

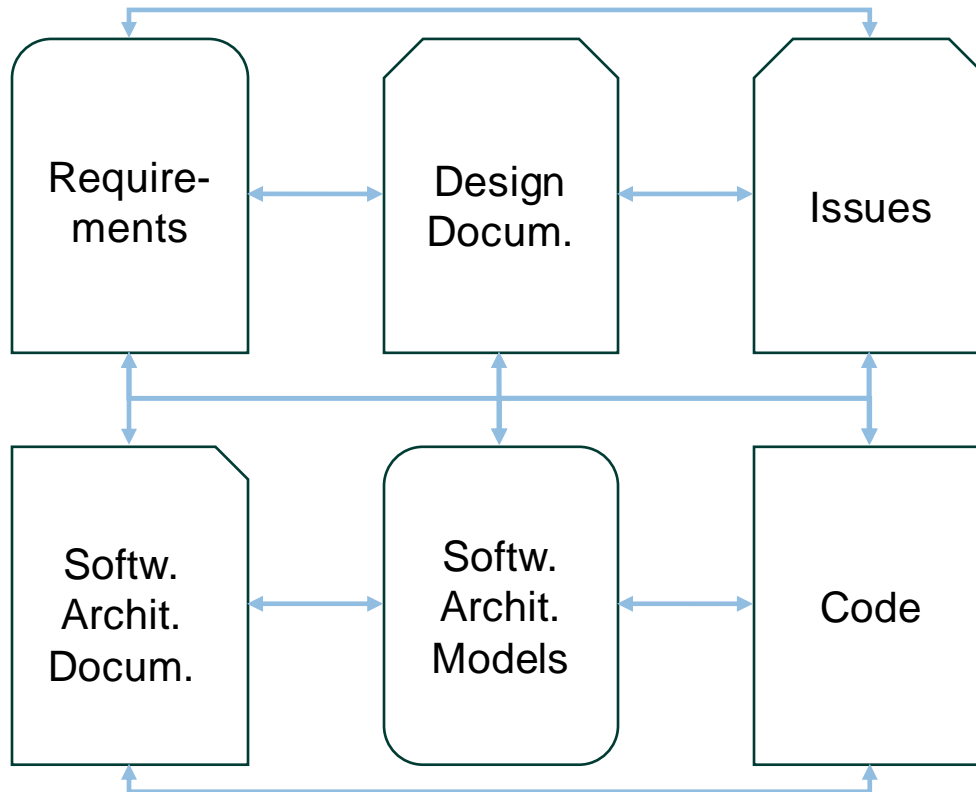
Recovering Trace Links Between Software Documentation And Code

Jan Keim, Sophie Corallo, Dominik Fuchß, Tobias Hey, Tobias Telge, Anne Koziolk
SE 2025, Karlsruhe.

Originally presented at
ICSE 2024 in Lisbon, Portugal



Why should we care about trace links?



Trace links are evidently useful for

Software Maintenance

Bug Localization

Change Impact An.

System Security

...

Traceability Link Recovery is difficult

Software Architecture Documentation (SAD)

The **controller** receives incoming requests and verifies them.

Then, **it** answers requests by querying the **persistence component**.

