



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

$$V = \{wr, ip, rr\}$$

$$C = \{c_1, c_2, c_3, c_4, c_5\}$$

$$T = \{t_1, t_2, t_3, t_4\}$$

$$dom(wr) = \{low, medium, high\}$$

$$dom(ip) = \{shortterm, mediumterm, longterm\}$$

$$dom(rr) = \{3 - 6\%, 6 - 9\%, > 9\%\}$$

$$c_1 : wr = medium \rightarrow ip \neq shortterm$$

$$c_2 : wr = high \rightarrow ip = longterm$$

$$c_3 : ip = longterm \rightarrow (rr = 3 - 6\% \vee rr = 6 - 9\%)$$

$$c_4 : rr = > 9\% \rightarrow wr = high$$

$$c_5 : rr = 6 - 9\% \rightarrow (wr \neq low \wedge wr \neq medium)$$

$$t_1 : wr = high \wedge rr = > 9\%$$

$$t_2 : rr = 6 - 9\% \wedge wr = medium$$

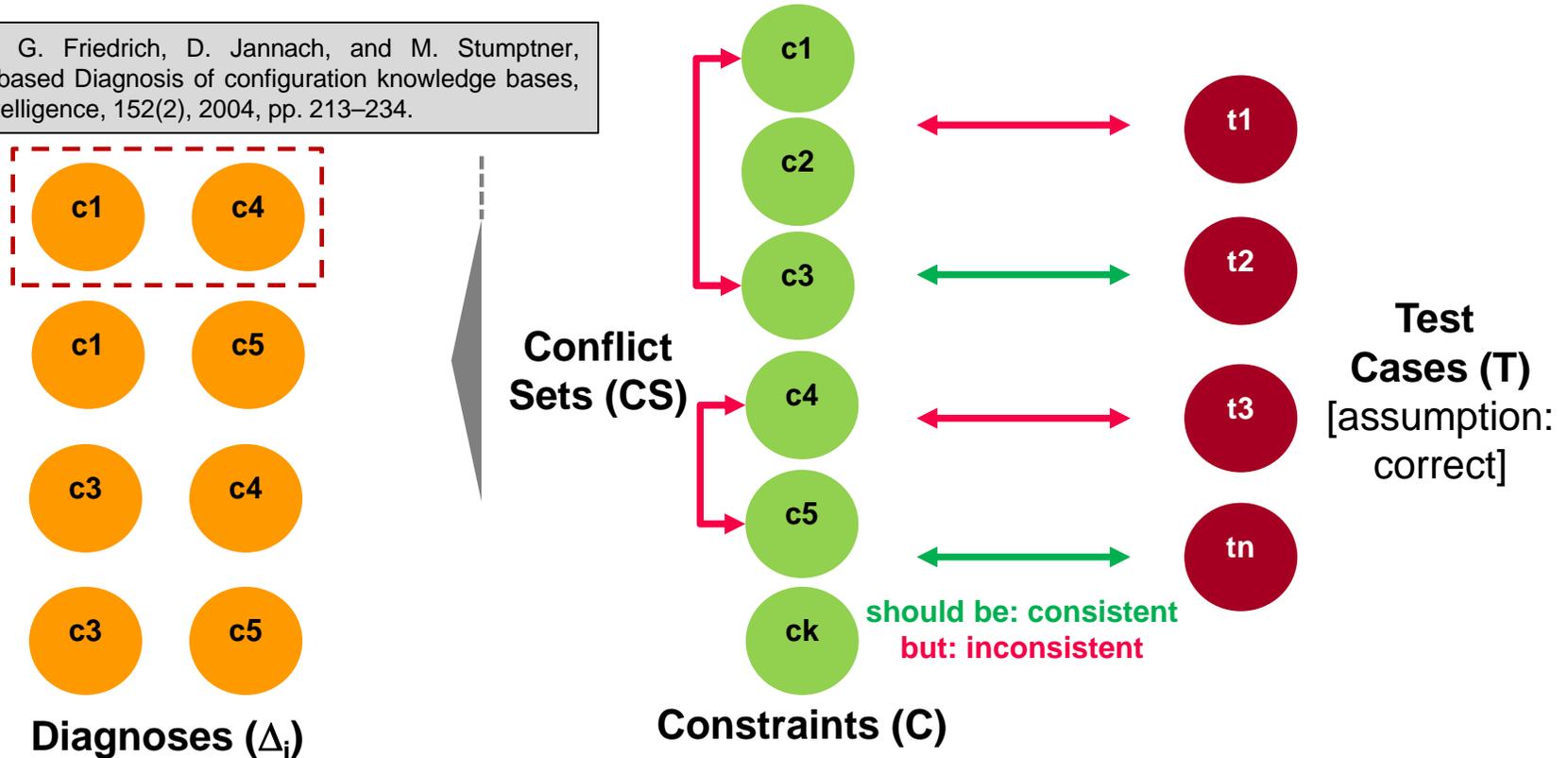
$$t_3 : ip = shortterm \wedge wr = medium$$

