Connecting the Dots: Examining Visualization Techniques for Enterprise Architecture Model Analysis

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Abstract. The discourse of Enterprise Architecture is based on modeling and performing 'holistic' (multi-layer) analyses. However, view centered methodologies offer a partial glimpse of the overall architecture, and current tools do not bring an explicit method of navigating the underlying model. Considering that we need a starting point for analysis and explore the whole model in order to drill down on more specific analysis techniques, we compare overview visualizations depending on topological properties of the model and a set of domain-specific requirements. Four techniques are examined, and they visualize five Analytical Scenarios that represent typical questions that could arise on a EA diagnostic.

Keywords: EA Visual Analysis, Visualizations, Enterprise Model Topology

1 Introduction

Nowadays, as we are more capable of capturing all kinds of information, the need to make sense of it is most compelling. Instead of facing the problem of collecting this data, the main issue is to propose methods and models, which can turn it into reliable and provable knowledge [1]. In complex domains we have seen the rise of experts (we usually call them *analysts*), that process this information using certain reasoning process, thus providing insights that generate knowledge and serve as input for decision making.

In this aspect, Enterprise Architecture (EA) has been proven as a valuable tool for aligning business strategies with Information Technologies projects and infrastructure. A key function of EA is the static analysis of current architectures in order to drive IT projects and close gaps. Given its broad scope –e.g. impact analysis vs. business process analysis–, and the use of different techniques, ranging from ad-hoc to quantitative analysis, it is important to point that no common definition of the term *EA Analysis* has emerged [2].

However, we invite the reader to think of EA analysis as more than a static process with a collection of techniques. We think that the analyst, his own experience and reasoning power are 'the spice' that give flavor to analysis, *making sense* of the information of the enterprise, that means, turning it into reliable and comprehensible knowledge [3], with the objective of providing valuable insights that support decision making at the different organizational levels. For this reason, making assessments of architectures is a core competency for an architect.

As all the collected information from the different domains of the organization –the EA model– is more detailed and complex, assessments are more difficult to perform. Given the iterative and reflective nature of this analysis process, EA Frameworks such as DoDAF emphasize on tool-assisted and tool-supported analyses whenever possible [4]. However, in our previous work [5] we have seen that there is still no starting point for analysis both in EA commercial products and in the research community. Most tools offer queries and partial views as the only means to perform analysis, with little support to ad-hoc analyses, and offering no traceability on their outcome and impact on the architecture.

In decision-making, "the useful information is drawn from the overall relationships of the entire [data] set" [6]. For this reason, a major challenge in EA is to find effective techniques to visualize enterprise architectures as a whole. Overview/holistic visualizations of the architecture harness the cognitive power of the visual domain and make more easy to find patterns and explore the architecture. This brings us to our research question: *How effective can be existing visualization methods when we apply them in the context of EA analysis?*

With the purpose of illustrating the different subjects at hand, we will provide the results of our experimentation with four VA techniques, that are widely used in other domains, to visualize the enterprise model of our case study. This experimentation is supported by five Analytical Scenarios, which are typical questions that can be formulated throughout the EA Analysis process. Each visualization is adapted to show the maximum amount of information, taking care of following the Visual and EA Analysis requirements defined in [5].

The structure of this paper is as follows: First, we will characterize enterprise models and their topology (Section 2) and introduce EA Analysis supported by Visual Overview (Section 3). In Section 4, we will explain the Case Study and Analytical Scenarios selected for this research. Finally, in Section 5 we will perform an evaluation of the effectiveness of the selected techniques for overview analysis.

2 The topology of Enterprise Models

Enterprise Architecture has been supported by different paradigms of Enterprise Modeling [7, 8, 9]. For this paper, we will adopt the following notion:

Definition 1. *An Enterprise Model (EM) is a representation of the information in all aggregate artifacts (including documents, diagrams, deliverables, or any structured piece of enterprise knowledge) that are relevant for an enterprise [10], which may come from a variety of sources, and is intended to be used by people different backgrounds.*

Analysis methodologies over these models encourage the identification of critical elements by examining their incoming and outgoing links [11], or in general, by asserting topological properties of these models. Thus, visualizing the global structure of EA models can lead to structural assessments of the model, such as discovering interesting elements and groups, or following paths between them.

In order to support this kind of assessments, we make a bridge between EM analysis and studies in graph analysis and complex networks. This will allow us to take advantage of existing properties of this kind of networks, and to formulate interesting topological properties specific to EMs. A complex network represents a complex system, where the relationships amongst the components of the system are usually more important than the components themselves [12].

