Automation and Process Control

ISS0080-Automatiseerimine ja protsessijuhtimine

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Automation and Process Control 2-1-1 5 ECTS E
http://www.a-lab.ee/edu/courses

Assessment methods

- Tests: 2 (2×20 points);
- Labs: 6 with report. Deadline for report is in 2 weeks.
  - On time 2 points,
  - With delay 1 point.
- Exam: written.

Exam prerequisites:

- Both tests should be written at least on 5 points.

Final grade:

1. Tests + reports give max 50+ points
2. Written exam gives max 50 points.

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Lectures

Wednesday 10:00–11:30 ICT-A1 2 academic hours/week

+

Exercises

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or

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Technological approach

There are two different approaches in automation: different skills, terminology and culture.

Technological approach

- Equipment, instrumentation
  - controllers, PLCs, computers, sensors, actuators, etc.
- Connecting devices: signals, networks, protocols;
- Tuning, programming, operation;
- Safety.

Control Instrumentation

Dates: Autumn 2018

Process approach

Approach based on the process

- Old ones: boilers, petrochemical, polymers, etc [1, 2, 3, 4, 5];
- New ones: bio-tech, pharmaceuticals, nanotechnology, etc;
- Knowledge of the characteristics of the process
  - chemistry, physics, thermal engineering, etc;
- Problems: cost, product cost, quality, environment, etc.
- Control algorithms, process safety [6, 7].

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Dates: Now

Management

Industrial processes should be designed to meet business needs.

- Technical conditions description
  - Specify the elements of the system
    - Who is the target customer?
    - What is considered "value" to the customer?
    - What is the geographic scope of the business?
    - Which skills and capabilities should be developed within the firm?
    - How can the firm grow, through both its base business and new business?
- Terminology
- Communication Skills /verbal, written/
- Formation of the Contracts

Technical

- Decomposition of the system into subsystems
  - description of the elements, models
- Realizability
- Choice of the technology
- System behavior and the environment
- At least one specialty
  - good knowledge of the given field

Implementation

New systems are implemented by the projects.

Project consists of:

- Requirements (specifications)
  - Problem Statement. **What** should we do.
  - Additional Terms and **Conditions**.
  - Does **not** include requirements **how** to do.
- Volume of work (time, costs)
- Contract
  - What work? Who does? How much?
  - Quality requirements?
  - According to what criteria?

Volume and Problems

Large projects

- Duration: years;
- Description: rockets, tunnels, weapon systems, etc.

Small projects

- Duration: weeks;
- Description: thermometer, door automation, etc.

Problems in the design of systems:

- Select the right technical solution.
- Knowing the environment where the project is working.
- Team work, relationships between people.
- Communication skills (verbal, written).
- Risks estimation
  - money, time, manpower, additional costs.

Aim

The course aim: automation.

Works in the field:

- Process control;
- Power production, distribution;
- Machinery control;
- Building automation.

Control task formulation and solving

- Object identification
  - Is it possible?
  - Which way?
- Simulations
- Realization (ISS0065)

Outcomes

Student knows how to

1. Describe a dynamic system.
   - Understanding steady-state behavior,
   - Transfer functions,
   - State-space models and their conversion;
2. Analyze the control problem and choose the appropriate controller;
3. Understand and describe mathematical models of the dynamical systems;
4. Use MATLAB to design a system and to do simulation tests;
5. Present the results on paper and orally;
6. Create simple protection circuits to reduce the risks.

Problems in the field of automation

- Articles http://www.controlglobal.com,
- Articles http://www.controldesign.com.

Automation at the nearest universities

- Aalto university: http://autsys.aalto.fi/Automation,
- Lunds University: http://www.control.lth.se/,
- University of Oulu: http://www.oulu.fi/pyosaaen/.

Other sources

- Online Resource http://www.controlguru.com/,
- Technical Aspects of Process Control and Simulation http://modelingandcontrol.com/,
- Basic Information for Engineering and Design http://www.engineeringtoolbox.com/.

Literature

Main literature

- *Process Control. Modeling, Design, Simulation.* B.Wane Bequette.
- *Process Control. A First Course with Matlab.* Pao C. Chau
- *Introduction to Process Control.* J.A. Ramagnoli, A.Palazoglu.
- *Process Control. Designing Process and Control Systems for Dynamic Performance.* Thomas E. Marlin.

Additional literature

- *Advanced PID Control.* K. Åström, T. Hägglund,
- *Control Theory.* T.Glad, L.Ljung.

