Project GRAAL: Towards Operational Architecture Alignment

Pascal van Eck *Henk Blanken* *Roel Wieringa*

Department of Computer Science
University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands
Email: {vaneck,blanken,roelw}@cs.utwente.nl

Abstract

This paper presents a framework for architecture alignment that can be positioned between approaches for software architecture (which concern software artefacts only) and strategic alignment models. The framework is currently applied in case study research to find alignment patterns used in practice. First results presented in this paper indicate that the framework might yield an operationalization of strategic architecture alignment models. We also present an alignment pattern found that shows a difference between how architectures are designed at the application level and the infrastructure level. We think this difference is significant for practical alignment models.

1 Introduction

Alignment of IT architecture and business architecture is a critical success factor for modern organizations. An IT architecture that aligns with the business architecture of an organization reduces operating costs and can provide the opportunity for new product and service offerings. On the other hand, a misalignment between the IT architecture and the business architecture leads to high maintenance costs and to the loss of opportunities to competitors.

Notwithstanding the importance of architecture alignment, practical guidelines for software architects to achieve alignment are still unavailable. First, current research on software architecture [1, 3, 9] focusses almost exclusively on software artefacts outside their information provisioning context. Second, research in the area of information management (e.g., [2]) focusses almost exclusively at the strategic level, without practical design guidelines for the operational level, which we take to include not only software development, but also e.g. the structure of the IT department or processes for architecture management.

In the GRAAL (Guidelines Regarding Architecture ALignment) project, the holy grail we are searching for would bring together software architecture and the architecture of the information provisioning function. Our (re)search method combines three approaches: (i) analytical research, in which we analyse frameworks and logical relationships among architecture decisions, (ii) case study research, in which we try to find out how architecture alignment is actually done in large organizations, identify best and worst practices, and formulate hypotheses, and (iii) empirical research to test these hypotheses, in which we conduct surveys of architectures and alignment relations and their evaluation by architects. GRAAL case studies focus on large-scale financial transaction processing (retail and wholesale banking and insurance) and government agencies.

In this paper, we present as a first, preliminary result from the first two steps, some findings that show how strategic alignment patterns can be observed in case studies. This will lead to an *operationalization* of strategic alignment models. The specific patterns found themselves are interesting as well. They show that in modern organizations, architecture at the application level is

managed in a different way than at the infrastructure level. Consequently, a key alignment problem is the alignment of IT infrastructure services to the application needs of business processes. We explain this in detail at the end of this paper.

The structure of this paper is as follows. We start out, in Section 2, by arguing that our approach can be positioned between the area of software architecture as pioneered by Shaw and Garlan [9] and elaborated by the Software Engineering Institute (see e.g. [1]) and the area of strategic alignment, of which we consider the paper by Henderson and Venkatraman [2] the most important representative. After that, Section 3 presents our framework for architecture representation, which constitutes the analytic part of our approach. In the GRAAL project, this framework is used to describe the architectures we find in a uniform way to discover alignment patterns. In Section 4, we present the first results obtained after a number of case studies have been performed. Section 5 concludes the paper.

2 Comparison with other research

We position our work between the area of software architecture (Section 2.1) as pioneered by Shaw and Garlan [9] and elaborated by the Software Engineering Institute (see e.g. [1]), and the area of IT strategy as characterised by Henderson's and Venkatraman's paper [2] (Section 2.2).

2.1 Software architecture

The difference between the area of software architecture and our approach is a difference in scope. Software architecture is concerned with the architecture of *software artefacts*, while our approach is concerned with the architecture of *information provisioning* of an organization. To elaborate on this difference, consider the Architecture Tradeoff Analysis Method (ATAM, see [4]), which has the same scope as the area of software architecture in general.

- As the ATAM is limited to software artefacts, it focuses on evaluation criteria such as performance and availability. However, in practice we find other evaluation criteria as well that do not fit well in these classes. (Note however that it may be possible to decouple the ATAM from its focus on software artefacts and expand its scope towards information provisioning.)
- In the GRAAL approach, the information provisioning function is never treated in general, but always in relation to other, concrete business functions for which information has to be provided. In contrast, as the ATAM does consider a software artefact in isolation, it is possible to apply the ATAM to for instance commercially offered general purpose software.

