SYSTEMS ANALYSIS
LECTURE 10 – CYBERNETICS

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Cybernetics

- Science on control and communication in living organisms and machines (Norbert Wiener)
- Using terms
  - Automata
  - Structure
  - Transition
  - Feedback

Control

- Consciously chosen chain of events (to reach a goal)
- Consciously chosen goal seeking process

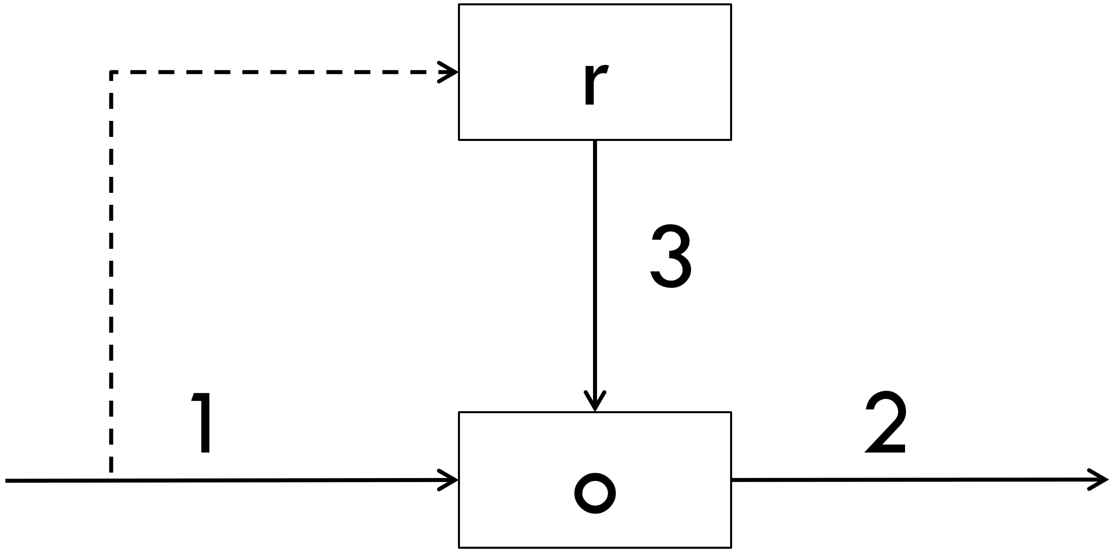
- Types of control
  - Explicit
  - Implicit

Topological types of control

Simple (open loop controller)

- Controlled part (system, or object “o“)
- Controlling part “r“

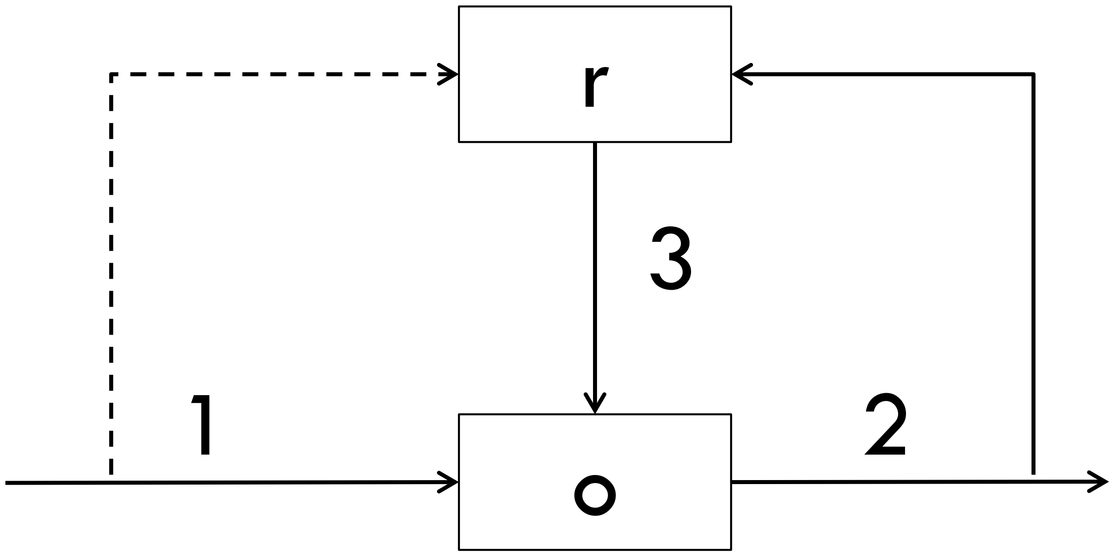
- System does not have information about its outputs. There is no explicit feedback.
- This type of control is used only when output is robust, safe – e.g. two state control (binary)



