Exploring Enterprise Architecture Knowledge Graphs in Archi: The EAKG Toolkit

Philipp-Lorenz Glaser[1][0000−0002−0710−8052], Syed Juned Ali[1][0000−0003−1221−0278], Emanuel Sallinger[2][0000−0001−7441−129X], and Dominik Bork[1] ✉[0000−0001−8259−2297]

[1]Business Informatics Group, TU Wien, Austria
[2]Database and Artificial Intelligence Group, TU Wien, Austria
{philipp-lorenz.glaser,syed.juned.ali,emanuel.sallinger,dominik.bork}@tuwien.ac.at

Abstract. This paper presents the *EAKG Toolkit* that entails a new Knowledge Graph-based representation of enterprise architecture (EA) models and further enables reasoning on EA knowledge. Our developed EAKG Toolkit is unique in the sense that it *i*) transforms ArchiMate models into a KG representation – the Enterprise Architecture Knowledge Graph (EAKG), *ii*) visualizes the EAKG for interactive exploration, and *iii*) extends the EAKG with additional nodes and edges to visually represent detected EA smells.

Keywords: Enterprise Architecture · Knowledge Graph · Modeling Tool · ArchiMate · Archi

1 Introduction

Enterprise architecture models are graphical representations that provide valuable support for, e.g., integrated IT and business decision-making [1], planning future states of the enterprise, and improving the business and IT alignment [2]. To support all these functions, EA models need to be analyzed efficiently. Such EA analysis involves querying models with the aim of evaluating various properties [7]. However, holistic EA models grow in size and complexity, thereby hampering manual human analysis while advanced and automated analysis of EA models is surprisingly underrepresented in research and EA tooling so far [12].

EA modeling tools do not take full advantage of the several structural properties of EA models represented as graphs, such as the differentiation of relations between elements, discovery of paths, clusters, or graph metrics. Current approaches are often tied to a concrete EA approach, offering a limited set of visualization techniques. EA modeling tools offer different features based on the supported EA approach and the analytical capabilities provided and thus, restrict the kind of analysis that they support [6]. A survey from 2016 yielded that *"Modern analysis approaches should combine interactive visualizations with automated analysis techniques"* [5]. The need for proper tool support was pointed out in the past as one EA [10] and business information systems modeling [3] research gap. Our EAKG Toolkit addresses this gap by utilizing the full potential of the graphical structure of EA models.

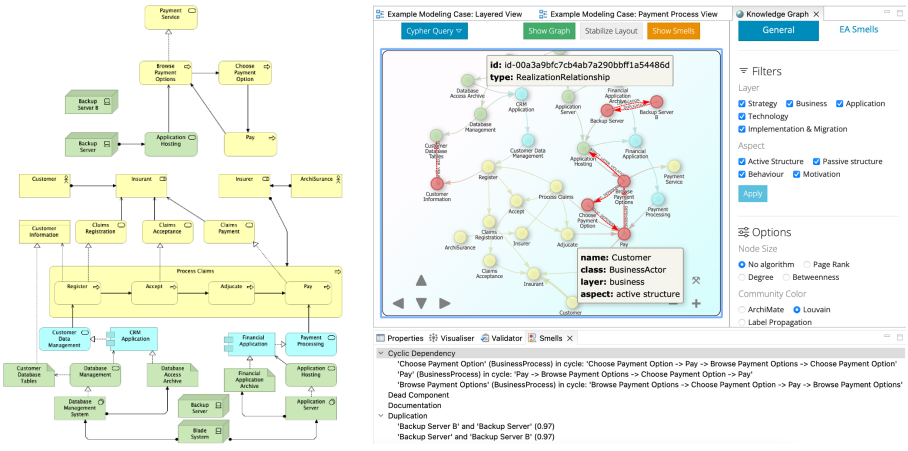
In the context of EA, graph-based formalisms have been applied for representation and reasoning of EA models [9, 12] but these works are merely constrained to the explicit knowledge encoded by the EA model (i.e., no further knowledge enrichment) and to basic model analysis (i.e., no KG-based reasoning). In this paper, we present a toolkit for Archi that exploits the benefits of KG-based representation and reasoning in EA, by constructing Enterprise Architecture Knowledge Graphs (EAKGs). The EAKG Toolkit visualizes and analyses the EAKG and supports the EAKG knowledge enrichment. EAKG provides a generic and unified intermediary representation of EAs which makes our approach easily extensible for the integration of other graph-based EA analysis tools.

