Diagnosis & Artificial Intelligence

The diagnosis Task: different approaches

What's diagnosis?

- R. Davies, 1982
  - Process of reasoning and acting
  - To identify the cause of a wrong behaviour
  - To restore the desire functionality
- L. Console, 2000
  - Task that given a **system** and a **set of observations** from an abnormal behaviour determines **what's wrong** in the system in order to **recover** its working order

Computer based diagnosis

- Fundamental area for AI from 70's
  - Area of experimentation of several methodologies
  - Meeting point for several methodologies
  - Good mixture of theoretical and practical issues
  - Several methodologies and techniques developed for diagnosis spread to other AI fields

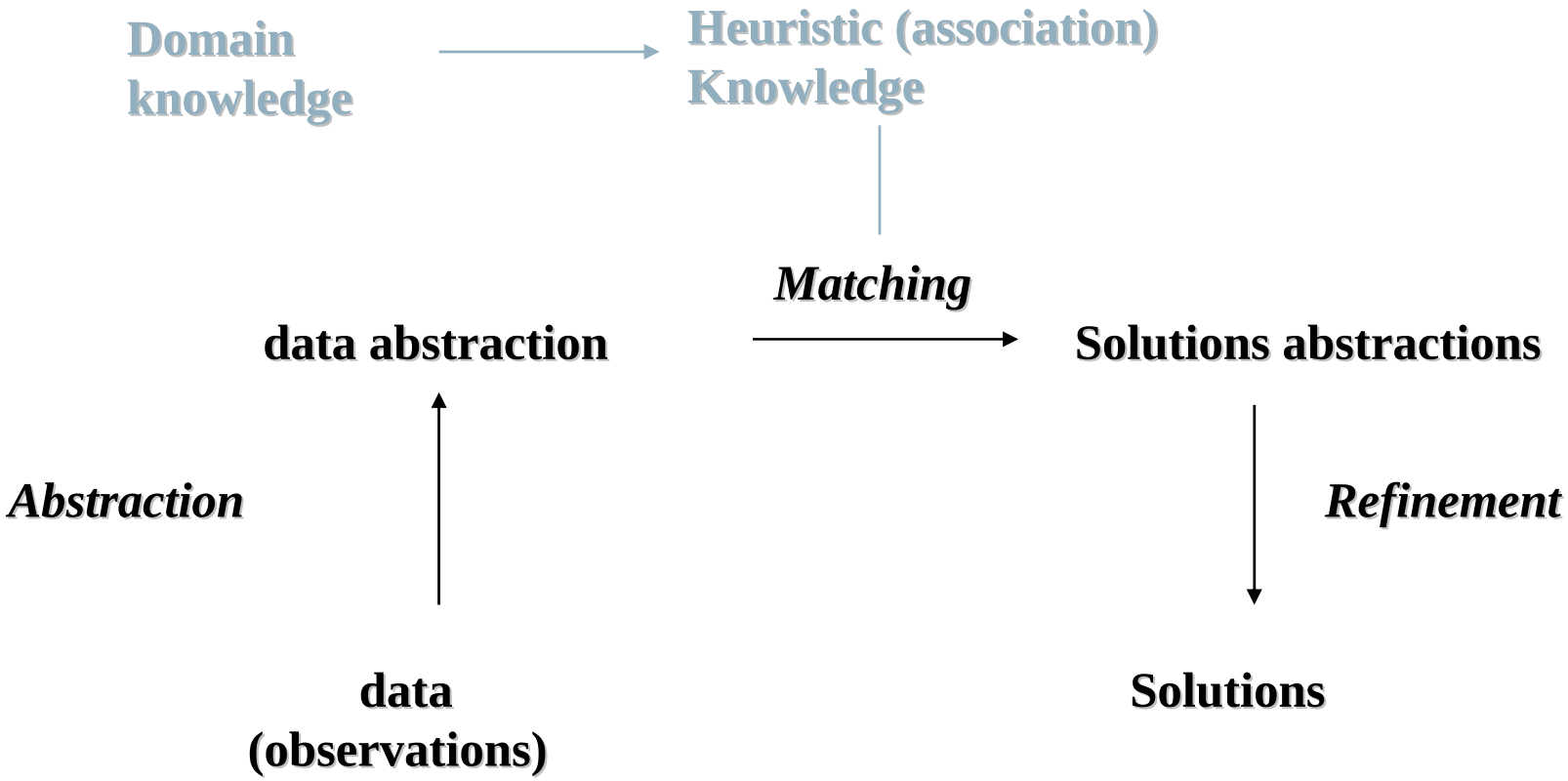
First attempts: expert systems

- 70's: diagnosis was the main application for expert systems

- Assumptions: diagnosis= heuristic process
  - Expert codes his heuristic knowledge in association rules:

