Intelligent Control Systems

Introduction Real-time Expert Systems

Katalin Hangos

Department of Electrical Engineering and Information Systems

September 2016

Contents

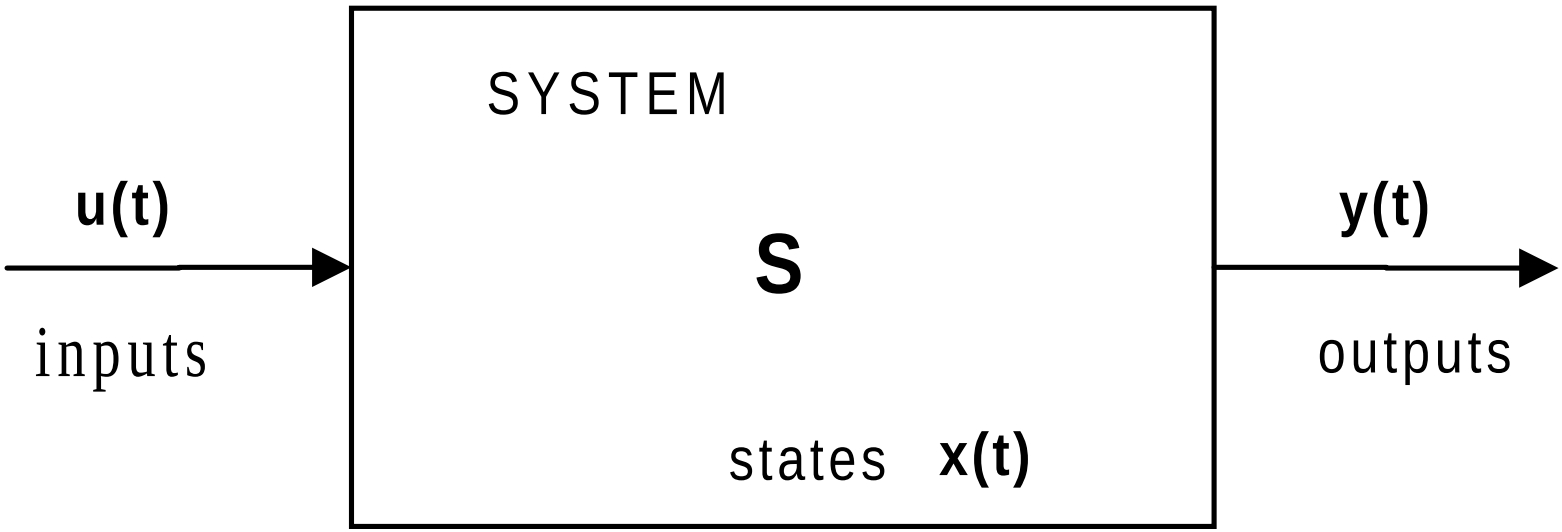
- Basic notions on systems and artificial intelligence
  - signals, systems
  - control and diagnosis
  - intelligent software systems
  - knowledge-based systems
  - expert systems
- Real-time expert systems
  - architecture of real-time expert systems
  - synchronization and communication between the real-time and intelligent subsystems

Signals and systems

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

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

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



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
- observes-based (state estimation or filtering)