Topological types of control

Control according variation (close-loop control)

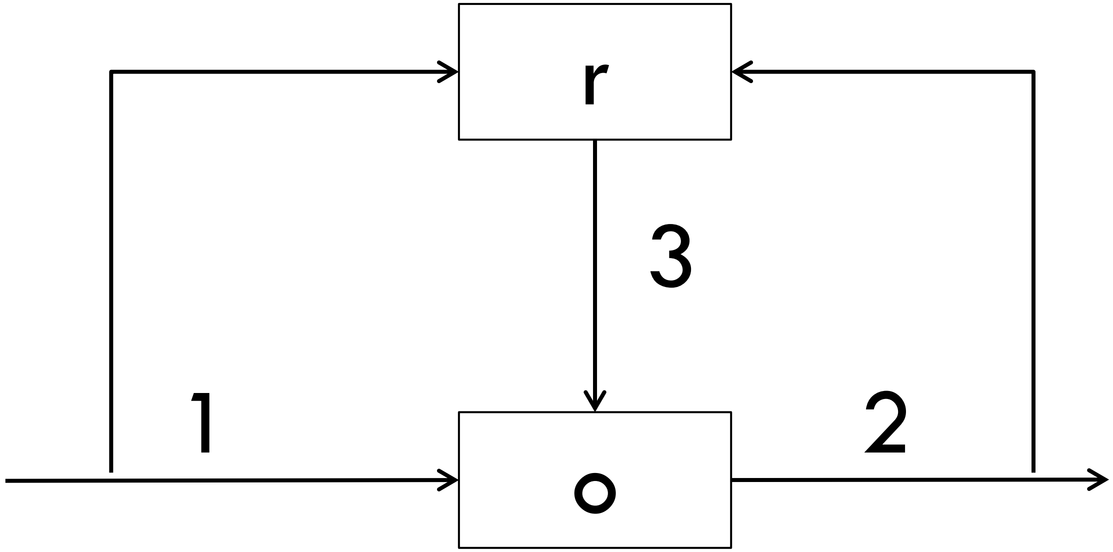
- Basic and the simplest type of feedback control. The controller „r“ is influenced by output „2“ (with value „x“). Output value is compared to the actual reference value „w“. Depending on the variation (x – w) „r“ creates („r“ is also called the regulator) value y, transmitted on the control connection „3“ and influencing „o“.
- Note: the reference value may change in time



Topological types of control

Adaptive control

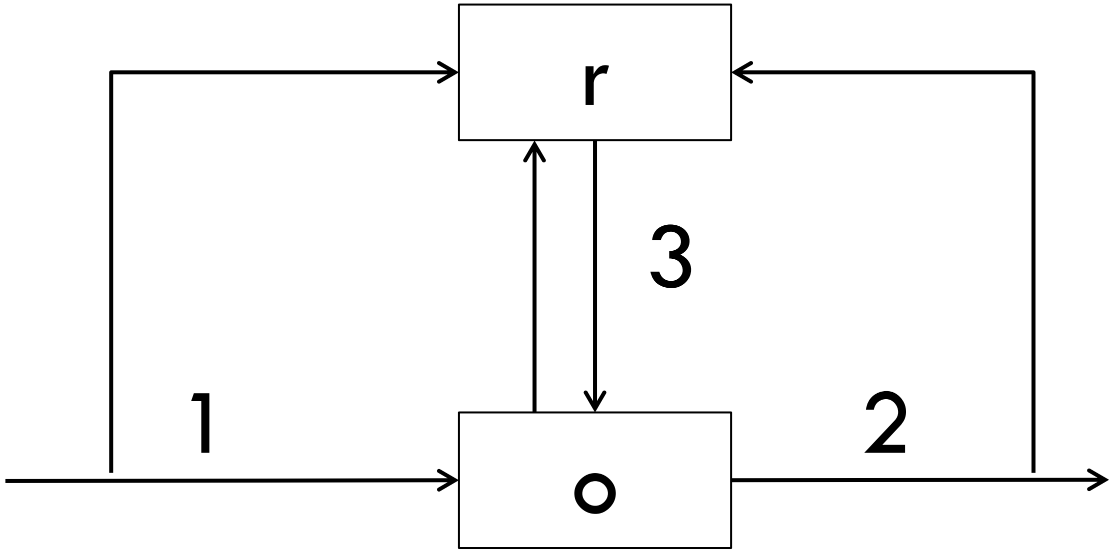
- Unlike the simple feedback control function „r“ is modified using input „1“. This enables more accurate control