    IF set of symptoms THEN Malfunction
  - Knowledge comes from experience
  - Knowledge may be extracted form expert and coded using a Knowledge Representation Language

Diagnosis through Heuristic Classification



"heuristic classification" [Clancey, Chandrasekaran, 83 85]

Diagnosis expert systems

- Different knowledge representations
  - Rules, frames, rules + frames
- Different fields
  - Medicine, Mechanics, Electronics, Process Control, Aeronautics, ...
- Some paradigmatic systems
  - MYCIN, Stanford, 71-79
  - DELTA-CATS1, General Electric, 84
  - INTERNIST, Carnegie Mellow, 77

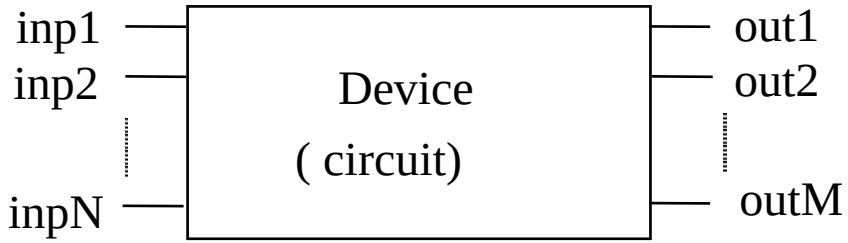
Mycin Example

- Diagnosis and therapy for bacterial infections
- Knowledge Base: production rules

  if (1) the stain of the organism is gram-negative
  (2) the morphology of the organisms is coccus
  (3) the growth configuration of the organism is chains
  then there is a suggestive evidence (0.7)
  that the identity of the organisms is streptococcus
- Backward chaining, meta-rule for additional control
- Approximated reasoning: certainty factors

Diagnosis of physical devices

- Physical device (i.e. electronic device)



- Heuristic Knowledge: associations between symptoms and faults
- Rules:

  if inpi1=x1 and ... and inpik= xk and outj1=Y1 and ... and outjl=Yl then (0.75) fault=P

