

Mathematical models
in
environmental, crop and food sciences

STAAA

Doctoral School in Agricultural, Environmental and Food Sciences

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Models ?

..is this a tale about Simulation software
.. or Math, Statistics .. or WHAT ?

PART I - Models & Modelling

- Technology, machines & Games
- System Theory

PART II - Model Languages

- Model
- Math Formalism

PART III - Simulation

- Programming
- Case Studies with Matlab

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WHICH is the AUDIENCE ?

- students of the Z-generation

Generation Z

Born: 1995-2012

“While we don’t know much about Gen Z yet...we know a lot about the environment they are growing up in. This highly diverse environment will make the grade schools of the next generation the most diverse ever. **Higher levels of Technology ...**”

[\(http://socialmarketing.org/archives/generations-xy-z-and-the-others/\)](http://socialmarketing.org/archives/generations-xy-z-and-the-others/)

TECHNOLOGY

from electromechanics to
electronics

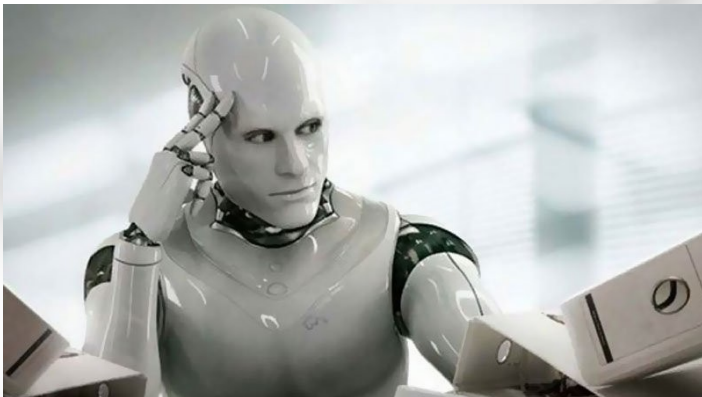
in the AGE of CONSUMERS



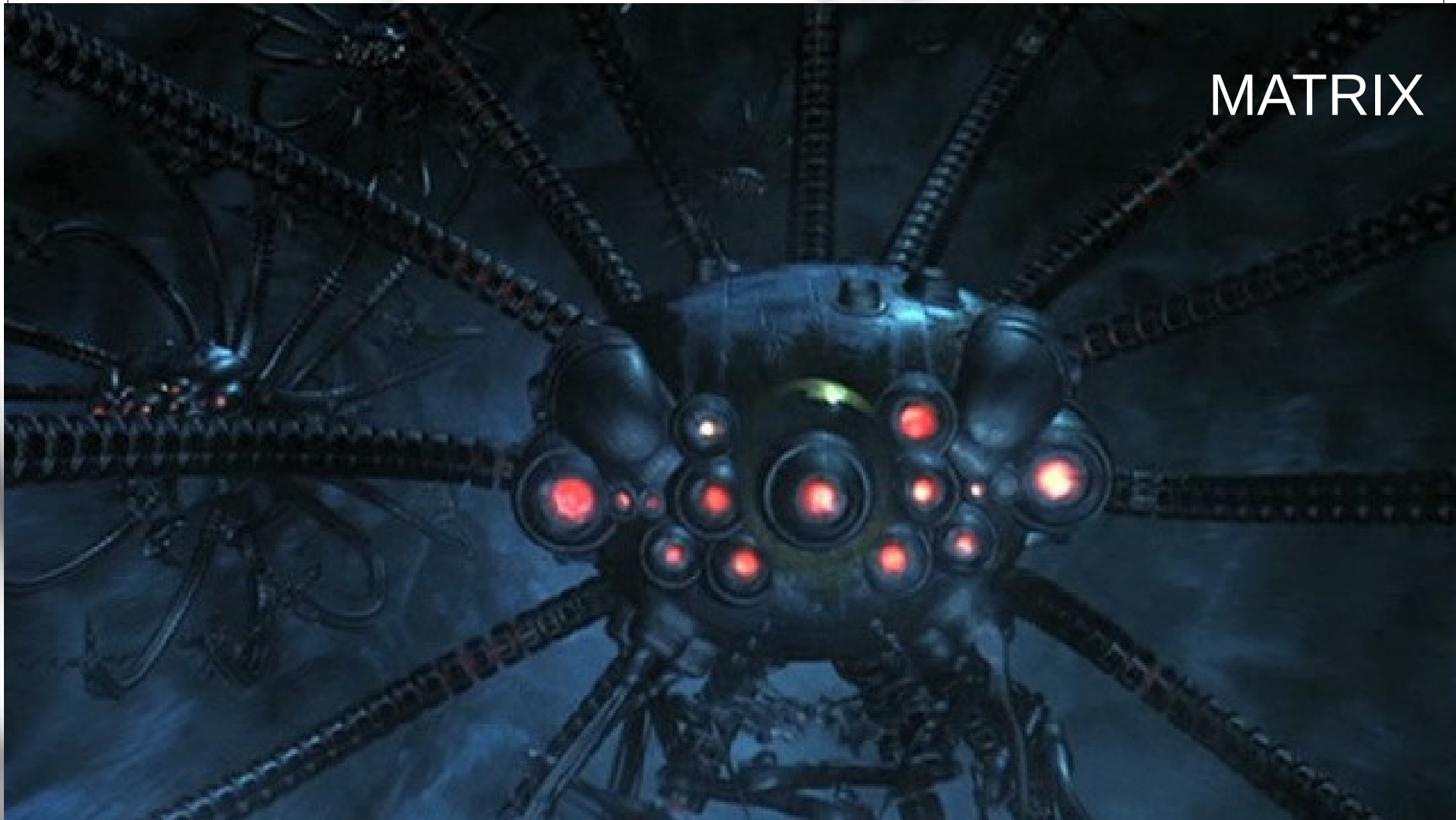
- Computer [pad, mobiles, gaming platforms]
- Internet [browsing “Socially”]
- cameras, drones, domotics [full ‘control’ everywhere]