Systems

Engineering activities are intended to create a system / process / component what we want / need and as the result

- Concept (necessity, requirements, functions) — documentation;
- Realization (design, tests, production).

In the course Automation and Process Control (A&PC) we will discuss

- Control /objects, aims, etc./ including
- Automatic control and industry control systems, where

Control system

- Implements control algorithms (process interface),
- Provides situation (user interface),
- Analyzes and estimates situation (alarms).

Technical Process

Process is the entirety of all interacting process within a system that transforms and stores material, energy of information.

Technical process is a process in which its physical parameters are recorded and influenced by technical means.

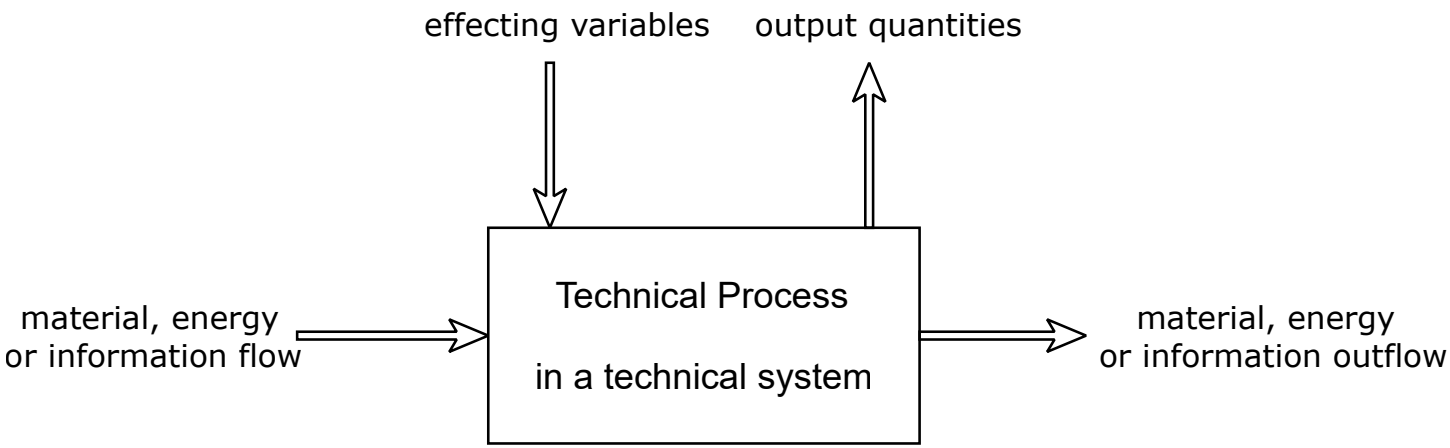

Figure: Technical Process

The Technical process runs on technical system.

