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Relaxed Abduction – Robust Information Interpretation for Industrial Applications

Dissertation Presentation

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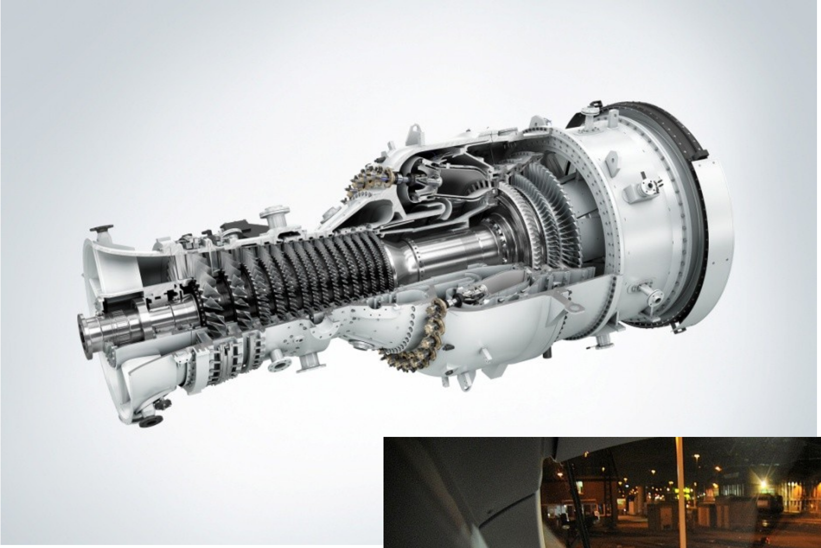
Presentation outline

- Motivation
- Background and target
- Relaxed abduction
- Conclusion and outlook

Interpretation for automated diagnostics



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Relation to model-based diagnosis

Model-based diagnosis (DeKleer, 2003) and qualitative reasoning (Struss, 1997)

- Complex and detailed physical models
- High accuracy in principle
- Low coverage in practice (effort)

Proposed approach

- Automated “first level support” for majority of easy cases
- Allow engineer to focus on long tail of hard cases where their expertise is really needed
- Save time and cost

Requirements to a solution

(R1) (Moderate) Expressiveness

(R2) Robustness w.r.t. incomplete observations

(R3) Robustness w.r.t. imperfect domain formalizations

(R4) Optimality of solutions

(R5) Coverage of solution space

Technical diagnosis formalized

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domain knowledge → [H., Grimm, Lamparter, 2012] → knowledge base $\mathcal{K}$

application problem → [H., Lamparter, Pirker, 2011] → (formally defined) computational problem

application problem - - - ? - - -> application solution

knowledge base $\mathcal{K}$, Observations $\mathcal{O}$ → (formally defined) computational problem → [H., Lamparter, Pirker, 2010] → computational solution

computational solution = [H., Legat, Seitz, 2011] → application solution

Relaxed Abduction + 2-dimensional preference

$\mathcal{K} = \{ \varphi \rightarrow \omega \}$

find Δ

~~s.t. $\mathcal{K} \cup \Delta \models \mathcal{O}$~~

s.t. $\mathcal{K} \cup \Delta \models \omega\theta \subseteq \mathcal{O}$

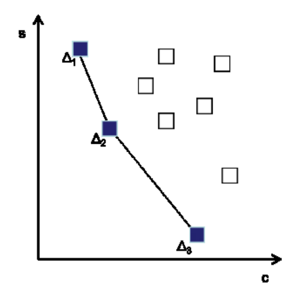
(here: $\Delta = \{\varphi\theta\}$)

simplicity: minimize Δ

consilience: maximize ω (goal: $\omega = \mathcal{O}$)

! more assumptions: simplicity ↓ / consilience ↑

⇒ cannot be combined into a single measure!