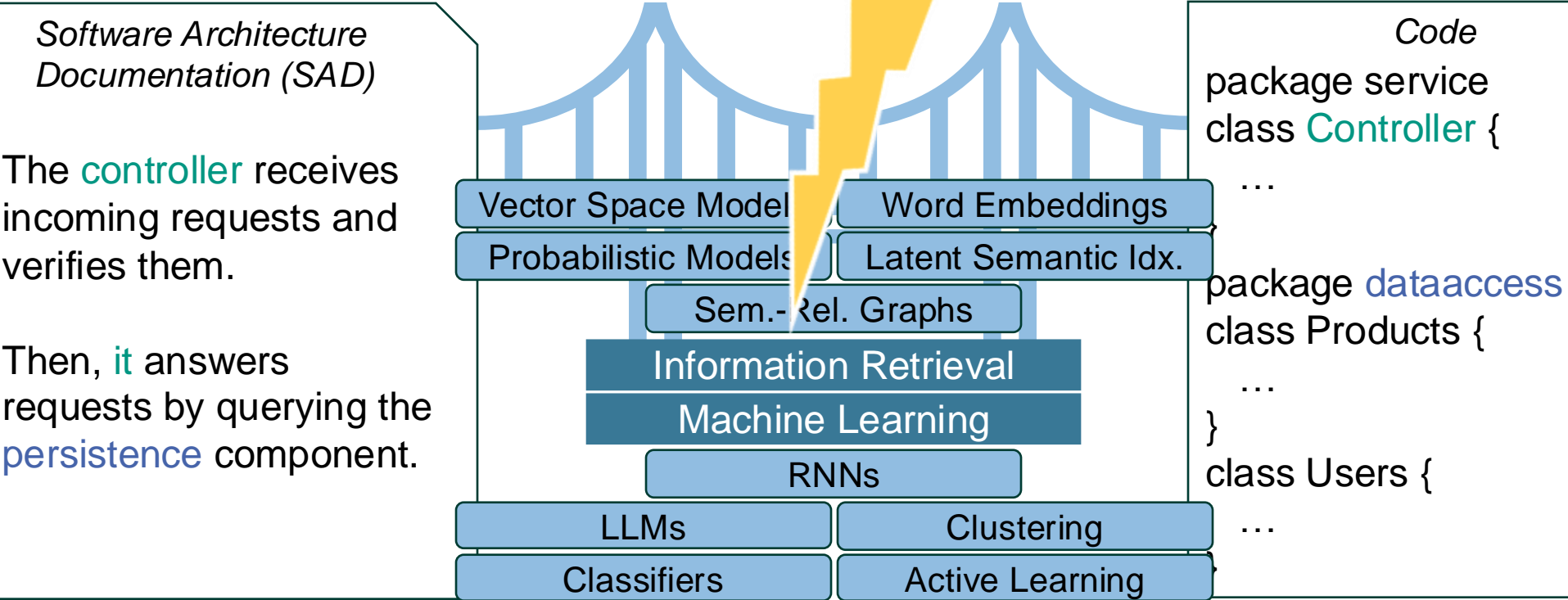
Code

```
package service  
class Controller {  
  ...  
}
```

```
package dataaccess  
class Products {  
  ...  
}
```

```
class Users {  
  ...  
}
```

Approaches need to bridge the semantic gap

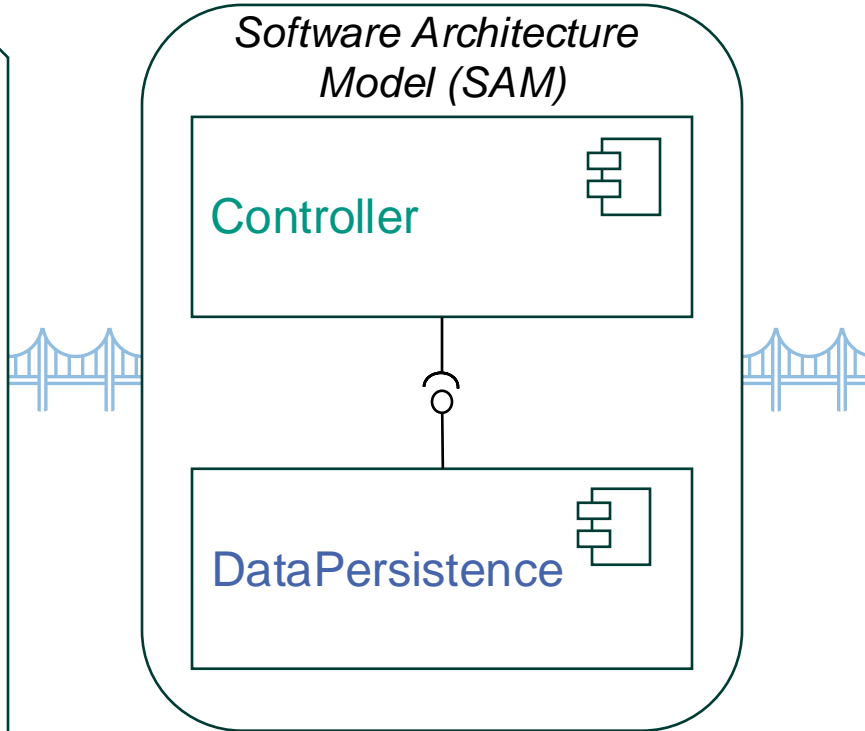


Intermediate Artifacts to reduce the gap

Software Architecture Documentation (SAD)

The **controller** receives incoming requests and verifies them.

Then, **it** answers requests by querying the **persistence** component.