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Automation System Structure

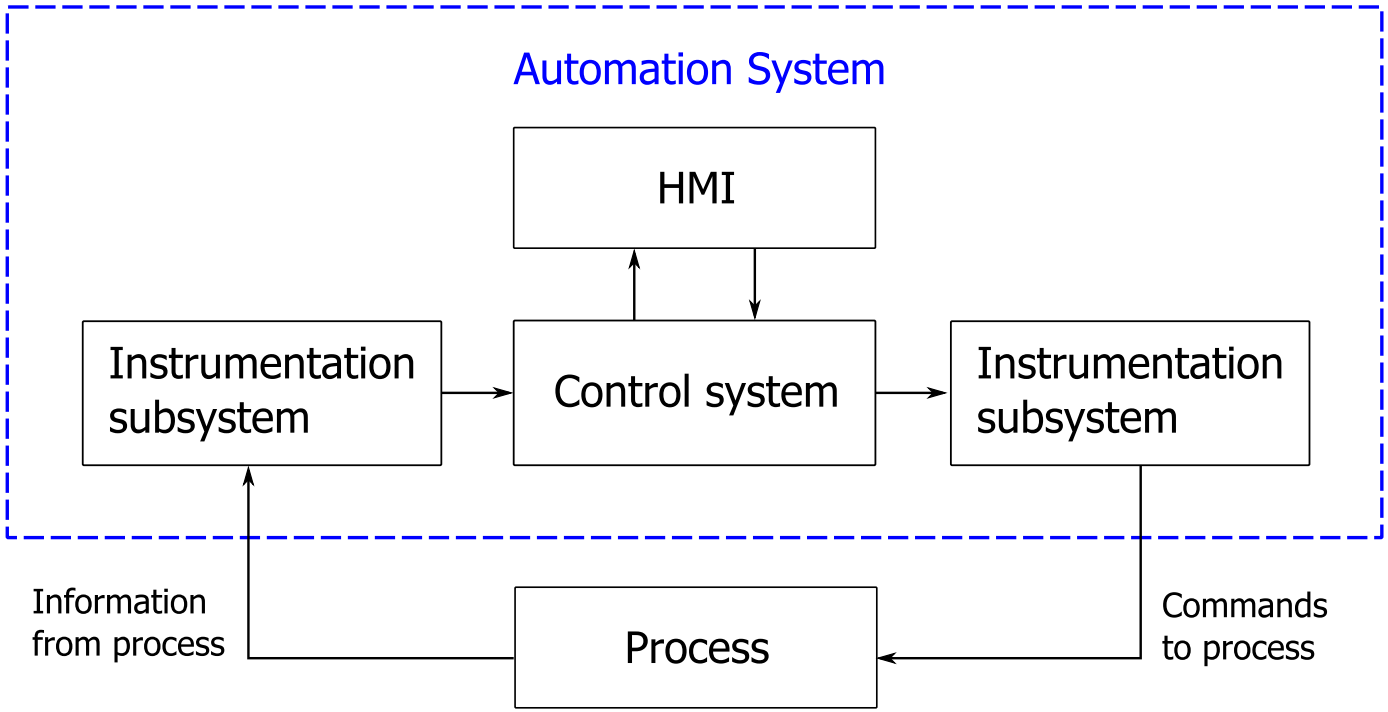


Figure: Basic structure of Automation System

Instrumentation acquires information from the process. Sends the information to the process to change its behavior.

Human interface allows operator manually interact with the process.

Industrial Automation System

Goal is the automation of operations in the technical process with the help of appropriate information processing units.

Human operators only place requests on the operating results.

Automation of the technical process in the foreground

Process Control System

Goal is management of the procedure of a technical process by human operators, supported by the automation of individual operations.

Operation in the foreground

Control System

Control system is the heart of automation systems and coordinates and controls the functions of other systems.

The control system is an essential mechanism for manipulating of the output of a specific process to achieve the desired result.

Control system consists of

- Basic control (PID, blocking);
- State-flow;
- Tracking control (set points);
- Specific situations (errors, emergency, startup, etc.);
- User interfaces (alarms, trends).

Regardless of the application automation has similar goals, algorithms, devices.

Control system will be integrated with business management.

Manufacturing

Manufacturing is a process of transforming inputs into final goods and products.

Company is a business unit

- Working with the purpose, owns assets;
- Located somewhere: Transport, Logistics;
- Consists of units: structure;
- Manufacturing activities: processing materials $\rightarrow$ product
  - processes: chemical, mechanical, thermal, etc.

Production Activities

The overall purpose of any business is profit.
Manufacturing adds value to the product, which is produced in order to sell at a higher price than the cost is.

