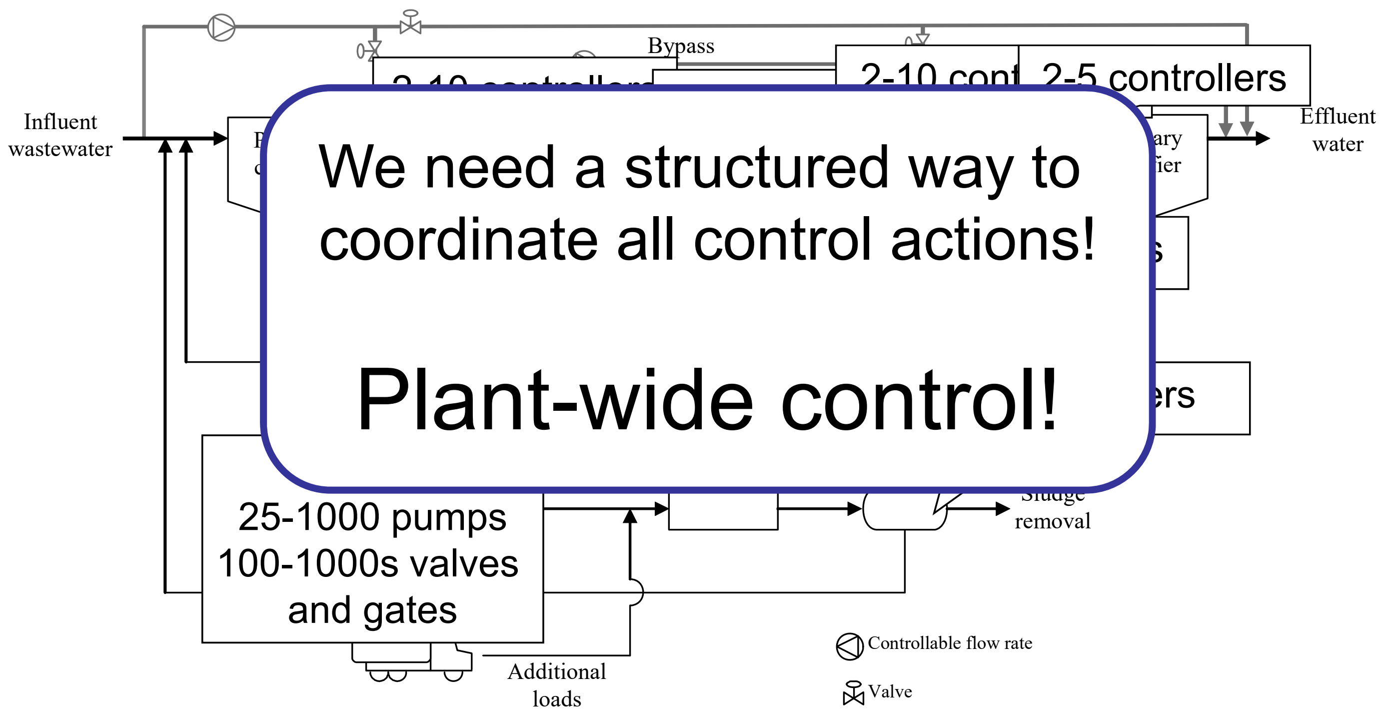
Course Summary

Automation in Complex Systems 2022

Plant-Wide Control

Plant-wide control



We need a structured way to coordinate all control actions!

Plant-wide control!