$$t_4 : wr = high \wedge ip = mediumterm$$

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

Configuration Models: Testing & Debugging

A. Felfernig, G. Friedrich, D. Jannach, and M. Stumptner, Consistency-based Diagnosis of configuration knowledge bases, in Artificial Intelligence, 152(2), 2004, pp. 213–234.

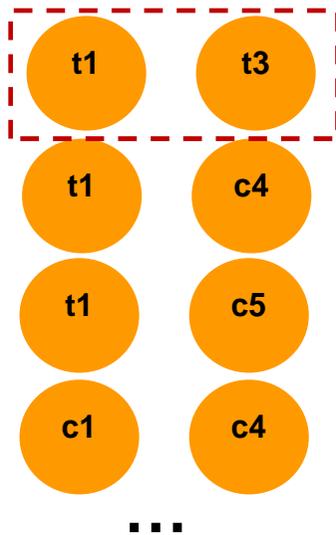


$$\text{Conflict Set } CS \subseteq C: \exists t_j \in T: \text{inconsistent}(CS \cup \{t_j\})$$

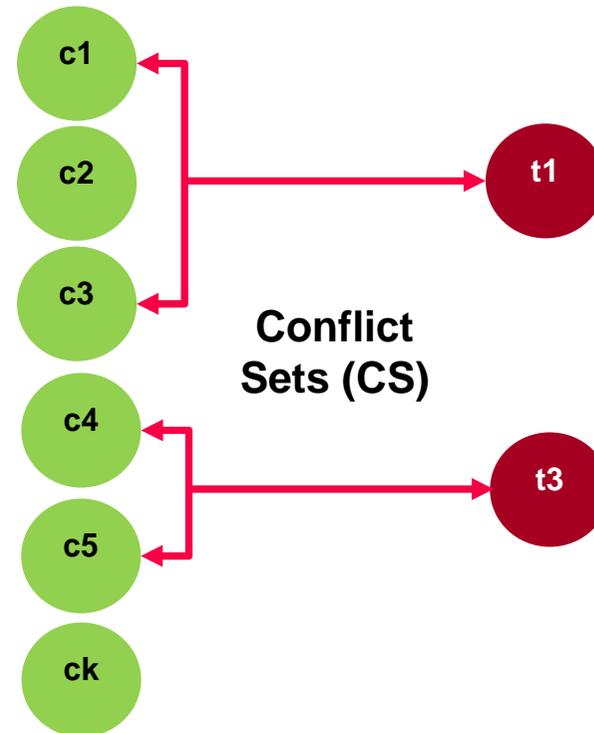
$$\text{Diagnosis } \Delta \subseteq C: \text{consistent}(C - \Delta \cup \{t_j\}) \forall t_j \in T$$

Testing & Debugging with Faulty Test Cases

A. Felfernig, S. Reiterer, M. Stettinger, and J. Tiihonen. Intelligent Techniques for Configuration Knowledge Evolution, Vamos 2015 Workshop, Hildesheim, Germany, 2015.