Product

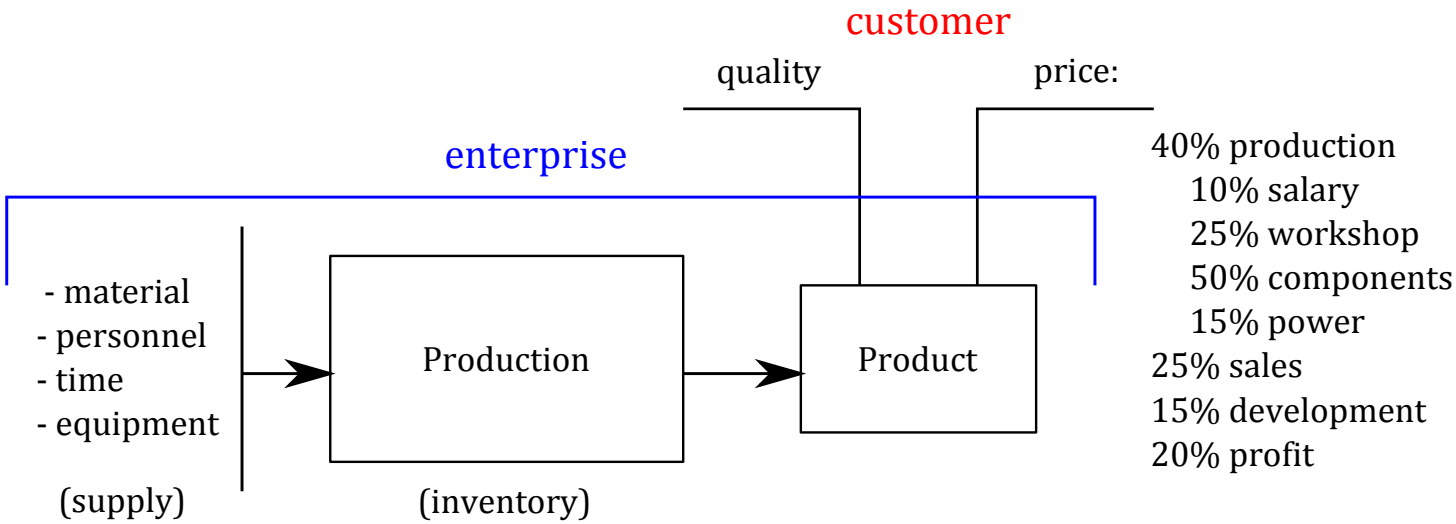


Figure: Production price

The technical and organizational level of production (capability).

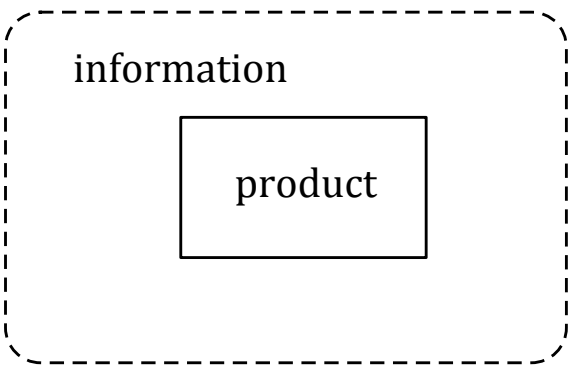
Product has a life cycle

- Design — devices configuration.
- Production — PLC programming.
- Support — HMI design.

Product II

Market becomes more global.
Number of customers and manufactures has increased

- Products have a lot of modifications;
- Orders are smaller but more frequent;
- Requires more information about the product and order.



Product is delivered to the final customer with information which should be collected, saved, stored, processed, etc.

Production process

Production process is changing

- Production volumes are changing
- Raw materials are changing
- Quality requirements increase
- Shorter deadlines
- Market is changing
- Safety, environmental requirements

Can be solved by: automation and data processing.
Equipment: computing hardware and networks.

Industry

In industry the knowledge of different fields is needed including knowledge of automation:

- Control systems;
- Computer science;
- Electricity, mechanics.

There are two environments:

Industry environment workshop, workers (blue-collar), control of the equipment, machinery, power, water, compressed air, PLC, regulators, fast networks, short messages.

Business office, staff (white-collar), business plan, production planning and management, orders, Internet, files (enterprise infrastructure), etc.

In industry we simultaneously have: production, design of the new products, construction, maintenance, market research, logistics.

Production

The production process is part of a long chain of economic activities.

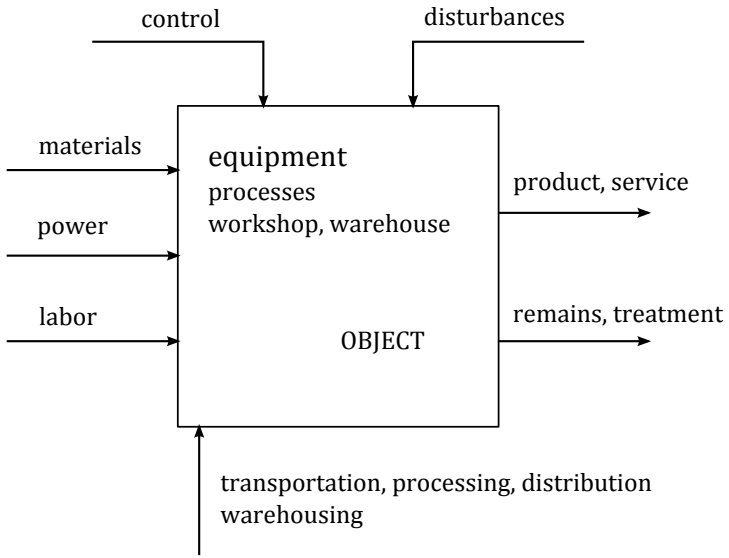


Figure: Production

Among continuous processes in world dominate

- Chemical and petrochemical;
- Biotechnology;
- Boilers, thermal processes;
- Waste water treatment, etc.