Challenges for plant-wide control

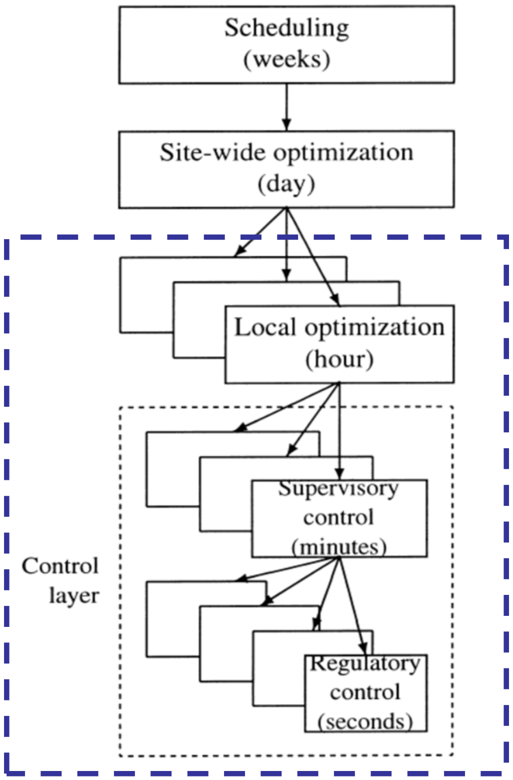
- The product quality varies
  - Different products
- The raw material may be varying
- Other disturbances
  - Should not propagate to the product
- Limited resources
  - Energy, steam, etc.
- Start-up and shut down situation
  - Speed and safety

The “optimal” control structure

- A multi-objective problem
  - Trade off between different objectives
- Combinatorial nature
  - Many different structures possible
- All information not available
  - Assumptions and decisions necessary
- Large multivariable problem
  - Several hundreds (thousands) measurements and manipulation possible
- Limited number of degrees of freedom
  - Satisfaction of all objectives simultaneously not possible

Structures

- Hierarchical structure
- Traditionally used
- Decomposition
  - According to time
  - According to process unit
- Several layers



Structures

- Why not one big multivariable controller?
- One need one plant-wide model
  - All time scales
  - The sub-models may be very different
- Calibration and tuning
  - Difficult
  - Costly
- Sensitive to disturbances
  - Model accuracy
  - When the model fails, local control needed

Design procedure (Skogestad)

1. Determine the operational objectives and constraints
2. Select the manipulated variables (the actuators of the process)
3. Determine the controlled variables (variables with set points)
4. Set the production rate
5. Regulatory control level (local control)
6. Supervisory control level
7. Optimization

1. Operational objectives

- Explicit objectives
  - Related to the physical process e.g. flow rates, temperatures, liquid levels, concentrations
- Implicit objectives
  - Functions of the explicit objectives, e.g. operational costs, product quality, process and operator safety
- Often many different objectives!

2. Selection of manipulated variables

- Degree of freedom (DOF)
  - Differs depending on objective
- Dynamic DOF (N_m)
  - The number of independent manipulated variables
- Steady-state DOF (N_{ss})
  - Number of manipulated variables that affects the steady state
- Optimization DOF (N_{opt})
  - DOF left after active constraints (N_{act}) are subtracted

2. Selection of manipulated variables

- The optimization DOF ($N_{opt} = N_{ss} - N_{act}$)
  - Must be sufficient to meet the operational objectives
- Additional manipulated variables
  - If the optimization DOF is not sufficient
  - Add more manipulated variables, i.e.add more equipment
- Inventory of the DOF very important!
  - Process insight

3. Selection of controlled variables

Controlled variable

- A variable that is measured and controlled (using manipulated variables) in a local loop
- The set point of the controlled variable is available for the supervisory controller

3. Selection of controlled variables

Requirements:

- The “optimal” value should be insensitive to disturbances
- It should be easy to measure and possible to control accurately
- It should be controllable, i.e. it should be sensitive to changes in the control
- It should be independent of other controlled variables

4. Set the production rate

- The maximum throughput is often determined by design
- The feed rate (determined upstream)
- Effluent rate (demand-driven)
- Bottlenecks in the process
- Otherwise: set the throughput so that a smooth rate is obtained

5. Regulatory control

What should be controlled?

- Unstable processes
- Drifting processes
- Safety critical processes
- Processes with disturbances

5. Regulatory control

Methods

- The complete set of methods within control theory
  - Linear control
  - Non-linear control
  - Multivariable control
- For SISO:
  - PI and PID controllers
  - Ratio control
  - Feed-forward control

6. Supervisory control level

Purpose:

- Keep the controlled variables at “optimum” set-points using the controlled variables as the degree of freedom
- Additional manipulated variables (not used on regulatory level)
- Structural choice:
  - Decentralized (SISO loops)
  - Centralized (multivariable control)

6. Supervisory control level

Decentralized

+ Tuning on-line
+ No model requirements
+ Easy updating
- Pairing needed
- Performance loss
- Difficult to handle constraints (logic)

Centralized

+ Coordinated control
+ Feed-forward easy
+ Handling of constraints
- Requires model
- Tuning difficult
- Sensitive to disturbances

6. Supervisory control level

What are the controlled variables of the supervisory control level?