**everything under your control from your
smartphone ..**

Control is delegated to an embedded intelligence



And not everybody agree with such a
RUSH to TECH !



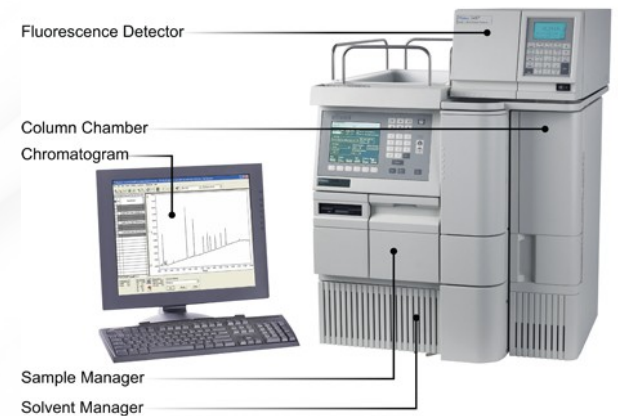
TECHNOLOGY in the workplace



sequencer



Gas-mass-spectroscope



hplc

..soon or later such **PRODUCTS** of **TECHNOLOGY** will
find their place in a **MUSEUM**

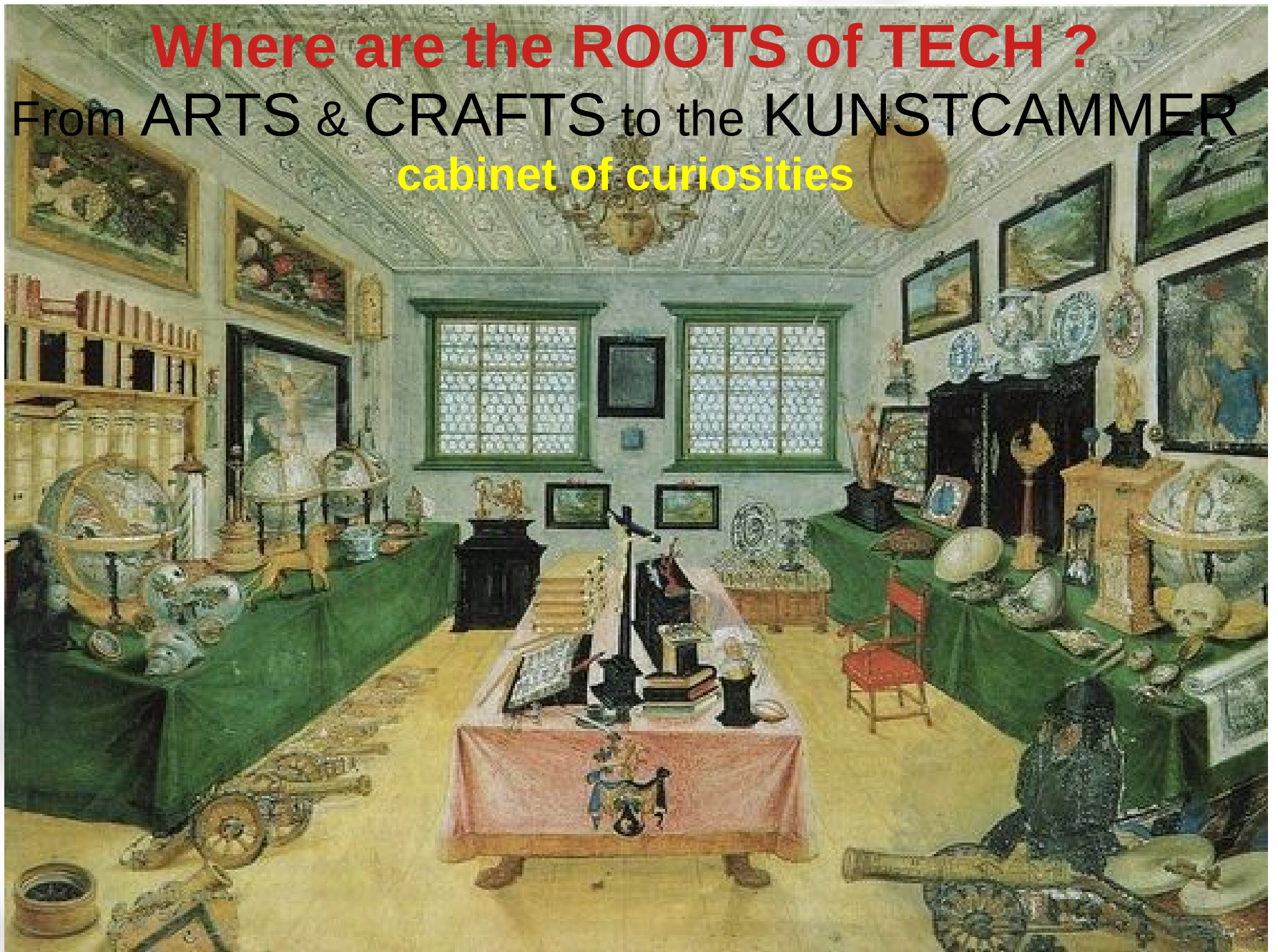


.. or perhaps sold out
as ANTIQUITIES



Where are the **ROOTS** of **TECH** ?

From **ARTS & CRAFTS** to the **KUNSTCAMMER**
cabinet of curiosities



WHICH are the most attractive objects ?

MACHINES

addicting MOTION & ENERGY



.. from an humble **SPRING** the mechanism
.. CARILLONS and further ... **AUTOMATA**

MACHINE has a wider meaning

