Computer Science

prof. Jerzy Świątek

System Analysis and Decision Support in Computer Science

Choose yourself and new technologies

L.1. Model in the systems research. Introduction – basic concept

https://dlaczegologia.pl/

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Contact hours

room 120, building C-3

- Monday (even week) time: 7^{00}-9^{00}
- Monday time: 12^{00}-13^{00} (by ZOOM platform)

  or after appointment room 120, building C-3,
- Wednesday time: 11^{00}-13^{00}

Exam

- Term 0: 22.06.2026. (Monday)
  room 23, building C-3, time: 9^{15}-11^{00}
- Term 1: 29.07. 2026. (Monday)
  room 22, building C-3, time: 9^{15}-11^{00}
- Term 2: 6.07. 2026. (Monday)
  room 22, building C-3, time: 9^{15}-11^{00}

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Term „zero”- necessary conditions

- Positive grades from practice (classes) and laboratory i.e. ≥3.0 not later then „zero” term
- Final grade proposition mean value integer number i.e.:
- $Final\ grade = \frac{[practice\ (classes) + laboratory]}{2} \geq 3.5$
- Must be present during „zero” term (otherwise reject bonus)

- About marks from this semester I will be informed by my assistants.
- About marks from previous years you must inform me by mail sending positive mark form USOS (JSOS) system with name of teacher, name of student and index number.

n6– requirements:

You must pass practice (exercises), laboratory and write exam. For final grade you must pass exam in term 1 or term 2 (three or four problems). There is also bonus (in "zero" term)

Term 0 (bonus) – last lecture:
22.06.2026. (Monday) room 23, building C-3, time: 9:15-11:00

Term „zero"- necessary conditions:

- Positive grades from practice (exercises) and laboratory i.e. ≥3.0 not later than in „zero" term
- Final grade proposition: (integer number from practice (exercise) plus laboratory)/2 ≥3.5

  i.e. Final grade=[practice (exercise)+ laboratory]/2≥3.5

- Must be present during „zero" term (otherwise reject bonus)

If you do not accept the above proposition or do not fulfill the above conditions you must write exam.
Term 1:
29.06. 2026. (Monday) room 22, building C-3, time: 9:15-11:00
Term 2:
6.07. 2026. (Monday) room 22, building C-3, time: 9:15-11:00

Attendance during lectures is not obligatory. Attendance will be checked randomly. Bonus (+0.5) on the exam for ≥ 50% of presence on the lists.

SUBJECT OBJECTIVES

- C1 Acquisition of skills to create mathematical models of technical and non-technical processes.
- C2 Learn how to formulate typical decision making problems and how to solve them .
- C3 Acquisition of skills to apply computer methods for decision making support.

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- **SUBJECT EDUCATIONAL EFFECTS**
- related to knowledge:
- PEK_W01 Knowledge of modern techniques of modelling and analysis of dynamical processes.
- PEK_W02 Knowledge of generic decision making problems in computer science.
-
- related to skills:
- PEK_U01 Knows how to apply rules of using class room and laboratory.
- PEK_U02 Knows how to apply system analysis in scientific and engineering problems.
- PEK_U02 Knows how to use MATLAB and SIMULINK for engineering computations, in particular for modelling and optimization.
-
- related to social competences:
- PEK_K01 Knows how to present results of its works in clear way.
- PEK_K02 Knows modern methods of dynamical processes analysis, comprehends the need for new solutions and his/her knowledge improvement

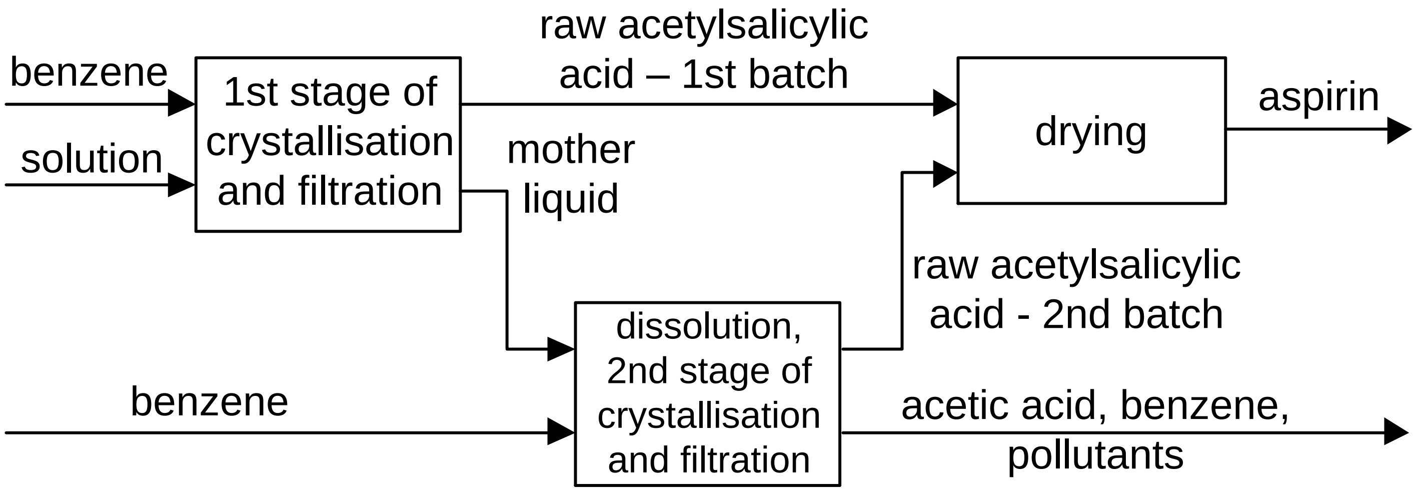
Model in the systems research. Introduction – basic concept

- Model in the systems research
- Identification task
- Model based decision
- Lecture review
- References