Production II

Production process:

- Distributed in space;
- Running in time;
- Influenced by the disturbance.

Equipment and process states:

Basic Concepts

Process is a change of indicator

- Number of activities
  development process, manufacturing process, the training process, etc.
- Human, technical
- Changes properties, can be controlled
- Requires: time, space, resources, skills, etc.

Industrial processes are systematic series of physical, mechanical, chemical, etc of operations that produce a result.

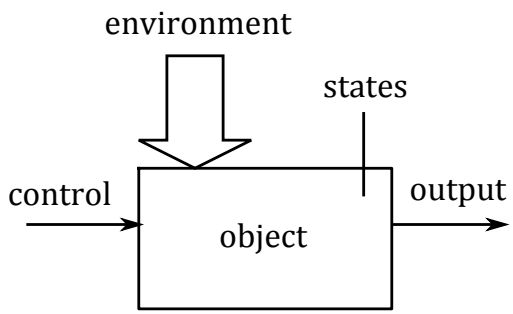
- ✓ Manufacture goods
  food, chemicals, etc.
- ✓ Provide services
  supply electricity, water, gas, etc.

Some processes are reversible.

Control

Control purposeful activity (has the goal!)
Process should be affected to meet the goal

Controlled object equipment, process



Automated control control without human aid

System components, transformations: inputs $\rightarrow$ outputs

Classification

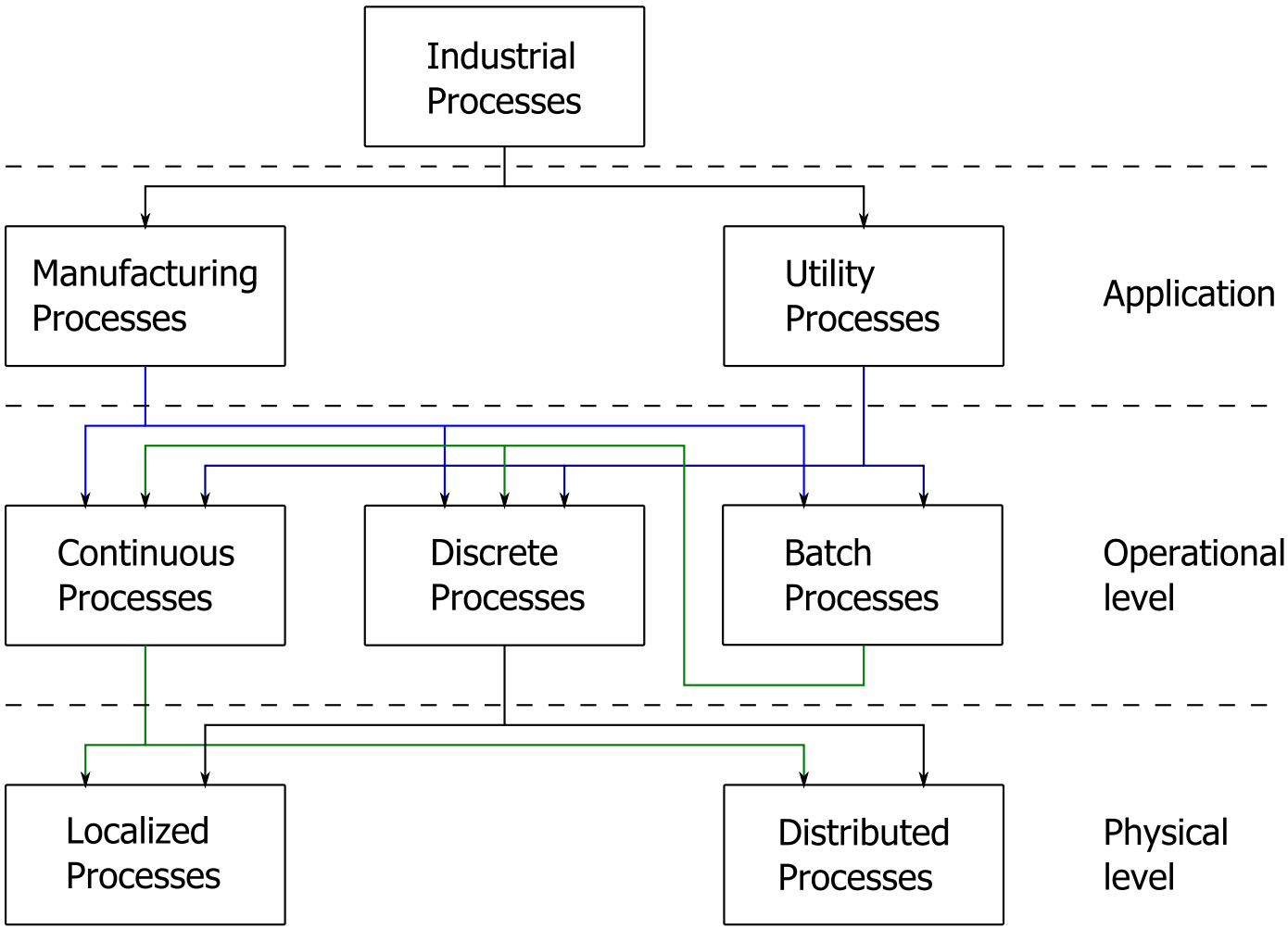
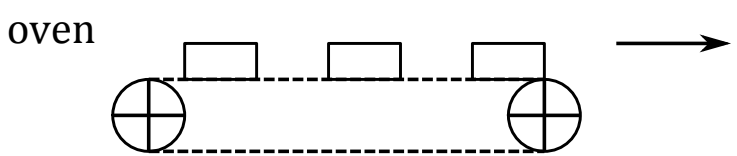