scene machinery



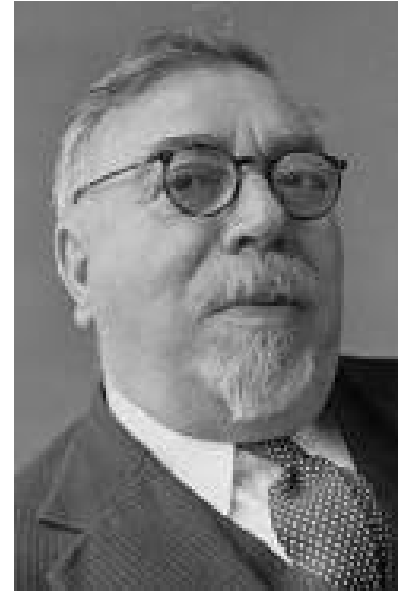
Deus ex machina

the god behind the machine

CYBERNETICS

the science of MACHINES

Norbert Wiener (1894-1964). **Swedish Mathematician**, member of the Cybernetics Group, one of the founders of cybernetics. With the age of 18 years N. W. graduated with a dissertation about questions of mathematical philosophy. Being engaged in probability research, theory of real functions, potential theory, functional analysis and mathematical physics he got involved in the development of electronic devices for ballistic calculations in world war II. In the interdisciplinary discourse with neuro-scientists his interest in questions of automatic control and communication grew up.