Topological types of control

Interactive control

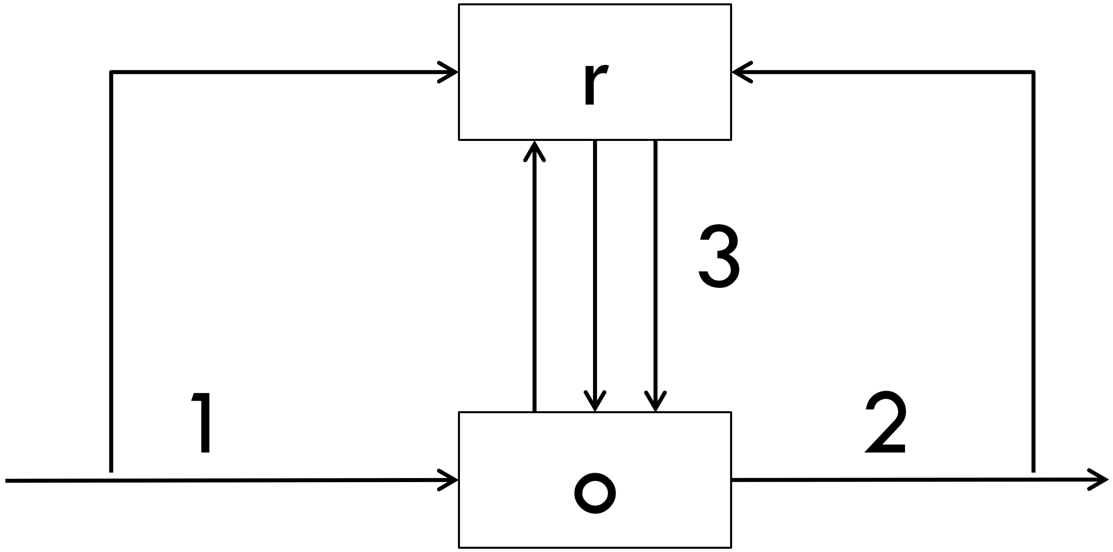
- A new connection is added, the inner connection. Using this connection „r“ gains information about current state „s“. This enables further improve qualitative, quantitative and dynamic parameters of the control.



Topological types of control

Control with premises (using genetic code)

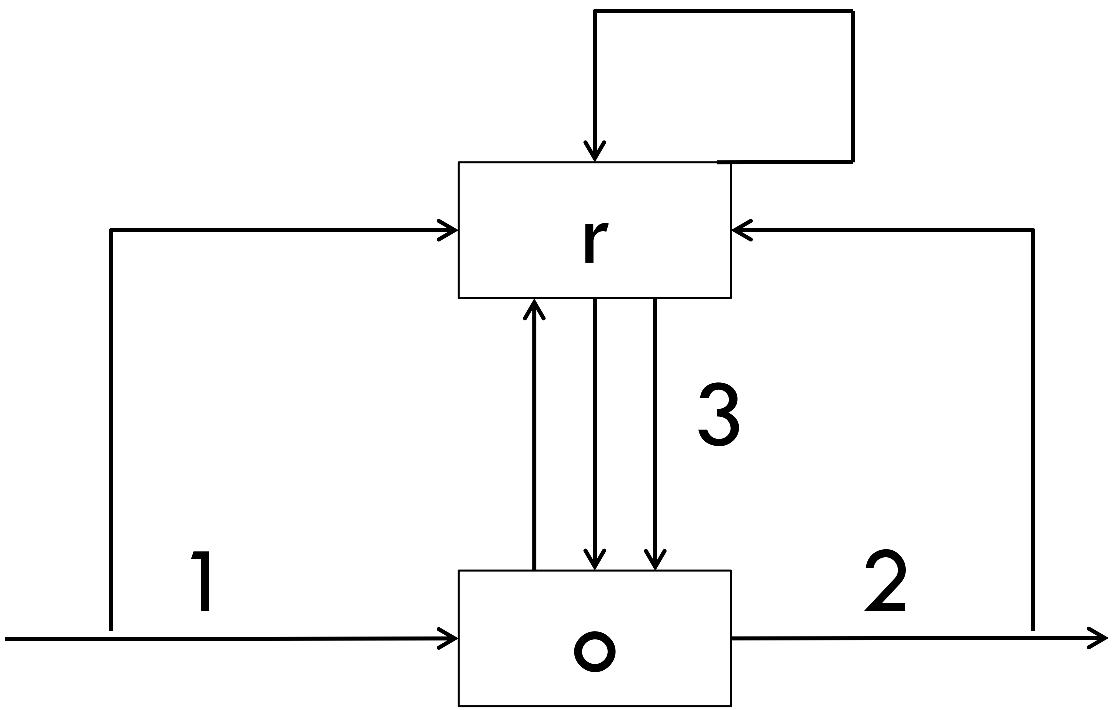
- In the structure there is a new connection, which serves for control of the process distance from the genetic code.