Computer controlled systems

Computer controlled system - real-time software system

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

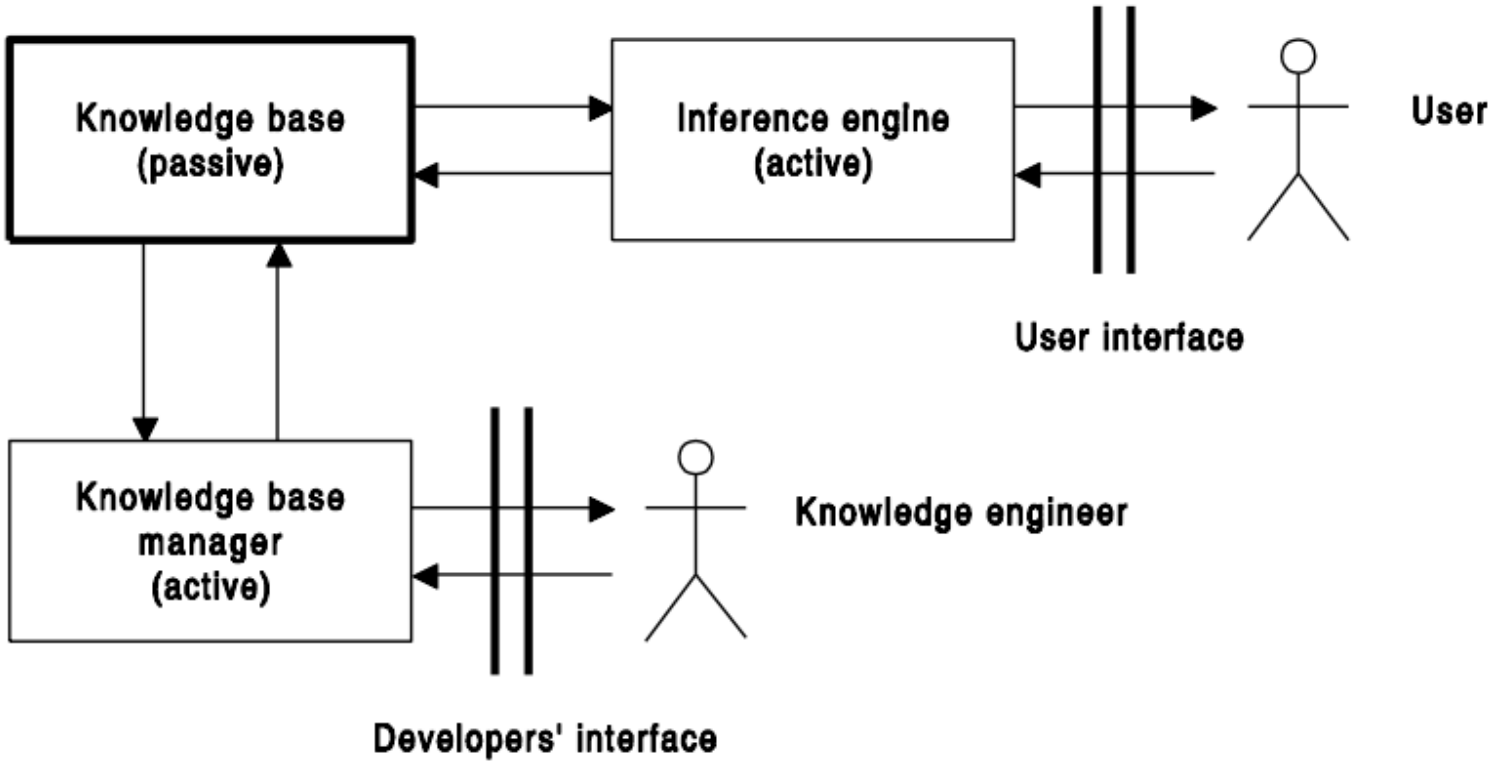
Software systems are based on Neumann's principle

- 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

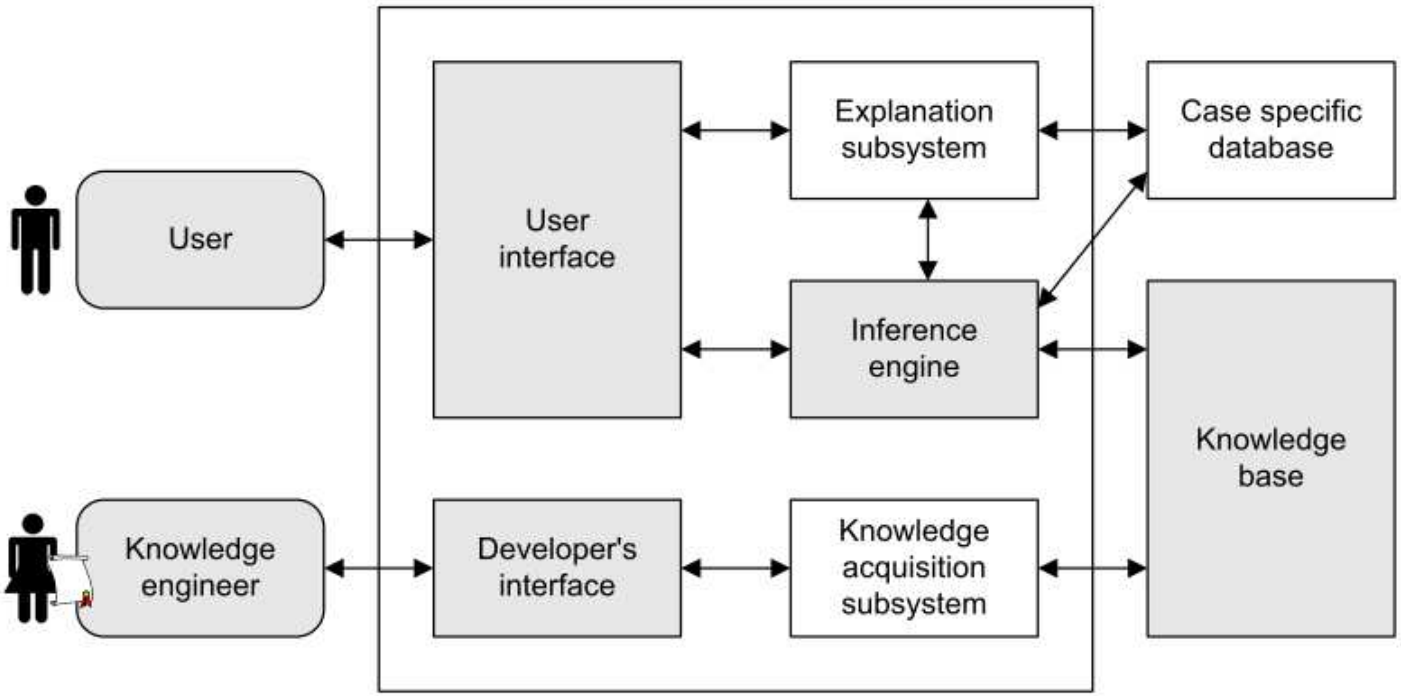
The architecture of knowledge-based systems