William Ross Ashby (1903-1972) **British psychiatrist** and one of the founders of cybernetics. A pioneer of the study of control and organization of complex systems and developed concept of homeostats, law of requisite variety, principle of self-organization, and law of regulating models. Being the director of research at Barnwood House Hospital in Gloucester (1947-1959) he wrote the outstanding books "Design for a Brain" (1952) and "Introduction to Cybernetics" (1956). After working as director of the Burden Neurological Institute (1959-1960) and in the Dept. of Electrical Engineering at the University of Illinois, Urbana (1960-1970), he was elected a fellow of the Royal College of Psychiatry in 1971.



Reference:

Ashby, W. R. (1956), "Introduction to Cybernetics", London, Chapman & Hall [PDF file provided by Principia Cybernetica]

General Systems Theory

Ludwig von Bertalanffy (1901-1972)

- Biologist and philosopher
- He found in 1957 the
 - Society for General Systems Research
- 1968: "General Systems Theory" - GST

"GST aims at seeking principles common to systems in general that may allow scientists and researchers to think more clearly about the goals of any possible system and about the methods for reaching them." by Ludwig von Bertalanffy (1956)

(<http://www.bertalanffy.org/>)



What is a **SYSTEM** ?

If you DON'T ask me
what is the **TIME**,
I know what it is,
BUT
IF you ask me to explain it
I don't know the meaning anymore.

Sant'Agostino

algebraic linear equation
SYSTEM

$$\left\{ \begin{array}{l} a x_1 + b y_1 + c z_1 = 0 \\ a x_2 + b y_2 + c z_2 = 0 \\ a x_3 + b y_3 + c z_3 = 0 \end{array} \right.$$

SYSTEM definition

- SET of INTERACTING ELEMENTS
- Input > STATE > Output

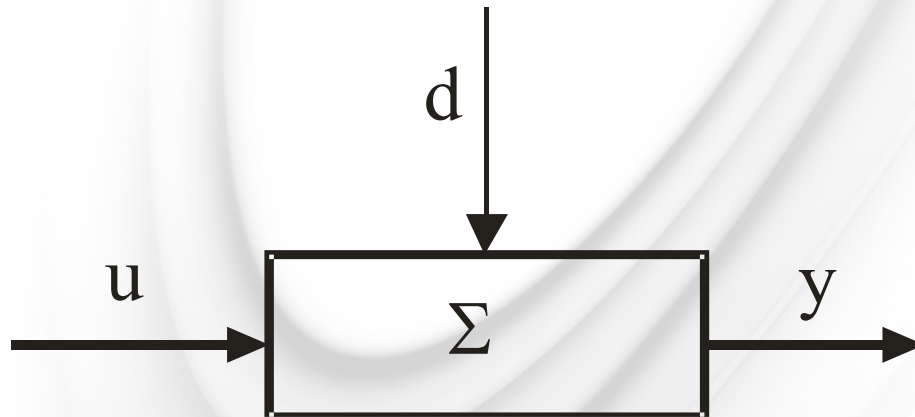
U : input

X : state

Y : output



Input vs Disturbances (d)



- **Deterministic System**
- **Stochastic System**
- *Chaotic System*

The TIME-line

Statical vs Dynamical system

- Statical = Instantaneous Systems: $y(u)$
- Dynamical Systems: $y(u, y, x, t)$
 - Autonomous Systems .. $y(y, u)$
 - There is not an EXPLICIT reference to the time (except of derivation/integration)
- Time \rightarrow (implies) Orientation
- \rightarrow Causality

