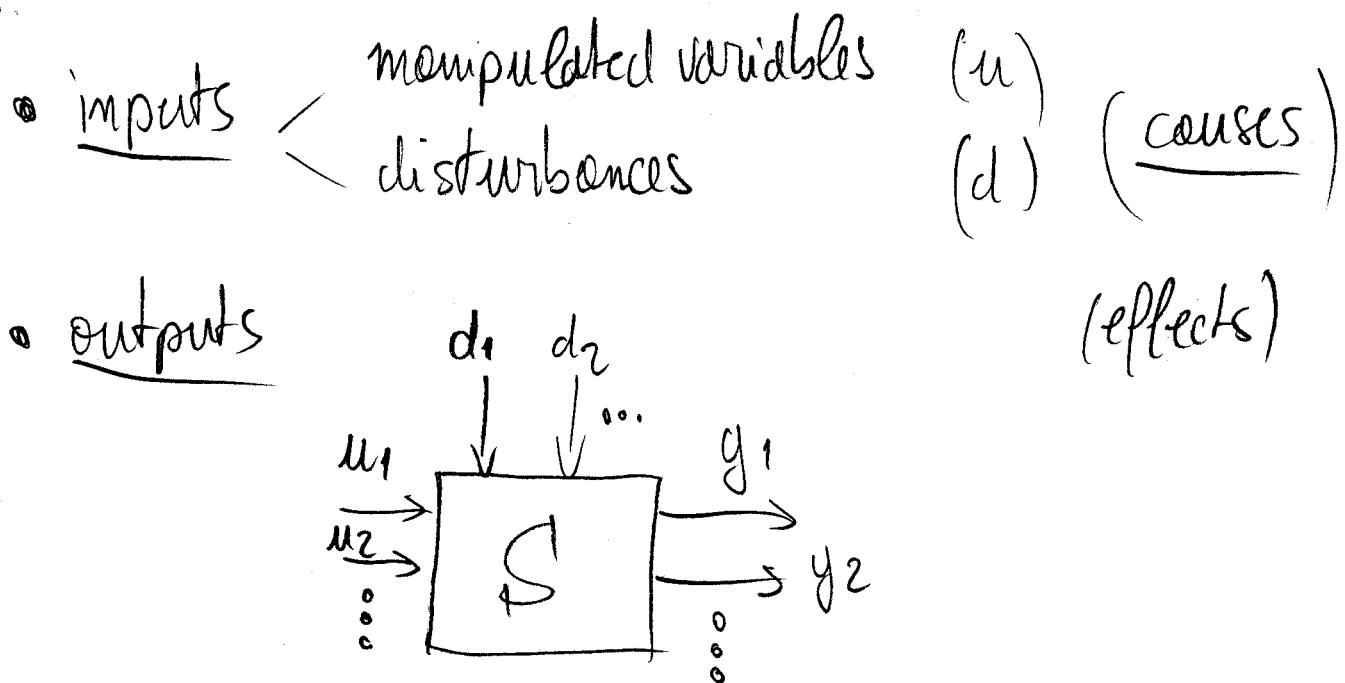


INTRODUCTION

①

- DYNAMICAL SYSTEMS

- A dynamical system S is an idealized representation of a real system, focusing on some specific features
- Two kinds of variables which are the function of time.

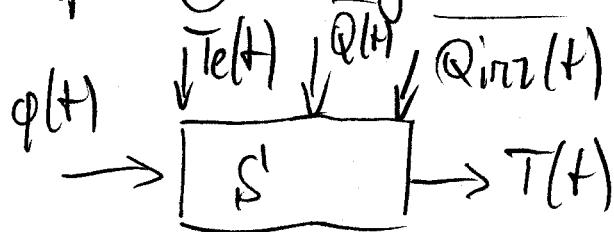


- Output variables depend on input variables
- Dynamic behaviour: $y(\bar{t})$ depends on $u(t), d(t), \boxed{t \leq \bar{t}}$
the current outputs depend on the input current values and past history
- Manipulated variables can be changed at will
- Disturbances are determined by the environment

INTRODUCTION

(2)

- Example ① Dynamics of the temperature in a room



$T(t)$: room temperature

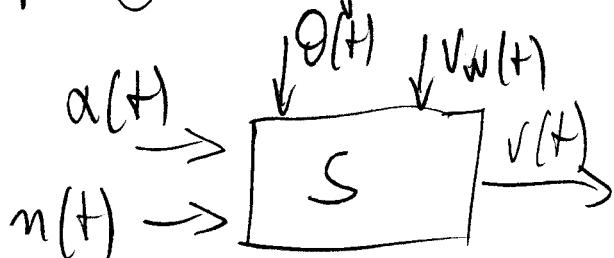
$q(t)$: hot water flow rate
in the heating elements

$T_{ext}(t)$: external temp.