Figure: Industrial processes

Continuous processes

- Steady state is an equilibrium point of the process
  Lasts a long time due to big time constants
- Dynamics of the process does not change (possible to use linearized model)
- Small disturbances, fixed

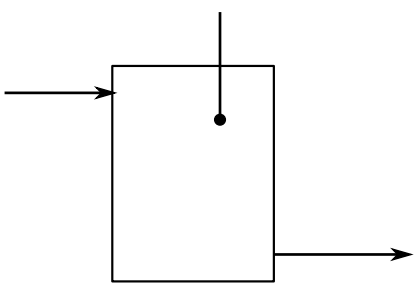
- Boilers (heat, steam)
- Chemical industry (polymers, paints, etc.)
- Petrochemical - quality, production volumes, profits
- Baking

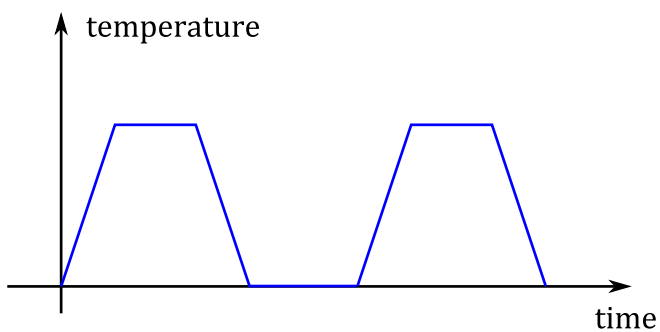


Batch processes

- Process depends on the quantity, composition and material
- Time constants change ($10\times$)
- Purposes are changing
- Errors can damage the product or equipment
- Controlled from the beginning till the end, changes are drastic

- Dough, concrete
- Pharmaceutical products
- Food, beverages
- Paints, varnishes





Management flows of the production

	Activities	Objectives
Business management	Strategic management (business plan) Orders, Logistics Resources Income/expenses	Economic optimization $\min \sum$ expenses ($\max$ profit) limitations
Workshops production	Tactical management (plan) Optimization, plan Monitoring Failure treatment Repair	Process optimization ($\max$) -quantity, speed quality ($\min$) -price, cost ✓ plan execution
Process control by equipment	Efficient control control state-flow interlocks, safety behavior	Implementation of the control and safety regulations

Control Goals

Goal of the control is not to obtain the maximal but the optimal result.

Purpose is to do:

- ✓ Cheaper;
- ✓ Better;
- ✓ Faster;
- ✓ More safe.

Automation tasks arise in business environment where the production goal is the profit (build something - make money). The role of **management** is to produce using people and equipment. Management must set out the challenges so that technical staff can understand it.

Automation tasks

Technical staff: production facilities are specified by the equipment.
Action: plan, build, tune, ...

What we want to achieve with automatics? It is used to
✓ to solve *specific* tasks
✓ to obtain process with *standard* (safe) features

The basic need of any process is to produce the goods or to provide the services that maintain

- Consistency,
- Quality,
- Cost-effectivness.

Tasks

Much attention is devoted to:

What is the result?
How do you measure results? Expenses? Risks?
What to do? What not to do? How much to do?

