Architecture Principles Compliance Analysis

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Abstract: The architecture principles play a key role in the enterprise architecture evolution. However, the architecture does not always address the principles intentions, which could result in unplanned deviations. Through the related work study, it's perceptible the lack of an architecture analysis that enables to evaluate the architecture compliance regarding the architecture principles. To surpass the referred lack, this research proposes an architecture analysis, which allows evaluating the architecture compliance with its guiding principles. An architecture principle could be considered the rationale for the presence of several elements and relationships in the architecture, which enables to characterize a principle through its expected impact. The proposed analysis consists in the principle expected impact recognition to evaluate the architecture, which consequently enables to identify its compliant elements. This impact is formalized, based on ArchiMate, which enables to analyze the architecture through its enterprise architecture descriptions. The proposed analysis includes a dedicated analysis for nine principles. To demonstrate the research proposal, it is applied to analyze the compliance of some specific architectures. These architectures, provided by a Portuguese insurance company, should address the considered principles instructions. Thus, regarding the guiding principles for each architecture are identified its compliant elements through the proposed analysis. Hereupon, the proposal feasibility positions this work as a contribution to the architecture principles field.

1 INTRODUCTION

Modern enterprises face a range of challenges imposed by their environment (Op't Land et al., 2008) which impacts how they hold their evolution, making them transform. This is where organizations position the enterprise architecture (EA) as an instrument to coordinate and steer their transformation (Greefhorst and Proper, 2011). The EA design defines the delivered services and all the alignment between the underlying business processes, information systems and IT infrastructure (Greefhorst and Proper, 2011). The robustness of this design is critical to face the imposed challenges.

Hereupon, the EA design must evolve in order to make effective the organization adaption to the environment. To properly guide this evolution, the architecture principles are positioned as the key ingredient. Therefore, it's important that EA design complies with their guiding principles, which is not always achieved. This emphasizes the need for an EA compliance evaluation based on architecture principles.

However, the related work study shows that an EA analysis to evaluate the EA compliance with their guiding principles still lack. Hereupon, our vision pretends to formalize architecture principles, based on ArchiMate to enable their EA compliance analysis. This formalization enables to analyse an enterprise architecture description (EAD) through the detection of architecture structures that represent the principle expected impact, and consequently identify their compliant elements.

1.1 Research Problem

Associated with the outlined strategy, there is a target architecture that should be reached. This is where the architecture principles give advice on how to design the pretended architecture by restricting the design freedom of EA projects (Hoogervorst, 2004; Hoogervorst, 2009). The architecture principles could also be considered the rationale for the presence of certain elements and relationships in the EA (Greefhorst and Proper, 2011).

As stated by (Greefhorst and Proper, 2011), the principles effectiveness is closely linked how stakeholders assimilate and interpret them. So, as a result of principles application is expected the stakeholders' decision-making aligned with the principles intentions, to be possible the achievement of the desired architecture (Lindström, 2006).

However, there are several factors that could endanger the proper principles interpretation. The ambiguity in the principle specification, the organizational context where the principle is being applied and the lack of precise information in the principle specification, represent some of the existent factors that could influence the stakeholders' interpretation (Greefhorst and Proper, 2011). Thus, a misinterpretation may imply deviations from the principle intended impact in the EA, which could result in the organizations failure to achieve their strategic objectives (Greefhorst and Proper, 2011). Hereupon, it's evident that organizations need to possess a mechanism to analyze whether their architecture design is or not compliant with their guiding architecture principles.

In the architecture analysis field, the EA models analysis plays a central role (Lankhorst, 2009). The enterprise holistic view provided by EADs, which could be adapted to the stakeholders concerns, present the EADs as artifacts with valuable information to plan and evaluate the EA evolution (Šaša and Krisper, 2011). However, through the literature study, none of the existing architecture analysis, based on EADs, addresses the architecture compliance with architecture principles.

Thus, regarding the relevance that EADs can play and the organizations need to assess the principle compliance, becomes evident that the non-existence of an architecture analysis that combines these two points is a substantial gap in the literature. This non-existence corresponds to the problem endorsed by this research.