System

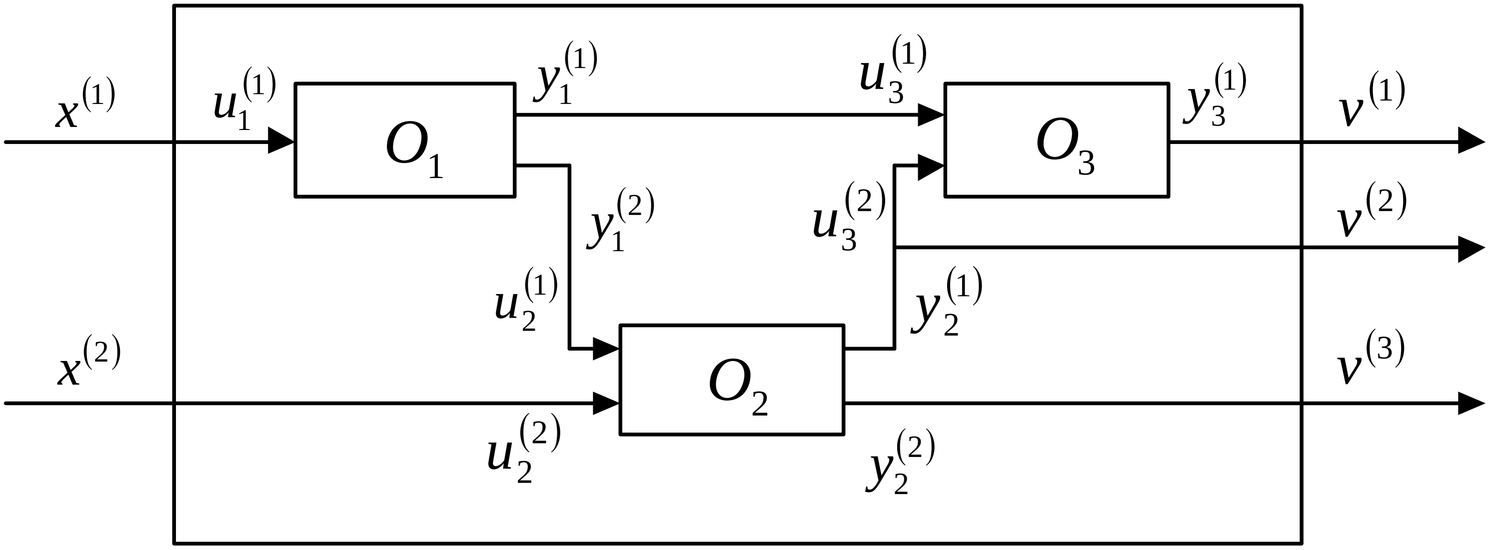
- **System** - set of elements forming a complex whole, bound by functional dependencies and having a specific goal (idea), e.g. a transport system.

System examlpe



Complex system of chemical nature

Complex systems description



Example of complex system

System analysis

- Systems analysis – set of methods and techniques supporting analysis, design, management and control in complex situations
  - A systematic way to analyze complex problems to **achieve a specific goal**
  - Development of proposals for various solutions **taking into account the complex goal** and many criteria for evaluating the solution
  - Helping decision-makers choose the optimal solution from a variety of possibilities

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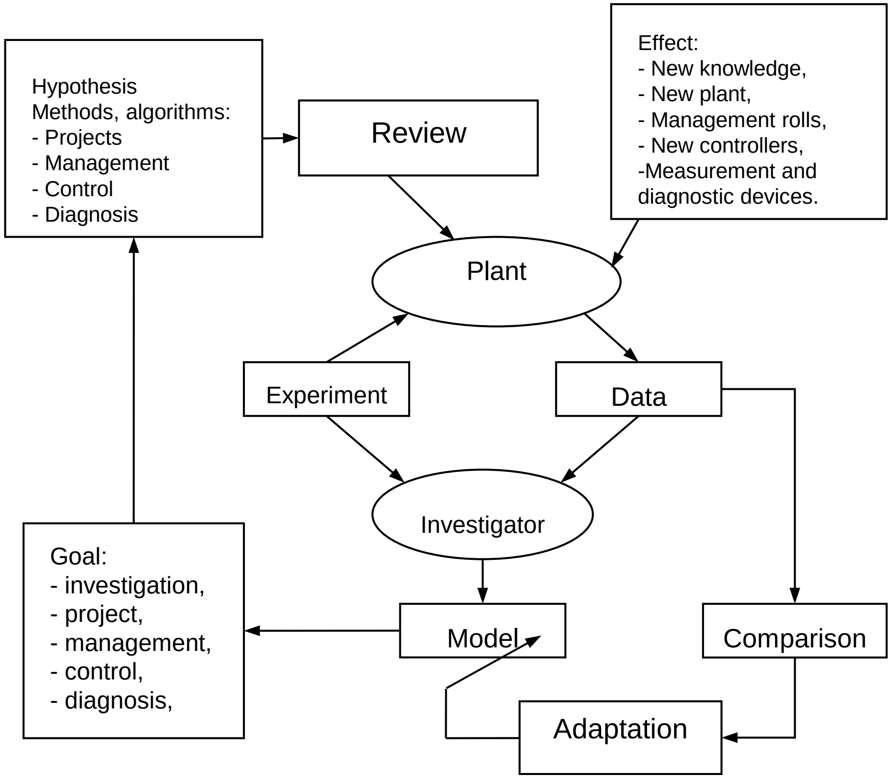
Model in the systems research



Model in the systems research

A model is a simplified representation of a system, in time and space, created with the intention of understanding the behavior of a real system.

- Conceptual models
- Physical models
- Analog models
- Mathematical models
- Computer models

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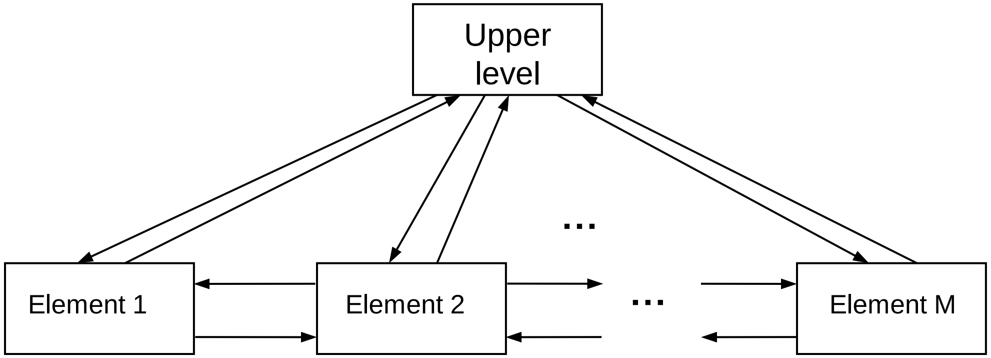
Conceptual models

- How process is organized?
  - Process elements
  - Connections
  - Elementary functions
- Example – Two stage management system



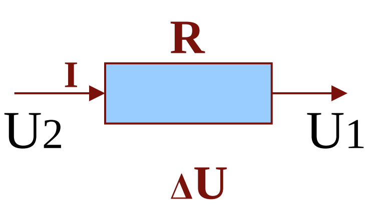
Physical models

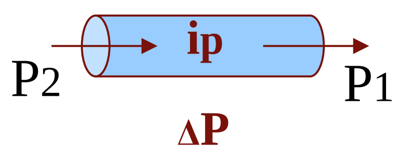
- Laboratory scale of the investigated process
  - Aerodynamic channel