Diagnoses (Δ_i)



Constraints (C)

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

Conflict Set $CS \subseteq C \cup \{t_j\}$: inconsistent(CS)

Diagnosis $\Delta \subseteq C \cup T$: consistent $(C - \Delta \cup \{t_j\}) \forall t_j \in T - \Delta$

Related Work

Determination of hitting sets (diagnoses)
for inconsistent CSPs 

R. Bakker, F. Dikker, F. Tempelman, and P. Wogmim. Diagnosing and solving over-determined constraint satisfaction problems. **IJCAI'93**, Chambéry, France, **1993**, pp. 276–281.

Testing and debugging inconsistent
configuration knowledge bases 

A. Felfernig, G. Friedrich, D. Jannach, and M. Stumptner. Consistency-based Diagnosis of configuration knowledge bases, in **Artificial Intelligence**, 152(2):213–234, **2004**.

Direct diagnoses for inconsistent CSPs
(efficient algorithm: FastDiag) 

A. Felfernig, M. Schubert, and C. Zehentner. An Efficient Diagnosis Algorithm for Inconsistent Constraint Sets, *Artificial Intelligence for Engineering Design, Analysis, and Manufacturing (AIEDAM)*, Cambridge University Press, 26(1):53–62, **2012**.

Inclusion of recommender algorithms for
diagnosis prediction 

Felfernig, A., Schubert, M., Reiterer, S.: Personalized Diagnosis for Over-Constrained Problems. **IJCAI'13**, Peking, China, **2013**, pp. 1990–1996.

Extensions for FastDiag, implementation
on the basis of SAT Solvers 

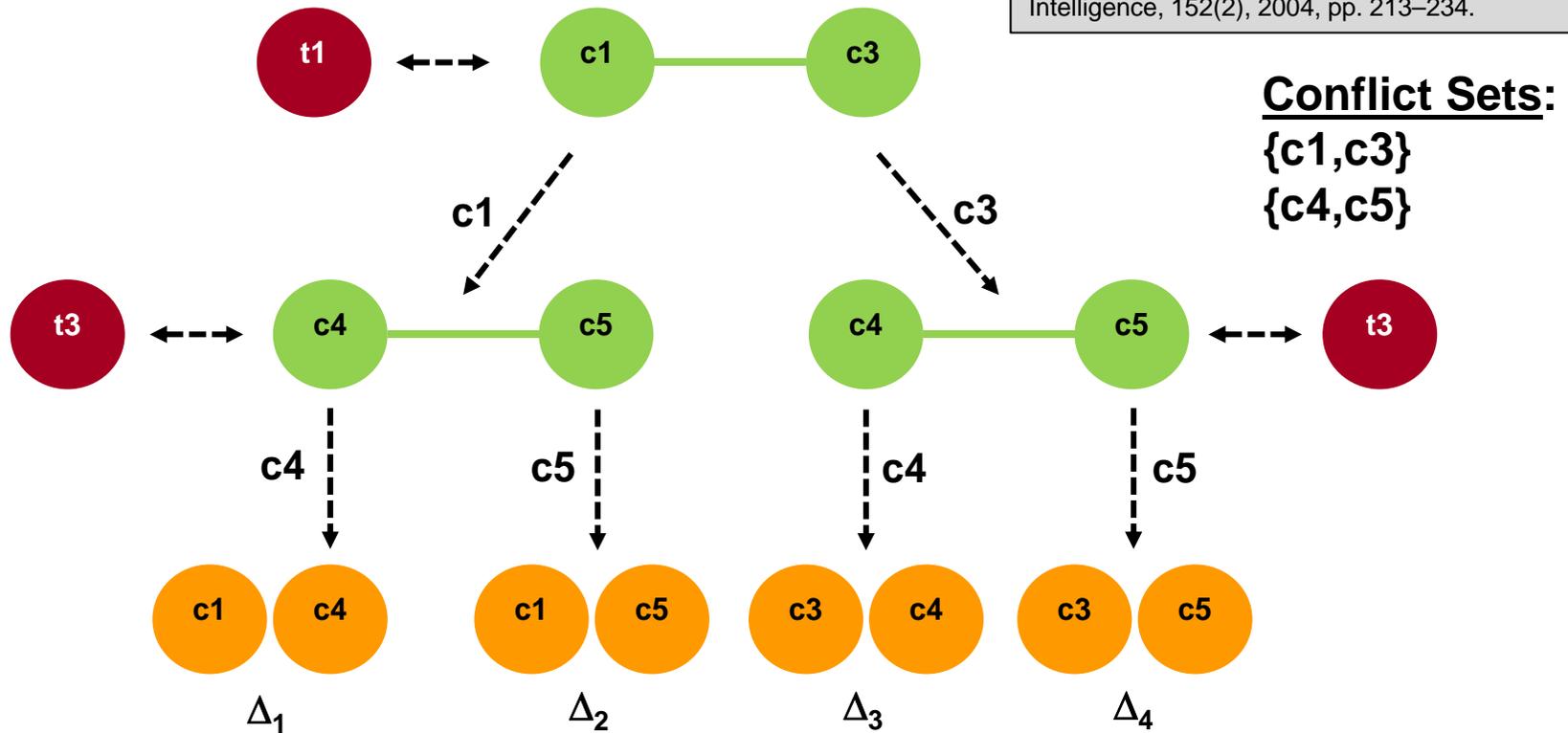
M. Janota A. Previti J. Marques-Silva, F. Heras and A. Belov. On computing minimal correction subsets. **IJCAI'13**, pp. 615–622, **2013**.