Hereupon, when we try to perceive how and what should be considered to approach the identified gap several questions emerge. The following questions address the research questions to be answered by this research.

Q1: What are the existing architecture analyses that could be used to enable the architecture principle compliance analysis through EADs?

Q2: The EADs could be used to verify the architecture compliance with its guiding principles?

Through this last question other questions arise.

Q3: What architecture elements and relationships are impacted by the architecture principles and should be analyzed in the compliance analysis?

Q4: What are the conditions to be followed by the impacted architecture elements and relationships to be compliant with the respective principle?

To summarize, the problem identified is the lack of an architecture analysis to evaluate the architecture compliance with its guiding principles, through the respective EADs. To address this problem, this work will seek to answer to the questions defined above.

1.2 Contributions

To surpass the identified problem, this research presents the following contributions:

- The proposal of an architecture analysis to evaluate the EA compliance with its guiding principles. This analysis consists in the recognition of architecture structures that represent the principle expected impact. This recognition is based on the formalization of these structures in ArchiMate, which enables to identify the compliant elements in the respective EADs.
- The architecture structures are formalized in a way to be used by EA management tools to proceed to an automatic principles compliance analysis.
- To demonstrate the research proposal, it's used a case study provided by Fidelidade. This case study besides being used to demonstrate the proposal feasibility is also valuable to the architecture principles field due to its novelty.
- To understand what could be addressed by this investigation, the literature study related with architecture principles and architecture analysis are presented. This study presents itself as a contribution due to non-existence of literature that relates these two fields.

1.3 Research Methodology

The Design Science Research Methodology (DSRM) has been considered to properly guide this research. The DSRM creates artifacts intended to solve organizational problems that are then evaluated based on the utility provided in solving those problems. The artifacts produced could be classified as constructs (vocabulary and symbols), models (representations), methods (algorithms and best practices) and instantiations (implementations and prototypes) (Hevner et al., 2004). The artifact proposed by this research could be characterized as a model since models aid problem and solution understanding, and frequently represent the connection between problem and solution enabling exploration of the effects of design decisions and changes in the real world (Hevner et al., 2004).

Peffers et al. (2008) propose an iterative process to apply the DSRM. The process composition and the document sections that endorse each step are presented in Table 1.

Table 1: Relation between DSRM and document structure.

DSRM Step	Section
1)Problem identification and motivation;	1.1, 2
2) Define the objectives for a solution;	1.2
3) Design and development;	3
4) Demonstration;	4
5) Evaluation;	5
6) Communication.	6.1

2 RELATED WORK AND MOTIVATION

2.1 Enterprise Architecture

The EA can be defined as a coherent whole of principles, methods, and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems, and infrastructure (Lankhorst, 2009). It enables a better decision making by sharing knowledge on architecture decisions and provides a way to describe and control an organization's structure, processes, applications, systems, and technology in an integrated way (Lankhorst, 2009).

2.2 Architecture Principles

The architecture principles can be seen as general rules and guidelines, intended to be enduring and seldom amended, that inform and support the way in which an organization sets about fulfilling its mission (The Open Group, 2009). They play a prominent role in the EA development giving advice how to design target architecture by restricting the design freedom of EA transformation projects (Aier et al., 2011). The architecture principles to be really effective and be considered good principles they must have a clear semantic, understandable syntax and the right focus (Lindström, 2006; Van Bommel et al., 2007). However, if any of these characteristics are violated some deviations in the expected impact could emerge (Greefhorst and Proper, 2011). This fact emphasises the need to verify if the EA impact is the prescribed by the architecture principles.

The principle application consists in the transformation activity, which is separated in two types. The first one called derivation consists in the principles transformation into statements that are relevant in a more specific context. The other is related with the principle transformation to models. This transformation it´s build on the fact that architecture principles can be the rationale behind a number of elements and relationships in a model (Greefhorst and Proper, 2011).