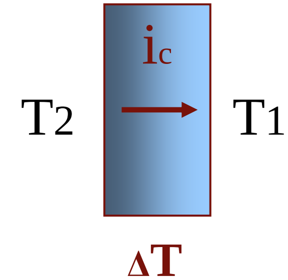
http://www.absoluteastronomy.com/topics/Wind_tunnel

Analog models

- Phisical analogs







$$U_2\text{-}U_1 = R\ I$$

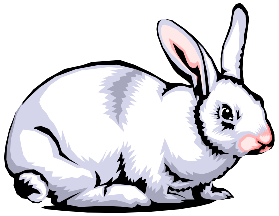
$$P_2\text{-}P_1 = i_p\ R_p$$

$$T_2\text{-}T_1 = i_c\ R_c$$

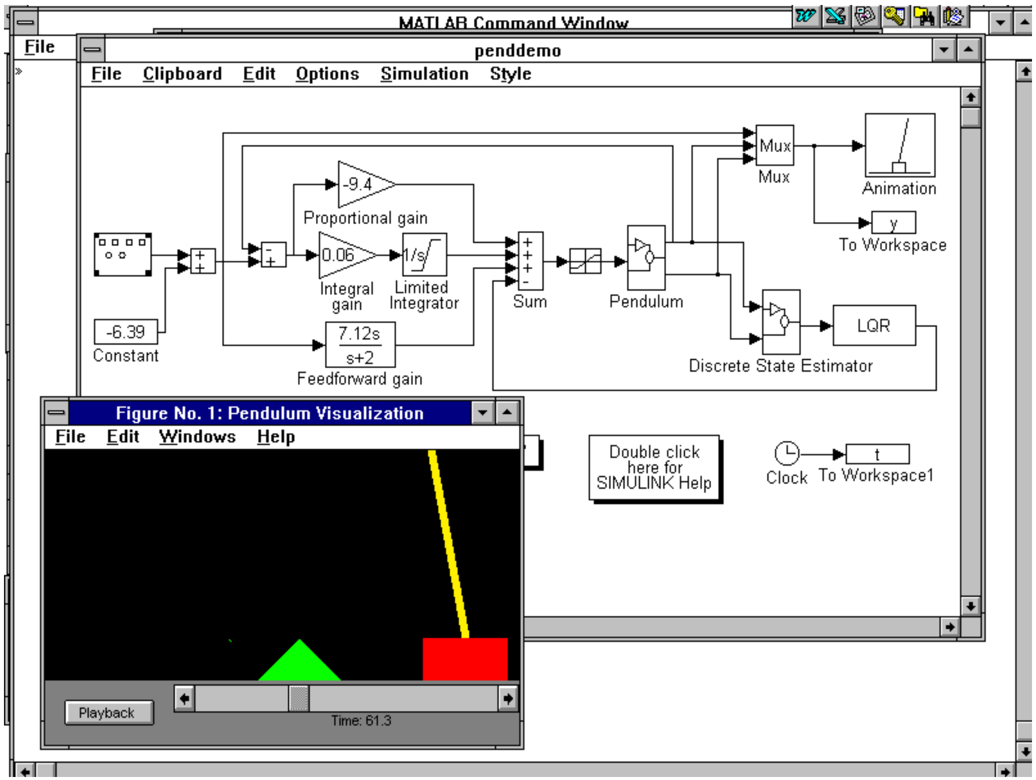
electrical object

hydraulical object

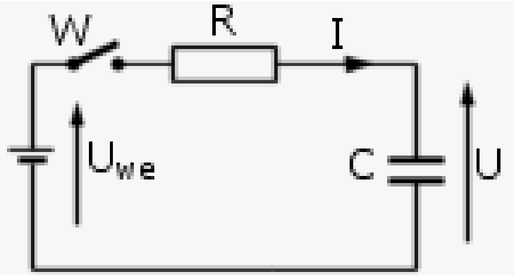
termal object

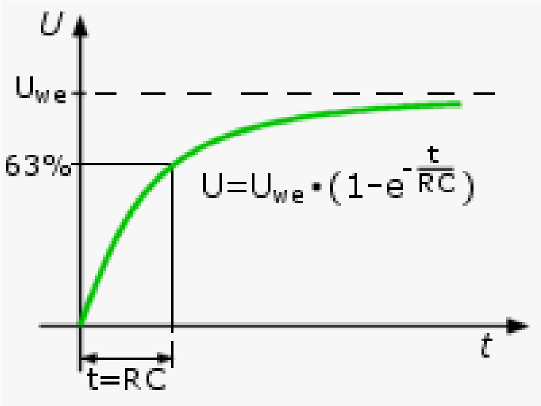


Analog models



Mathematical models





$$I = C\frac{dU}{dt} \qquad I = \frac{U_{we} - U}{R}$$

$$\frac{U_{we} - U}{R} = C\frac{dU}{dt} \quad \text{to} \quad \frac{dU}{dt} = \frac{U_{we} - U}{RC}$$

$$U = U_{we}\,(1\text{-}e^{-\frac{t}{RC}})$$

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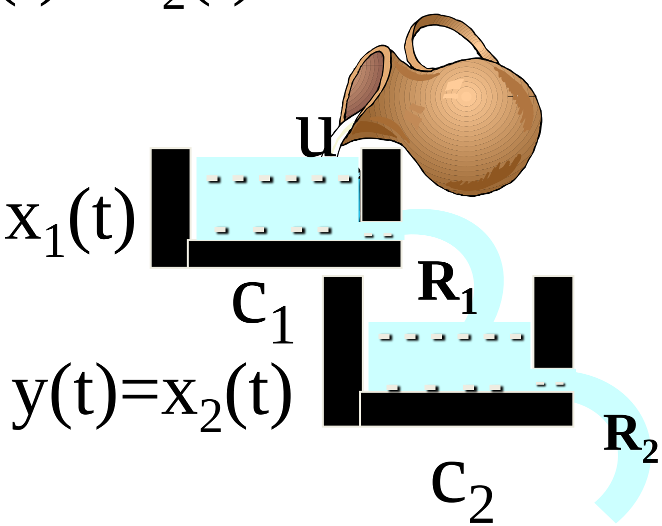
Example 1

