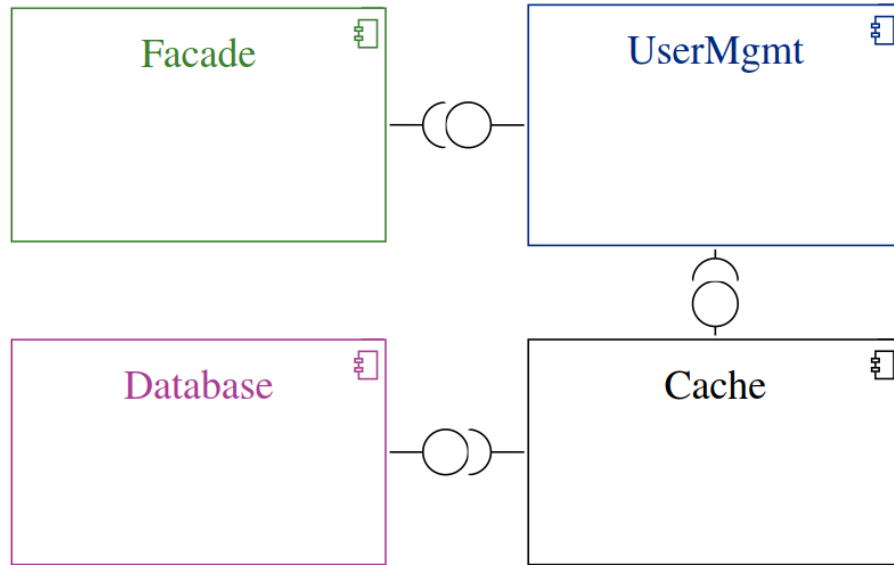# Detecting Inconsistencies in Software Architecture Documentation Using Traceability Link Recovery

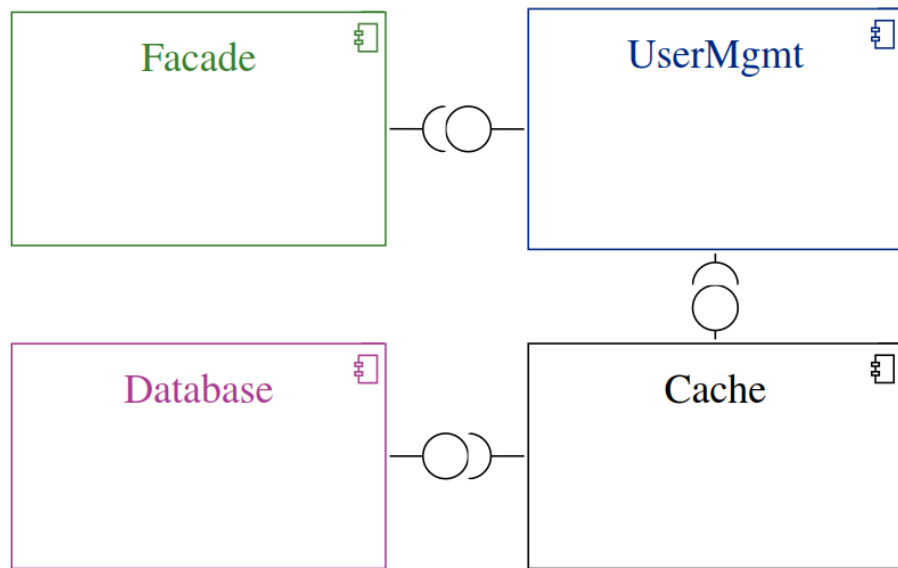**Jan Keim**, **Sophie Corallo, Dominik Fuchß, Anne Koziolek**
SE24 – Linz

Software Architecture Documentation (SAD)

1) The system adheres to layered architecture.

2) The Facade is the entry point to the service.

3) It passes calls to the user management.

4) The user management then accesses the DB.

5) The Common component contains utility functionality.

Connecting SADs with Traceability Link Recovery

using the TLR approach SWATTR [Keim2021]

1) The system adheres to layered architecture.

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Unmentioned Model Elements

1) The system adheres to layered architecture.

2) The Facade is the entry point to the service.

3) It passes calls to the user management.

