MEDITO
a logic-based meta-diagnosis tool

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1. Can we trust model-based diagnosis?

2. A theory of meta-diagnosis

3. Some diagnostic system’s potential abnormalities

4. MEDITO: a logic-based meta-diagnosis tool

5. Meta-diagnosing an Airbus Landing Gear Extraction and Retraction System (LGERS)

6. Conclusions
Can we trust model-based diagnosis (MBD)?
Model-based diagnosis

(Reiter, 1987)
(de Kleer & Williams, 1987)
Model-based diagnosis

Structure of information ($\Psi$)

Real system

Reiter, 1987

de Kleer & Williams, 1987
Definition (Believed System) A believed system is a pair $\langle DS, COMPS \rangle$ where:

1. $DS$, the system description is a set of first order sentences.
2. $COMPS$, is a finite set of constants representing the real-world system physical units to diagnose.
Definition (Observations) The set of observations, OBS, is a set of finite first order sentences.
Definition (Health state) Let $\Delta$ be a set of components considered abnormal. The health state of a believed system, $\sigma(\Delta, \text{COMPS}\setminus\Delta)$, is:

$$\land_{c \in \Delta} \text{Ab}(c) \land_{c \notin \text{COMPS}\setminus\Delta} \neg\text{Ab}(c)$$
Model-based diagnosis

(Reiter, 1987)
(de Kleer & Williams, 1987)

Structure of information ($\Psi$)

Diagnostic Algorithm ($A$)

Observations ($OBS$)

System Description ($SD$)

Definition (Diagnosis) A diagnosis $D$, for the diagnostic problem ($DS, COMPS, OBS$) is the set of all diagnosis hypotheses $\sigma$ such that:

$SD \cup OBS \cup \sigma$

Is satisfiable.

Real system
Can we trust MBD?

Structure of information ($\Psi$)

Diagnostic Algorithm ($A$)

Observations ($OBS$)

System Description ($SD$)

Real system

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MEDITO: a logic-based meta-diagnosis tool
Possible Abnormalities

Structure of information ($\Psi'$)

Observations ($OBS$)

System Description ($SD$)

Diagnostic Algorithm ($A$)

Real system

Example (Davis, 1984)

A : \{A1\}, \{M3\}, \{M1,M2\}, \{A1,M2\}

M1desc: \neg \text{Ab}(M1) \Rightarrow (v(x) = (v(a) + 1) \times v(c))

M2desc: \neg \text{Ab}(M2) \Rightarrow (v(y) = v(b) \times v(d))

M3desc: \neg \text{Ab}(M3) \Rightarrow (v(z) = v(c) \times v(e))

A1desc: \neg \text{Ab}(A1) \Rightarrow (v(f) = v(x) + v(y))

A2desc: \neg \text{Ab}(A2) \Rightarrow (v(g) = v(y) + v(z))

Ob1: v(a) = 1 \land v(b) = 2 \land v(c) = 3 \land v(d) = 4 \land v(e) = 5 \land v(f) = 11 \land v(g) = 22

S

D

Real

M1

M2

M3

x

y

z

f

g

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MEDITO: a logic-based meta-diagnosis tool
A theory of meta-diagnosis
Characterising meta-diagnoses

(Belard, Pencolé & Combacau, 2011)
Characterising meta-diagnoses

(Belard, Pencolé & Combacau, 2011)

Diagnostic System: (SD, COMPS, OBS, A)

Structure of information ($\Psi'$)

Observations (OBS)  Diagnostic Algorithm (A)  System Description (SD)

Characterising meta-diagnoses (Belard, Pencolé & Combacau, 2011)

Meta-system description (M-SD)

Structure of information ($\Psi$)

Definition (Meta-System Description)
The meta-system description is a pair (M-SD, M-COMPS) where:
1. **M-SD**, the meta-system description, is a set of first order sentences.
2. **M-COMPS**, is a finite set of constants representing the meta-components of the diagnostic system.