$$\frac{d}{dt}x_1(t) = -\frac{R_1}{c_1}x_1(t) + \frac{1}{c_1}u(t)$$

$$\frac{d}{dt}x_2(t) = \frac{R_1}{c_2}x_1(t) - \frac{R_2}{c_2}x_2(t)$$

$$y(t) = x_2(t)$$



Example 2

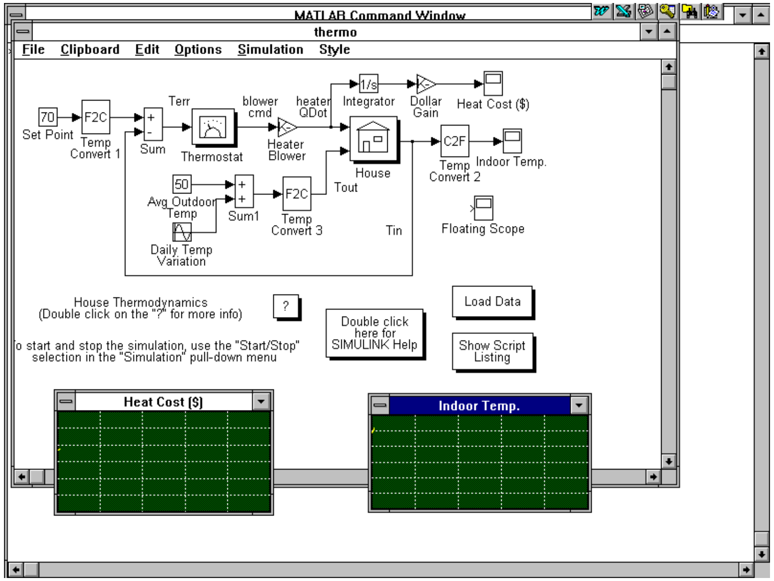
$$x_{n+1} = |x_n + u_n| \text{ modulo } 2$$

$$y_n = x_n$$

$$u_n \in \{0,1\}$$

Computer models

- Analog



- Digital

```
program ADA;
 var i,klucz :integer;
    Napis     : string;
    Napis_sz  : array[1..100] of char;
 Procedure czytaj;
  begin
    Write('Podaj klucz: ');
    readln(klucz);
    If klucz <=0 then writeln('Błędne dane')
    else
…
…
…
readln;
   end.
```

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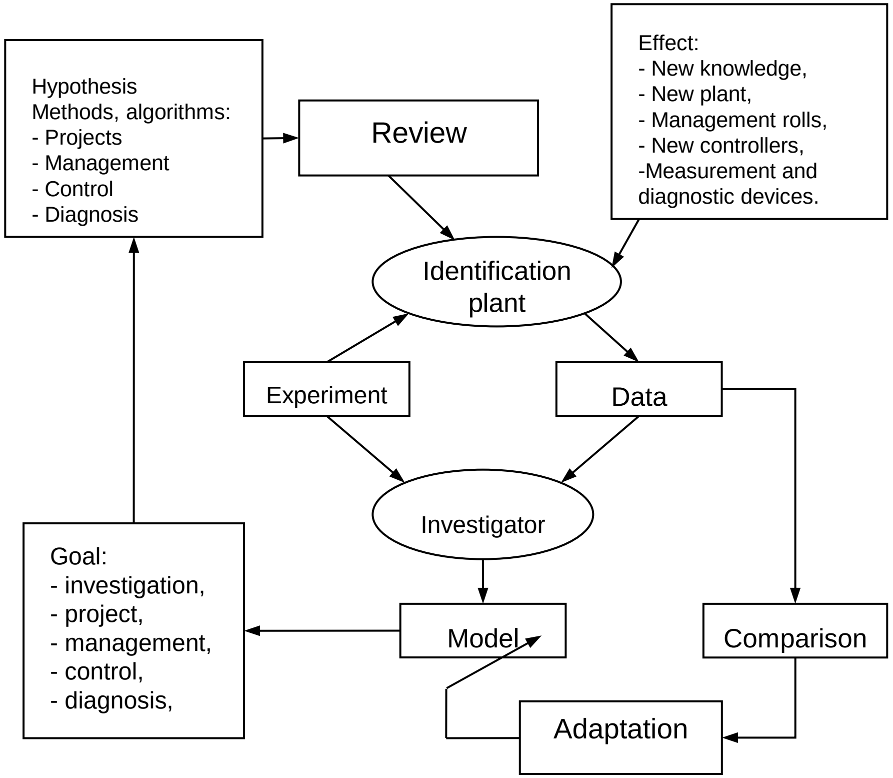
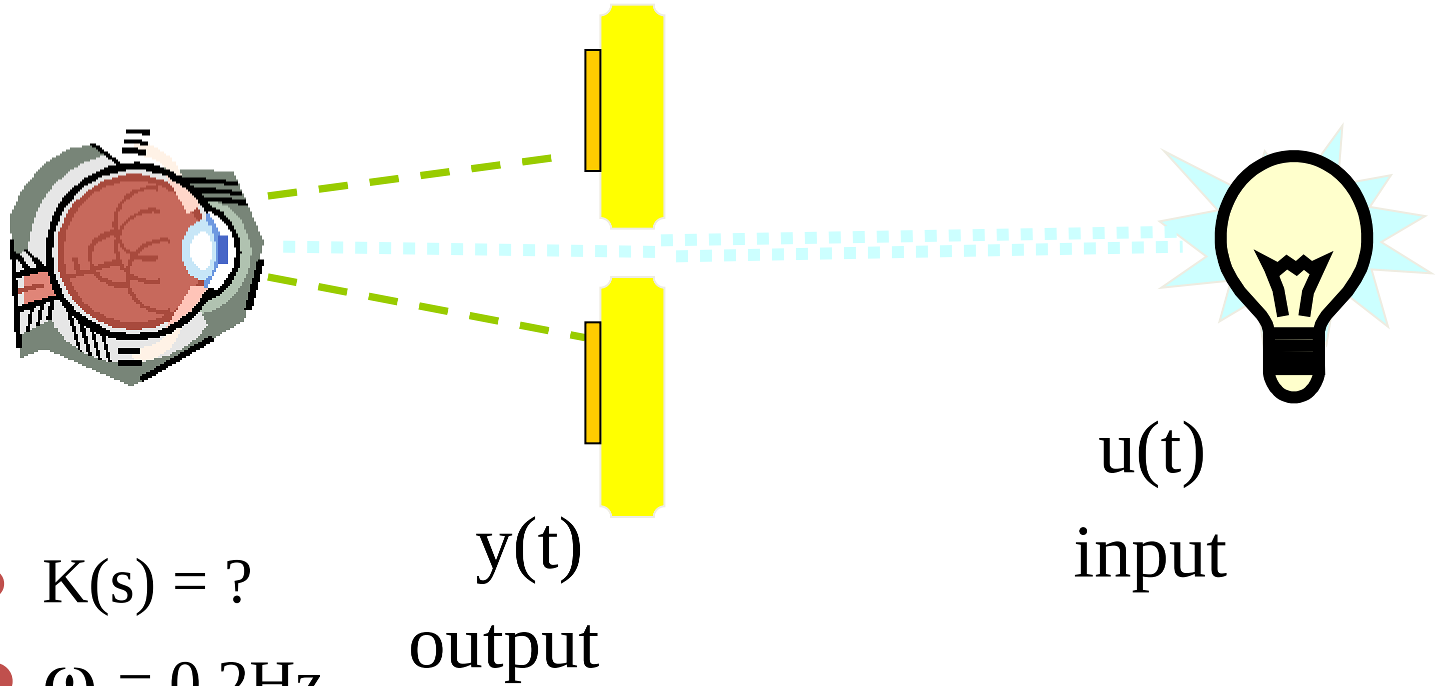
Model in the systems research