Topological types of control

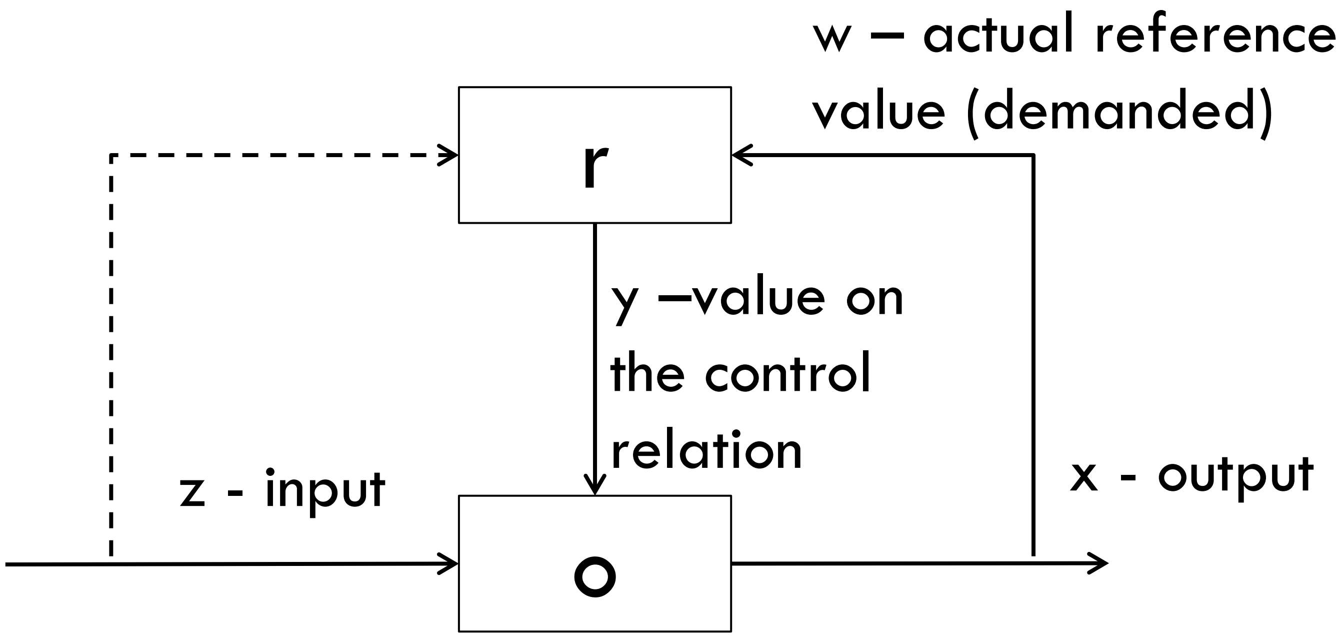
Control with learning

- In the structure we can additionally identify loop in the control subsystem „r“. This means (in the simplified form) the possibility of storing information about control process in time and gaining experience from this.