Preferred diagnoses for explaining
anomalies in feature models 

A. Felfernig, D. Benavides, J. Galindo, and F. Reinfrank. Towards Anomaly Explanation in Feature Models, **Workshop on Configuration**, Vienna, Austria, pp. 117-124, **2013**.

Breadth-First Diagnosis Search (Standard)

A. Felfernig, G. Friedrich, D. Jannach, and M. Stumptner, Consistency-based Diagnosis of configuration knowledge bases, in Artificial Intelligence, 152(2), 2004, pp. 213–234.



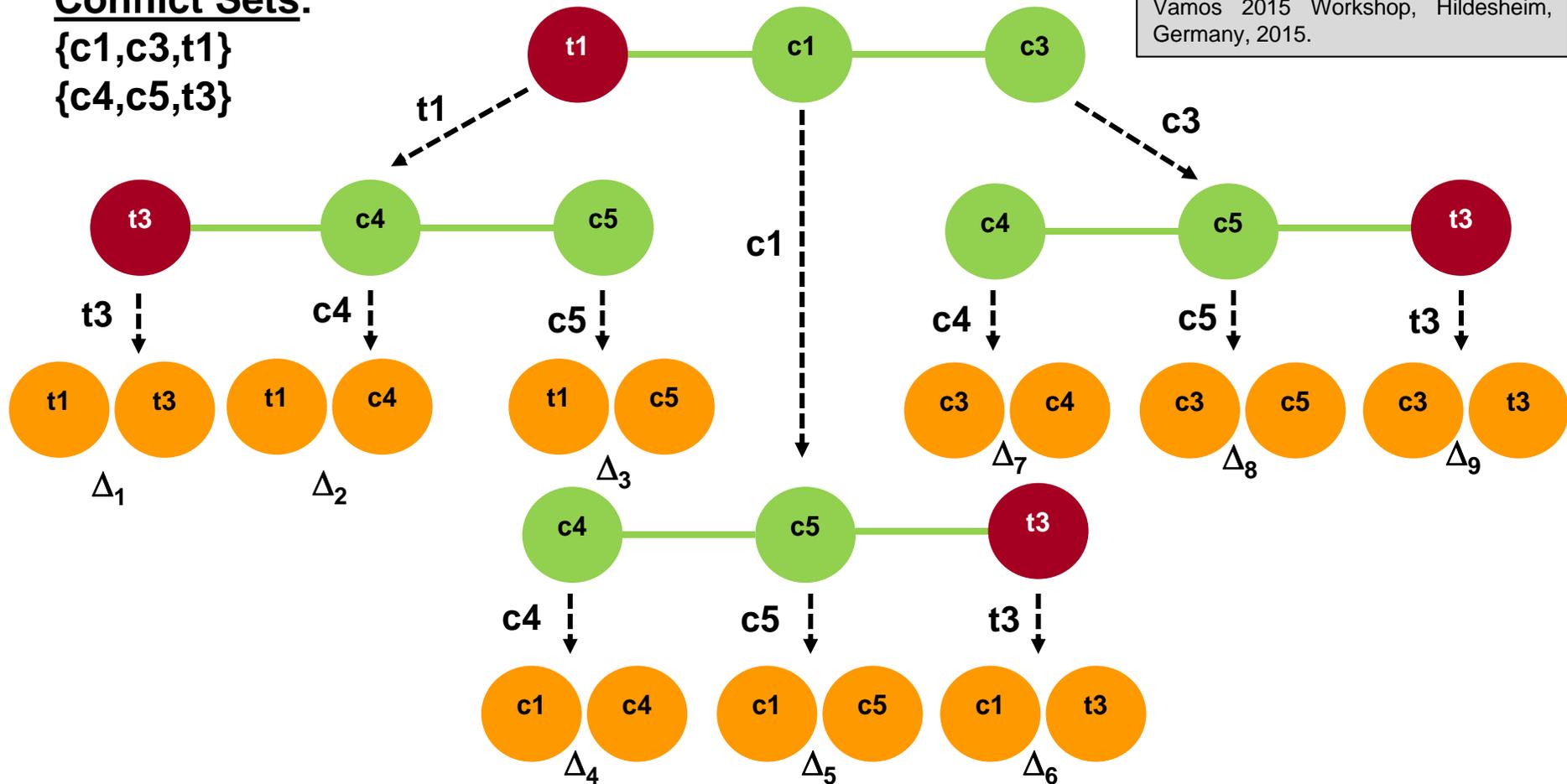
Breadth-First Diagnosis Search with Faulty Test Cases