It's also important to relate these transformations with the respective compliance management. In the compliance management is advised the principle refinement into requirements and then in design decision to perform the compliance verification (Greefhorst and Proper, 2011). However, this advice maps with the derivation transformation. So, it‘s evident a lack of a compliance verification to the principle transformation to models, which evidence the non-consideration of EADs in the principle compliance management. It is here that our work presents itself as a contribution.

Finally, the architecture principles used are selected from the catalogue in (Greefhorst and Proper, 2011). Another catalogue is provided by TOGAF (The Open Group, 2009) although the principles from the previous catalogue present some advantages. They are based on real-world architectures (Greefhorst and Proper, 2011), they are aligned with ArchiMate and are more level-specific (Vieira,2012). The principle specification objectivity is another issue endorsed by the principle choose. The chosen principles have to be sufficient objective that enable to perceive of what are their EA impact.

2.3 Enterprise Architecture Modeling

The analysis intended by this research is intimately connected how EA could be represented. The ArchiMate comprises an EA modelling language providing precise descriptions of the architecture in different domains and different stakeholders, a feature that is not allowed in other modelling languages (The Open Group, 2012).The integrated representation between domains, enabled by ArchiMate (Lankhorst, 2009)., turn easier to analyse the principle impact that propagates through multiple domains.

The possibility to extend the ArchiMate metamodel (The Open Group, 2012) represents also another important issue. Some specific cases in principle analysis could require the unambiguously identification of a certain element or relationship that is not endorsed by the metamodel.

Beside these considerations justify the ArchiMate use, the alignment between ArchiMate and the architecture principles from the catalogue referred in Section 2.2 (Vieira, 2012) represent also another justification for ArchiMate consideration.

2.4 Enterprise Architecture Analysis

The EA discipline advocates the use of models to support decision-making (Johnson et al., 2007). These decisions can be supported by appropriate analysis techniques that show why a solution is better or to detect inconsistencies (Šaša and Krisper, 2011). Lankhorst (2009) describes different architecture analysis techniques that can be used with ArchiMate. Quantitative and qualitative analysis techniques are distinguished.

Quantitative analysis focuses on the quantitative aspect of relationships between different EA elements and layers. It can be used for optimization by quantifying the effect of alternative design choices obtaining measures to support impact-of-change analysis (Šaša and Krisper, 2011).

Qualitative analysis enables to understand how a system that conforms to the architecture works, to find the impact of a change on the architecture, or to validate the architecture correctness. This analysis distinguishes structural and dynamic aspects (Lankhorst, 2009). The structural analysis is used to determine the EA change impact which implies traverse the architecture and consider each relation and its meaning to determine whether the change might propagate. Description logics are useful formalisms to perform this analysis. For dynamic analysis, techniques based on formal interpretations are used. Dynamic analysis improves consistency and focuses on logical aspects of the models. (Šaša and Krisper, 2011).

Other approaches based on EA patterns exist for business support analysis (Šaša and Krisper, 2011). The approach used consists in the pattern formalization to detect architecture structures that characterize each pattern. The detection of the referred structures enables to be aware of what could be changed and how the EA could evolve. The pattern formalization is based on ArchiMate.

The approach considered in (Šaša and Krisper, 2011) is divided in three main steps. The first step consists in the perspective (viewpoint) definition, where the elements and relationships that have to be considered in the respective pattern are highlighted. The second step defines the characteristics to be addressed by the architecture elements presented in the views that describe the architecture. These views are based on the perspectives previous defined. These characteristics are then used to recognize the architecture structures that correspond to each pattern. The last step corresponds to the establishment of a mechanism to automatically recognize the referred characteristics. The recognized patterns are then used in the comparison with other formalized patterns to identify how the architecture should evolve.

The architecture principles and patterns share the point of being the rationale for the presence of several architecture elements and relationships in the EA. This shared point enables to perceive that the approach presented by (Šaša and Krisper, 2011) could provide the basis for our analysis.