$Q(t)$: power dissipated
by the occupants

$Q_{irr}(t)$: heat input by
irradiation

- Example ②: longitudinal dynamics of car



$v(t)$: vehicle speed

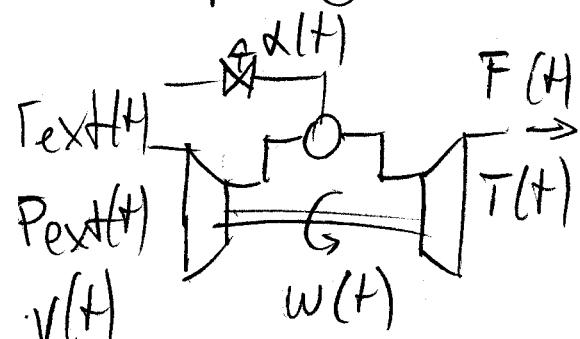
$\alpha(t)$: throttle position

$n(t)$: gear shift position

$\theta(t)$: road slope

$v_w(t)$: head wind speed

- Example ③: Gas turbine airplane engine

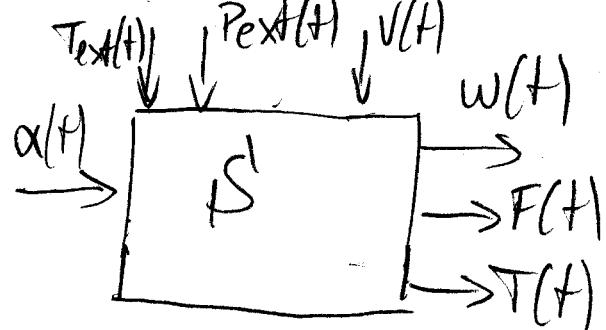


$\alpha(t)$: fuel valve opening

$T_{ext}(t)$: external temp.

$P_{ext}(t)$: external pressure

$V(t)$: intake speed



$w(t)$: shaft rotational speed

$F(t)$: engine thrust

$T(t)$: exhaust temperature

INTRODUCTION

(3)

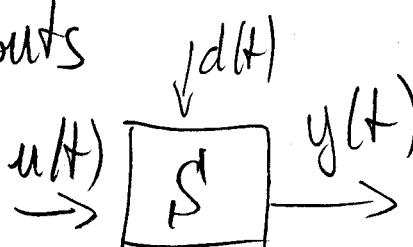
- THE CONTROL PROBLEM

- Given a dynamical system and some requirements on the values or time history

of some of its outputs

$$y^0(t)$$

Set point



Dynamical system

y^0, u, d, y
can be
vectors

- control problem

- determine the values of the manipulated variables (or control variables) $u(t)$

- such that $y^0(t) \approx y(t)$

despite

- the uncertainty on the values of the disturbances $d(t)$

- the uncertainty on the actual behaviour of S

- Solutions :

↗ manual control (a human determines u)

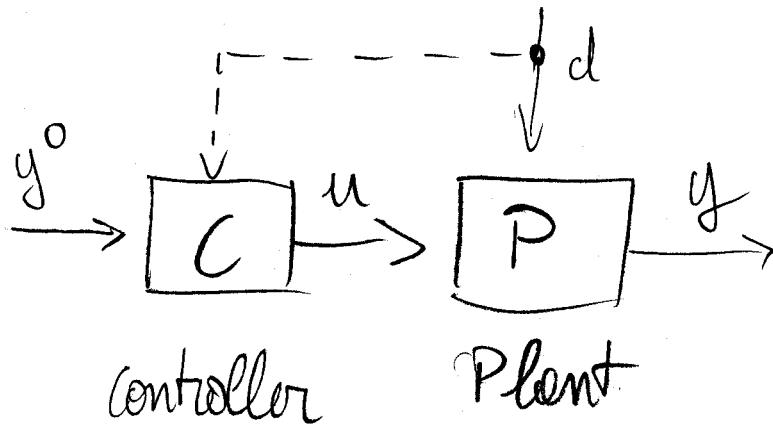
↘ automatic control (some artificial system determines u)