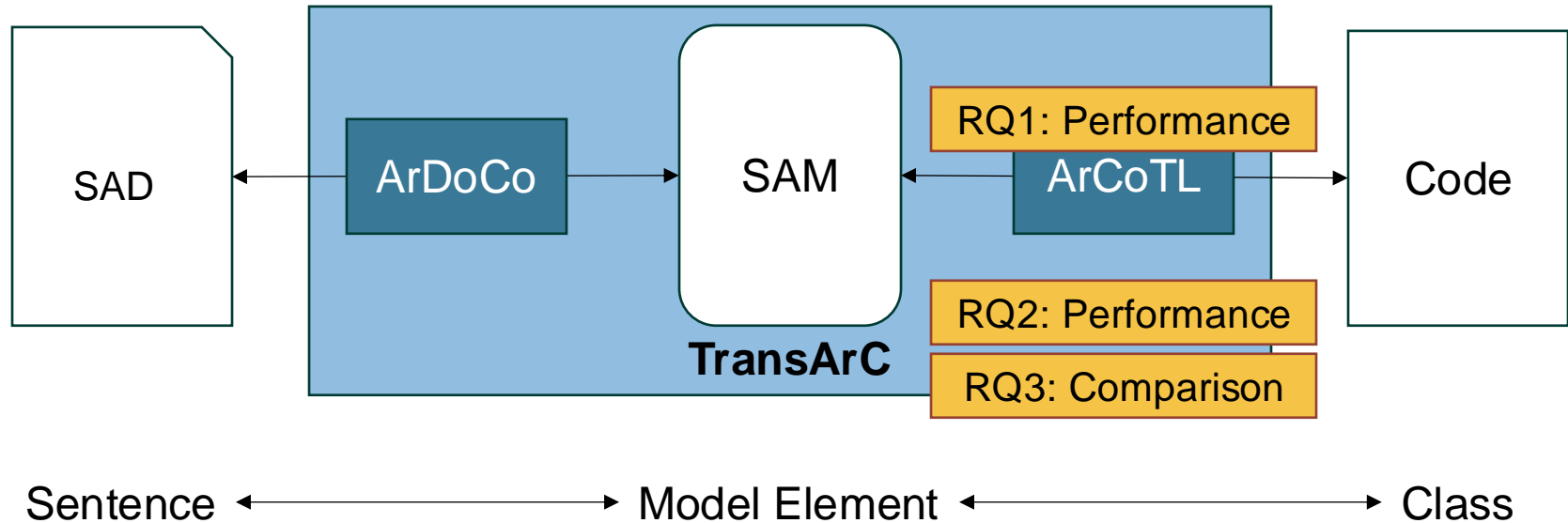


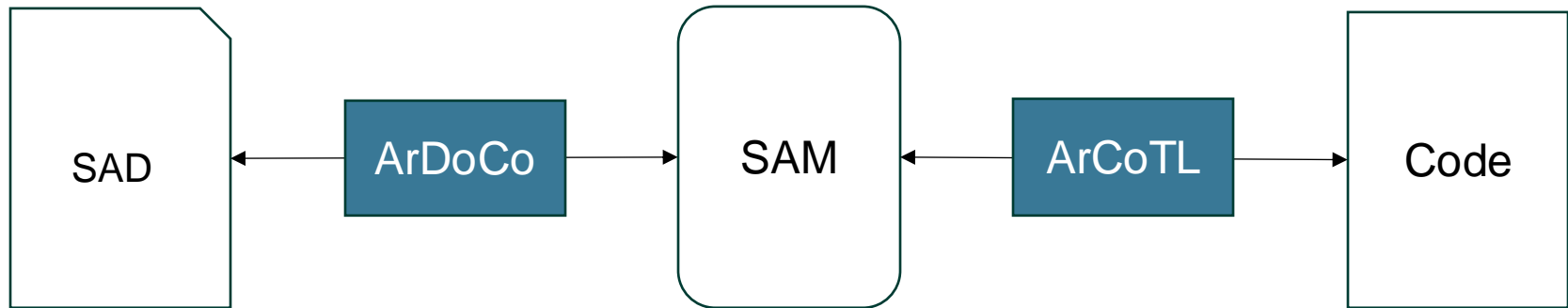
Code

```

package service
class Controller {
    ...
}
package dataaccess
class Products {
    ...
}
class Users {
    ...
}
  