Diagnostic System: (SD, COMPS, OBS, A)
Diagnostic System: (SD, COMPS, OBS, A)

Meta-observations (M-OBS)

Meta-system description (M-SD)

Structure of information (Ψ)

Definition (Meta-Observations)
The set of meta-observations, M-OBS, is a finite set of first order sentences.
Definition (Meta-health state) Let $\Phi$ be a set of meta-components considered abnormal. The meta-health state $\pi(\Phi,M-COMPS\setminus\Phi)$ is the conjunction:

$$\forall mc \in \Phi \ M-Ab(mc) \land \forall mc \in (M-COMPS\setminus\Phi) \neg M-Ab(mc)$$
Definition (Meta-Diagnosis) A meta-diagnosis, $M-D$, for the meta-diagnostic problem $(M-SD,M-COMPS,M-OBS)$ is the set of all meta-diagnosis hypotheses $\pi$ such that:

$$M-SD \cup M-OBS \cup \pi$$

Is satisfiable.
M-A: {M1desc}, {M2desc}, {A1desc}

\[
\neg M \rightarrow \neg Ab(M1) \Rightarrow (v(x) = (v(a)+1)*v(c))
\]

\[
\neg M \rightarrow \neg Ab(M2) \Rightarrow (v(y) = v(b) * v(d))
\]

\[
\neg M \rightarrow \neg Ab(M3) \Rightarrow (v(z) = v(c) * v(e))
\]

\[
\neg M \rightarrow \neg Ab(A1) \Rightarrow (v(f) = v(x) + v(y))
\]

\[
\neg M \rightarrow \neg Ab(A2) \Rightarrow (v(g) = v(y) + v(z))
\]

\[
\neg M \rightarrow \neg Ab(A1desc) \land \neg Ab(A2desc) \land \neg Ab(M3desc) \land \neg Ab(M2) \land \neg Ab(M1)
\]

\[
v(a)=1 \land v(b)=2 \land v(c)=3 \land v(d)=4
\]

\[
\land v(e)=5 \land v(f)=11 \land v(g)=22
\]

\[
\neg Ab(M1) \land \neg Ab(M2) \land \neg Ab(M3) \land \neg Ab(A1) \land Ab(A2)
\]

Diagnosis and Meta-Diagnosis are semantically different, but syntactically the same. Therefore, diagnostic-world techniques, algorithms and tools can be directly used in meta-diagnosis.
Some diagnostic systems’ potential abnormalities
Definition (Truth): Let \( \Omega \) be the set of all structures and \( \Psi \in \Omega \) the structure of raw information about the reality. The observations OBS are an ontological truth iff'

\[ \exists_{s \in \text{Mod(OBS)}} \exists_{t \in \Omega}: (s \subseteq t) \land (t \prec \Psi). \]
**Definition (Truth):** Let $\Omega$ be the set of all structures and $\Psi \in \Omega$ the structure of raw information about the reality. The observations OBS are an ontological truth iff

$$\exists s \in \text{Mod}(\text{OBS}) \exists t \in \Omega : (s \subseteq t) \land (t \not< \Psi).$$

**Definition (Truth):** Let $\Omega$ be the set of all structures and $\Psi \in \Omega$ the structure of raw information about the reality. A believed system is an ontological truth iff, for all ontologically true OBS,

$$\exists s \in \text{Mod}(\text{OBSUSD}) \exists t \in \Omega : (s \subseteq t) \land (t \not< \Psi).$$
Definition (Truth): Let $\Omega$ be the set of all structures and $\Psi \in \Omega$ the structure of raw information about the reality. The observations OBS are an ontological truth iff

$$\exists s \in \text{Mod(OBS)} \forall t \in \Omega: (s \subseteq t) \land (t \leftrightarrow \Psi).$$

Definition (validity): Let $\sigma_{\text{real}}$ be the believed system health state such that for every $c \in \text{COMPS}$, if $c$ is the image of $r \in \mathbb{R}$, 1) if $r$ is normal, $\sigma_{\text{real}} \Rightarrow \neg \text{Ab}(c)$, and 2) if $r$ is abnormal $\sigma_{\text{real}} \Rightarrow \text{Ab}(c)$. A diagnosis, $D$, is valid iff $\sigma_{\text{real}} \in D$. 