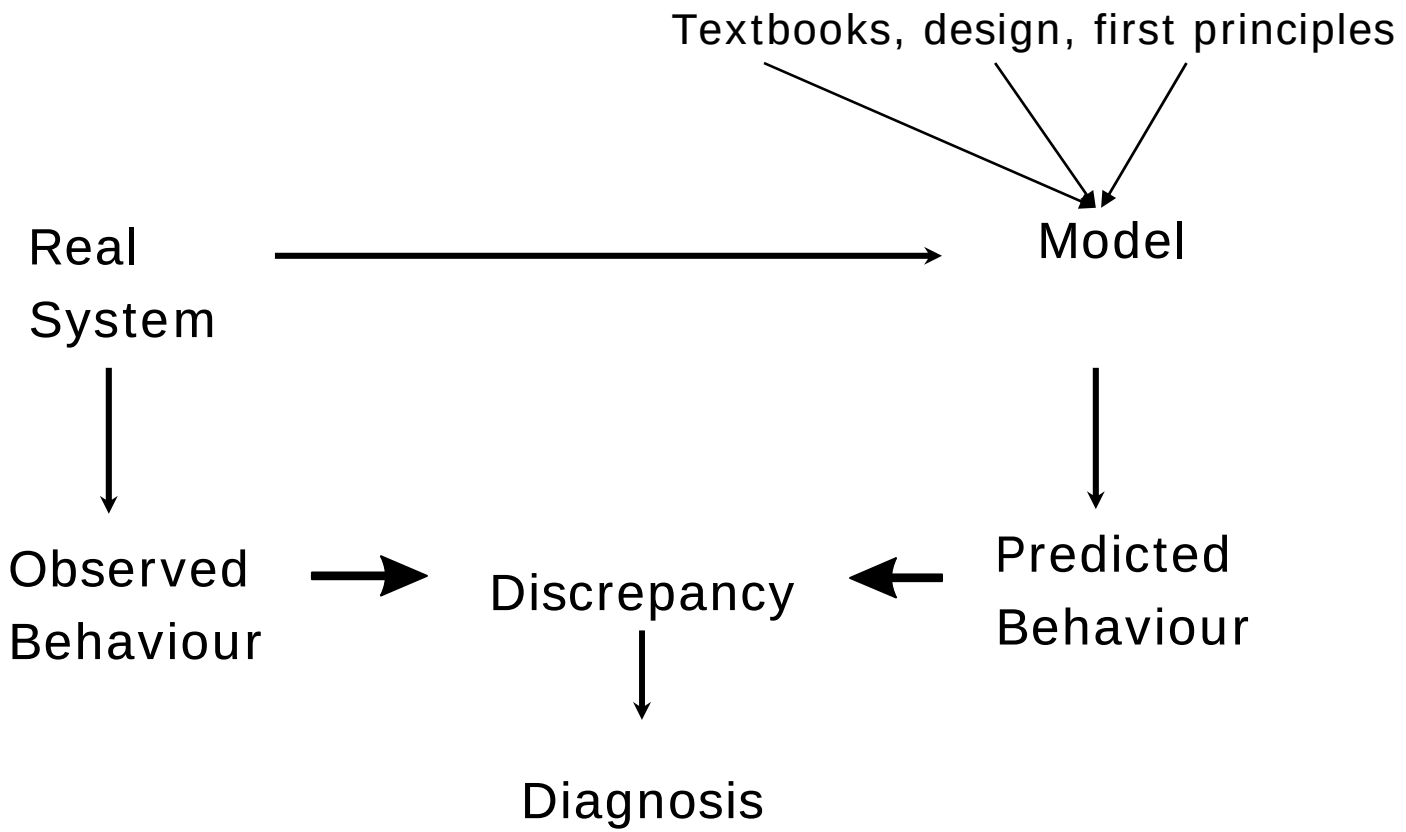
Advantages of expert system approach

- Consolidate approach
  - Methodologies, working systems
- Suitable when
  - Enough experience available
  - No other knowledge available
  - Enough sensors
  - The system remains stable

Disadvantages of expert systems approach

- Related to experience
  - Knowledge acquisition is a complex task
  - Availability of experts/experience
  - **Device dependence**
- Related to classification method
  - **New faults**
  - Combination (multiple) faults
  - Brittleness
- Software engineering
  - Knowledge reuse: different devices, **task**
  - **Maintenance** of (the consistency of) the knowledge base

