Intelligent Techniques for Configuration Knowledge Evolution

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Overview

• Configuration Models as CSP
• Testing & Debugging of Configuration Models
• Testing & Debugging with Faulty Test Cases
• Related Work: Short History of Diagnosis Algorithms
• Ranking Heuristics for Diagnosis Discrimination
• Future Work & Conclusions
Configuration Models as CSP

\[
\begin{align*}
V &= \{wr, ip, rr\} \\
C &= \{c_1, c_2, c_3, c_4, c_5\} \\
T &= \{t_1, t_2, t_3, t_4\} \\
dom(wr) &= \{\text{low, medium, high}\} \\
dom(ip) &= \{\text{shortterm, mediumterm, longterm}\} \\
dom(rr) &= \{3 - 6\%, 6 - 9\%, > 9\%\} \\
\end{align*}
\]

\[
\begin{align*}
c_1 &: wr = \text{medium} \rightarrow ip \neq \text{shortterm} \\
c_2 &: wr = \text{high} \rightarrow ip = \text{longterm} \\
c_3 &: ip = \text{longterm} \rightarrow (rr = 3 - 6\% \lor rr = 6 - 9\%) \\
c_4 &: rr = > 9\% \rightarrow wr = \text{high} \\
c_5 &: rr = 6 - 9\% \rightarrow (wr \neq \text{low} \land wr \neq \text{medium}) \\
\end{align*}
\]

\[
\begin{align*}
t_1 &: wr = \text{high} \land rr = > 9\% \\
t_2 &: rr = 6 - 9\% \land wr = \text{medium} \\
t_3 &: ip = \text{shortterm} \land wr = \text{medium} \\
t_4 &: wr = \text{high} \land ip = \text{mediumterm} \\
\end{align*}
\]

**Test Cases (T):** specify intended behavior of the knowledge base (concepts easy to extend with negative test cases).
Testing & Debugging with Faulty Test Cases


\[
\text{Diagnoses } (\Delta_i) \quad \text{Constraints } (C)
\]

- **Conflict Set** \( CS \subseteq C \cup \{t_j\}: \text{inconsistent}(CS) \)
- **Diagnosis** \( \Delta \subseteq C \cup T: \text{consistent } (C - \Delta \cup \{t_j\}) \forall t_j \in T - \Delta \)

Test Cases \( (T) \) [assumption: could be faulty]

\[t1\]
\[c1 \quad c2 \quad c3 \quad c4 \quad c5 \quad ck\]
\[t3\]
Determination of hitting sets (diagnoses) for inconsistent CSPs

Testing and debugging inconsistent configuration knowledge bases

Direct diagnoses for inconsistent CSPs (efficient algorithm: FastDiag)

Inclusion of recommender algorithms for diagnosis prediction

Extensions for FastDiag, implementation on the basis of SAT Solvers

Preferred diagnoses for explaining anomalies in feature models
Breadth-First Diagnosis Search (Standard)

Conflict Sets:
\{c1,c3\}
\{c4,c5\}

Breadth-First Diagnosis Search with Faulty Test Cases

Conflict Sets:
\{c1,c3,t1\}
\{c4,c5,t3\}

Ranking of Diagnoses (Best First)

Conflict Sets:
\{c1,c3,t1\}
\{c3,c5,t3\}

Diagnosis \(\Delta_1\)

\[
\text{relevance}(\Delta) = \frac{1}{\text{cardinality}(\Delta)}
\]
Ranking of Diagnoses (Rating-Based)

Conflict Sets:
\{c1,c3,t1\}
\{c3,c5,t3\}

c1, t3 [0.33]
c1, c3 [0.22]
c1, c5 [0.2]

c1 [1.0]
c3 [0.28]
t1 [1/4.5 = 0.22]

Diagnosis \( \Delta_1 \)

\[ relevance(\Delta) = \frac{1}{\sum_{x \in \Delta} \text{rating}(x)} \]

Element | Avg. Rating
---|---
c1 | 1.0
c3 | 3.5
c5 | 4.0
t1 | 4.5
t3 | 2.0
Overview of Heuristic Functions for Diagnosis Discrimination

- Minimal Cardinality
  \[ relevance(\Delta) = \frac{1}{\text{cardinality}(\Delta)} \]

- Actuality-Guided
  \[ \text{actuality}(x) = \frac{1}{\text{time since last user access}(x) + 1} \]

- Rating-Guided
  \[ relevance(\Delta) = \frac{1}{\sum_{x \in \Delta} \text{rating}(x)} \]

- Utility-Guided
  \[ \text{utility}(x) = \frac{\sum_{d \in \text{Dimensions}} \text{val}(x, d)}{|\text{Dimensions}|} \]

- Ensemble-Guided
  \[ relevance(\Delta) = \sum_{r \in \text{Occurrences}(\Delta, r)} \times \text{rankutility}(r) \]
Future Work

- Development of further ranking heuristics
- Long-term studies in industrial projects
- Complexity metrics for diagnosis discrimination
- Integration into „Direct Diagnosis“ Algorithms
Conclusions

• Diagnosis is a **key technology for automated testing and debugging** of knowledge bases

• **Many approaches** exist (e.g., for determining basic, personalized, and direct diagnoses)

• **Low-quality test cases** are not taken into account

• **Integration of test cases in diagnosis processes** shown in this paper

• **Many issues for future work**
Knowledge-Based Configuration

The purpose of this book is to expose the reader to a field of Artificial Intelligence that has been successfully integrated and used in the industry for more than 30 years. It provides configuration-related material for interested readers from the fields of industry, education, and research.

www.configurationbook.org
Thank You!