Control according variation (close-loop control) -regulation

- control transmission : ***x/w = ro/(1+ro)***
- failure transmission: ***x/z = o/(1+ro)***



Types of regulation

- According linearity
  - Linear
  - Non-linear
- According continuity
  - Continuous
  - Discrete
- According determinism
  - Deterministic
  - Stochastic
  - Fuzzy
- According regulator type
  - **P:** control value ***y*** is directly proportional to the variation ***(x – w)***
  - **PI:** control value ***y*** is directly proportional to the variation and integral of variation
  - **PD:** control value ***y*** is directly proportional to the variation and derivation of variation
  - **PID:** control value ***y*** is directly proportional to the variation, intergral of variation and derivation of variation

Regulation stability

Regulation stability – ability to return to the original state after the disturbance signal has ended

$$\lim_{t\to\infty} x(t) \quad = 0 \Rightarrow \text{regulation is stable}$$

$$= \infty \Rightarrow \text{unstable}$$

$$=(0,\infty) \Rightarrow \text{neutral}$$

Limit of active filtration - Law of requisite variety

Uncertainty removed via control is upper bounded by the median shared information between the controller (r) and environment.

Communication

- Information transmission
- In cybernetics:
  - Forms of representing information and their transformation
  - Languages
  - Question of processes initiation

Signalling systems

- First signalling system – direct initiation of processes (reflexive level)
- Second signalling system – mediated initiation of processes
- First and half signalling system – modification of events by internal premises

Language

- Natural
- Artificial

Language components

- alphabet – set of basic symbols
- syntax – system of rules how to construct (higher) symbols
- semantics – meaning assigned to syntactic constructs

Alphabet + syntax = grammar

Grammar

- Grammar is foursome G=(N, T, P, S)

  where:
  - *N* - set of non-terminal symbols
  - *T* - set of terminal symbol
  - *P* - set of rules
  - *S* - grammar starting symbol ($S \in N$)

Rules

- Set of rules

$$P \subset (N \cup T)^* N (N \cup T)^* \times (N \cup T)^*$$

$$(N \cup T)^*$$

is any string of terminal and non-terminal symbols

- rule $(\alpha,\beta) \in P$ is written as $\alpha \rightarrow \beta$

  the meaning is: „ rewrite α to β“

- On the left side of the rule there is always a non-terminal symbol (i.e. using the rule it is always possible to rewrite some non-terminal symbol)

Example of simple grammar

- Grammar generating symetric strings of zeros and ones 0000…01…11111
- G = (N,T,P,S)

  $N = \{ S, A \}$

  $T = \{ 0, 1 \}$

  $P = \{ S \rightarrow 0A1,\ A \rightarrow 0A1,\ A \rightarrow \varepsilon \}$

  (symbol ε means empty symbol)

- Example of generated string (sentence):

  $S \rightarrow 0A1 \rightarrow 00A11 \rightarrow 000A111 \rightarrow 000111$

Chomski types of grammars 0-3

- According rule types
  - Type-0 grammars (unrestricted grammars)
  - Type-1 grammars (context-sensitive grammars)
  - *Type-2 grammars (context-free grammars)*
  - *Type-3 grammars (regular grammars)*
- Unrestricted – all formal grammars
- Context-sensitive
  - $\gamma 1 A \gamma 2 \rightarrow \gamma 1 \beta \gamma 2$, $A \in N$, $\gamma 1, \gamma 2$ is context, $\beta \in (N \cup T)+$
- Context-free
  - $A \rightarrow \beta$, $A \in N$, $\beta \in (N \cup T)+$
- Regular
  - $A \rightarrow aB$ or $A \rightarrow a$, where $A, B \in N$, $a \in T$

Semantic

- Axiomatic
- Compiler oriented (Translation between languages)
- Logic (Semantics of construct is generated as the output of certain logic functions)
- Denotation based (reality of use)

Scales

Scales – type of ordering

- Nominal – names, no relations
- Ordinal – order according size of parameter (e.g. colours in spectrum, degrees Celsius)
- Cardinal– order according parameter proportion (e.g. Kelvin degrees)
- Axiological –according distance from standard

Homeostasis

- the tendency of a system to maintain internal stability, owing to the coordinated response of its parts to any situation or stimulus that would tend to disturb its normal condition or function.

Isomorphism between language and automaton→ epistemological consequences :

1. System can be recorded as a set of languages and corresponding set of rules of their mutual translation
2. Real object can be expressed as a construct in certain language.