INTRODUCTION

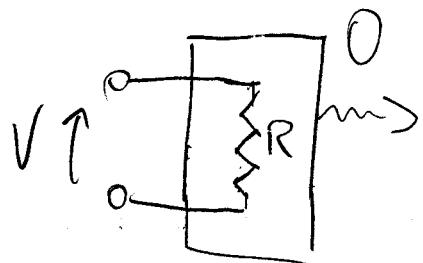
④

- CONTROL SYSTEM STRATEGIES

(A) Open-loop / Feed-forward control



- The controller is a dynamical system determining u based on y^0 and (possibly) on d
- Works well if uncertainty is limited!
- Example: Electrical heater



1^{st} law of thermodynamics
+ Ohm's law,

$$\text{at equilibrium } Q = \frac{V^2}{R}$$

no uncertainty, if V and R are well-known

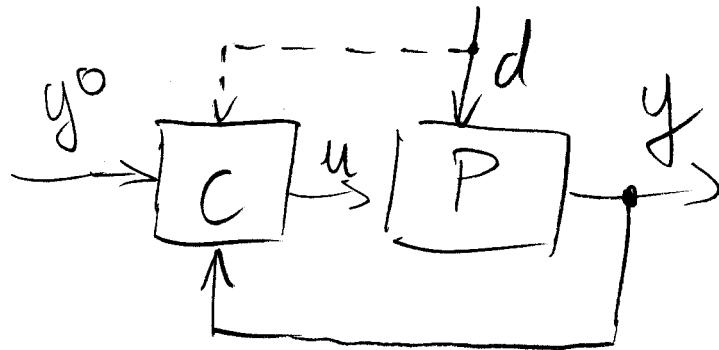
Feed-forward controller $\xrightarrow{Q^0} \boxed{\frac{V^2}{Q^0}} \xrightarrow{R}$

INTRODUCTION

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- In case of significant uncertainty (unknown disturbances / uncertain behaviour of P) an open-loop controller cannot guarantee $y \approx y^*$ (it is blind)
- Example: room temperature control based on external temperature only

(B) Closed-loop / Feed-back control



- The controller C determines u based on y^* , \underline{y} , and (possibly) d
- Comparing the desired y^* and the measured y helps coping with uncertainty: until $y = y^*$, the controller can try to "do something"
- Potential problem: stability

INTRODUCTION

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- EXAMPLE: CONTROLLING THE SHOWER TEMPERATURE

S: shower with mixer control

u: mixer position

y: perceived temperature of water on your back

- The effect of a change in u onto a change in y is affected by a (large) time delay due to the water transport time & thermal inertia of the tubes
- Chain of events:

water cold \rightarrow move mixer to hot \rightarrow water still cold

temp. OK \leftarrow pipe fills with \leftarrow move mixer to hotter
not water

temp. too hot \rightarrow move mixer to cold \rightarrow temp. still hot

temp. too cold \leftarrow temp. OK \leftarrow move to colder
 \hookrightarrow repeat..

INTRODUCTION

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- If the human's (controller's) response is too nervous, the system will oscillate wildly
 - Note that a shaver does not oscillate on its own \rightarrow controller-induced oscillations
- \rightarrow The dynamics behaviour of the plant is crucial to determine the closed-loop behaviour (equilibrium behaviour of the plant is trivial, if the tube is well-insulated)
- SUMMARY

Open-loop control : OK if limited uncertainty doesn't change plant stability

Closed-loop control : More robust w.r.t. uncertainty, but can destabilize the plant (it could also stabilize an unstable plant...)

INTRODUCTION

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- COURSE OVERVIEW

- Part I Study of simple control systems
(one controlled variable)
 - Techniques for describing & analyzing dynamic behaviour
 - Techniques for linear controller design
 - Goals :
 - ~ understand the issues at stake
 - ~ using rigorous math methods
- Part II Architecture of complex and industrial control systems
 - Extensions of the basic concepts laid out in part I
 - More descriptive approach
- Special emphasis on energy and thermal systems