4) The user management then accesses the DB.
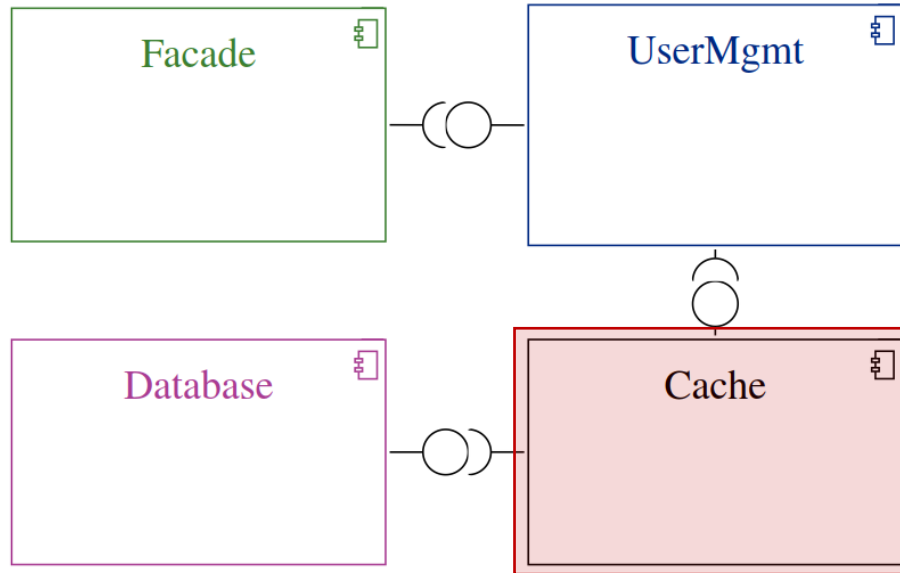
5) The Common component contains utility functionality.

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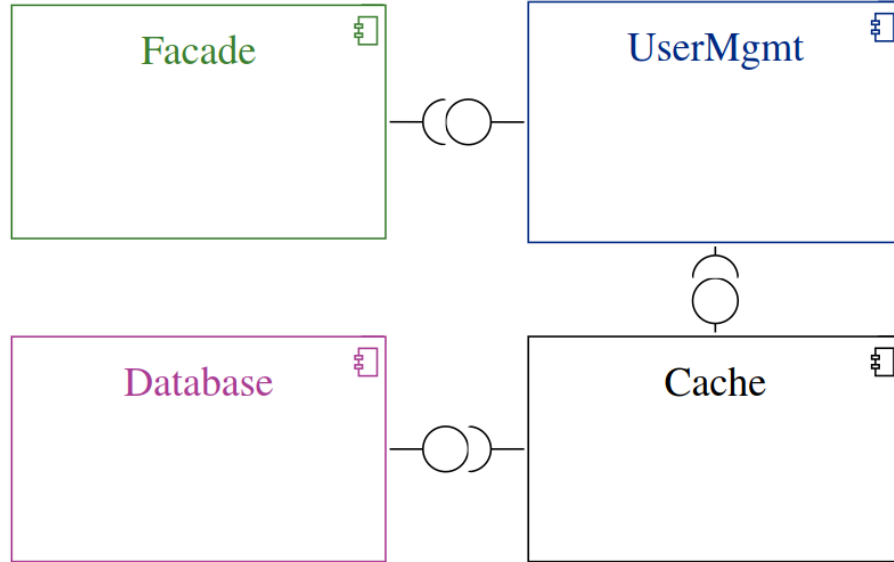KIT Department of Informatics

Missing Model Elements

1) The system adheres to layered architecture.

2) The Facade is the entry point to the service.

3) It passes calls to the user management.

4) The user management then accesses the DB.

5) The Common component contains utility functionality.

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Research Questions & Contributions

1) To what extent do changes to the previous approach SWATTR improve the performance for Traceability Link Recovery?
2) How does the approach perform for detecting unmentioned model elements?
3) How well does the approach detect missing model elements?

Contributions

1. Extending TLR and add capabilities to identify inconsistencies
2. Novel approach (ArDoCo) to identify inconsistencies
3. Replication package 👁️🤝

Related Work

- Inconsistency Detection between API/Code documentation and Code, e.g., Kim & Kim 2016
- Inconsistency Detection for requirements, e.g., Fantechi & Spinicci 2005, Kamalrudin et al. 2010
- Inconsistency Detection for Software Architecture, e.g., Lytra & Zdun 2014

→ No work looking at inconsistencies between natural language software architecture documentations and software architecture models

Background: SWATTR

Text Extraction → **Element Identification** → **Element Connection**

Model Extraction

Traceability Link Recovery

Architecture Doc.

Architecture Model

Trace Links

[Keim2021]