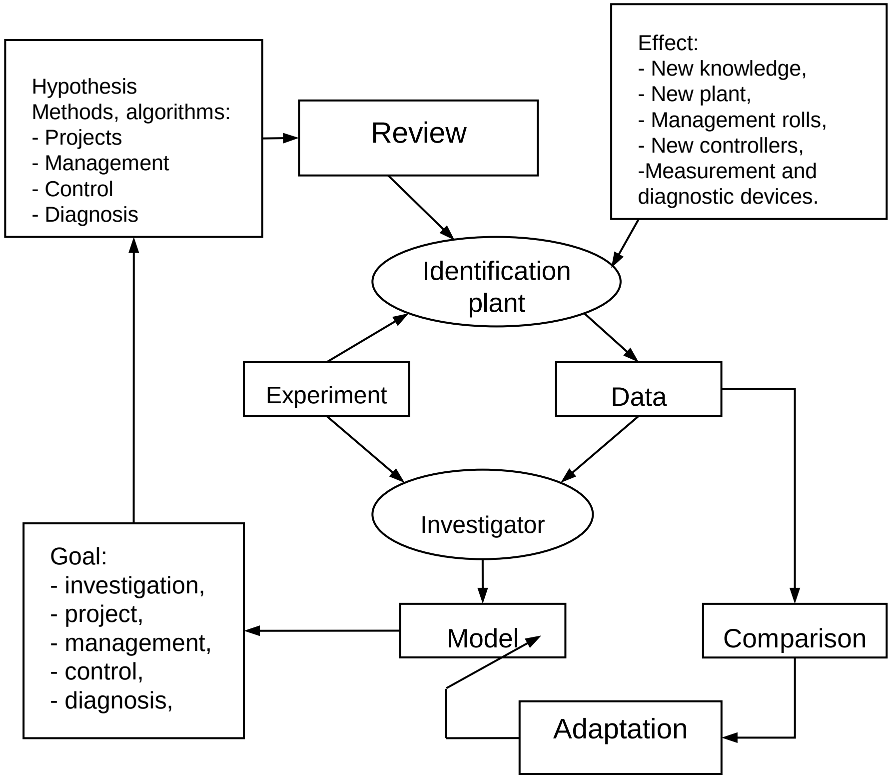


Mathematical model in the plant investigation

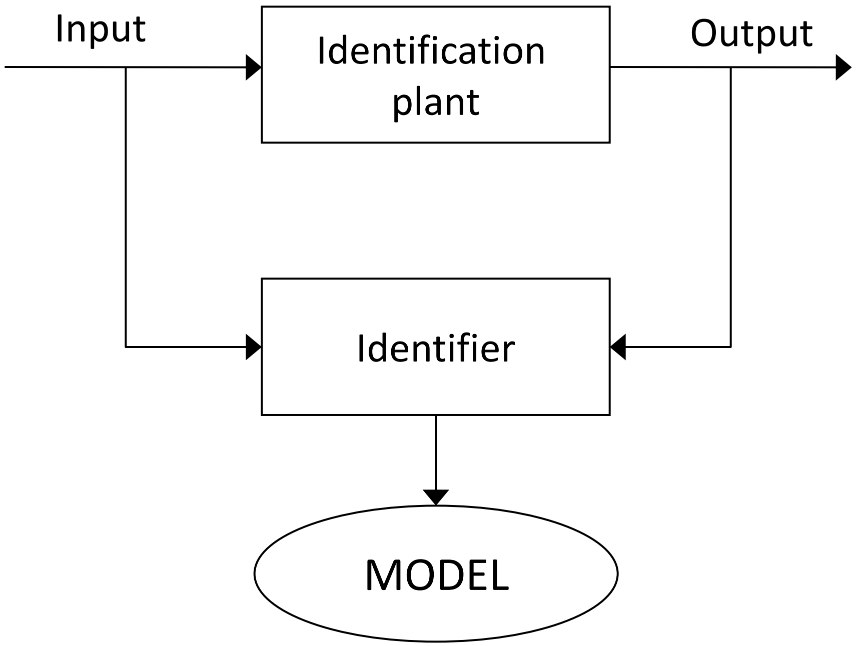


- K(s) = ?
- ω = 0,2Hz

Model in the systems research



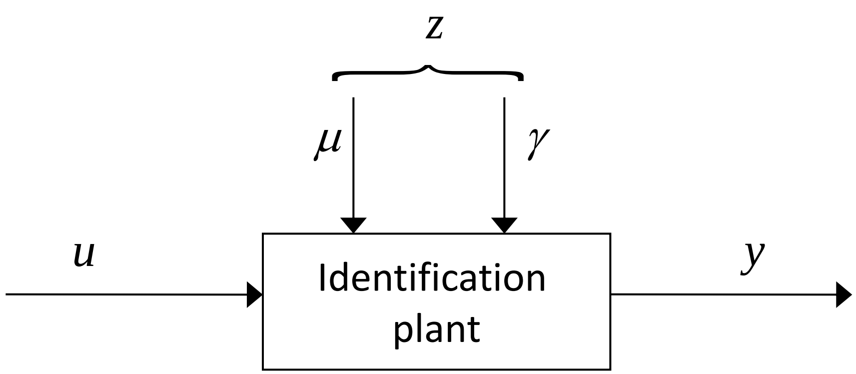
Identification Task



Identification task

1. Determination of the identification plant
2. Determination of the class model
3. Experiment organization
4. Determination of the identification algorithms
5. Identifiers realization