Good, necessary, fashionable, important, etc. ←**meaningless!**

Reduction of disturbances, increasing the speed, increase the quality, reliability, safety, etc. ←**important content**

Automation Steps

1. Information Acquisition
2. Information Analysis and Decision Making
3. Control Execution

Automation goals

- ✓ Profit - is the main purpose!
  - Recoupment of investments
- ✓ Effective production
  - Schedule work
    - orders, resources
  - Availability
    - unit failure shall not cause the process shutdown (heating, power, water, etc.)
    - monitoring of the equipment work and protection
    - goal: reservation, automated switching, scheduled repair, diagnostics, emergency notifications
  - Materials and energy savings
    - monitoring: consumption

Automation goals II

- ✓ Quality - customer satisfaction
  - Stable production, quality monitoring
- ✓ Standards, regulations and laws satisfaction
  - Safety - avoid the risk to the staff and environment
    - achieved by: monitoring parameters, human activities testing, failures localization, operator assistance
  - Meet the environmental pollution standards
    - wastewater, gases, dust, etc.
- ✓ Flexibility
  - Products, raw materials, requirements, market, etc.

Automation Level

Automation level should be appropriate:

too much / too little automation.

Management and decisions based on available information

Data acquisition / processing / traffic is the same as in logistics industry or government (the same IT technology).

To control processes their knowledge (model), standards, limitations, accurate and flexible (and therefore complex) management are needed.