System Observation & MONITORING: trajectories and states

STATE Trajectory = $\{X\}$

- A trajectory is called FREE MOTION
IF *u is nil (no forcing)*

Output Trajectory = $\{Y\}$

Response = $\{t, Y\}$

- A Response is a FREE RESPONSE
IF *u is nil (no forcing)*

*System undergoing a **PROCESS** of state change*



- Continuous Systems
- Discrete Systems

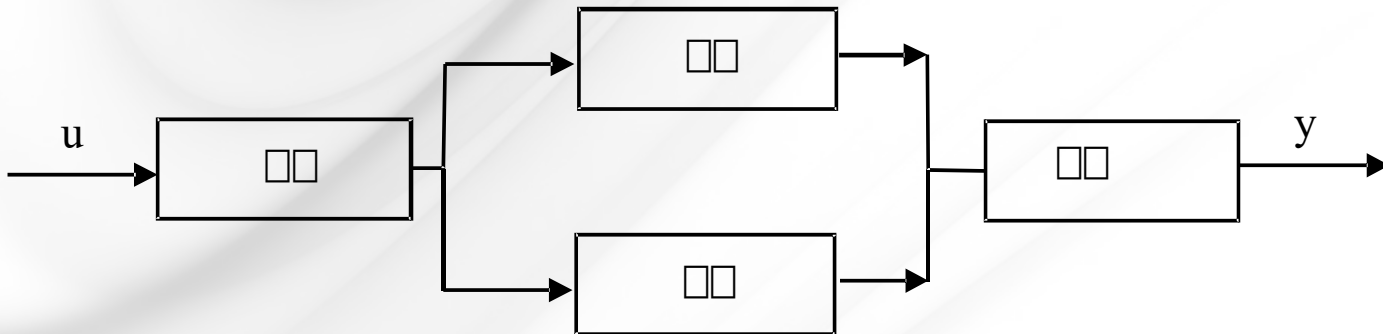
- Finite State Machine (FSM) = **Automata**
- Combinatorial Systems (*instantaneous with N outputs*)
- Sequential System (*with **memory***)

Compound Systems

- Series

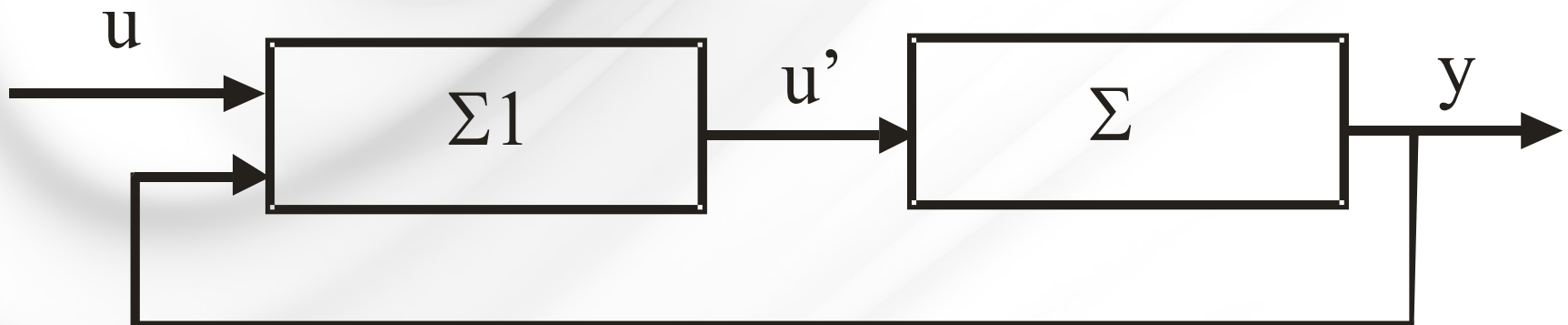
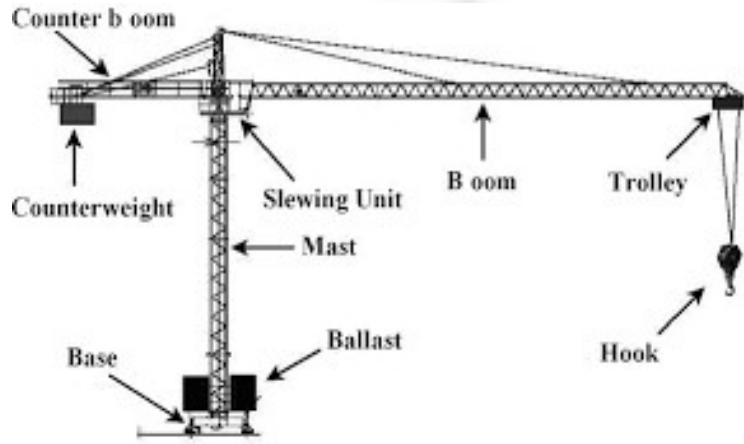


- Parallel



Feedback

(NOT reaction !)