2 The EAKG Toolkit

The aim of the toolkit is to make KG-based EA analysis available to enterprise architects, i.e., an audience that not necessarily has graph theoretic knowledge. In this section, we first present the features of our toolkit, then we present the internal architecture and implementation details. Eventually, we showcase the usage of our toolkit with a running example (see Fig. 1).

2.1 EAKG Features

The main features of the EAKG toolkit include the visualization of the transformed EAKG and the additional analysis support provided by the graph characteristics and EA smells enrichment of the EAKG. Fig. 1b shows the integration of the toolkit within the Archi application, containing both the main *Graph View* (top), and the *Smells Report View* (bottom).



(a) Source EA model (b) Transformed EAKG with toolkit UI

Fig. 1: EAKG toolkit in Archi

Knowledge Graph Visualization. The main view in Fig. 1b visualizes the EAKG generated from the source EA model shown in Fig. 1a. Nodes denote ArchiMate elements, while edges denote ArchiMate relationships. The transformation maps the properties related to layers (e.g., *Business, Application*) and aspects[1] (e.g., *Active Structure, Passive Structure*) in the original EA model to the properties of the nodes in the resulting EAKG (extended from [11]). The relationship type (e.g., *Realization, Assignment*) is stored in the properties of the relationships in the EAKG. Further properties are exposed by hovering over nodes and edges, as exemplified by the *Customer* element and the relationship between the elements *Database Access Archive* and *CRM Application*.

Graph characteristics visualisation. EAKG allows applying graph algorithms (e.g., page rank, degree) on the transformed EAKG to represent centrality and community metrics. The applied algorithms enrich the EAKG with additional properties: graph centrality measures are reflected via the node size, whereas community measures are reflected via node color. EAKG also allows the customization of the EAKG visualization, e.g., by filtering specific ArchiMate layers/aspects and configuring how to represent graph analysis results. Note that in the figure all filters are checked and no graph algorithms are set, thus EAKG visualizes all elements of the source EA model with the same node size and the color according to the ArchiMate layer.

EA Smells Detection. The EAKG Toolkit allows the detection and visualization of EA smells [8, 13] in the EAKG. EA smells provide necessary information to the modeler to rectify models designed with bad modeling practices. Our tool visualizes the found smells by means of, e.g., additional relationships and highlighting of affected nodes in red color as shown in Fig. 1b. We contribute here a much richer visualization of EA smells that again uses a Knowledge Graph that allows exploration of the smell in its context. Currently, the EAKG toolkit detects eight different EA smells by running cypher queries on the EAKG. The tool moreover supports the execution of custom cypher queries.

2.2 EAKG Architecture

The EAKG Toolkit (see Fig. 2) is primarily developed with Java and built upon the Eclipse Rich Client Platform (RCP). In the following, we describe the architecture based on our model-based KG creation process [4].

Knowledge Graph Creation. Once the creation process is initiated (from a dedicated action in the menu of Archi), the toolkit creates the *Knowledge Graph Database Manager*, which is responsible for interacting with an *Embedded Neo4j Graph Database*. The manager starts a new database, stored on the local file system, and opens a *Bolt Connector* for remote access (used, e.g., by drivers). After the database is started, the *Knowledge Graph Exporter* uses the current ArchiMate model to iterate over the elements and retrieve its metadata. Each element corresponds to a node and gets stored in the graph database, together with initial properties, e.g., layer and aspect. Next, the CSV export provided by Archi is reused to export all the relationships of the model and load the resulting

[1] `https://pubs.opengroup.org/architecture/archimate3-doc/`

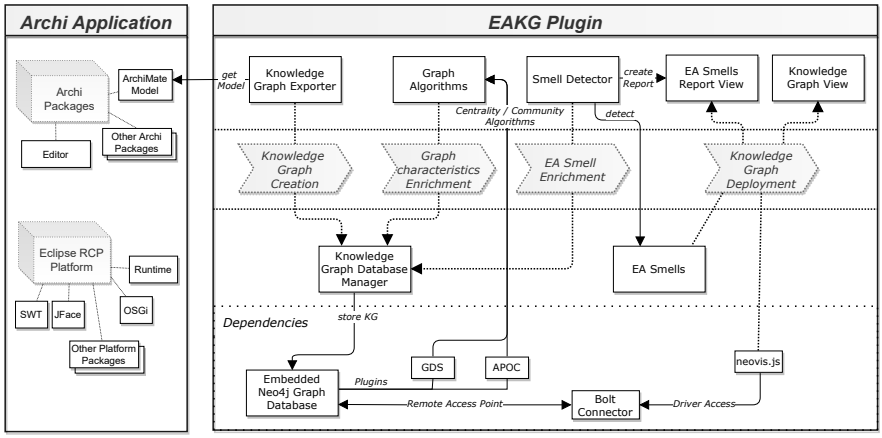


Fig. 2: EAKG toolkit architecture

CSV file with a single query into the graph database. The query creates the initial edges between nodes and also stores the relationship type as an edge property.