```

Transitively combine TLR approaches

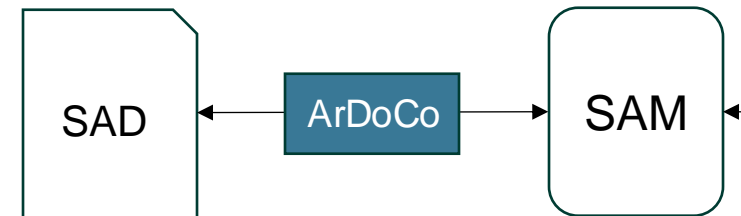




ArDoCo – TLR between SAD and SAM

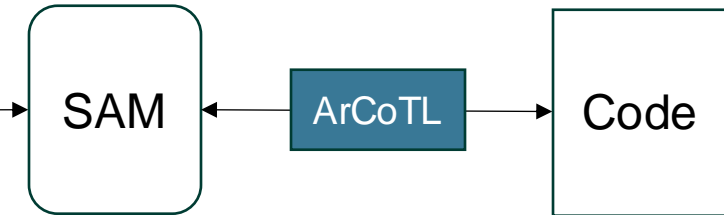
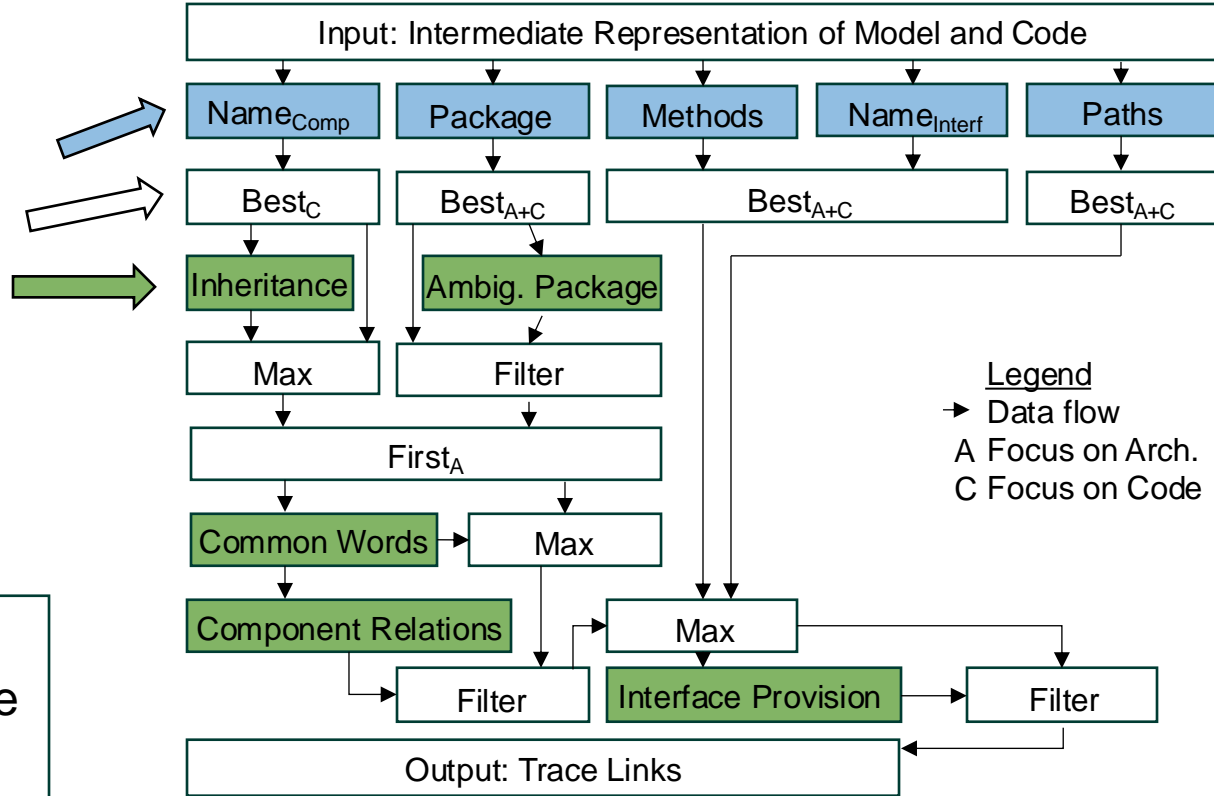
- Existing work [Keim et al. 2021], [Keim et al. 2023]
- Entity identification in text
- Heuristic-based
- Tracing entities to model based on similarity