A. Felfernig, S. Reiterer, M. Stettinger, and J. Tihonen. Intelligent Techniques for Configuration Knowledge Evolution, Vamos 2015 Workshop, Hildesheim, Germany, 2015.

Conflict Sets:

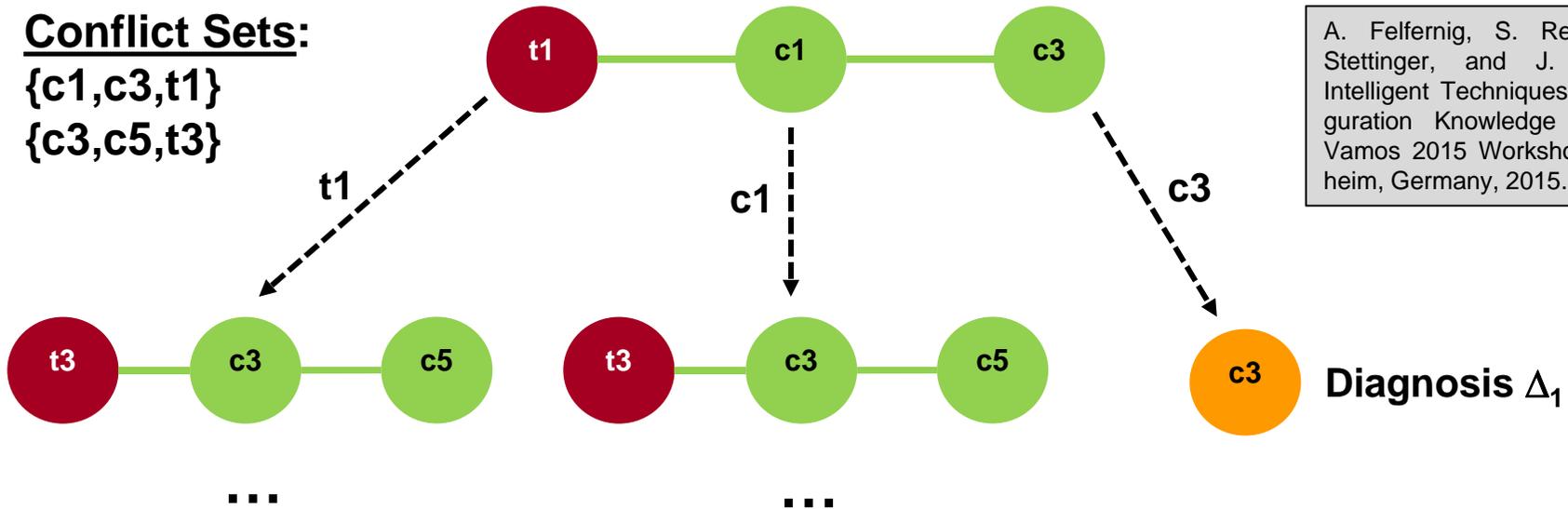
{c1,c3,t1}

{c4,c5,t3}



Ranking of Diagnoses (Best First)

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