The proposed analysis could be positioned in the structure analysis, however it is not intended to analyse the EA change impact. It allows evaluating the EA coherence which could result in the improvement of the architecture dynamics. These improvements could represent the rationale underlying the prescribed architecture principle.

3 PROPOSAL

To surpass the research problem, this work proposes an architecture analysis based on architecture principles. This analysis enables to identify the principle compliant elements, in the respective EADs, with the EA guiding principles.

The architecture principles are considered the rationale for the existence of several EA elements and relationships (Greefhorst and Proper, 2011), which enable to characterize them through their expected impact in the EA. This characterization represents the basis underlying the proposed analysis. In this analysis, the architecture structures concerning each principle are recognized, when the architecture is analyzed. If these structures are recognized, the compliant elements are identified.

So, the analysis proposal endorses the identification of the elements and relationships impacted by each principle. It also addresses, how the impacted elements should relate with each other in order to not violate the principle intentions. This last consideration represents the construction of the architecture structures that represent the principle impact. It's also important to know how the architecture principles and the analyzed architecture could be described. In this analysis, the ArchiMate modelling language will be used for that purpose.

3.1 Approach

In this section is presented the approach behind the proposed analysis. This approach, based on (Šaša and Krisper, 2011), consists in the identification of the EA elements and relationships needed to perform the principle compliance analysis. Then, the architecture structures that represent the principle expected impact are recognized. This recognition enables to determine the compliant elements in the analyzed EAD. This approach is applied for each principle and is composed as follows:

- **To define relevant EA perspectives.** These perspectives can be seen as the necessary viewpoints that represent the elements and relationships impacted by the principle.
- **To define characteristics that address the principle perspectives.** These characteristics define the conditions, prescriptions imposed by the principle. They enable to recognize the principle expected impact in the EAD and consequently identify the compliant elements.
- **To establish a mechanism to automatically recognize the characteristics prescribed by the principle.** This automatic recognition, through an EA management tool, enables to proceed to a larger and complex analysis.

For each principle analysis the two first steps are addressed in the research proposal (Section 3) and the third in the Case Study (Section 4). In summary, we represent an architecture principle as a set of elements, which is formalized with its membership conditions. If an EA element respects the principle membership conditions it is compliant. The principles definition in their membership set conditions is formalized in a way which enables their implementation using an EA tool that supports the ArchiMate metamodel. Regarding the third step of the referred approach, the EAMS (Available at: http://www.linkconsulting.com/eams) is the EA management tool considered by this research.

Before proceeding to the proposed analysis it's important to notice the following considerations. The ArchiMate elements used to formalize the principles impact are presented in Table 2 as symbols. These symbols are based on (Šaša and Krisper, 2011). However, as can be seen not every elements belong to the ArchiMate metamodel. The new elements and relationships correspond to extensions to the metamodel (The Open Group, 2012). The reason for each extension is explained in the principle analysis that requires it.

It's also relevant to understand how the principle perspectives are defined. If PIA represents a set of all element and relationships of an EAD, then a viewpoint can be defined as a function vp that maps a given EA into a subset of its elements and their relations. Function $vp(PIA)=P$, $P \subseteq PIA$, where P represents a view of the EA from the viewpoint vp. Hereupon, two functions are defined to represent a viewpoint (Šaša and Krisper, 2011):

- Function $Elt(x)$, where $x \subseteq PIA$, is a function which returns all elements in a given EAD x or in a given view x of an EA.
- Function $Rel(x)$, where $x \subseteq PIA$ is a function which returns all relationships in a given EAD x or in a given view x of an EA.

3.2 Architecture Principles Used

As mentioned in Section 2.2, the architecture principles choose is a critical part of this research. The principles used in the proposed analysis represent the principles sufficiently objective to be evaluated through their EA impact. They are the A.11, A.12, A.14, A.15, A.28, A.29, A.42, A.43 and A.56 principles from (Greefhorst and Proper, 2011). However, in this document only is presented the compliance analysis relative to the A.14 principle.