Definition (truth): Let $\Omega$ be the set of all structures and $\Psi \in \Omega$ the structure of raw information about the reality. A believed system is an ontological truth iff, for all ontologically true OBS,

$$\exists s \in \text{Mod(OBSUSD)} \forall t \in \Omega: (s \subseteq t) \land (t \leftrightarrow \Psi).$$
**Theorem:** If (SD,COMPS) is an ontologically true believed system, then for every diagnostic problem (SD, COMPS,OBS) with ontologically true observations, every diagnosis D is valid.
MEDITO: a logic-based meta-diagnosis tool
MEDITO: a logic-based meta-diagnosis tool architecture
Data injection
Data injection

MEDITO: a logic-based meta-diagnosis tool
Data injection

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1. System manager
   - Set system components and observables
   - Set system description

2. Diagram showing the workflow of MEDITO: a logic-based meta-diagnosis tool.
Data exploitation
Data exploitation

MEDITO: a logic-based meta-diagnosis tool
Data exploitation

1. Parsing of user-input text SD and M-OBS into java objects.
Data exploitation

1. Parsing of user-input text SD and M-OBS into java objects.

2. Creation of CHOCO model depending on user-input hypotheses. (Choco Team, 2010)
Data exploitation

1. Parsing of user-input text SD and M-OBS into java objects.

2. Creation of CHOCO model depending on user-input hypotheses.
   (Choco Team, 2010)

3. Running of Zhao and Ouyang diagnostic algorithms using CHOCO for consistency checking.
   (Zhao & Ouyang, 2006)
   (Zhao & Ouyang, 2007)

MEDITO: a logic-based meta-diagnosis tool

11/3/2011
1. Parsing of user-input text SD and M-OBS into Java objects.

2. Creation of CHOCO model depending on user-input hypotheses. (Choco Team, 2010)


Data exploitation
Meta-diagnosing an Airbus LGERS
The real-world system (Airbus)

CPIOM W
CPIOM X

RDC A

RDC B

RDC C

RDC D

CPIOM Y
CPIOM Z

AFDX Network

Sensors

NLG / WLG / BLG
Actuators

EPDC 1

EPDC 2

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MEDITO: a logic-based meta-diagnosis tool
For confidentiality issues, the believed system (BS) in this slide is not a perfect copy of Airbus’ LGERS BS (roughly with 6000 nodes)
For confidentiality issues, the situations presented in this slide, although representative, are not Airbus’ real-life situations.
Situation 1

CMS

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus’ real-life situations.
Situation 1

CMS

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Line mechanic

LGERSCTL1+2FAULT = \( \perp \)

LGERSCTL1FAULT = \( T \)

LGERSCTL2FAULT = \( \perp \)
For confidentiality issues, the situations presented in this slide, although representative, are not Airbus’ real-life situations.

**Situation 1**

- LGERSCTL1+2FAULT = \( \perp \)
- LGERSCTL1FAULT = \( T \)
- LGERSCTL2FAULT = \( \perp \)

**CMS**

- \( \neg Ab(CPIOMZ) \)
- \( \neg Ab(SoftCPIOMXCOM) \)
- \( Ab(CPIOMW) \)
- \( \neg Ab(CPIOMX) \)

**Line mechanic**

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Situation 2

CMS

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus’ real-life situations.

Situation 1

Situation 2

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus’ real-life situations.

CMS

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CMS

For confidentiality issues, the situations presented in this slide, although representative, are not Airbus’ real-life situations.

CMS
Meta-diagnoses

MEDITO: a logic-based meta-diagnosis tool
Where SD-sentence4 is:

\[ \text{Ab(CPIOMX)} \lor \text{Ab(SoftCPIOMXCOM)} \iff [\text{LossCOM1AFDXDataFromXtoW=\text{T}}] \]
Where SD-sentence4 is:

\[
\text{Ab}(\text{CPIOMX}) \lor \text{Ab}(\text{SoftCPIOMXCOM}) \iff [\text{LossCOM1AFDXDataFromXtoW}=T]
\]
Where SD-sentence4 is:

\[ \text{Ab(CPIOMX)} \lor \text{Ab(SoftCPIOMXCOM)} \iff [\text{LossCOM1AFDXDataFromXtoW=T}] \]

Engineers later determined that lack of preconditions \( \text{Ab(CPIOMW)} \lor \text{Ab(SoftCPIOMWCOM)} \) explained the SD-sentence 4 abnormality.
Conclusions
1. The theory of meta-diagnosis provides a formal framework for detecting and isolating abnormalities in diagnostic systems.

2. MEDITO provides empirical proof supporting meta-diagnosis claim that any sound and complete diagnostic algorithm can be used to solve a meta-diagnostic problem.

3. The usage of MEDITO for treating an Airbus problem supports the usage of meta-diagnosis in real-world problems.

4. Meta-diagnosis inherits from diagnosis complexity problems. This is why we plan, in future works, on using classical Model-Based Diagnosis complexity management techniques such as hierarchical approaches.
Thank you for your attention