- Typically the optimization criteria (cost functions)
- Implicit objectives
  - The formulation of the objectives important!

7. Optimization

- Find the “optimal” operational set points
  - On the supervisory level
  - On the regulatory level
- Off-line (manual) optimization
- On-line optimization
  - New “optimum” calculated at certain time interval

Data bases

The database (DB)

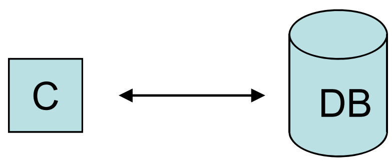
- Contains data
- Grouped data
- Describes a part of the world
- Data described by a schema
- Consistent contents
- Handled by a DBMS

DBMS

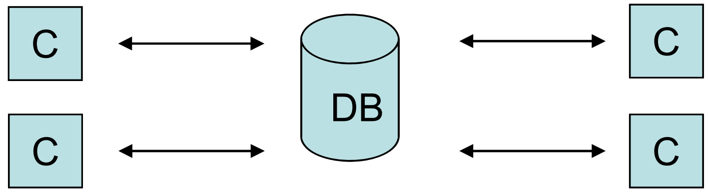
- DataBase Management System
- Often referred to as "database system"
- Complex software systems
- Tasks
  - Storage
  - Programming interface (query processor)
  - Manage transaction

Client –Server structures (1)

- One client – one server

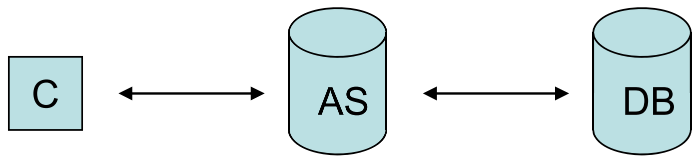


- Many clients – one server
  - Realtime considerations

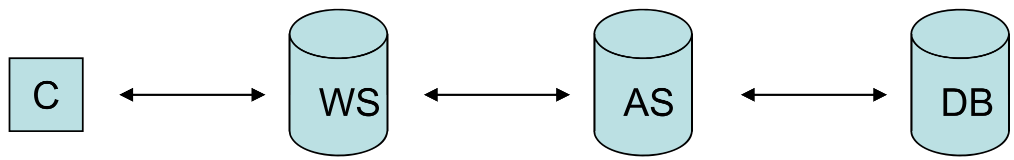


Client –Server structures (2)