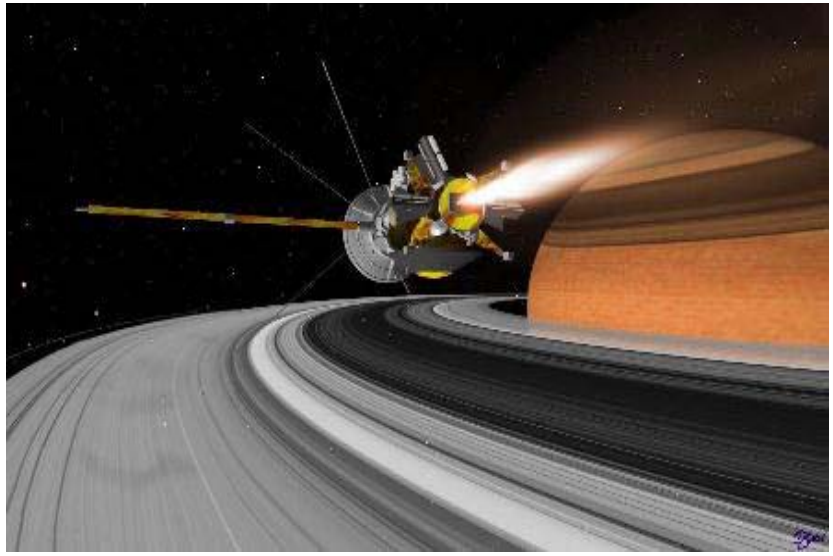
Model based approach to diagnosis

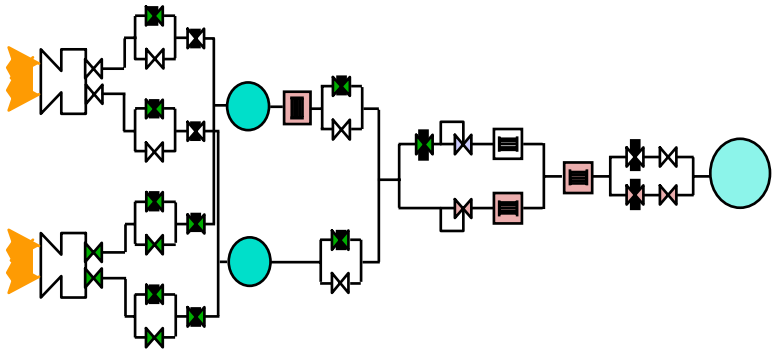


Diagnosis through Model Based Reasoning (DX community)

- Knowledge: model (task independent) of the device
- Diagnosis: process of reasoning with model to identify cause of deviation of expected behaviour
- History
  - Second generation expert systems (deep knowledge,Davies,82)
  - First work USA, Standford, MIT, first 80`s (constrain suspension)
  - General Diagnostic Engine: computational paradigm, de Kleer, Williams,87
  - Sound theoretical foundations, Reiter,87

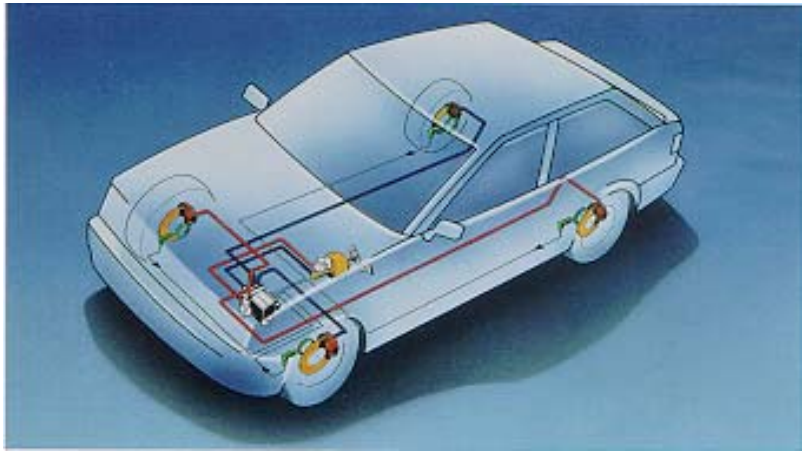
Basic Assumptions (de Kleer 03)





- Physical system
  - Set of interconnected components
  - Known desired function
  - Design achieves function
  - System is correct instance of design
- All malfunctions caused by faulty component(s)
- Behavioural information
  - Only indirect evidence