Our premise is that EMs are complex, and we can define their complexity in terms of its number of relations, as it surpasses the number of elements of the model. We will describe five properties of EMs inspired on this premise.

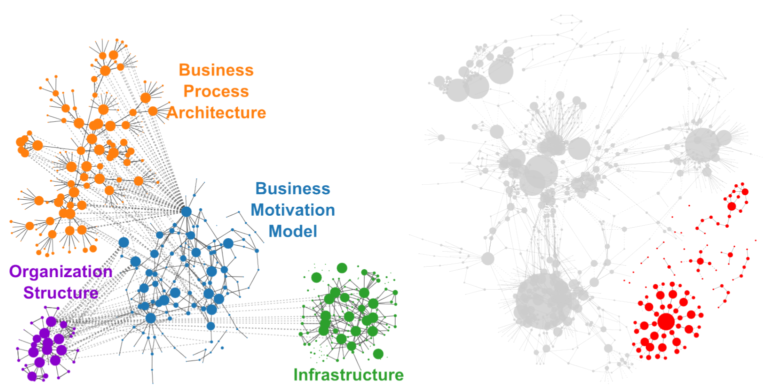
P1 - Enterprise models grow over time

While EMs are abstractions [13] that should be kept simple and small [14], our perception is that these models grow over time, given the incremental nature of EA projects, and taking into account the role of EA as a continuous business function. Also, EMs are an asset that represents enterprise knowledge and therefore should be managed [13].

As semi-automated mechanisms for collecting architectural information are more widely used, enterprise model scalability becomes a critical issue. For instance, Binz et al. point to the complexity of Enterprise Topologies –a snapshot of all services and applications in an enterprise, together with their supporting infrastructure and relations [15]– that may consist of thousands to millions of nodes.

P2 - Enterprise models are structured

One of the goals of EA is to provide alignment of the different business and technological resources, by establishing relations between the elements on different architectural domains.



(a) Detail of some domains on an EM (b) Weak Components of the model

Fig. 1. Force directed graphs consist of nodes whose position is given by a force model, considering the arcs that connect them. Nodes represent model elements, while arcs represent relations.

In EMs, this organizing structure is explicit: they conform to a **metamodel** that integrates the different **domains** of the organization and offers a clear view on the structure of and dependencies between relevant aspects of the organization.

Definition 2. *An **enterprise metamodel** is the common language on which the enterprise model is 'spoken' by the means of concepts, relations and constraints that bring consistency to the architectural description.*

Instead of a "one-size-fits-all" metamodel, recent approaches to enterprise modeling focus on integration [8], adaptability [16] and multi-perspective modeling [9] by the integration of standards and reference models, complemented with domain-specific models, specifically tailored to support the management tasks [17] and analysis needs of the enterprise. Interesting dependencies for overall analysis are the ones that connect the different domains/perspectives such as Goal, Process, Organization Structure, Infrastructure or Application models (see Fig. 1(a)).

Definition 3. *An **enterprise domain** is a subset of the enterprise metamodel that aggregates similar concepts, forming communities that are connected between them by inter-domain relations.*

Taking into account that we are interested in the relations between domains, unaligned/isolated elements are meaningless on their own. Therefore, a first step when analyzing the model is to identify 'islands' or weak components, i.e. disconnected groups of elements (see Fig. 1(b)).

P3 - Enterprise models are semi-hierarchical

Organizations are complex systems that are conformed of a number of parts which are inherently hierarchical, i.e. they are composed of interrelated subsystems, and interact in a non-simple way.

Under this light, EMs are semi-hierarchical, as each domain manages different levels of detail on its concepts by composition (i.e. aggregation) relations. For instance, Process Models are defined under a vertical scope, where each depth level also involves more granular sub-processes and activities (see Fig. 2(a)).

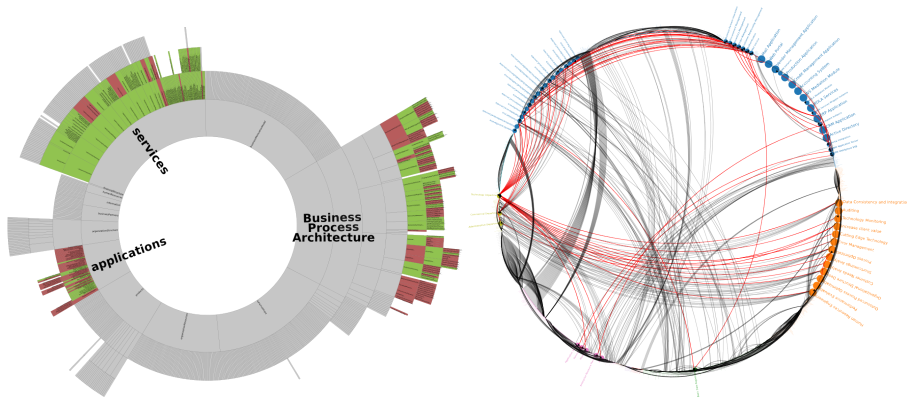
An advantage of this property is that hierarchies are one of the most recurring information structures in computing, and offer a natural way for navigating the model.