Regulation vs Control

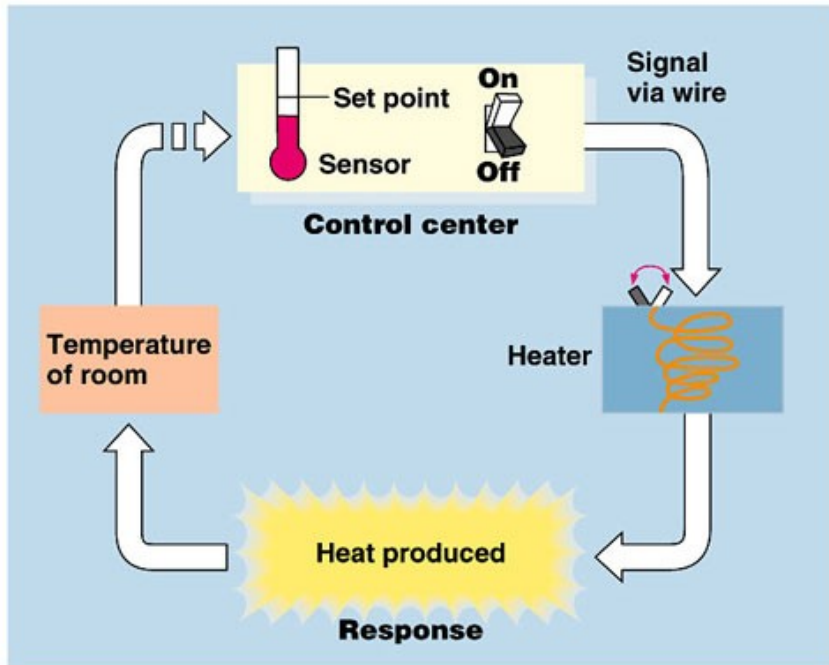
*Regulation: tuning by an actuator
changing a continuous variable*

*Control: toggling by an actuator a discrete
variable (not to be confused with monitoring)*

Design a system to control an oven temperature

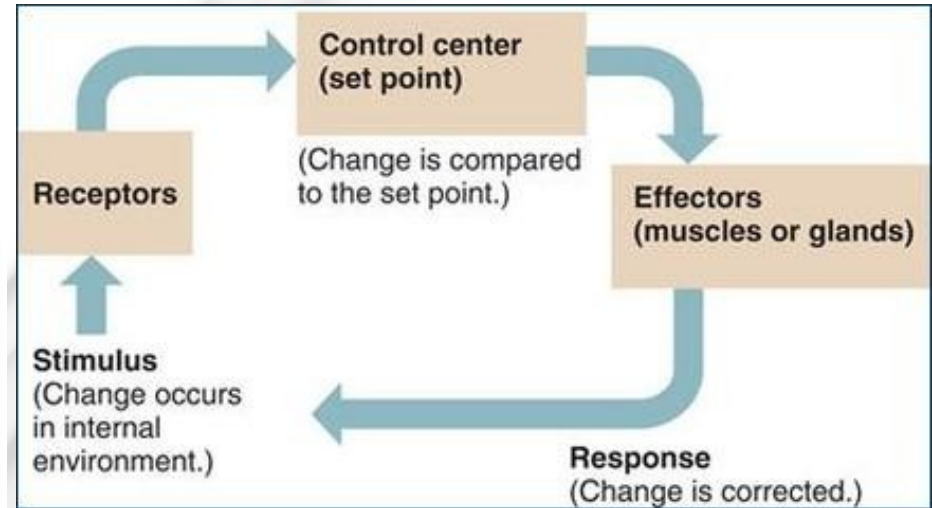
- objective: maintain T constant
- system: heating element, oven (closed container), thermometer
- output: T internal from T sensor
- disturbances: T external
- **commands: valve OR switch**

Regulation vs Control



(a) Control of room temperature

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.. up to now

- technology**
- machine**
- system**
- feedback**
- control**

**..a bunch of basic concepts
in a researcher workbench !**