Diagnosis (01)

Definitions

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Presentation

Modeling of a diagnosis problem

Formal definition of diagnosis

Presentation

- Diagnosis problem
- Diagnosis as a logic problem
- Model-Based Diagnosis

Modeling of a diagnosis problem

Formal definition of diagnosis

Diagnosis problem

- Given
  - a system
  - a set of observations
- Goal
  - find if an anomaly happens, and if yes which one
  - restore a good bahevior

Example: car

- System:

- Observations: the car does not start
- Possible diagnoses: the battery does not work, the starter is broken, the car is out of petrol, *etc.*
- Possible repair: first, test plan to discriminate between the diagnoses (check the battery, *etc.*)

Example: human body

- System:

- Observations: Fever (40 degrees), headache
- Possible diagnoses: cold, migraine
- Possible repair: take three pills per day

Deduction

Famous syllogism of Aristotle:

- Socrates is a man
- Every man is mortal

- Deduction
  - Socrates is mortal

Abduction

- Every man is mortal
- Socrates is mortal

- Abduction (eg. Sherlock Holmes)
  - Socrates is a man

- Every ET is mortal
- But ETs do not exist

- Not an abduction
  - ~~Socrates is an ET~~

Induction

- Socrates is a man
- Socrates is mortal

- Induction
  - Every man is mortal
  - Every mortal is a man
  - No man but Socrates is mortal
  - *etc.*

What is diagnosis?

- Deduction?
- Abduction?
- Induction?

Expert Diagnosis *vs* Model-based Diagnosis

- Expert Diagnosis
  - Need an expertise (human experience, logs from past experience, *etc.*)
  - Efficient: direct mapping from the observations to the diagnosis
- Model-based Diagnosis
  - Need a model of the system
  - Robust
  - Justification

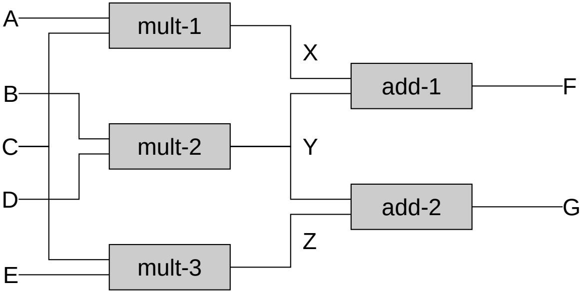
Historical

- Heuristic approaches
  - Expert systems (70)
- Approaches of static systems based on model (80)
- Approaches of dynamic systems based on model (90)
- Approches of reconfigurable systems based on model (00)

Static system

System whose state does not depend on the previous states

Example: Davis Circuit



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Model

Knowledge about "how the world works"

[Russel and Norvig, 2003]

Mathematical representation of the behavior of the environment that enables to simulate it.

[Grastien, 2005]

Model of a diagnosis problem

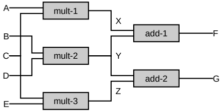
A system model is a couple $(SD, COMP)$ where

- SD is a set of first-order logic sentences describing the behavior of the system
- $COMP$ is a set of constants, a constant = one component

An observed system is a couple $(SD, COMP, OBS)$ where

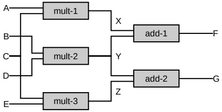
- $(SD, COMP)$ is a system model
- OBS is the set of observations

Model – example



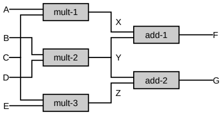
- $COMP = \{a_1, a_2, m_1, m_2, m_3\}$

Model – example



- Adder (SD):
  - $Add(x) \wedge \neg Ab(x) \wedge In1(x,u) \wedge In2(x,v) \wedge Sum(u,v,w) \Rightarrow Out(x,w)$
  - $Add(x) \wedge \neg Ab(x) \wedge In1(x,u) \wedge Out(x,w) \wedge Sum(u,v,w) \Rightarrow In2(x,v)$
  - $Add(x) \wedge \neg Ab(x) \wedge Out(x,w) \wedge Out(x,w) \wedge Sum(u,v,w) \Rightarrow In1(x,u)$
- Multiplier (SD):
  - $Mult(x) \wedge \neg Ab(x) \wedge In1(x,u) \wedge In2(x,v) \wedge Prod(u,v,w) \Rightarrow Out(x,w)$
  - $Mult(x) \wedge \neg Ab(x) \wedge In1(x,u) \wedge Out(x,w) \wedge Prod(u,v,w) \Rightarrow In2(x,v)$
  - $Mult(x) \wedge \neg Ab(x) \wedge Out(x,w) \wedge Out(x,w) \wedge Prod(u,v,w) \Rightarrow In1(x,u)$

