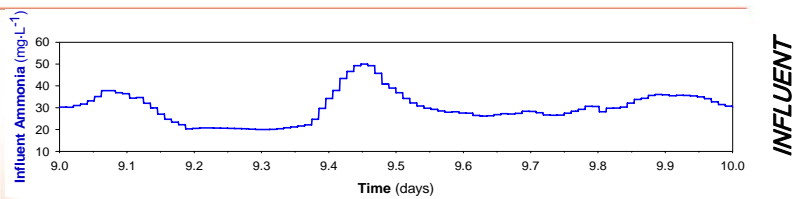
## Control - Definition of scenarios

- Simulations done using different DO and ammonia sensor classes and the characterized sensors

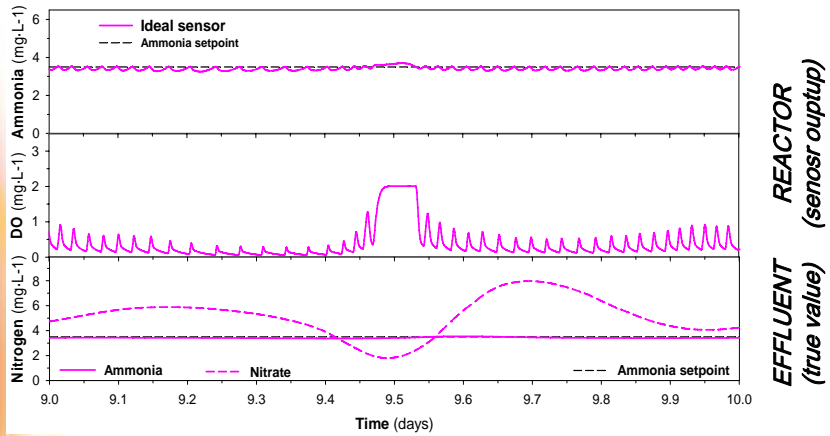
	Scenario	DO	NH <sub>4</sub> <sup>+</sup>
Ideal sensor	1	Idéal	Idéal
Fast sensor	2	A	A
	3	A (T90=5min)	B0
Slow sensor	4	A	B0
	5	A	B1
	6	A	C0
	7	A	C1
	8	A	C1 (T90=30min)
	9	A (T90=5min)	C1 (T90=30min)

Increase  
in sensor  
response  
time

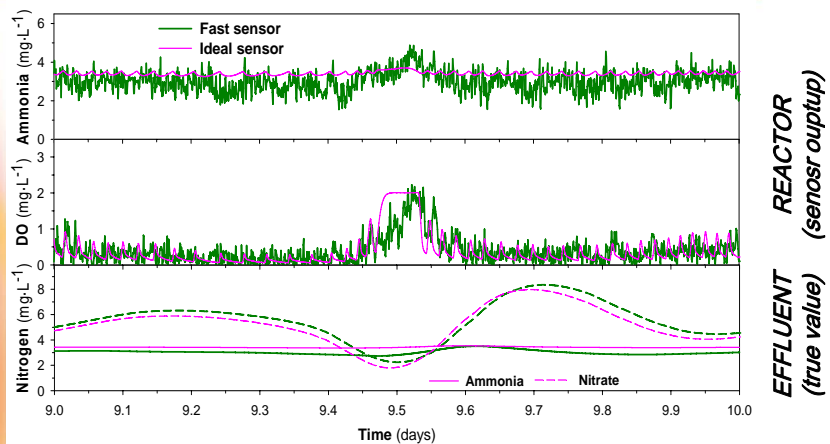
## Results



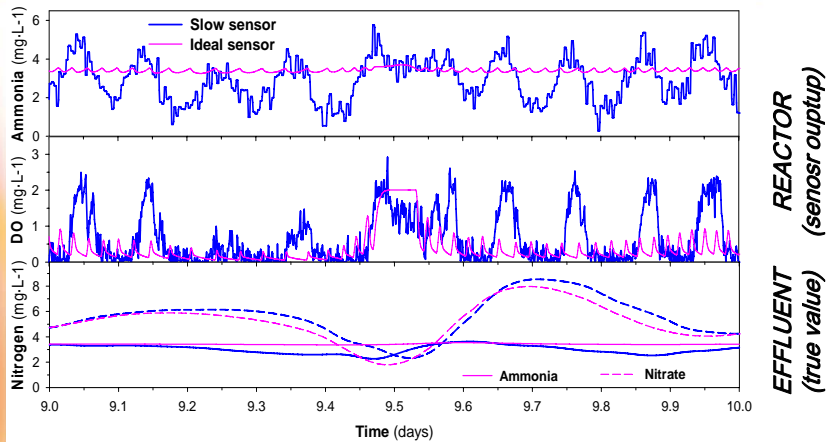
# Results



# Results

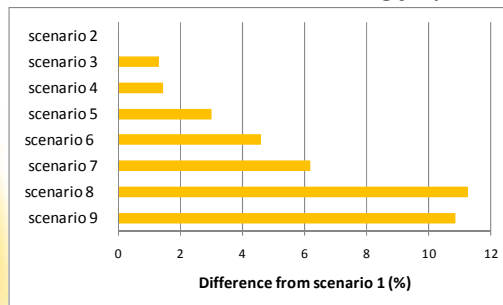


## Results



## Results

### Overall Aeration Energy (kWh/year)



Scenario	DO	NH <sub>4</sub> <sup>+</sup>
1	Idéal	Idéal
2	A	A
3	A (T90=5min)	B0
4	A	B0
5	A	B1
6	A	C0
7	A	C1
8	A	C1 (T90=30min)
9	A (T90=5min)	C1 (T90=30min)

Aeration energy of scenario 1 : 96 000 kWh/an  
 Aeration energy is around 50% of total cost

## Conclusion

- Sensor models should be included in dynamic simulations of WWTP detailed analysis and design of control systems
- Costs, effluent quality and controller dynamics change if sensor models are added
- Using sensor models can provide a common language to the different experts involved in setting up control systems

## Acknowledgment



Canada Research Chair in  
Water Quality Modeling