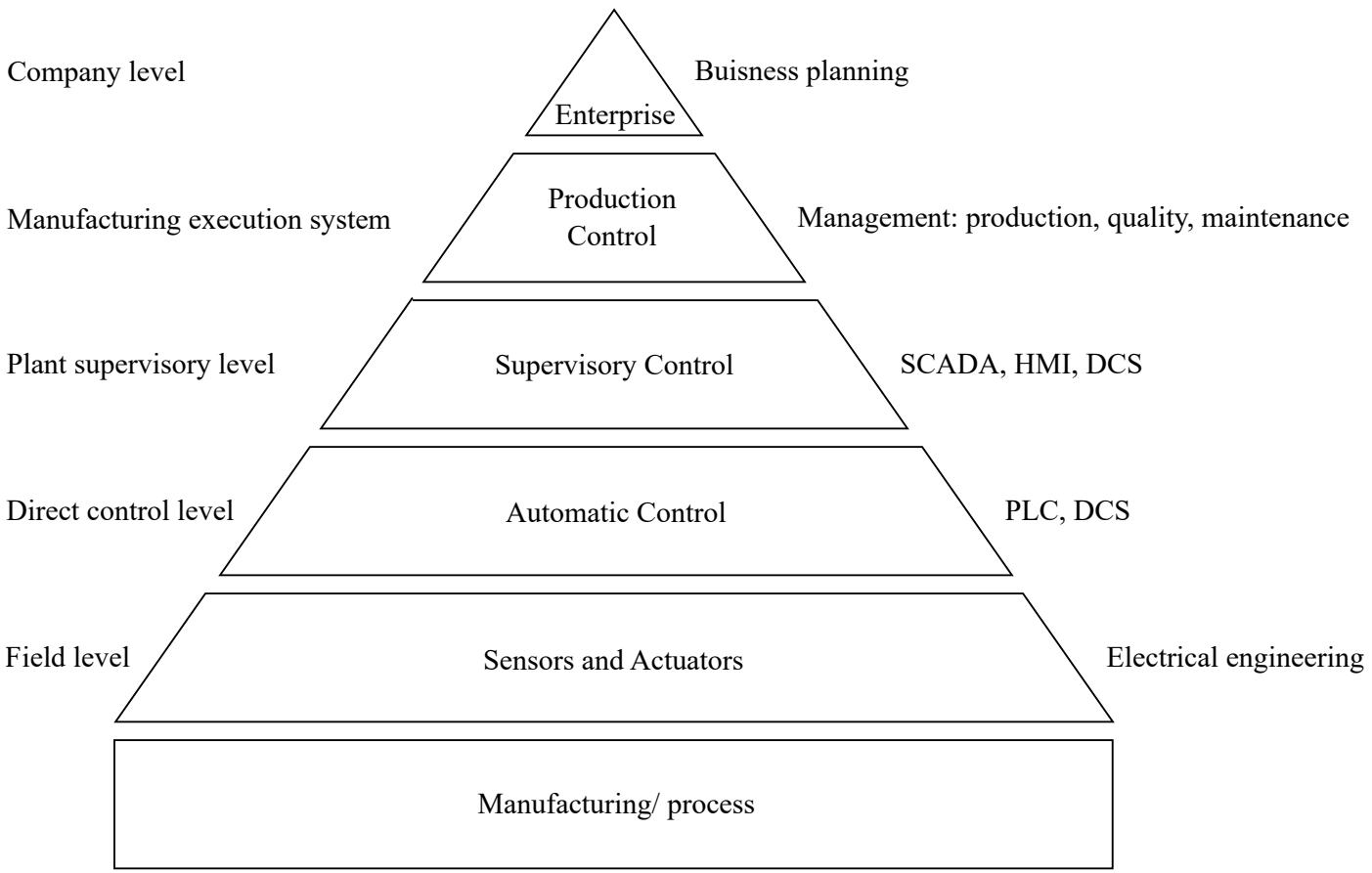
Activity Classification

(Control) activity classification by the complexity

	Human based	Automatics
Skill based (known situations)	reflexive actions fast routine	simple, fast algorithms
Rule-based (more complex situations)	follows the rules thinks as-makes	emergency interlocking reserve usage start/stop
Knowledge-based (unknown situations)	analyzes, calculates making plans model slow	identification fault-detection changes in the structure new algorithms

Automation Pyramid

The classic automation pyramid model shows a series of well-defined layers structured in such a way that information flows upwards from devices to enterprise via all levels.



Automatic control history

Early theory: 1932 amplifiers (Nyquist).
Practice: 1922- Control of ships' movements.

Two branches of automatic control applications:

1. Control of the movement/motion
   - World War II (1939)
     ✓ tracking systems (servo): gun pointing, ship steering
2. Process control
   - chemical industry, food industry
     ✓ terminology did not work, fixed operating point
     ✓ large time constants, delays

History

before 1940 (materials, energy) controlled manually: valves /ventiilid /вентили;

- Large number of operators (knowledge of the process, experience);
- Warehouses for intermediate products storage (separates the process);
- Expensive labor, increased production, new equipment.

$\sim$ 1950 Controllers, feedback

- Rules and experience, process dynamics is not taken into account

$\sim$ 1960 optimal control ($\min$ \$)

- How to use the theory?

$\sim$ 1970 increase of the fuel price (to minimize energy costs)

- More complex process, more connections

$\sim$ 1980 MPC (Model Predictive Control), DCS (Distributed Control System / Hajusüsteemid)

Processes

Restrictions on the process: equipment, personnel, legislation, etc.

Process has restriction on the parameters values:

- law of physics, safety requirements, product quality, technical potential ($\max$ productivity).

Problems with existing control systems

- ✓ Some systems are important and have to work, halt can cause accidents.
- ✓ Many systems are integrated or embedded.
- ✓ Data traffic is huge.
- ✓ Functionality documentation is poor, user does not know the full functionality of the system.
- ✓ Information and "know-how" related to staff, critical knowledge and skills.
- ✓ The information is scattered in many systems, is it available in an appropriate format?
- ✓ The complexity, capability, flexibility.

Control

Goals can change

- ✓ The aim to produce more - goal of the past!
- ✓ To produce with a better quality - goals of the past!
- ✓ Recoupment of investments - $\max$ profit for the investment.

Current situation in automation:
many unconnected (outdated) systems, which is an obstacle to the further integration.

Automation development has two possible paths:

1. Evolution, continuous improvement. Reduces the risk to make step-by-step, minimize the risks.
2. Replacement to the new one.

Today's Automation

Additional features:

- Servers: heart of automation system
  - store the real-time data;
  - coordinate the activities of all subsystems;
  - have redundancy.
- Remote clients
  - operator stations.
- History server: alarm data, event data, process data
  - off-line analysis.
- Enterprise resource planing (ERP): arrangement for integration and management of information
  - business activities: accounting, sales;
  - manufacturing;
  - supply;
  - service.

Trends

- Closer to the process
  local PID controller in the sensor or actuator
- Remote control
  works on the parent company servers:
  orders, realization, scheduling (expensive software)
- Integration (control and IT)
  manufacturing optimization: smarter, safer.

Today	Almost there
Manufacturing centric	Customer centric
Forecast dependent (warehouses)	Demand dependent (orders)
Replenish stores	Direct to customers
Regulated yields	Optimized yields
Breakdown and preventive maintenance	Predictive and reliability-centered maintenance

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