[Keim et al. 2021] „Trace Link Recovery for Software Architecture Documentation“, ECSA 2021
[Keim et al. 2023] „Detecting Inconsistencies in Software Architecture Documentation Using Traceability Link Recovery“, ICSA 2023



ArCoTL – TLR between SAM and Code

- Computational graph
- Independent Heuristics
- Aggregators and Filter
- Dependent Heuristics

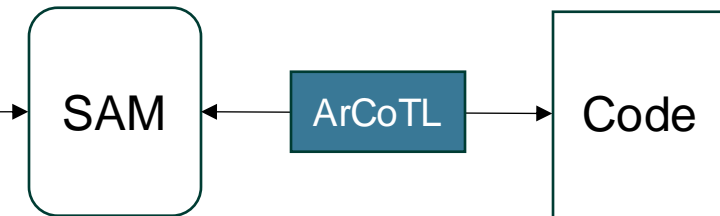


Evaluation Setup

Artifact Type		MediaStore	TeaStore	TEAMMATES	BigBlueButton (BBB)	JabRef
SAD	#Sentences	37	43	198	85	13
SAM	#Model Elements	23	19	16	24	6
Code	#Files	97	205	832	547	1,979
SAM-Code	#Trace Links	60	164	1,616	730	1,956
SAD-Code	#Trace Links	50	707	7,610	1,295	8,240

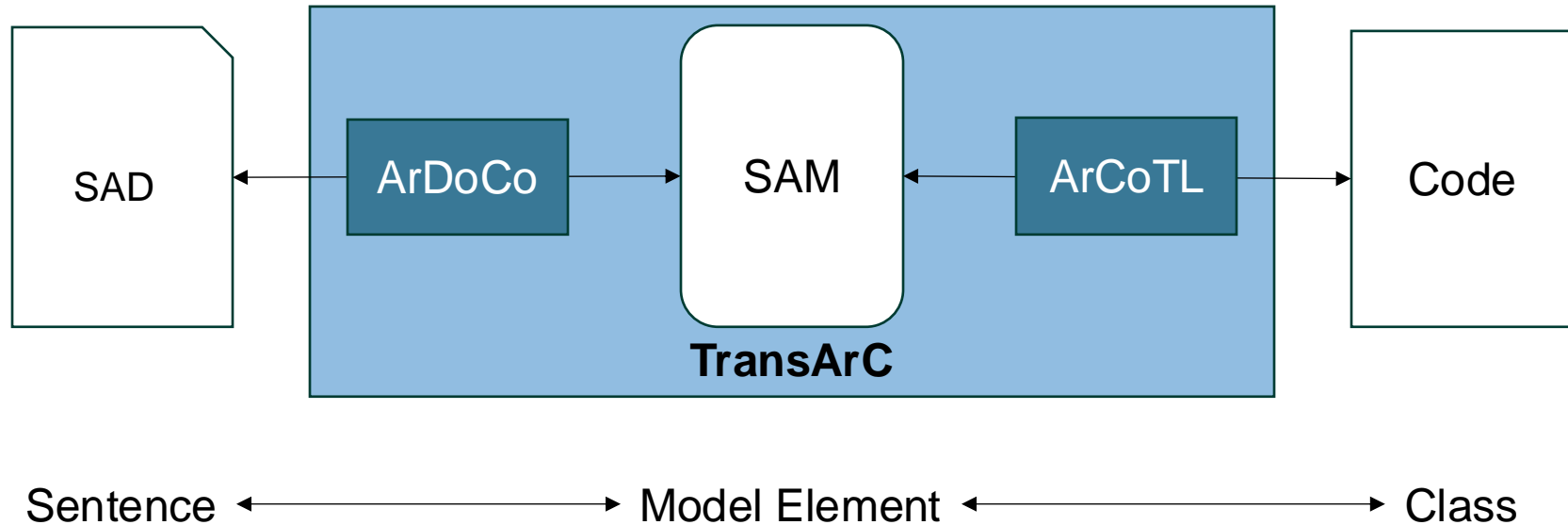
ArCoTL: Evaluation Results

Project	Precision	Recall	F1-Score
MediaStore	0.98	1.00	0.99
TeaStore	0.98	0.98	0.98
TEAMMATES	1.00	1.00	1.00
BigBlueButton	0.94	0.96	0.95
JabRef	1.00	1.00	1.00
Average	0.98	0.99	0.98