Graph characteristics Enrichment. The Graph Database Manager also registers additional procedures, provided by the *Graph Data Science (GDS)* and *Awesome Procedures On Cypher (APOC)* Neo4j plugins, to leverage efficient *Graph Algorithms* in the graph database. The exporter runs the query procedures and sets the corresponding properties in the graph.

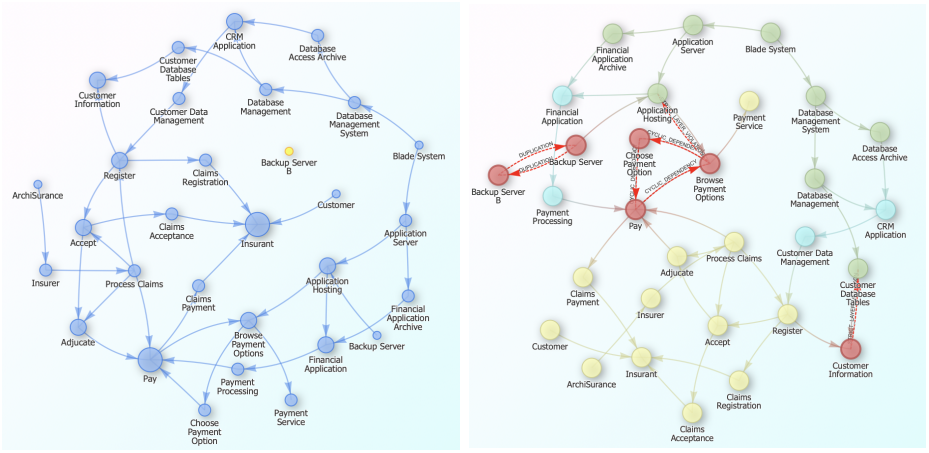
EA Smells Enrichment. The *Smell Detector* runs additional cypher queries to further enrich the EAKG with detected *EA Smells*. The detector also stores additional information such as the affected elements and creates the tree structure for the report.

Knowledge Graph Deployment. The graph database now holds the EAKG enriched both with graph characteristics and EA Smells and can now be fully deployed within Archi. The *EA Smells Report View* incorporates the tree structure created from the smell detector. The *Knowledge Graph View* is part of a web browser component, which simply displays an HTML document with additional CSS, JavaScript, and a neovis.js configuration for the visualization[2].

2.3 EAKG Use

We finally elaborate on the usage of our toolkit in order to demonstrate the aforementioned features. After adding the toolkit to Archi, the Knowledge Graph menu and its items are exposed in the Archi menu bar, where the EAKG creation process can be initiated. Once the database is started and the EAKG creation is finished, the visualization and EA smell report views can be opened (see Fig. 1b). The toolbar at the top allows changing the representation of the graph by running custom cypher queries or visualizing the detected smells.

[2] neovis.js: `https://github.com/neo4j-contrib/neovis.js/`



(a) Graph Analysis View (b) Smell Detection View

Fig. 3: KG-based EA Analysis Representations in EAKG

The right-hand sidebar includes a filter and option menu. Enterprise architects can filter the displayed elements based on specific layers or aspects of ArchiMate. The option menu on the bottom right offers configuration for the *Graph characteristics Knowledge Graph Enrichment*. Fig. 3a visualizes the resulting graph after *Node Size* is set to *Degree* and the *Community Color* to *Weakly Connected Components*. Degree denotes the number of connections, and, as can be seen, the size of nodes increases with the amount of incoming and outgoing edges. Similarly, the weakly connected components algorithm detects individual sub-graphs that are rendered in different colors.