P4 - Relation have their own semantic

EA Analysts need to find pathways between the different model elements, which is important when they want to assess the overall impact of a change in the architecture, e.g. the cost of making changes to enterprise-wide software systems [17]. This assessment is made almost intuitively: even without previous knowledge, most pairs of vertices in complex networks seem to be connected by a short path.

Nevertheless, these paths are made by different kinds of relations, e.g. composition and association relations. The latter provide a horizontal scope to the model, i.e. a 'is related to' semantic, which is mostly given by their name, and depends on the metatype of their target. For instance, an Application may be *used by* a Role, which in turn *is responsible* for some Resources, and *belongs to* an Organization Unit.

For this reason, it is common in analysis techniques to assign weights or other attributes to relations, translating this abstract semantic to more quantitative means.



(a) Sunburst (b) Radial Graph

Fig. 2. Sunbursts offer an overview of the whole model, while being constrained by a circumference. Radial graphs position elements in a circumference, while inter-domain relations are displayed inside the circle.

P5 - Not every element has the same importance

Analyzing resilience of enterprises is important to discover points of failure under different domains, such as vulnerabilities in infrastructure security, core processes in business process analysis, or even overly-coarse services that need to be decomposed. For this reason, it is crucial to prioritize which elements have more influence in the topology of the model. This is useful when an analyst wants to assess the connectivity of the network: the removal of vertices or groups may affect, or even dismantle its structure.

In this aspect, several ranking algorithms exist to discover the relative importance of elements (e.g. PageRank, HITS, SALSA) based on their occurrence and connectedness. However, importance may be driven also by other semantic criteria that are based in the metamodel, not in the model itself. For instance, when analyzing which processes are supported by IT, we want to focus on Macro-Processes, Processes, and IT elements such as Applications and Services (see Fig. 2(b), where these elements are given some emphasis in size).

3 Giving a shape to the architecture

We often see the use of the term *Analysis* on different levels of granularity: as the overall process and also as a concrete strategy or technique. On the remaining of this paper, we will use the following definition:

Definition 4. ***EA Analysis:*** *All of the processes that transform architectural data into useful information [4], which serves as a basis for bringing an assessment or concept.*

In concrete, we are interested in the *static analysis* of this information, i.e. a snapshot of the architectural description, to offer a value judgment of a given state of the architecture.

In previous work [5], we evaluated a set of tools that support EA modeling and Analysis, and suggested that Visual Modeling Languages (VMLs) and queries are just a localized/filtered view on the model. As DoDAF [4] points out, "Architectural views are no longer the end goal, but are described solely to facilitate useful access to information.". Visual exploration of the whole model is mostly neglected, even tough it is useful when a person simply does not know what questions to ask or when the person wants to ask better, more meaningful questions [18].

Instead of using queries as the main way to inspect the model, our focus is on total visualizations that provide an overview of the EM and help the analyst on finding new properties of the overall set, thus we encourage top-down analysis for pattern discovery.

Definition 5. *A **visualization technique** can be seen as the combination of **marks** [19, 20] (atomic graphical elements, e.g. circles, squares, or lines), a* **layout** *algorithm, some **visual attributes** (e.g. color, size, shape), a set of supported **interactive operations** and a **mapping** between data and such visual attributes.*

Considering the overwhelming number of visualization techniques available, in our case is certainly complex to assess which ones can be applied for such a specific application domain. For this reason, instead of approaching this problem with an existing taxonomy, we employ a set of Visual Requirements (see [5]) as the criteria for selecting interesting visualization techniques for showing the landscape of the architecture.

In our search for visualizations, we analyzed the different artifacts, views, viewpoints, diagrams, pattern catalogs and tools from our domain (EA), and confronted them with visualization taxonomies and tools/ frameworks. The selected techniques were: 1) Force-directed Graphs, 2) Radial Graphs, 3) Treemaps, and 4) Sunbursts.

4 Analytical Scenarios for EA Visual Analysis

In order to evaluate and interact with each visualization, we visualized the EA model of a fictional company from our EA Laboratory, *Muebles de los Alpes*.