Some overlap between both scopes can also be identified. For instance, on the one hand, the area of software architecture identifies so-called 'business drivers': the business goals that motivate the development of a software artefact. However, as we will see in the next subsection, this is only one of four ways to approach architecture alignment. On the other hand, software artefacts are components of an architecture in the scope of GRAAL, and therefore GRAAL studies the relations between these artefacts, the processes they support, and the infrastructure they are supported by.

The difference between the GRAAL project and the currently popular Model Driven Architecture (MDA, see [5]) proposed by the OMG is comparable to the difference between software architecture and our approach: the MDA is primarily concerned with software artefacts and not with the information provisioning function of an organization as a whole.

2.2 Strategic alignment

Our work can be compared to the Strategic Alignment Model (SAM) proposed by Henderson and Venkatraman [2]. The SAM is depicted in Figure 1, in which bidirectional arrows represent alignment relations. As some of our preliminary results are based on an interpretation of the SAM

in the GRAAL model, we describe the SAM rather detailed before discussing the relation between our work and the SAM.

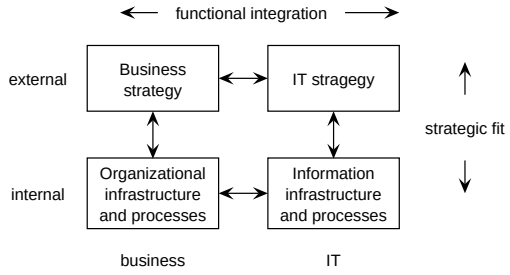

Fig. 1: Henderson's and Venkatraman's Strategic Alignment Model [2].

The SAM distinguishes four areas, along two dimensions (called 'strategic fit' and 'functional integration') that together constitute the overall strategy of an organization. The strategic fit dimension distinguishes between the external and internal domains of alignment. The external domain concerns the position of an organization relative to its competitors with respect to its product/market-combinations, partnerships, integration, etc. The internal domain concerns the structure of the organization, i.e. its departments, its processes, governance, etc. The functional integration dimension distinguishes between the information technology (IT) function and all other functions of an organization. The IT function concerns the scope, competencies, governance, architectures, processes and skills with respect to information provisioning for the business. The other side of this dimension concerns the same aspects with respect to the mission of the organization.

Perspective	Driver	Role of top management	Role of IT management	Performance criteria	Alignment approach
Strategy execution	Business strategy	Strategy formulator	Strategy implementer	Cost/service center	
Technology transformation	Business strategy	Technology visionary	Technology architect	Technology leadership	
Competitive potential	IT strategy	Business visionary	Catalyst	Business leadership	
Service level	IT strategy	Prioritizer	Executive leadership	Customer satisfaction	

Tab. 1: Alignment perspectives distinguished by Henderson and Venkatraman [2].

Henderson and Venkatraman argue that, except for very simple cases, strategic alignment always needs to involve both dimensions. In other words, except for very simple cases, strategic alignment never only concerns one (bidirectional) arrow in Figure 1, but a combination of two arrows, one horizontal and one vertical. They describe four perspectives on strategic alignment

that involve both dimensions and differ by which strategy area acts as a driver, the role of top management and IT management, and performance criteria for assessing the IT function. Table 1 summarizes the four perspectives. In the arrow patterns, an arrow denotes the direction of a driving force.

The merit of the SAM is in its recognition of an external orientation of IT strategy. It is all too easy to approach internal strategy from an internal point of view only (as in the strategy execution perspective). Notwithstanding this, there are many cases in practice in which the specific position of a business with respect to its IT competences enables creating a strategic advantage, which indicates IT strategy has to be present in a model of strategic alignment. However, the SAM model has several drawbacks for the practising architect. First, it is hard to apply the model in practice, as Henderson and Venkatraman do not provide an operationalisation of their model (and to the best of our knowledge, no accepted, tested and sufficiently disseminated operationalisation exists to this date). Thus, given a specific alignment case study, there are no objective, concrete criteria to determine which of the alignment perspective(s) plays a role in the case. Second, the SAM is not a constructive theory of strategic alignment: it does not provide any guidelines on how to reach specific alignment goals. This is the main difference with our approach, as the goal of the GRAAL project is to find such guidelines.