Ad.1. Determination of the identification plant



u – input

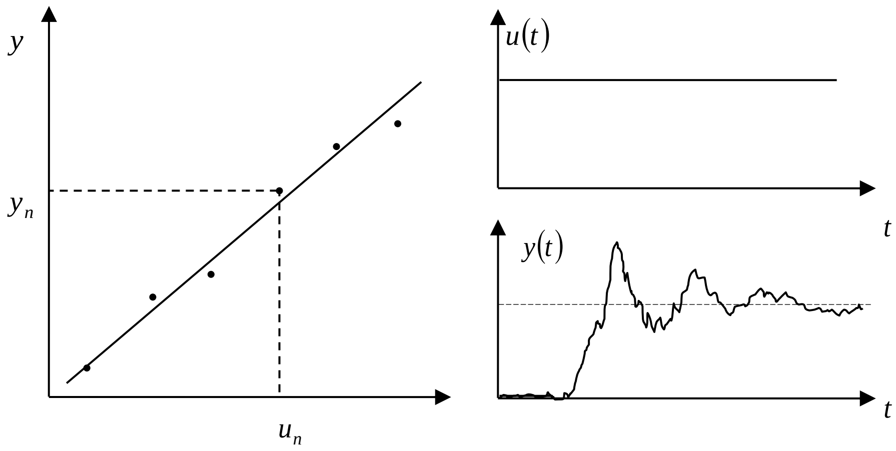
y – output

μ – measured disturbances

γ – unmeasured disturbances

Ad.2. Determination of the class of model

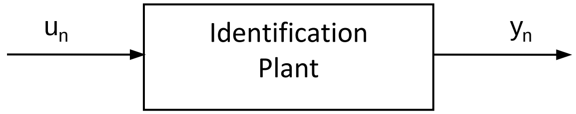
- Process analysis
- Data analysis

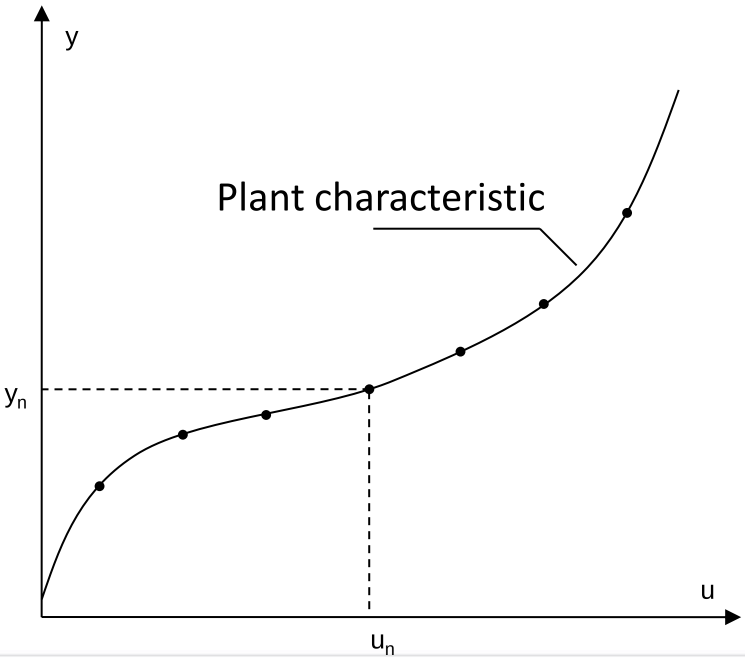


- Arbitrary model
- Expert model

Ad.2. Determination of the class of model

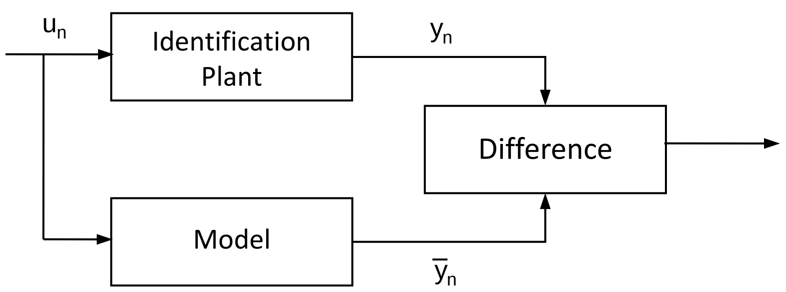
- Plant in the class of model

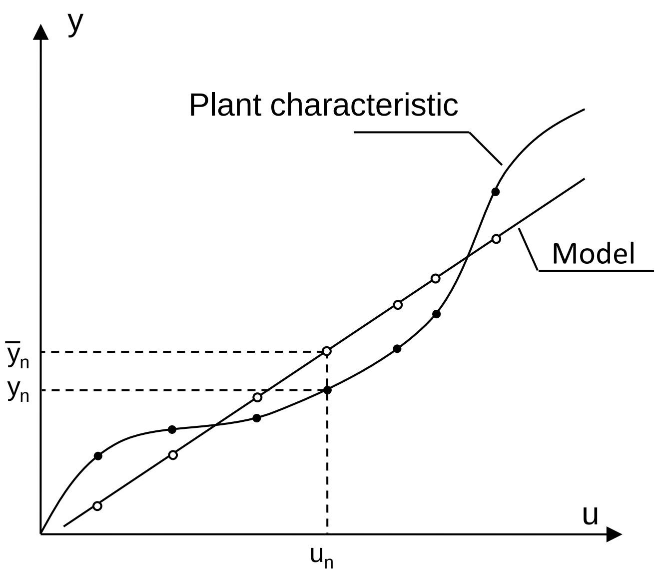




Ad.2. Determination of the class of model

- Choice of the best model





Ad.3. Experiment organization

Static plant

$$U_N = [u_1 \quad u_2 \quad \cdots \quad u_N], \quad Y_N = [y_1 \quad y_2 \quad \cdots \quad y_N]$$