The EA metamodel of this Retail/Manufacturing company incorporates concepts from several metamodels (e.g. Business Motivation Model, ArchiMate, BPMN, TOGAF), as well as specifically tailored representations of standards, frameworks such as Service Oriented Architecture, or even formalizations of domains such as Applications, Information, Organizational Structure, Financial Management, and Human Resources.

The enterprise model was developed by a group of experts, and validated by different architects. It is based on the different architectural deliverables, and reflects the current state of the organization, which is supported by a real set of IT components, such as a CRM, an ESB, an ERP, in-house applications, and several infrastructure deployed in the virtualized platform of our EA laboratory.

For the visualization of typical questions over EMs we designed five analytical scenarios that fall into three main categories that correspond to common concerns of architects, and are inspired on the properties described in Sec. 2 (see Table 1):

It is also noteworthy that the visualizations generated display patterns that are difficult to envision by other means (i.e. queries or views).

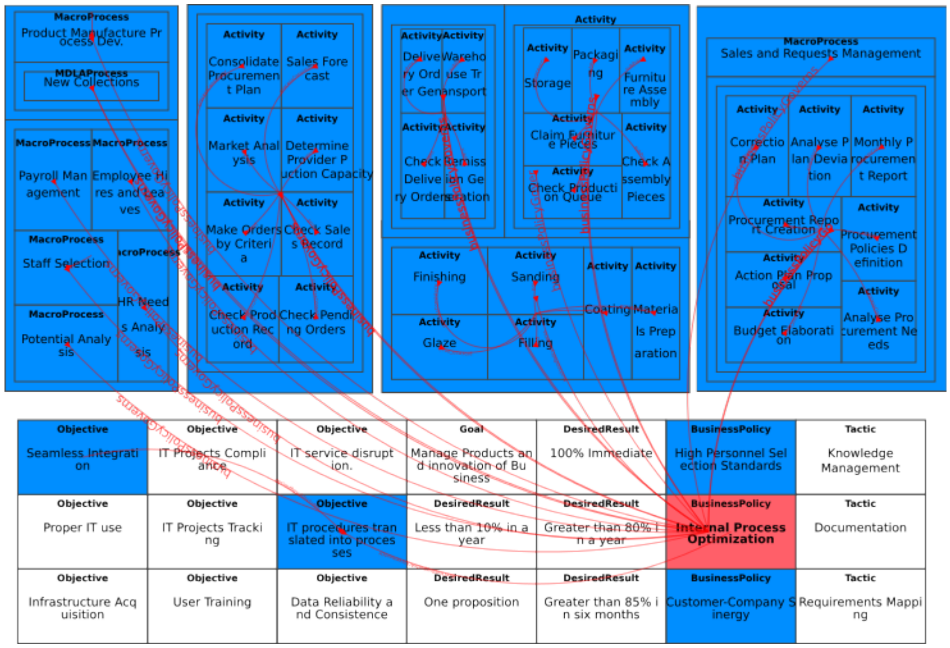


Fig. 3. Very small fragment of a Treemap, describing the impact of the change of a Business Policy on the Motivation Model, affecting several Process Model elements, such as Macro Processes and Activities.

Table 1. Analytical Scenarios for EA.

Category	Topic	Question	Strategy	Technique
Business-IT	Motivation Realization	*Which goals/objectives are realized by IT?*	Find paths between Motivation and IT elements	Sunburst (Fig. 2(a))
Alignment	Process Support	*Which processes are not supported by IT?*	Cross-reference processes and applications	Radial Graph (Fig. 2(b))
EA Management	Domain Connectivity	*What is the dependency between domains/layers?*	Display inter-domain relations	Force Graph (Fig. 1(a))
	Impact Analysis	*What is the impact of a change in the model?*	Find all the shortest paths from a given element	Treemap (Fig. 3)
Anomalies	Structural Holes	*Are there isolated elements or groups?*	Discover all the isolated sub- graphs of the model	Force Graph (Fig. 1(b))

5 Evaluation

Many authors [21, 22, 23] have studied the cognitive power of the different visual attributes and their capacity to display different (e.g. quantitative, ordered, nominal) kinds of information, and how we can combine these attributes for better results.

Based on the characterization of Bertin [6], and in order to measure the expressive potential of a visualization technique, we propose a method for evaluating its global effectiveness:

Table 2. Usage of the visual variables by each technique. Convention: **Available**, **Used to differentiate domains**, **Used by the technique**, **Does not apply**.