3.3 Data are Provided by the Source Analysis

The compliance architecture analysis presented in this section is based on the principle highlighted in Table 3. Concerning this analysis, it was necessary to proceed to a few extensions in the ArchiMate metamodel. These extensions are:

- The **Creation** and **Provide relationships**. These relationships could be considered as a specification of the access relationship in the ArchiMate metamodel. To avoid ambiguity in the principle verification we need to extend the metamodel with the referred relationships.
- The **CR** set enables unambiguously identify the business roles that correspond to customers.
- The **EF** set is used to identify business interfaces that represent electronic forms.

3.3.1 Definition of DPS Perspectives

The DPS viewpoint (DPSV) addresses the elements and relationships of the set *DPSV⊆PIA*, which is defined with the following:

$$(1)Elt(DPSV) = \{x|(x \in AS) \lor (x \in AC, \exists as1:(x,as1) \in Realization) \lor (x \in DO, \exists as2 \in AS:(as2,x) \in Provide \lor (as2,x) \in Creation)\} \cup \{y|(y \in BS) \lor (y \in BI, \exists bs \in BS:(x,bs) \in Assignment \land \exists br \in BR:(y,br) \in Used\ by)\}$$

$$(2)Rel(DPSV) = \{(x,y,z)|x \in AS, y \in DO, z \in AC, ((x,y) \in Provide \lor (x,y) \in Creation) \land (z,x) \in Realization\} \cup \{(t,u,v)|t \in BR, u \in BI, v \in BS, (u,z) \in Assignment \land (u,t) \in Used\ by\}$$

The elements and relationships defined in the previous functions is presented in Figure 1.

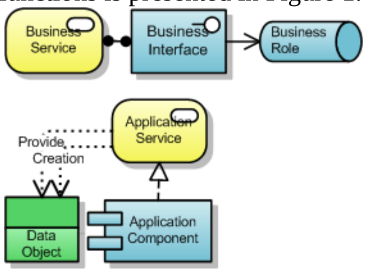

Figure 1 : DPS Viewpoint.

3.3.2 Definition of DPS Characteristics

By analyzing the referred principle, we perceive that we have to consider two main prescriptions. The first one is related with the fact that data objects only could be provided by application services from their application component source. The application source of a certain data object is the application component responsible for its creation.

This prescription is endorsed by the ASDOASource set, which defines the application services that only provide data objects if the application component responsible for those services corresponds to the application source of the referred data objects.

$$(3)ASDOASource = \{as1|as1 \in AS \land \forall do \in DO:(as1,do) \in Provide \land (\exists as2 \in ASAC(as1):(as2,do) \in Creation \lor (\exists ac \in AC:(ac,as1) \in Realization \land (ac,do) \in Creation))\}$$

The used ASAC function identifies all application services realized by the application component that realizes a determined application component. This

Table 2: Symbols for principle formalization.

Symbols			
PIA	Set of all elements and relations of an EAD	*AC*	Set of all application components in the EAD
BR	Set of all business roles in the EAD	*DO*	Set of all data objects in the EAD
CR	Set of all customers in the EAD: *CR ⊆ BR*	*(a,b) ∈ Creation*	a is related to b with the Creation relationship: *a* creates *b*
BI	Set of all business interfaces in the EAD	*(a,b) ∈ Provide*	a is related to b with the Provide relationship: *a* provides *b*
EF	Set of all electronic forms in the EAD: *EF ⊆ BI*	*(a,b) ∈ Realization*	a is related to b with the Realization relationship : *a* realizes *b*
BS	Set of all business services in the EAD	*(a,b) ∈ Used by*	a is related to b with the Used by relationship: *a* is used by *b*
AS	Set of all application services in the EAD	*(a,b) ∈ Assignment*	a is related to b with the Assignment relationship: *a* is assigned to *b*

Table 3: Data are provided by the source principle (Greefhorst and Proper, 2011).