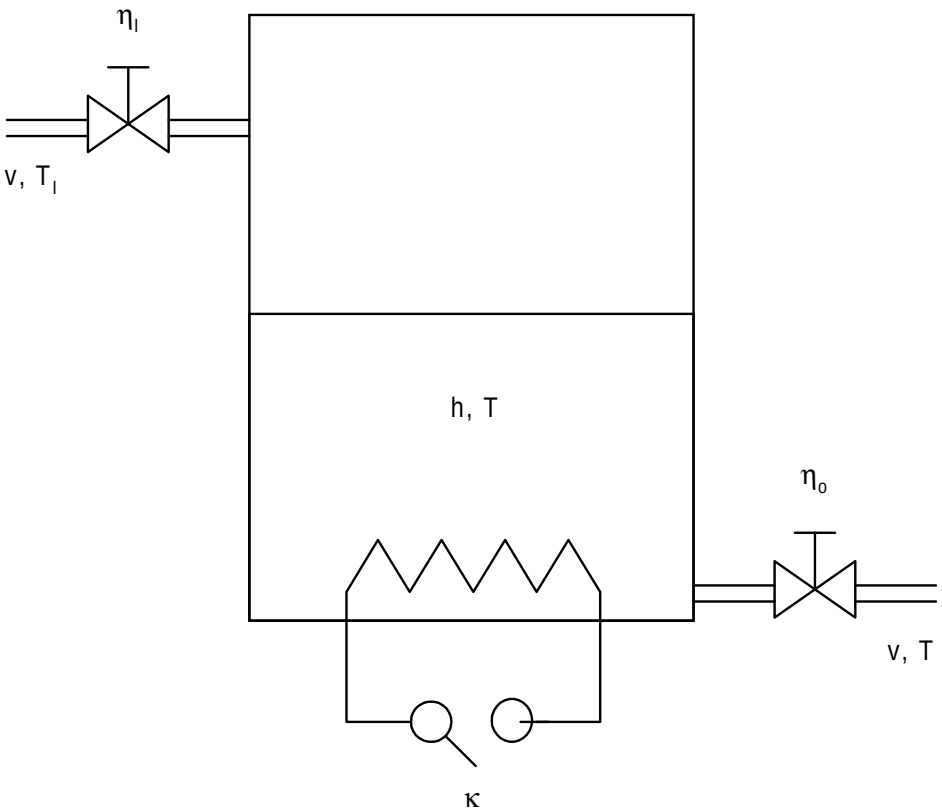
Expert systems

- Expert systems (ESs) are special knowledge-based systems
  - employ experts' knowledge
  - applied in a narrow specific field
  - solve difficult problems (that demands special knowledge)
  - specialized human experts are needed
  - experts must agree on the fundamental questions of their professional field
  - learning examples and raw data are needed
- ***Expectations from an ES (like a human expert):***
  - to make intelligent decisions: to offer intelligent advice and explanations
  - question/answer mode of operation ("treated as an equal conversation partner")
  - to be able to explain results and answers
  - to give acceptable advice even in case of uncertain situation