- Application server – DB server

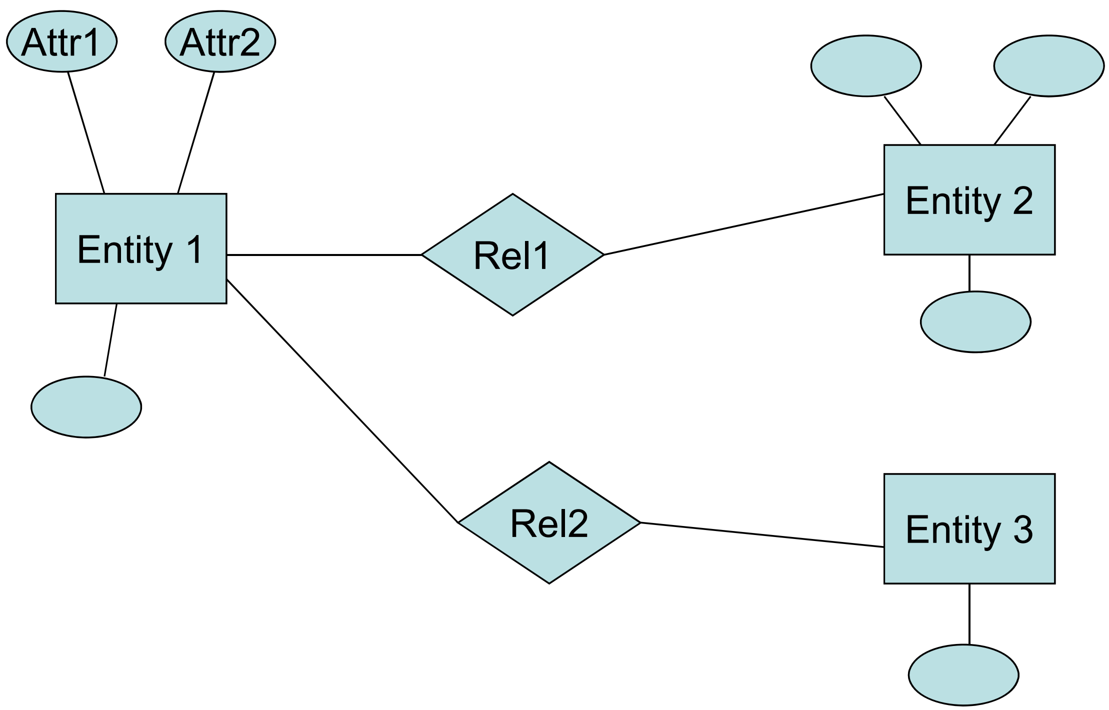


- E.g. web server – application server – DB server



Put the heavy load as early as possible!

Entity-Relationship Model (2)



Simple SQL Querie

SELECT ...
FROM ...
WHERE ...

E.g.

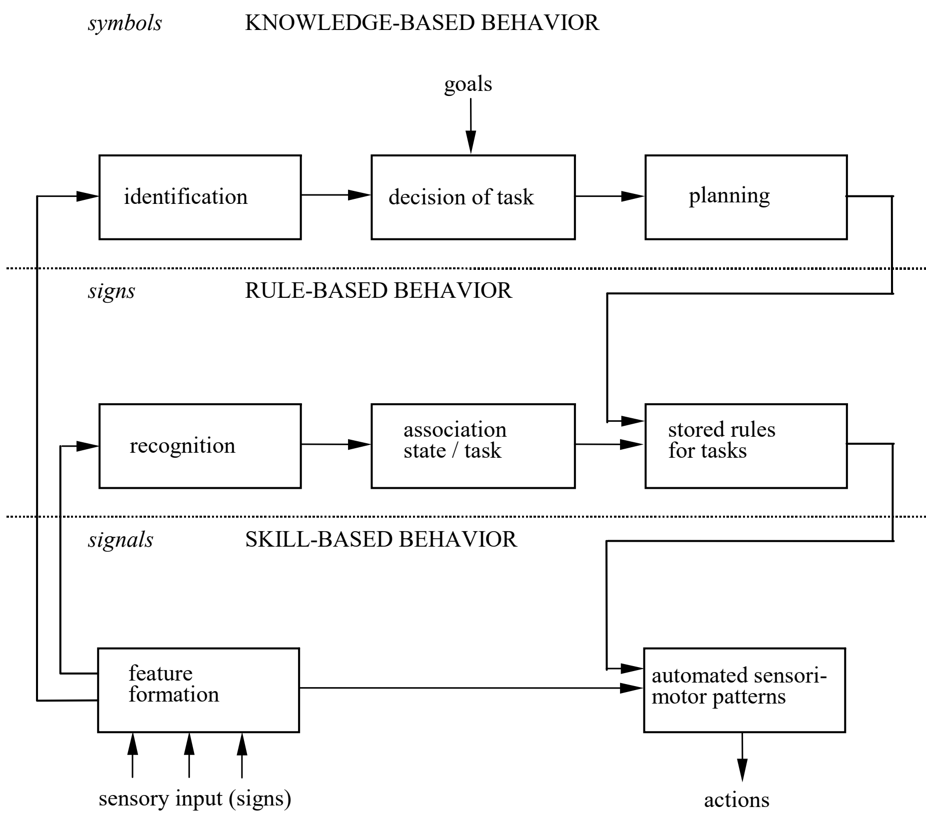
```
SELECT *
FROM Components
WHERE Price>300
```

Operators: *, +, -, >, <, >=, <=, <>, || (concat)