Maes et al. [8] have adapted the SAM by extending both dimensions with one extra level (Figure 2). In their framework, the internal level of the strategic fit dimension is split in two levels, called 'structure' and 'operations'. This extension is motivated by the observation that within the internal domain, operational processes first have to be designed (to determine their structure) before they can be executed. These activities have different frequencies of occurence and are managed in different ways. In the functional integration dimension, the IT level is split in 'technology' and 'information and communication' and to distinguish between pure technology (software development and maintenance, and exploitation) and information dissemination within an organization. This extension reveals a fundamental difference in motivation: while Henderson and Venkatraman emphasise that an organization's competences with respect to information technology is important enough to develop a model for strategic alignment that makes IT strategy explicit, Maes [7] argues that "information itself rather than ... technoglogy as the real carrier of value and source of competitive advantage ...", thus downplaying the importance Henderson and Venkatraman attribute to the technology itself.

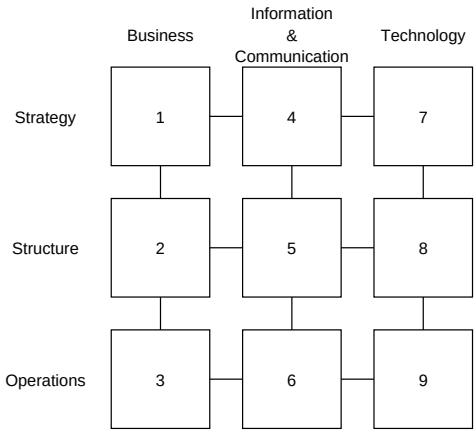

Fig. 2: The alignment model proposed by Maes et al. [8].

2.3 Software architecture in the Dutch software industry

Over the years, several practitioners in the Dutch software industry have published books about architecture alignment (see e.g. [10, 6, 13]). This work is comparable in scope with our approach and therefore the GRAAL project intends to relate our results to these publications. However, at least one important difference can be identified as well: these publications present alignment *methods* developed analytically from practical experience that describe how architecture alignment *should be* managed, while our approach aims to develop *recurring patterns* that describe how architecture alignment *is currently* managed in practice. Our results have the form "If A happens, then B is the effect". The value of this for design is that this observation can be used to make design decisions: "If you want to achieve B, you can choose to do A; and if you want to avoid B, don't do A".

3 The GRAAL framework

3.1 Service layers and refinement

In the GRAAL project, each case study is represented in a uniform way according to the GRAAL framework. In its most extended form, the GRAAL framework consists of four dimensions [11]. We give a brief overview and then discuss the elements relevant for this paper.

- Lifecycle. The process in which the architecture is planned, designed, realised and deployed.
- Aspects.
  - External: Functions, behavior, communication, dictionary, quality.
  - Internal: Composition.
- Service layers. Components provide services to one another, ands this can be strucutred into layers, as explained in more detail below.
- Refinement. The amount of detail the description of the architecture provides.

Note that unlike the other dimensions, the refinement dimension is strictly a description dimension: It concerns descriptions, not the described entities. Similar to our earlier work [14], in this paper we use a version of the paper in which only the service and refinement dimensions are explicit.

At the service layer dimension, we distinguish five service layers. Products provide services (have functions) toward one another. We assume that service provision is structured as an directed graph that shows who delivers services to whom. This graph can itself be structured into layers, such that lower layers provide services to higher layers but not vice versa. So cycles in the service-provision graph are restricted to layers and do not cross layer boundaries. The layers and the interfaces between the layers are depicted in Figure 3.

- The *business environment* consists of the value chain in which the business operates. This includes clients and client groups, suppliers, competitors, government bodies, distribution and communication channels.
- The business is an organization of people and machines with a common purpose to deliver a product or service to a market. To deliver a product or service, the business has to execute *business processes*: Operational processes that respond to external and temporal events to deliver products and services, supporting processes and management processes.
- *Application systems* support or fully perform parts of the operational and other business processes.
- The *implementation platform* is the collection of standard general-purpose software needed to run the application software. It is also called "implementation platform". It ranges from operating systems, middleware, network software to database management software.