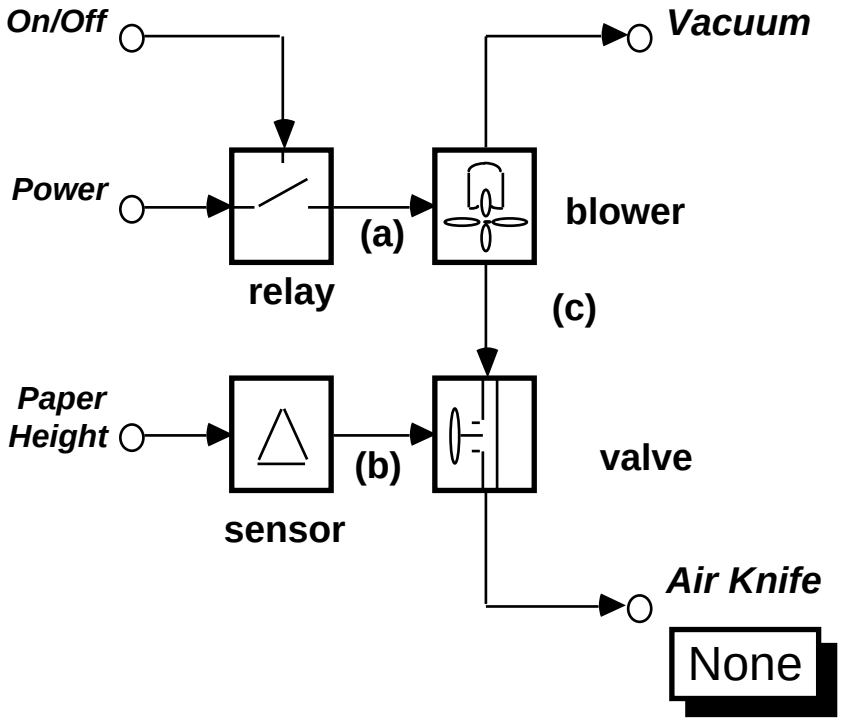
Automotive industry



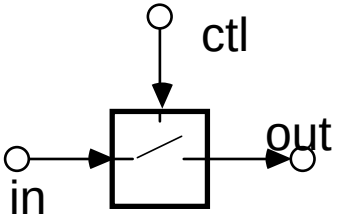
- On board diagnosis
- Workshop diagnosis
- FMEA
- Preventive diagnosis

- Of great interest because of
  - Security
  - Environmental
  - Economical
- Why model based?
  - Variant problem (several component, several manufacturers, different models!)
- Several projects

Modeling a Xerographic Copier
(de Kleer 2003)



relay



GOOD

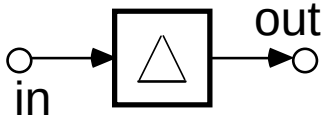
in	*ctl*	*out*
off	off	off
on	off	off
off	on	off
on	on	on

BAD

in	*ctl*	*out*
x	*x*	off

(*x* means don't care)

stack-height sensor



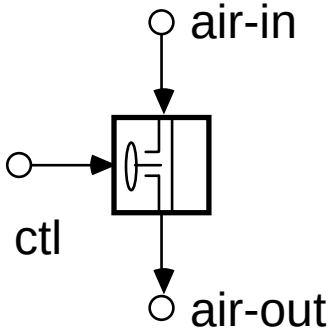
GOOD

in	*out*
none	none
short	low
medium	normal
tall	high

BAD

in	*out*
x	none

air-valve



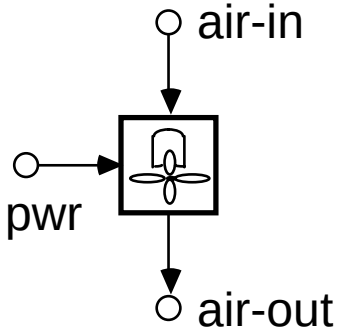
GOOD

ctl	*air-in*	*air-out*
none	*x*	none
x	none	none
low	low	low
normal	low	low
high	low	low
normal	normal	normal
normal	high	high
high	high	high

BAD

ctl	*air-in*	*air-out*
x	*x*	none

blower



GOOD

pwr	*air-in*	*air-out*
off	none	none
on	normal	normal

BAD

pwr	*air-in*	*air-out*
off	none	none
on	low	low

WORN

pwr	*air-in*	*air-out*
off	none	none
on	low	low

Why model based diagnosis ? (DX community)

- Experience independence
  - Works with new devices
- Device independence
  - Variant problem
- Multiple faults
- Soundness and completeness
  - Respect to the models
- Knowledge maintenance and reuse
  - Library of models, available from design

Other diagnosis approaches (I)

- No universally accepted taxonomy
- Balakrishnan y Honavar, 1998
  - How are given the relations between symptoms and causes?
  - How is this knowledge represented?
  - How is this representation used to obtained the diagnosis?

Other diagnosis approaches (II)

- Balakrishnan y Honavar, 1998
  - Knowledge based
    - Tzafestas 87, Guida y Tasso 94, Stefik 95, Jackson 98, Schreiber et al. 99
  - Case Based Reasoning
    - Schank 82, Kolodner 93, Watson 97
  - Machine learning:
    - Goldberg 89, Quinlan 93, Venkatusugramanian and Chan 97, Mitchell 97, Muggelton 99
  - Model based
    - DX: Hamscher, Console and de Kleer 92, DX proceedings, IEEE special number 04
    - FDI: Patton and Chen 1991, Isermann 93, Gertler 98