A.14 Data Are Provided by the Source (DPS)
Type of information: data, application **Quality attributes:** reliability, efficiency
Rationale: • When those who have the data also provide them, unnecessary intermediate layers (e.g. people or IT components) are prevented. • The performance and reliability of the data also increases, since each link in the chain adds performance overhead and potential errors.
Implications: • Electronic forms are provided to customers to enter their requests. • Applications acquire data from the source application.

function in ASDOASource is used to verify if exists any of the referred services is responsible for the creation of the data object that is being analyzed.

$$(4) ASAC(a) = \{as \mid as \in AS \wedge \exists ac \in AC : (ac,a) \in Realization \wedge (ac,as) \in Realization\}$$

The Figure 2 illustrates a simple example of the application services identified by ASDOASource.

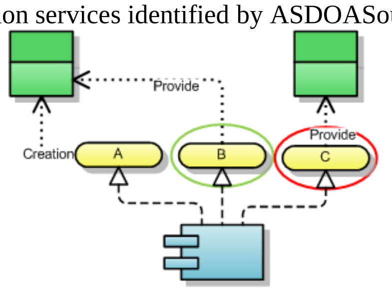

Figure 2: ASDOASource Application Example.

Through the first principle implication, it's also prescribed that should be provided electronic forms to customers enter their requests and use the respective business services. This prescription is endorsed by the BSEF set. A BSElecF example is presented in Figure 3.

$$(5) BSElecF = \{bs \mid bs \in BS \wedge \exists bi \in EF : (bi,bs) \in Assignment \wedge \exists br \in CR : (bi,br) \in Used\ by\}$$

Hereupon, the DPS set identifies the principle compliant elements. This set is composed by application and business services. The application services are related with the prescription treated by ASDOASource and the business services with BSElecF.

$$(6) DPS = ASDOASource \cup BSElecF$$

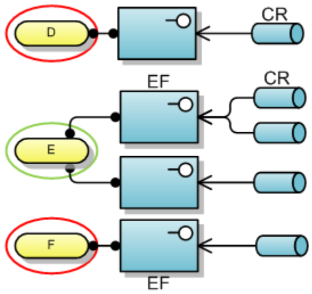

Figure 3: BSElecF Application Example.

In Figure 4 is presented a DPS application example. It's important to notice that the obtained result is in line with the sequence of the previous examples.

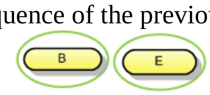

Figure 4: DPS Application Example.

4 CASE STUDY

To demonstrate our proposal, the compliance analysis was applied to real EADs provided by Fidelidade, which is one of the largest Portuguese insurance companies. The Fidelidade historic evolution is characterized by several merges with other companies which result in a large and complex EA. This complexity presents itself as a valuable point to apply the proposed compliance analysis.

The presented case study consists in the representation of some specific architectures, which subsequently are used to evaluate their compliance with their guiding principles. For each architecture, through the respective architecture principle compliance analysis is expected the identification of the elements that address the principle intentions.

For each analysis, besides the obtaining of the architecture compliant elements it's expected consequently, to obtain the knowledge about the elements that need to be fixed to be considered compliant in the future.

Hereupon, initially the analyzed architectures are introduced, and their respective EADs are presented. Then, for each architecture the respective compliance analysis is applied and the resulting compliant elements are identified in green. It's important to notice that the EADs used to describe a certain architecture, are based on the principle perspectives that is being analyzed. For each analysis, the same obtained result is also presented by performing the same analysis automatically through the EAMS parameterization. This automatic analysis corresponds to the third step presented in the used approach (Chapter 3).

4.1 A.14 Principle Analysis Application

The DPS compliance analysis is applied to one specific solution, the Leve solution. The Leve solution is based on a retirement savings plan (PPR), which offers two investment options with different risk levels, where the client can invest in one of the options or allocate their investment between them. In Figure 5 is presented a view where is described a Leve partition. The described architecture should address the A.14 principle intentions. So, in the referred view is applied the DPS set to perform the pretended compliance analysis.