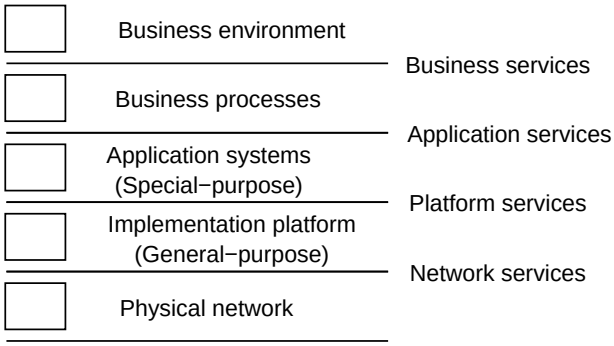

Fig. 3: Service layers in the GRAAL framework.

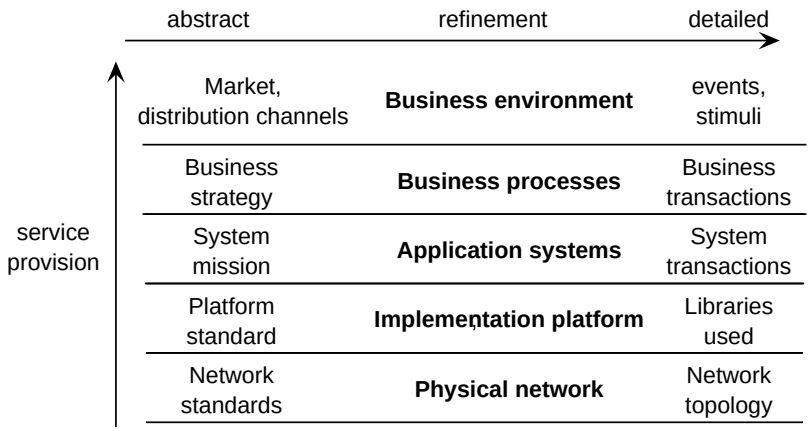

Fig. 4: Refinement.

- The *physical network* consists of the physical resources that run the software platform and the application software. "Physical" means "having a size and weight". The network consists of boxes that contain metal, plastic and silicium, copper wires and other physical entities.

In Figure 3, each line between two layers generally represents a many-many mapping between entities of the two adjacent layers.

The refinement dimension (Figure 4) takes us from abstract descriptions (containing little detail) to detailed description. At the same time, it takes us from strategic decisions (taking the long term global view) to operational decisions (taking the short term detailed view).

3.2 The Strategic Alignment Model interpreted in GRAAL

The Strategic Alignment Model (SAM)can be mapped to the GRAAL framework by equating the strategic fit dimension of the SAM with our refinement dimension, and by equating the functional integration dimension with our service provisioning dimension (Figure 5). We motivate this as follows:

- The organizational infrastructure and processes are designed such that they serve the business strategy, and their description should *elaborate* and *explain* their relationship with strategy. In this sense, (the description of) strategic fit equals refinement: strategy is elaborated and

explained in terms of the tactical and operational choices made to execute the strategy. Note that in all four perspectives described by Henderson and Venkatraman (Table 1), the external domain is always the driver of the internal domain and not the other way around.

- As the IT function of an organization is a supporting function for the business functions, functional integration can be equated with service provisioning in the context of this paper. Note that although our stack of service layers is directed (a lower layer provides services to a higher layer and not the other way around), it is possible that a lower layer drives decisions with respect to the design of a higher layer. This is similar to the four perspectives depicted in Figure 1, in which horizontal arrows go either way.

The four areas of the SAM (Figure 1) can be placed in our dimensions as follows (see Figure 5):

- The *Business strategy* area describes the position of a business relative to its competitors with respect to its product/market-combinations and its place in the value chain. This is precisely the contents of the environment layer in the GRAAL framework.
- The *IT strategy* area describes the position of a business relative to its competitors with respect to its IT competences, IT outsourcing, etc. Notwithstanding the external orientation of this area, it is important to note that *information technology itself is internal in that it serves the primary business of an organization*[1]. Therefore, this area is in the lowest three layers of the GRAAL framework, and not in the upper two. Due to the problems of the SAM with respect to operationalization mentioned in Section 2.2, it is difficult to determine exactly whether IT in the SAM includes aspects of software applications that are not of a technological nature, such as for instance requirements engineering and management.
- The *Organizational infrastructure and processes* area describes the processes and organization of a business. In the GRAAL framework, the business processes layer, which may include descriptions of the business structure, serves the same purpose. Again, as the border between information technology and its applications in the SAM is not exactly clear, it may be the case that this area extends for some part in the applications layer.
- The *Information infrastructure and processes* area is placed at the same layers as the IT strategy area, and the same remark with respect to the exact borders of the area applies. This area is a refinement of (the description of) the IT strategy in the sense that it elaborates on the IT strategy.