The architecture of expert systems



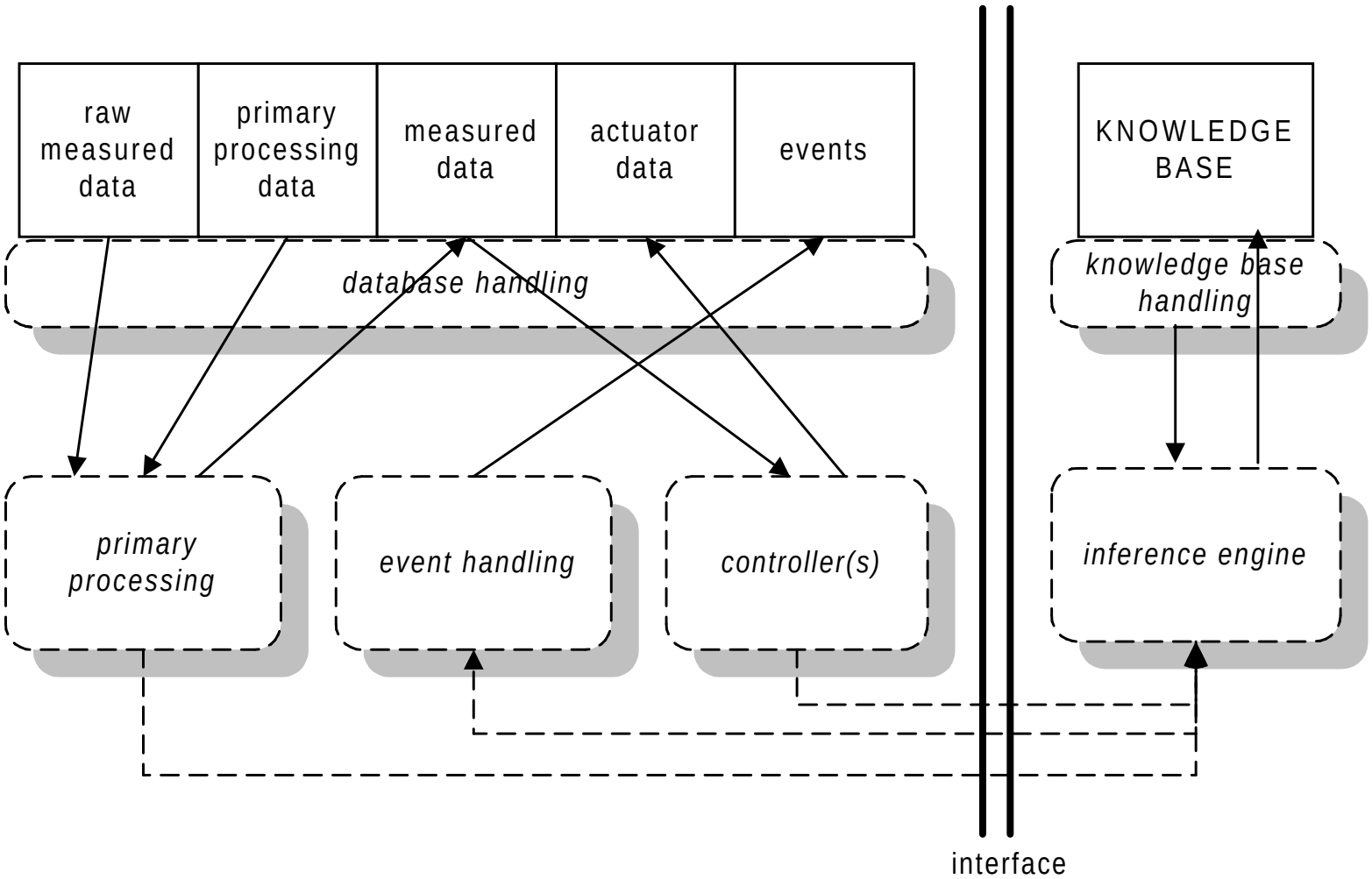
The operation of the coffee machine



Engineering model equations

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

The architecture of real-time expert systems



The real-time subsystem

Required key properties

1. time-dependent reactions
2. finite prescribed response time
3. time-out
4. no loss of raw data
5. priority handling
6. "nice degradation"

Key elements to be interfaced with the intelligent subsystem:

- *primary processing*
- *event handling*
- *controllers* in wide sense

The intelligent subsystem

Key properties of the elements for interfacing

a. *The knowledge (data) elements in a knowledge base are strongly related.* =>
The whole knowledge base should be locked for the inference engine when it performs a reasoning task.

b. *Reasoning is computationally hard.* =>
No definite upper limit for the time needed to perform a reasoning task, therefore a "loose" communication is to be implemented between the real-time and the intelligent subsystems.

Course contents

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

Requirements

For each participant an **individual small system and control task** is given

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 on Monday of the last week of the teaching period***