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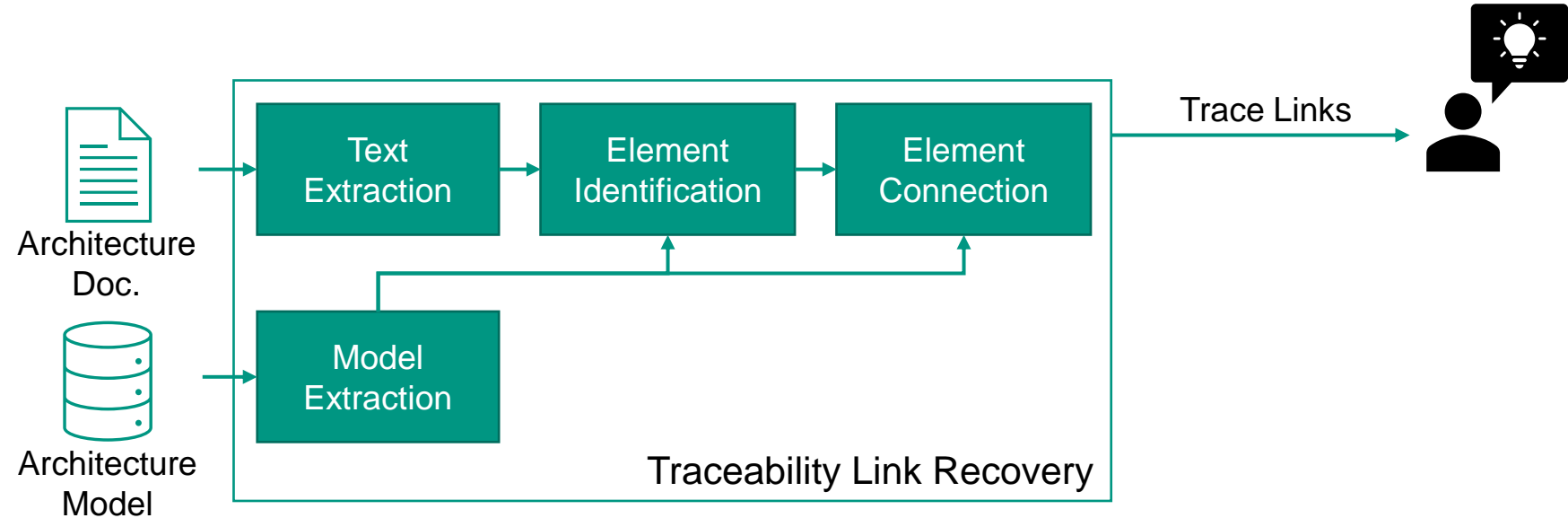
Our Approach

ArDoCo (Architecture Documentation Consistency)

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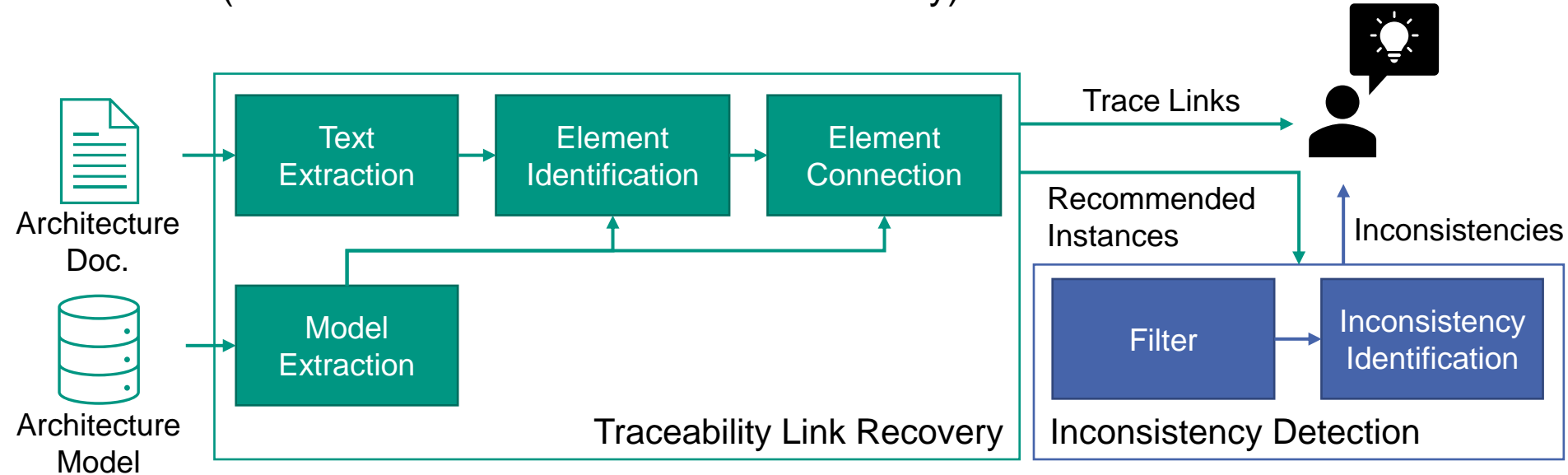
Detecting Unmentioned Model Elements

- Look for absent trace links for model elements (e.g., components)
- Each model element needs to have at least *one* trace link

- Configuration options to adjust to needs
  - Minimum number of needed trace links
  - Types of model elements that are checked (e.g., components, interfaces)
  - Regex-based whitelist