RQ1 (Performance)
 ArCoTL achieves excellent results

TransArC – Transitive Trace Links



TransArC: Evaluation Results (F1-Scores)

Approach	MediaStore	TeaStore	Teammates	BBB	JabRef	Average	Weighted Avg.
TAROT	0.13	0.27	0.11	0.10	0.49	0.22	0.29
FTLR	0.19	0.21	0.10	0.07	0.48	0.21	0.28
CodeBERT	0.17	0.36	0.12	0.12	0.61	0.28	0.36
ArDoCode	0.09	0.31	0.53	0.13	0.80	0.37	0.62
TransArc	0.68	0.83	0.80	0.84	0.94	+122% ↓ 0.82	+40% ↓ 0.87

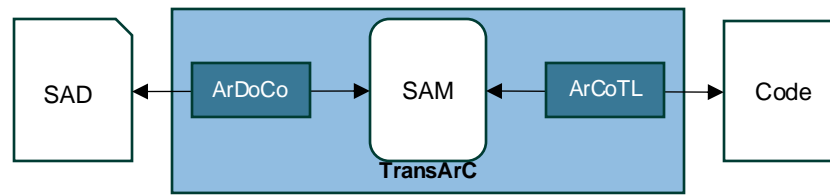
RQ2 (Performance)

TransArc achieves excellent results

RQ3 (Comparison)

TransArc significantly outperforms the baseline approaches

Conclusion



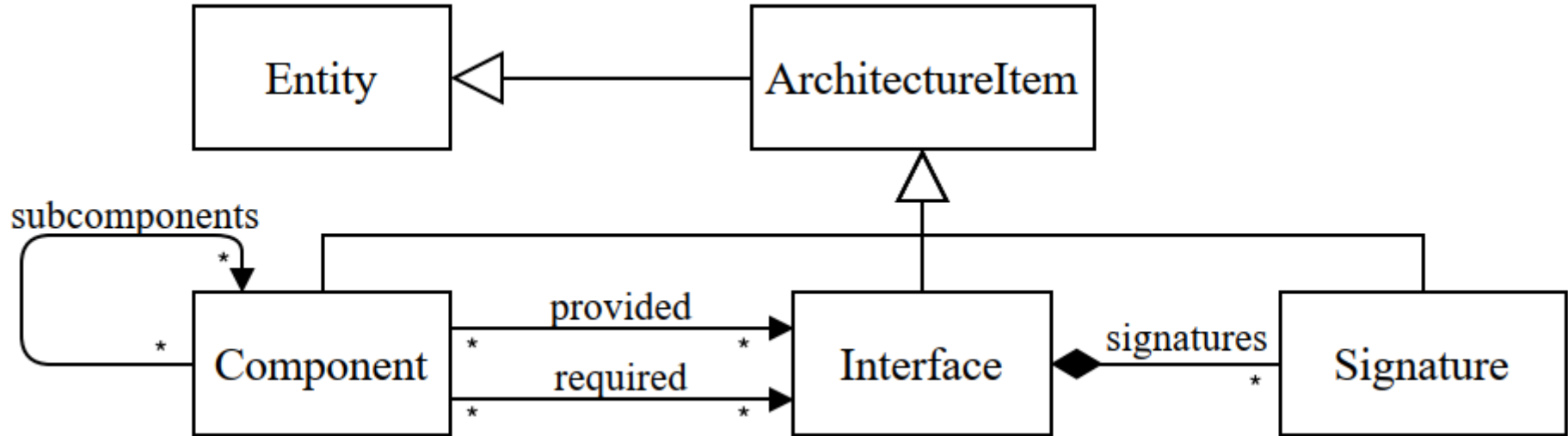
- TransArC transitively combines ArDoCo and the new approach ArCoTL to try to better bridge the semantic gap
- In the evaluation,
 - ArCoTL performs excellently (avg. F1: 0.98)
 - TransArC significantly outperforms the baseline approaches (avg. F1: 0.82 → +122%)
- Outlook
 - Evaluate on more (different) projects
 - Experiment with other kinds of artifacts
 - Explore further intermediate artifacts
 - Combine our approach(es) with others