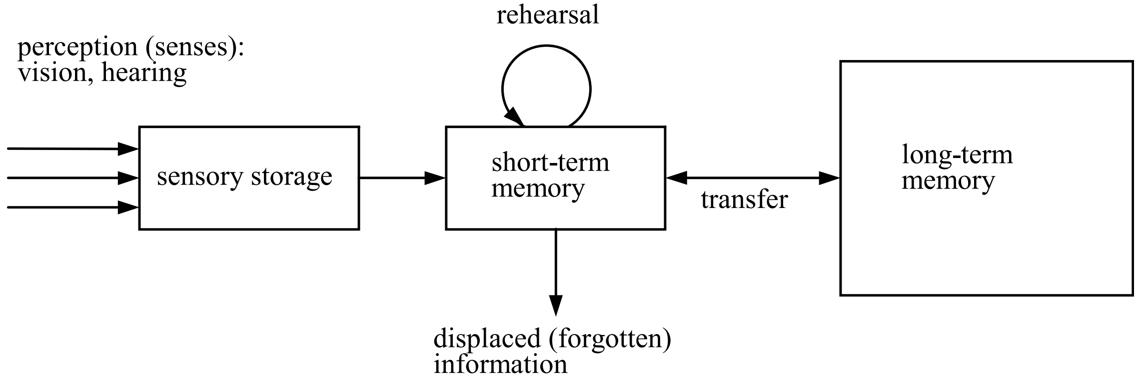
HMI

Human Machine Interaction

Levels of Human Performance



Dual Memory Model



How to Remember?

4687834000

or

46 - 8 - 783 4000

- Remember the 7 +/- 2 rule!

Seven Steps to High Performace HMI

(From Hollifield et al)

1. Adopt a High Performance HMI Philosophy and Style Guide
2. Assess and benchmark existing graphics against the HMI Philosophy
3. Determine specific performance and goal objectives for the control of the process, for all modes of operation

Seven Steps to High Performace HMI

(From Hollifield et al)

4. Perform task analysis to determine the control manipulations needed to achieve the performance and goal objectives

5. Design and build high performance graphics, using the design principles in the HMI Philosophy and elements from the style guide

Seven Steps to High Performace HMI

(From Hollifield et al)

6. Install, comission, and provide training on the new HMI
7. Control, maintain, and periodically reassess the HMI

Alarms (2)

- Alarm limits are crucial
- Alarm groups
- Priority
- Summary/History
- Alarm sequences – one cause many alarms – find the root
- Included in the datastructure

DDE –Dynamic Data Exchange

- Available in Windows for a long time
- Net DDE also early (Win 3.11 ?)
- Simple addressing:
  - Application
  - Topic
  - Item
- Single access or subscription

Microsoft Component Object Model (COM)

- Distributed COM – DCOM
- No language definition, no implementation details, a platform independent standard for COM objects to interact.
- The foundation technology for OLE and ActiveX

OPC

- OLE for Process Control
  - Redefined: Open Platform Communications
- OLE Object Linking and Embedding (based on DCOM)
- Event and Alarmhandling included
- http://www.opcfoundation.org/

.NET

- An even more improved framework
- Replaces COM and DCOM
- From Windows Vista COM is not included!
- Problems for the automation business (OPC)
- Solution has been developed(OPC UA)

OPC today…

- Problems for the automation business when COM/DCOM was removed
- OPC UA : *Unified Architecture* is preferred today.
- Based on SOA: *Service Oriented Architecture* rather than OS functions.
- ***OPC=Open Platform Communication***

The Exam

What you may use

- The book
- Calculator
- The articles
  - Shampine and Gear, 1979
  - Wise and Gallagher, 1996
  - Kramer and Fjellheim
  - Skogestad, 2004
- HMI excerpt
- ISA88/95 and Industry 4.0 whitepapers

Also remember

- Obviously: read the articles before!
- Three previous exams are available
- Guest lectures (Olsson, Rosén, Gillblad, Johnsson, Antius) are also included
- Project work and simulation exercises included
- More understanding than calculations
- Make use of your own lecture notes ☺
- Wednesday, June 1, 14:00-19:00 Sparta C

Online exam

- Wednesday, June 2, 14.00 – 19.00
- Only registered students
- Computer and webcam
- Same procedure as Automation
- Zoom/Canvas
- Detailed instructions will be sent out soon

Best of Luck!

and

Thanks,

Ulf, Ramesh and Gunnar