Through the principle analysis demonstrated above, it's perceptible that all application services realized by eGIS are non-compliant with the principle. The reason for the referred inconformity is due to the fact that these services provide data objects that are not created by eGIS. The non-recognition of these application services as compliant is performed when the ASDOASource set is applied. In this case, only the services realized by GIS Vida should provide that information which represents the reason for their identification as compliant. In Figure 6 is presented the same result, but is obtained through the automatic application of this analysis.

5 EVALUATION

5.1 Results Discussion

Through the compliance analysis previously applied some general considerations could be made:

- It's possible to determine the principle expected impact in the EA. In the research proposal, this impact represents the basis for the principle compliant elements identification. The principle expected impact, initially endorses the principle perspective definition and then, consists in the principle formalization, where are analyzed the architecture structures that characterize each principle.
- If a certain EAD or EADs possess the elements and relationships needed to perform the compliance analysis of a certain principle it's

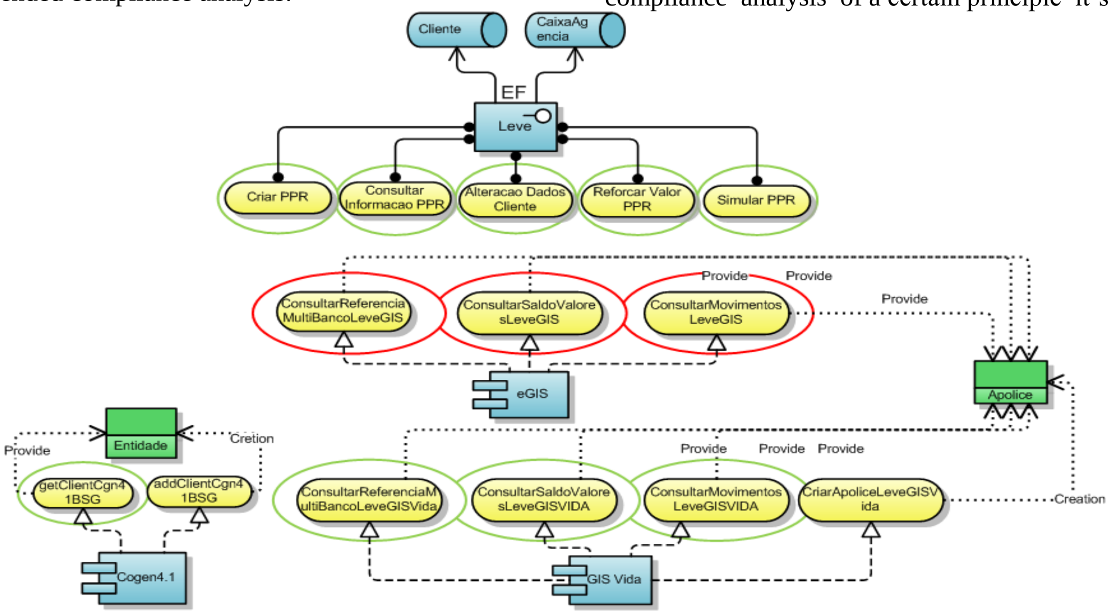

Figure 5: A.14 analysis demonstration in Leve.

Figure 6 : A.14 analysis automatic demonstration in Leve.

possible to recognize its compliant elements.

- The principle formalization behind the proposed compliance analysis, is defined in a way that enables its parameterization in an EAM tool that provides a form of script/query language.
- The compliance analysis for each principle could be applied to non-ArchiMate based EADs, since the underlying metamodel endorses the elements and relationships used in the compliance analysis.

The recognition of the principle compliant elements through the proposal application, also enables to acquire the knowledge of what the non-compliant elements are. Below, it's performed the match between some specific unconformities and the Fidelidade EA evolution to make explicit the justification for the obtained results.

- Concerning the A.14 analysis (Figure 5), it was identified a redundancy in Fidelidade middleware layer. The existence of this redundancy is known by the architects and is explained by the acquisition of eGis and GIS Vida components as a package. When other components want to obtain the Apolice object from services provided by GIS Vida they can't, since eGIS is responsible for the communication with GIS Vida. So, the Apolice object only could be provided through eGIS, which does not represent its application source. Consequently, the services realized by eGIS are not recognized as compliant.