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A simplified example

domain knowledge (incomplete)

- production system with MCU, gripper, conveyor, PROFINET bus
- minor power fluctuations affect MCU
- MCU SW error affects all components

knowledge base (excerpt)

$\mathcal{K}$

- $\texttt{MCU} \sqsubseteq \exists\, \texttt{partOf}\,.\,\texttt{System}$
- $\texttt{MCU} \sqcap \exists\, \texttt{partOf}\,.\,(\exists\, \texttt{hasDiag}.\,\texttt{PowerFluct}) \sqsubseteq \exists\, \texttt{shows}\,.\,\texttt{IntOutage}$

$\mathcal{A}$

- $\texttt{System} \sqsubseteq \exists\, \texttt{hasDiag}\,.\,\texttt{PowerFluct}$
- $\texttt{System} \sqsubseteq \exists\, \texttt{hasDiag}\,.\,\texttt{SWError}$

application problem

- diagnose system
- observed symptoms: MCU outages , gripper functional, <u>conveyor vibrations</u>.

computational problem

RAP = ($\mathcal{K}$, $\mathcal{A}$, $\mathcal{O}$, ⊆, ⊇), with $\mathcal{O}$ =

- $\texttt{MCU} \sqsubseteq \exists\, \texttt{shows}\,.\,\texttt{IntOutage}$
- $\texttt{Gripper} \sqsubseteq \exists\, \texttt{shows}\,.\,\texttt{OK}$
- $\texttt{Conveyor} \sqsubseteq \exists\, \texttt{shows}\,.\,\texttt{Vibration}$

computational solutions

- A_1={$\texttt{System} \sqsubseteq \exists\, \texttt{hasDiag}\,.\,\texttt{PowerFluct}$ },
  O_1={$\texttt{MCU} \sqsubseteq \exists\, \texttt{shows}\,.\,\texttt{IntOutage}$, $\texttt{Gripper} \sqsubseteq \exists\, \texttt{shows}\,.\,\texttt{OK}$ }
- A_2={$\texttt{System} \sqsubseteq \exists\, \texttt{hasDiag}\,.\,\texttt{SWError}$},
  O_2={$\texttt{MCU} \sqsubseteq \exists\, \texttt{shows}\,.\,\texttt{IntOutage}$ }

Properties and scientific relevance

declaratively defined
computational problem
(instead of engine)

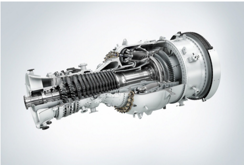
provable properties
- soundness
- completeness
- optimality
- runtime

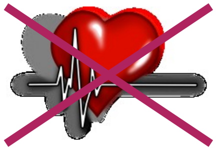
$\cong$

empirical results
- computational problem does solve application problem
- runtime

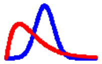
technical diagnostics of production systems

application to other domains





interpretation of data / "data science"



measurements → symbolic features

=

RAP

symptoms → high-level interpretations

[Espinosa, Kaya, Möller, 2011]

What could not be addressed here…

Thesis contents not mentioned in the talk

- **Alternative use case:** Relaxed abduction an also be used for **debugging of rule bases**.
- **Different instantiations:** The thesis describes effects of various preference orders on runtime, and how **safe pruning** must be applied to retain the complete set of solutions.
- **Expressiveness**: The **algorithmic approach can be extended** straightforwardly to other DLs such as **$\mathcal{EL}$++** and **Horn-SHIQ** by adding **new completion rules** for, introducing **nogoods** , and extending the maps R, S.
- **Incrementality**: For $\mathcal{EL}$+ (and $\mathcal{EL}$++), **axiom additions and retractions to T, A and O can be processed incrementally**, alleviating the need for a full re-computation. The required algorithmic extensions are described in the thesis.
- **Generality**: Relaxed abduction can **simulate a number of other abduction frameworks** including standard abduction, preferential abduction, concept-based abduction and subsumption-based abduction. It is shown to be **similar to ATMS**, yet providing more expressiveness on the logical layer.

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Thank you for your attention!

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