Dynamic plant

$$U_T = \{u(t)\}_{t=t_0}^{T}, \quad Y_T = \{y(t)\}_{t=t_0}^{T},$$

Discrete type observations

$$t_1, t_2, \cdots, t_N, t_n \in [t_0 \ T], n = 1, 2, \ldots, N$$

$$U_N = \{u(t_n)\}_{n=1}^{N}, \quad Y_N = \{y(t_n)\}_{n=1}^{N}.$$

Dynamic, discrete type plant

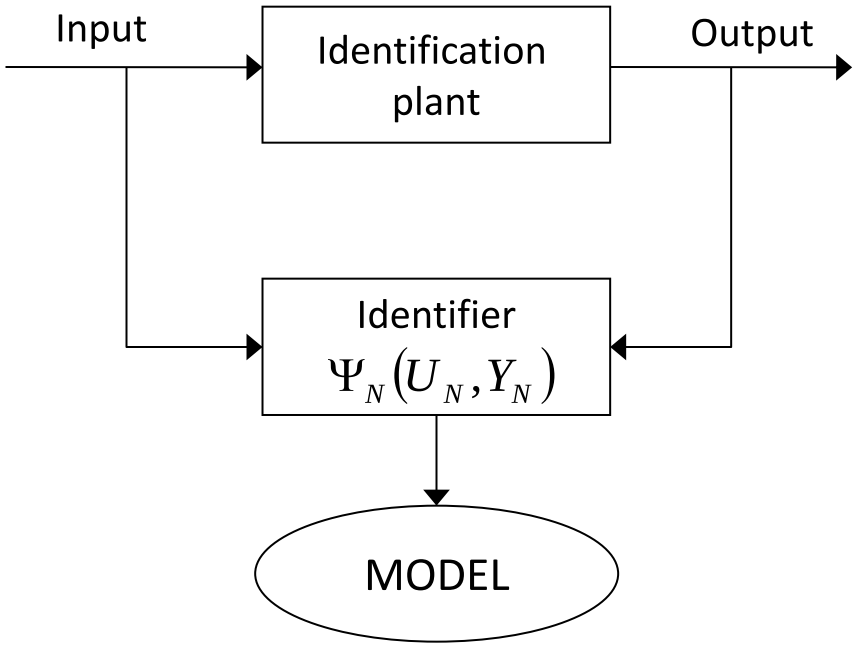
$$U_N = \{u_n\}_{n=1}^{N}, \quad Y_N = \{y_n\}_{n=1}^{N}.$$

Ad.3. Experiment organization

Passive experiment: U_N is measured

Active experiment: U_N is designed

Ad.4. Identification algorithm



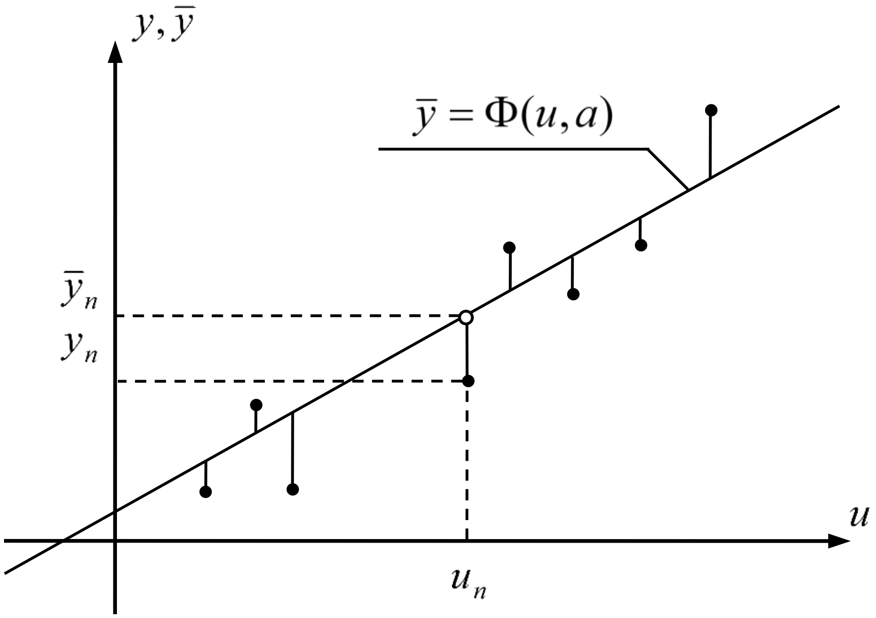
U_N – measurements of input signals

Y_N – measurements of output signals

Ψ_N – identification algorithm

Ad.4. Identification algorithm

$$a^* = \Psi(U_N, Y_N)$$



$$Q(a) = \sum_{n=1}^{N} (y_n - a u_n)^2$$

$$a_n^* = \frac{\sum_{n=1}^{N} y_n u_n}{\sum u_n^2}$$

Identifiers realization

- Identification algorithm
  - Computer program
  - Hardware realization

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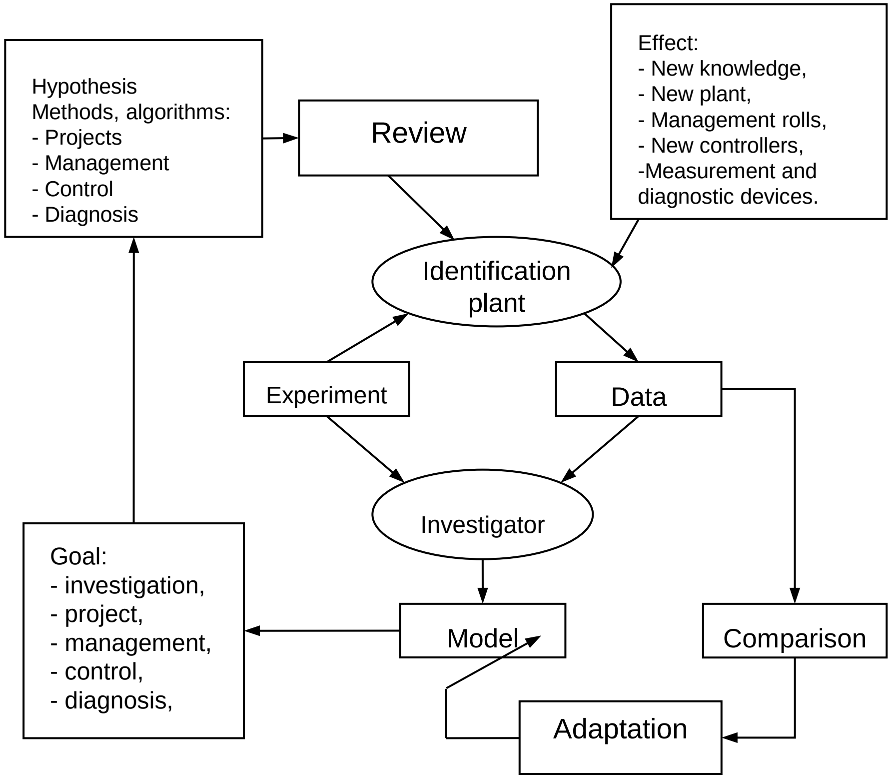
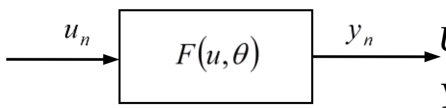
Model in the systems research