Hereupon, the compliance analysis proposed by this work presents itself as a mechanism to evaluate the EA, based on architecture principles.

5.2 Results Analysis

In this section, the obtained results are analyzed to verify if the research questions are answered and also, if the proposed contributions are accomplished.

The question **Q1** is answered through the related work study (Section 2.2). This study endorses the architecture principles field, where is recognized their importance and more specifically, it's identified a gap in the existing techniques to verify the EA principle compliance. This gap represents the lack of techniques to verify the principle compliance through EADs. In the literature review of the existing architecture analyses to evaluate the EA quality, it is also perceptible the non-consideration of architecture principles to evaluate the EA.

Regarding the question **Q2**, its answer is positive, which could be verified by the results obtained in the Fidelidade case study (Section 4). However, it's important to notice that to perform a determined principle compliance analysis all the elements and relationships endorsed by the respective analysis have to be considered in the used EADs.

The question **Q3** is answered by the perspectives definition regarding each compliance analysis. These perspectives identify the elements and relationships impacted by the principle and represent what is needed to perform the respective analysis. The Table 1 is also endorsed in this answer.

The question **Q4** is answered, when are defined the characteristics that should be obeyed by the elements and relationships impacted by the principle. These characteristics are obtained through the principle prescriptions, which are formalized in the principle expected impact. This formalization enables to identify the elements and relationships aligned with the principle intentions.

Hereupon, the contributions proposed by this research are achieved, which positions this research as a contribution in the principle compliance management.

6 CONCLUSION

In this paper was proposed an EA analysis based on architecture principles. This analysis enables to identify the compliant elements of an EAD with their guiding principles. The analysis endorses nine principles sufficiently objective to realize which impact they have on the EA. The principle expected impact and the ArchiMate language provide the basis for the approach underlying the proposed

analysis. Initially, are defined the architecture perspectives, which provide the elements and relationships impacted by the principle. Then, for each perspective are formally defined the conditions prescribed by the principle. This formalization is used to verify if the elements of a certain perspective are or not compliant with the respective principle. The principle formalization is then used to parameterise an EAM tool to perform the proposed architecture analysis in an automatic way.
The analysis feasibility was demonstrated in real architectures where compliant elements are identified and the non-conformities are justified.

6.1 Communication

This section corresponds to the communication step of DSRM (Section 1.3), which consists in the research communication to the adequate audiences. During this research, it was submitted and subsequently accepted the following publication:

- Alves, J., Vasconcelos, A., Sousa, P., 2014. Architecture Principle Compliance Analysis. In: *16th International Conference on Enterprise Information Systems (ICEIS 2014).*

6.2 Limitations

As mentioned before, the architecture principles are characterized for being immature. Due to this fact, there are few organizations that already adopt the architecture principle concept to evolve their EA. Thus, the proposed solution only is demonstrated in one organization, which represents a limitation.

The contextual factors influence in the principle interpretation could also represent a limitation. The interpretation made in the proposed analysis could differ in some points from other interpretations. Consequently, from different interpretations could result different principles formalization.

6.3 Future Work

As mentioned before, the architecture principles and architecture patterns present some similarities which could be explored. The architecture patterns, such as the architecture principles represent the rationale for certain elements and relationships in the EA. The architecture structures identification that characterizes a pattern could or not respect the expected impact of a certain principle. In this case, the determination of what patterns are compliant with the principles analyzed can be exploited. This direction would require the patterns formalization in ArchiMate as realized in (Šaša and Krisper, 2011). This relationship between patterns and principles are also referred by Hoogervorst (2009), which states that patterns are specific standards which form a subset of principles. This idea is shared by (Greefhorst and Proper, 2011), which refers that a principle could be realized by patterns.

The research proposal application to other organizations could represent another future direction to address. This could result in the principle formalization extension as consequence of other interpretations and other EADs. This extension could be a different way of formalizing the principle impact and therefore result in a more complete analysis.

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