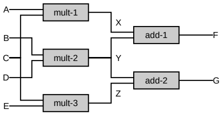
Model – example



- Component types
  - $Add(a_1), Add(a_2), Mult(m_1), Mult(m_2), Mult(m_3)$
- Connections
  - $Out(m_1, u) \wedge In1(a_1, v) \Rightarrow u = v$
  - $Out(m_2, u) \wedge In2(a_1, v) \Rightarrow u = v$
  - $Out(m_2, u) \wedge In1(a_2, v) \Rightarrow u = v$
  - $Out(m_3, u) \wedge In2(a_2, v) \Rightarrow u = v$
  - $Out(m_1, u) \wedge In1(m_3, v) \Rightarrow u = v$

Observations

- *OBS* is a set of atomic sentences
- each atomic sentence represents an observation



- $In1(m_1, 3), In2(m_1, 2)$
- $In1(m_2, 2), In2(m_2, 3)$
- $In1(m_3, 2), In2(m_3, 3)$
- $Out(a_1, 10), Out(a_2, 12)$

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State

- A state of the system $(SD, COMP)$ is an Ab-clause Φ_Δ where $\Delta \subseteq COMP$ defined by:

$$\bigwedge_{c \in COMP \setminus \Delta} (\neg Ab(c)) \wedge \bigwedge_{c \in \Delta} (Ab(c))$$

- The components in Δ have an abnormal behavior (they are faulty)

- $\Delta = \{a_1, a_2\}$
  - $Ab(a_1) \wedge Ab(a_2) \wedge \neg Ab(m_1) \wedge \neg Ab(m_2) \wedge \neg Ab(m_3)$
- $\Delta = \{\}$
  - $\neg Ab(a_1) \wedge \neg Ab(a_2) \wedge \neg Ab(m_1) \wedge \neg Ab(m_2) \wedge \neg Ab(m_3)$
- $\Delta = \{a_1, a_2, m_1, m_2, m_3\}$
  - $Ab(a_1) \wedge Ab(a_2) \wedge Ab(m_1) \wedge Ab(m_2) \wedge Ab(m_3)$

Definition of diagnosis

- A diagnosis of the observed system $(COMP, SD, OBS)$ is a state Φ_Δ such that

$$SD \wedge OBS \wedge \Phi_\Delta$$

  is satisfiable (consistent)

- The state is possible according to $(SD, COMP, OBS)$

- A diagnosis exists if

$$SD \wedge OBS$$

  is satisfiable. If not, the model is either not well-designed or incomplete

Abnormal observations

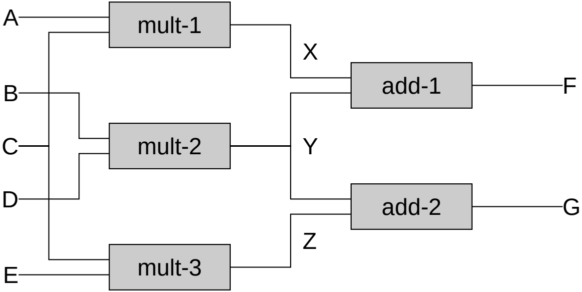
- The observations are abnormal if

$$SD \wedge OBS \wedge \Phi_{\{\}}$$

is not satisfiable

Example

How many diagnoses can you find in this example?



Observations

$In1(m_1, 3)$, $In2(m_1, 2)$, $In1(m_2, 2)$, $In2(m_2, 3)$
$In1(m_3, 2)$, $In2(m_3, 3)$, $Out(a_1, 10)$, $Out(a_2, 12)$