The Report view at the bottom lists all detected EA Smells together with the affected elements in the model. In the main view above, the toolbar offers buttons to either show the default graph or to also include EA Smells in the visualization, with affected elements highlighted in red and references to other elements of the smell represented as dashed, red edges. Fig. 3b showcases this behavior with nodes and edges that are part of a detected EA Smell highlighted in red with the name of the detected EA Smell as a label. The *EA Smells* tab in the sidebar provides information about each EA Smell, including a visualization, a description, and a solution to fix the smell.

3 Conclusion and Future Work

We presented an Archi-based tool that transforms EA models into Enterprise Architecture Knowledge Graphs (EAKGs) that can be semantically enriched by general graph knowledge and domain-specific enterprise architecture knowledge. Our approach allows full automation for the entire EAKG construction process and provides an efficient and intuitive GUI to explore and analyze the EAKG. The most innovative contribution we make with this tool is that we not only use the KG for EA visualization and analysis but also for represent-

ing EA knowledge using, e.g., the added nodes and relationships for EA Smells. Consequently, we propose to not only use KGs for automated analysis of overarching EA models, but also to improve human understandability by appropriate interactive visualizations. The EAKG Toolkit is open source on `https://github.com/borkdominik/archi-kganalysis-plugin` and a video can be found here: `https://youtu.be/a59OawYwiqE`.

Acknowledgements

This work has been partially funded through the Erasmus+ KA220-HED project Digital Platform Enterprise (project no.: 2021-1-RO01-KA220-HED-000027576) and the Austrian Research Promotion Agency via the Austrian Competence Center for Digital Production (contract no. 854187).

References

1. Buschle, M., Holm, H., Sommestad, T., Ekstedt, M., Shahzad, K.: A tool for automatic enterprise architecture modeling. In: CAiSE 2011. pp. 1–15. Springer (2011)
2. Florez, H., Sánchez, M., Villalobos, J.: A catalog of automated analysis methods for enterprise models. SpringerPlus **5**(1), 1–24 (2016)
3. Frank, U., Strecker, S., Fettke, P., vom Brocke, J., Becker, J., Sinz, E.J.: The research field "modeling business information systems" - current challenges and elements of a future research agenda. Bus. Inf. Syst. Eng. **6**(1), 39–43 (2014)
4. Glaser, P.L., Ali, S.J., Sallinger, E., Bork, D.: Model-based construction of enterprise architecture knowledge graphs. In: 26th International EDOC Conference (EDOC'2022). pp. 57–73 (2022). https://doi.org/10.1007/978-3-031-17604-3_4
5. Lantow, B., Jugel, D., Wißotzki, M., Lehmann, B., Zimmermann, O., Sandkuhl, K.: Towards a classification framework for approaches to enterprise architecture analysis. In: Proceedings PoEM 2016. pp. 335–343 (11 2016)
6. Naranjo, D., Sánchez, M., Villalobos, J.: Primrose: a graph-based approach for enterprise architecture analysis. In: ICEIS 2014. pp. 434–452. Springer (2014)
7. Närman, P., Buschle, M., Ekstedt, M.: An enterprise architecture framework for multi-attribute information systems analysis. Softw. Syst. Model. **13**(3), 1085–1116 (2014)
8. Salentin, J., Hacks, S.: Towards a catalog of enterprise architecture smells. In: Gronau, N., Heine, M., Krasnova, H., Poustcchi, K. (eds.) Internationalen Tagung Wirtschaftsinformatik, Community Tracks. pp. 276–290. GITO Verlag (2020)
9. Santana, A., Fischbach, K., de Moura, H.P.: Enterprise architecture analysis and network thinking: A literature review. In: Bui, T.X., Jr., R.H.S. (eds.) 49th Hawaii International Conference on System Sciences. pp. 4566–4575. IEEE (2016)
10. Santana, A., Simon, D., Fischbach, K., de Moura, H.: Combining network measures and expert knowledge to analyze enterprise architecture at the component level. In: 2016 IEEE EDOC Conference. pp. 1–10. IEEE (2016)
11. Smajevic, M., Bork, D.: From conceptual models to knowledge graphs: a generic model transformation platform. In: Int. Conference on Model Driven Engineering Languages and Systems Companion. pp. 610–614 (2021)
12. Smajevic, M., Bork, D.: Towards graph-based analysis of enterprise architecture models. In: International Conference on Conceptual Modeling. pp. 199–209 (2021)
13. Smajevic, M., Hacks, S., Bork, D.: Using knowledge graphs to detect enterprise architecture smells. In: Practice of Enterprise Modeling. pp. 48–63. Springer (2021)