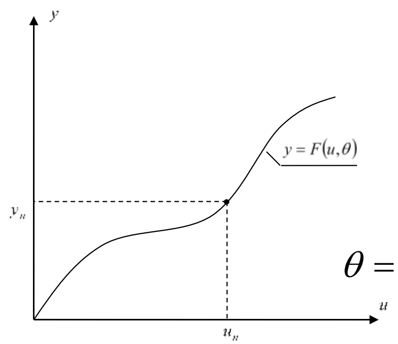


Plant in the class of model

D e t e r m i n i s t y c z n y

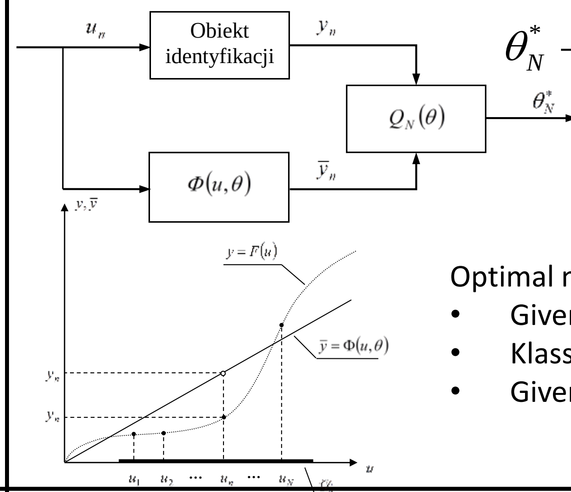


$$U_N = [u_1 \quad u_2 \quad \cdots \quad u_N],$$
$$Y_N = [y_1 \quad y_2 \quad \cdots \quad y_N]$$



$$y_n = F(u_n, \theta),$$
$$n = 1, 2, \ldots, N$$
$$Y_N = \overline{F}(U_N, \theta)$$
$$\theta = \overline{F}^{-1}(U_N, Y_N) \overset{df}{=} \Psi_N(U_N, Y_N)$$

Choice of the best model

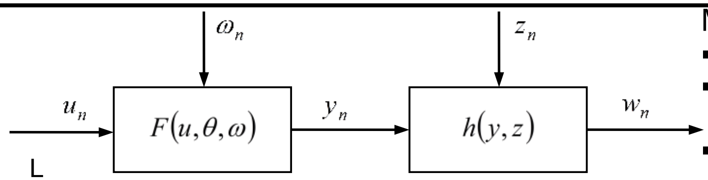


$$\bar{y} = \Phi(u, \theta_N^*)$$
$$\theta_N^* \to Q_N(\theta_N^*) = \min_{\theta} Q_N(\theta)$$
$$\theta_N^* = \Psi_N(U_N, Y_N)$$
$$U_N = [u_1 \quad u_2 \quad \cdots \quad u_N],$$
$$Y_N = [y_1 \quad y_2 \quad \cdots \quad y_N]$$

Optimal model for:

- Given measurements sequences
- Klass of models
- Given performance index

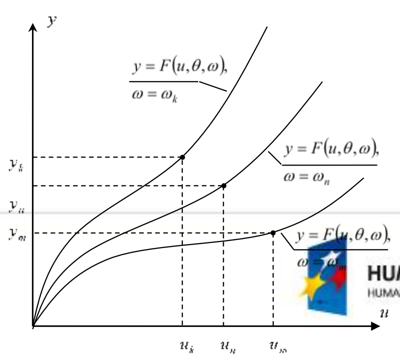
L o s o w y

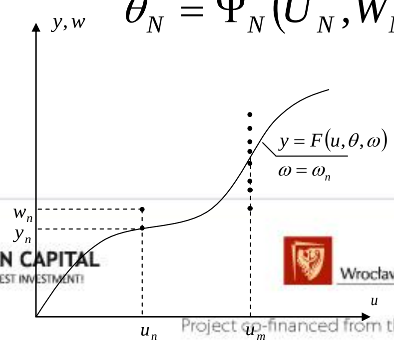


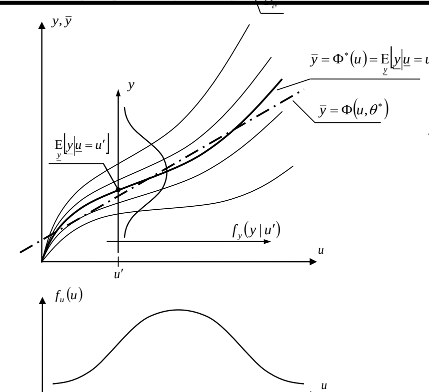
Methods:

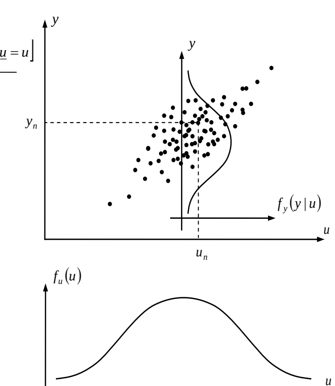
- Least square
- Maximum likelihood
- Bayes'a

$$\theta_N = \Psi_N(U_N, W_N)$$









Full probabilistic knowledge

- First type regrsesion
- Second type regression

Unknown probabilostic knowledge

- Performance index estimatin
- Parameter estimation of the probability distribution
- Probabilit ditribution estimatoin

Lecture program

1. Model in systems research. Introduction – basic concept.
2. Model building task based on experiment – identification problem.
3. Identification of static plant. Deterministic problem – determination of the plant parameters.
4. Identification of static plant. Deterministic problem – choice of the best model.
5. Noised measurements of the physical values.
6. Estimation of plant parameters with noisy measurements.
7. Choice of the best model – probabilistic case. Regression functions.
8. Determination of the regression functions based on the experimental data.

Lecture program

9. Identification of dynamic systems.
10. Recursive identification algorithms.
11. Selected problems of complex systems modeling.
12. Modeling of complex of operation systems.
13. Model based decision making (optimal decision, satisfactory decision, acceptable decision).
14. Analytical and numerical optimisation methods
15. Optimal Decisions with uncertainty
16. Dynamical programming
17. Decomposition and coordination
18. Multi criteria decision task

Classes and laboratory

- Illustration of problems presented during the lecture, and in particular:
  - presentation of the models of chosen computerized plant,
  - exercises connected with the description and analysis of physical signals,
  - a synthesis of chosen identification algorithms,
  - formulation o decision problems based on process model.

References

- Basic literature:
  - Bubnicki Z., Identyfication of control plants, PWN, Warszawa, 1980.
  - Bubnicki Z. Modern Control Theory, Springer, Berlin-Heidelberg-New York, 2005. 2006.
  - Ikonen E., Najim K., Advanced identification and control, CRC Press LLC, 2002.
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  - Hayek S.I., Advanced mathematical methods in science and Engineering, Marcel Dekker, Inc. 2001.
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  - Chong E.K.P., Żak S.H., An Introduction to Optimization, Wiley-Interscience, 2008.
  - Ogata K., Modern Control Engineering, Prentice Hall, 2009.

Thank you for attention