Detecting Missing Model Elements

- Make use of Recommended Instances (RIs) of SWATTR
→ RIs without a trace link are (potential) inconsistencies

- Problem: SWATTR detects many RIs to increase recall for TLR
- Therefore, filtering RIs based on
  - (dynamic) threshold regarding overall confidence
  - confidence for name and type of the RI
  - Number of occurrences
  - Unwanted words: general and project/domain-specific blacklists

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Evaluation Projects

Project	Language (kLOC)		Forks	Contributors
MediaStore (MS)	Java	4	-	-
TeaStore (TS)	Java	12	0.1k	~ 15
TEAMMATES (TM)	Java	91	2.6k	~ 500
	TypeScript	54		
BigBlueButton (BBB)	JavaScript	69	5.8k	~ 180
	JSX	47		
	Scala	22		
	Java	21		
JabRef (JR)	Java	157	2.0k	~ 490

Current and historic versions of documentation used

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Evaluation: Traceability Link Recovery

> RQ1: To what extent do changes to the previous approach SWATTR improve the performance for TLR?

- Goals
    - To measure how well we can link sentences that mention a certain model element to the model elements
    - To compare the results
- Process
    - Comparison with gold standard

- Metrics
    - Precision, Recall, F1 – Score
    - Accuracy, Specificity
    - Φ – Coefficient
    - Average, Weighted Average

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Evaluation: Comparing TLR results

- Baseline Approach
  - Assumption: Elements that should be linked have equal or really similar naming
  - Extracts n-grams for sentences and model elements (n = {1,2,3})
  - Compares n-grams from text and models using normalized Levenshtein distance
  - Create TLs if comparison shows (high) similarity

Approach	Precision*	Recall*	F1-Score*	Accuracy*
Baseline	.80	.37	.50	.89
SWATTR	.49	.63	.52	.94
ArDoCo	**.81**	**.81**	**.80**	**.98**

* weighted Average

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Evaluation: Inconsistency Detection - UMEs

> RQ2: How does the approach perform for detecting unmentioned model elements?

- Goal
  - To measure how well we can detect unmentioned model elements
- Process
  - Comparison with gold standard

- Metrics
  - Precision, Recall, F1 – Score
  - Accuracy, Specificity
  - Φ – Coefficient
  - Average, Weighted Average

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Evaluation: Inconsistency Detection - UMEs

Project	# Elements		Precision		Recall		F1-Score		Accuracy	
MS		4		.67		1.0		.80		.88
TS	6	5	1.0	1.0	.83	1.0	.91	1.0	.91	1.0
TM	1		1.0		1.0		1.0		1.0	
BBB	4	1	.50	1.0	.75	1.0	.60	1.0	.73	1.0
JR	3	1	1.0	1.0	.67	1.0	.80	1.0	.83	1.0
w. Avg.			.86	.88	.79	1.0	.80	.93	.85	.95
			.87		.88		.86		.90	

Historic
Current

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Evaluation: Inconsistency Detection - MMEs

> RQ3: How well does the approach detect missing model elements?

- Goals
  - To measure how well the approach detects missing model elements
  - To compare with a simple baseline
  - To measure the influence of filter lists
- Process
  - Remove model elements to create (artificial) inconsistencies

- Metrics
  - Precision, Recall, F1 – Score
  - Accuracy, Specificity
  - Φ – Coefficient
  - Average, Weighted Average

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Evaluation: Inconsistency Detection - MMEs

Project	Precision		Recall		F1-Score		Accuracy	
MS		.21		.79		.33		.70
TS	.16	.96	.98	.70	.28	.79	.38	.96
TM	.17	.18	.63	.76	.26	.28	.86	.85
BBB	.09	.89	.18	.46	.11	.43	.81	.96
JR	.22	1.0	.11	.44	.15	.44	.57	.85
w. Avg.	.14	.60	.47	.63	.19	.43	.71	.87
	.39		.64		.34		.77	

Historic
Current

Discussion

- Good results, some outliers
- Outliers when text and model diverge too much → Low precision

- Threats to Validity
  - Few (open source) cases, unclear how well this generalizes
  - Artificial inconsistencies introduced when evaluating MME-detection
  - Benchmark dataset with potentially biased gold standards

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Conclusion

- We investigated automatic detection of inconsistencies in software architecture documentation using trace links

- We improved the approach for TLR and proposed an approach to identify missing model elements and unmentioned model elements

- We evaluated using five projects
  - TLR: F1-Score 0.81, Accuracy 0.98
  - ID – UMEs: F1-Score 0.89, Accuracy 0.93
  - ID – MMEs: F1-Score 0.39, Accuracy 0.77
  - Outperforming baselines

- Needed Improvements & Future Work
  - Make use of relations and check their consistency
  - Experiment with deep learning/language models

Resources at
https://ardoco.github.io/c/icsa23/

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