Technique	Color	Size	Position	Shape	Transp.	Ang.pos.	Orient.	Texture
Force Graph	Used to differentiate domains	Available	Used by the technique	Used by the technique	Available	Does not apply	Does not apply	Available
Radial Graph	Used to differentiate domains	Available	Used by the technique	Used by the technique	Available	Used to differentiate domains	Does not apply	Available
Sunburst	Available	Used by the technique	Used by the technique	Used by the technique	Available	Used to differentiate domains	Does not apply	Does not apply
Treemap	Available	Used by the technique	Used to differentiate domains	Used by the technique	Used by the technique	Does not apply	Does not apply	Does not apply

$$\varepsilon_v = \Sigma(A_v * w_A) \quad (1)$$

where A_v is the availability of a visual variable for a given visualization (see Table 2), and w_A is the weight -expressive power- of each variable. On the other hand, we defined in previous work [5] a set of evaluation criteria for assessing the support for EA Visual Analysis offered by some EA management tools and general purpose visualization tools, in order to assess the gap between what is offered by the former and what is possible by the latter. We incorporated a metric for each EA requirement, ending with four quantitative and four qualitative criteria (see Table 3).

Table 3. Criteria for the evaluation of each EA Requirement and their associated metrics.

ID	Measure	Type	Units	Scale
C1	Domains differentiated/Total Domains	Quantitative	% differentiation	0-1
C2	Display of inter-domain relations	Qualitative	Scale	0-5
C3	Visual Effectiveness (ε_v) of the visualization	Quantitative	Effectiveness	0-3
C4	Easiness of selecting arbitrary elements	Qualitative	Scale	0-5
C5	Number of levels of detail supported	Qualitative	Level of detail	0-4
C6	Perception of similarity and grouping	Quantitative	Gestalt principles	0-8
C7	Level of differentiation of relations	Qualitative	Scale	0-5
C8	Has the visualization significantly changed when applying different models?	Quantitative	Yes/No	0-1

5.1 Results

Evaluation results are displayed in Fig. 4 by using a Parallel Coordinates visualization, which provides a visual summary of the effectiveness of each technique.

We can see that graph visualizations point to *convergent* analysis, as their strong points are when searching concrete elements and groups, displaying the dependency between domains. At the same time, hierarchical techniques offer an interactive way of exploring the model, facilitating abstraction of elements and offering *divergent* analysis, where it is more important to characterize the architecture as a whole.

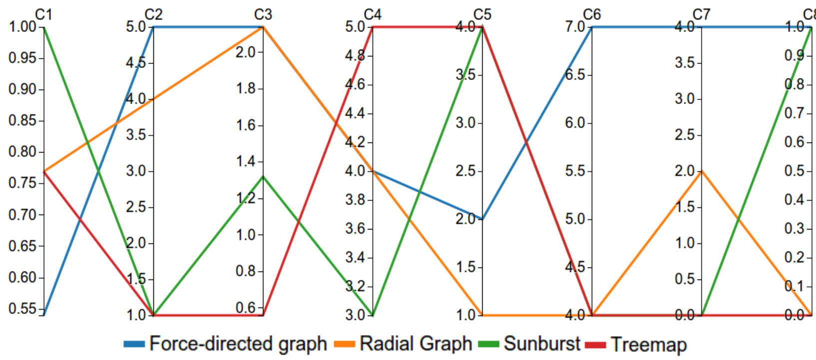


Fig. 4. Evaluation results.

6 DISCUSSION

A previous step before proposing new domain-specific visualization techniques is the assessment of existing ones, in order to derive which aspects of each technique prove useful in our context.

When addressing the visual analysis of complex systems by displaying the overall structure, the analyzed visualizations employ different methods to show the 'big picture' of these complex systems. The visual patterns that they display point to structural assessments of this information. These kind of conclusions are fundamental for the analysis and evolution of the architecture, as well as a way to leverage the complexity of EA Management.

However, this overview analysis is mediated by the concerns of the analyst. This trade-off is reflected on the EA requirements, where some emphasize convergent analyses, i.e. the discovery of interesting elements, while others on Divergent analyses, which are a characterization of the architecture as a whole.

This study opens the door to more specialized research on EA visualization and tooling, as well as the proposal of innovative visualization techniques for the field. Other interesting research opportunities, such as the correspondence between visual and architectural patterns need to be further developed, and a Visual Analysis tool for EM has some requirements in the overall process that we didn't touch, e.g. Provenance (persisting previous hypotheses/analyses and annotations), Traceability of the analysis, or even interactive visualizations specific for EA, as well as an architecture to support all of these features, integrated with current EA modeling tools.

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