INTELLIGENT CONTROL SYSTEMS

Introduction

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Lecture overview

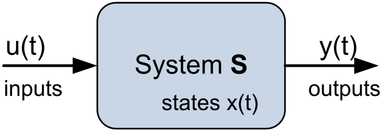
1. Basic notions of signals and systems
   - Typical tasks for dynamic systems
   - Characterization of control systems
2. Intelligent systems
3. Course contents and requirements
   - Requirements and evaluation
   - The lecturer's project - the coffee machine

Signals and systems

System (**S**): acts on signals

$$y = \mathbf{S}[u]$$

- inputs (u) and outputs (y)
- states (x): internal, not unique



- state variables (x): often conserved extensive quantities (or their intensive pairs)
- input variables (u): appear on the right-hand sides of the model equations, manipulable (measurable)
- output variables (y): measurable, not directly manipulable (state variable or depends thereon)

General form of continuous time state space models

Concentrated parameter: (=finite dimensional) general form

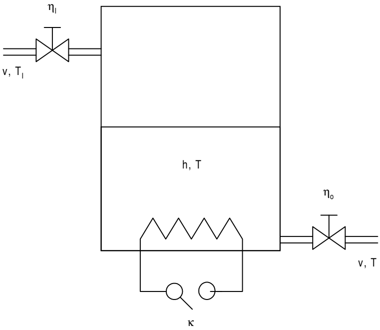
$$\dot{x}(t) = \widetilde{f}(x(t), u(t)) \qquad (\textit{state equation})$$
$$y(t) = \widetilde{h}(x(t), u(t)) \qquad (\textit{output equation})$$

with

- the state, input and output vectors x, u and y and
- the smooth nonlinear mappings

$$\widetilde{f} \ : \ \mathbb{R}^n \times \mathbb{R}^r \mapsto \mathbb{R}^n \quad , \quad \widetilde{h} \ : \ \mathbb{R}^n \times \mathbb{R}^r \mapsto \mathbb{R}^p \quad .$$

Example: a coffee machine



Engineering model equations

$$\begin{aligned} \frac{dh}{dt} &= \frac{v}{A}\eta_I - \frac{v}{A}\eta_O && \text{(mass balance)} \\ \frac{dT}{dt} &= \frac{v}{Ah}(T_I - T)\eta_I + \frac{H}{c_p \rho h}\kappa && \text{(energy balance)} \end{aligned} \tag{1}$$

State variables: h (water level), T (temperature)
(potential) Input variables: v (in/out flow rate), η_I, η_O (binary valve switches), κ (heater switch)

Control - general problem statement

Given

- a system model
- ***control goal***

Compute

an ***input record*** to fulfil the control goal

Control goals:

- stabilization
- disturbance rejection
- optimal control

Diagnosis - general problem statement

Given

- a set of ***possible faults***
- ***a system model for each fault***
- measured data from the system to be diagnosed

Compute/determine

the fault that ***best explains*** (measure of fit is needed!) the measured data

Diagnosis approaches:

- prediction-based
- identification (parameter estimation) based
- observer-based (state estimation or filtering)

Computer controlled systems

Important

Time is the primary variable in control systems

Computer controlled systems are real-time software systems

Main functions

- data collection (measurement), data processing
- control and regulation
- system analysis
- control
- diagnosis

Software elements

- data files: raw measured data, measured data, events, etc.
- tasks: primary processing, event handling, control diagnosis

Intelligent systems

Intelligent human

- solves non-trivial, complex, complicated problem
- in case of difficult, non-trivial, new circumstances
- main characteristics: heuristic - problem solving driven by experience, intuition

Intelligent system

- problem solving: human-like way
- learning: systematization of collected knowledge
- heuristic: key characteristic of intelligent methods

Characteristics of intelligent problems

- complicated (even for human!)
- there is no predefined algorithm for solution
- solution can be defined with a sequence of elementary actions
  - not fixed in advance
  - can be chosen among several possible sequences
- solution: search
  - enumeration the set of potential solutions
  - choosing next action (step): with systematic trying
- problem space (search space): can be huge
  - trying all the possibilities in systematic way is not possible: combinatorial explosion
  - directed search is needed
- human skill/intuition/practical experience is needed: heuristic knowledge
- "good enough" solution is sufficient

Intelligent software systems

Software systems are based on Neumann's principle

- data (passive)
- program (active): executable part (stored in the form of data)

Knowledge-based systems are intelligent software systems based on Neumann's principle

- knowledge: data-like part, not necessary passive
- inference engine: processing part, active

Course structure

The course is given in the form of

- lectures-tutorials
- consultations for helping with the individual project

Important (Course web page)

https://virt.uni-pannon.hu/index.php/hu/oktatas/tantargyak/143-intelligens-iranyito-rendszerek-vemisam454i

Contents (Lectures and tutorials)

Most common techniques applied in intelligent control systems

- time-dependent ***rule sets***: notion and verification
- ***qualitative models***: signed directed graphs, confluences, qualitative difference equations
- ***Petri nets***: ordinary and coloured
- ***fuzzy rules***

Knowledge representation forms and reasoning methods
applied for control and diagnosis

Evaluation

The pre-requisite of the course signature is

- to submit in the given deadline at least 90% of the homework specified on the lectures-tutorials-laboratories,
- to submit the individual project results and documentation to the given deadline.

Important

The evaluation is based upon an individual project work.

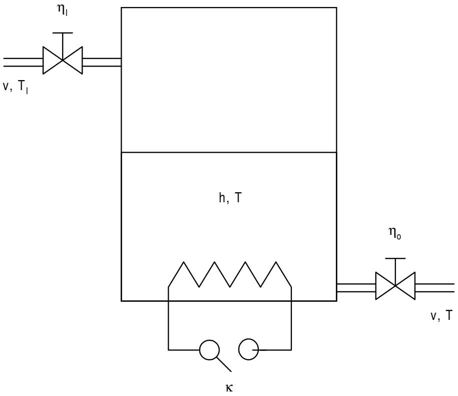
The individual project

For each participant an **individual small intelligent control task** is given (can be chosen from a pre-defined set)

Individual project: to be carried out with consultation

- for each technique perform the tasks specified in the homework section using your own individual system
- ***to be send in electronically to the given deadline***

The operation of the coffee machine



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