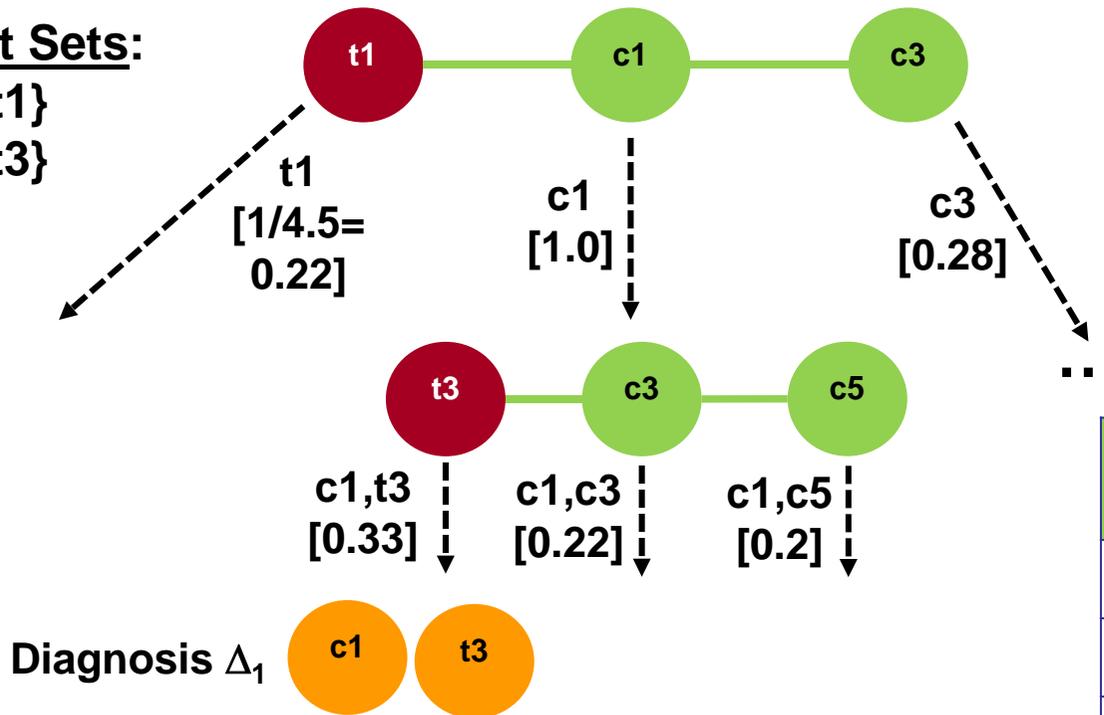
A. Felfernig, S. Reiterer, M. Stettinger, and J. Tiihonen. Intelligent Techniques for Configuration Knowledge Evolution, Vamos 2015 Workshop, Hildesheim, Germany, 2015.

$$relevance(\Delta) = \frac{1}{cardinality(\Delta)}$$

Ranking of Diagnoses (Rating-Based)

Conflict Sets:

- {c1,c3,t1}
- {c3,c5,t3}



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element	avg. rating [1..5]
c1	1.0
c3	3.5
c5	4.0
t1	4.5
t3	2.0

$$relevance(\Delta) = \frac{1}{\sum_{x \in \Delta} rating(x)}$$

Overview of Heuristic Functions for Diagnosis Discrimination

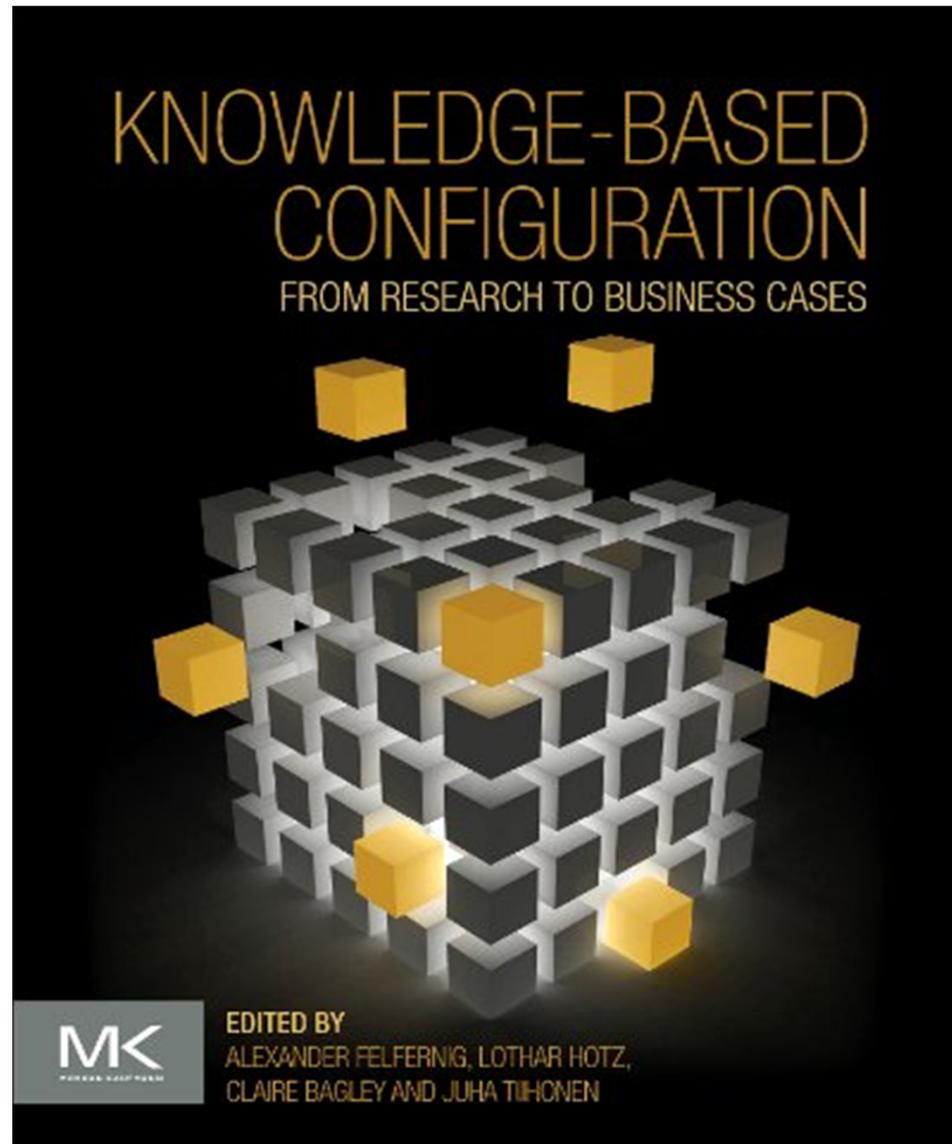
- Minimal Cardinality $relevance(\Delta) = \frac{1}{cardinality(\Delta)}$
- Actuality-Guided $actuality(x) = \frac{1}{time\ since\ last\ user\ access\ (x) + 1}$
- Rating-Guided $relevance(\Delta) = \frac{1}{\sum_{x \in \Delta} rating(x)}$
- Utility-Guided $utility(x) = \frac{\sum_{d \in Dimensions} val(x, d)}{|Dimensions|}$
- Ensemble-Guided $relevance(\Delta) = \sum_{r \in ROccurrences}(\Delta, r) \times rankutility(r)$

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
by: *A. Felfernig, L. Hotz, C. Bagley,*
and *J. Tiihonen.*

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



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