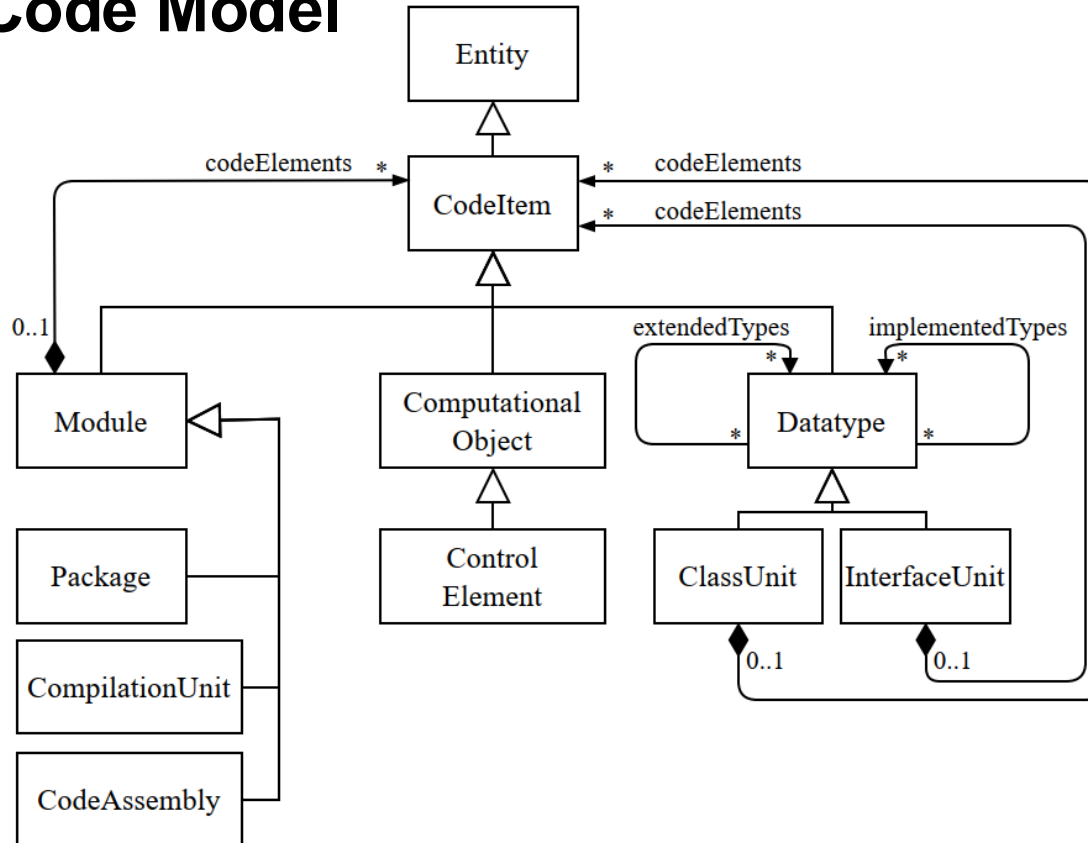
ardoco.de/c/se25

Appendix

Appendix: Architecture Model



Appendix: Code Model



Appendix: Evaluation Data

Artifact Type		MS	TS	TM	BBB	JR
SAD	# Sentences	37	43	198	85	13
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Code	# Files	97	205	832	547	1,979
SAM-Code	# Trace links	60	164	1,616	730	1,956
SAD-Code	# Trace links	50	707	7,610	1,295	8,240

Appendix: Detailed Results TransArC

Approach	MS			TS			TM			BBB			JR			Avg.			w. Avg.		
	P	R	F ₁	P	R	F ₁	P	R	F ₁	P	R	F ₁	P	R	F ₁	P	R	F ₁	P	R	F ₁
TAROT	.09	.24	.13	.19	.44	.27	.06	.32	.11	.07	.18	.10	.32	1.0	.49	.15	.44	.22	.19	.63	.29
FTLR	.15	.26	.19	.19	.25	.21	.06	.30	.10	.04	.42	.07	.32	.93	.48	.15	.43	.21	.19	.59	.28
CodeBERT	.29	.12	.17	.26	.57	.36	.09	.22	.12	.07	.49	.12	.49	.83	.61	.24	.45	.28	.28	.53	.36
ArDoCode	.05	.66	.09	.20	.74	.31	.37	.92	.53	.07	.57	.13	.66	1.0	.80	.27	.78	.37	.47	.92	.62
<i>TransArC</i>	1.0	.52	.68	1.0	.71	.83	.71	.91	.80	.77	.91	.84	.89	1.0	.94	.87	.81	.82	.81	.94	.87