Similarly, we can map the model by Maes et al. [8] to the GRAAL model. See appendix A for how this is done.

4 Preliminary Results

4.1 Research method

Since the start of the GRAAL project, we have studied three cases: one in a small Internet startup [14] and two in government organizations. (A fourth case study, in a large insurance company, is currently being carried out). In this section, preliminary results are presented based mainly on the two governmental case studies. The two government organizations are a large one at the national level (case A) and a medium-size local government office (case B). Our preliminary results lead to hypotheses for further study, which are presented in Section 5.

The case studies have been carried out primarily on the basis of project documentation. For each case study, project documentation was obtained which was studied off-site. After that, for each

[1] In the case of a business in the software/hardware or content industry, there are in fact two kinds of information and IT: the information and IT that is on sale, and the information and IT that supports selling the first kind. In this paper, information and IT always refer to the second kind.

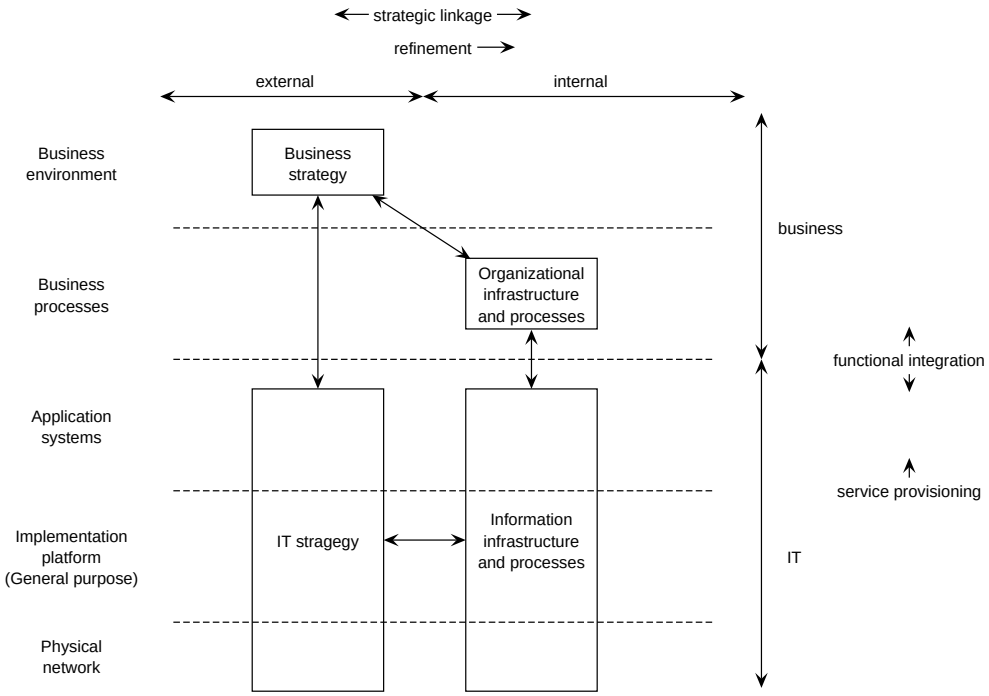

Fig. 5: The Strategic Alignment Model (SAM) in the GRAAL framework.

case study a document was prepared describing observations regarding organizational structure, the architecture development process and architecture documentation, an analysis of the alignment relations found, hypotheses and further research questions, and recommendations. If needed, extra documentation was obtained. This report was discussed with architects from the respective organizations to identify factual errors and present recommendations.

4.2 Strategic Alignment: Application Level and Infrastructure Level

As stated above, for each case study we have analyzed alignment relations as described in the project documentation. In project documentation, alignment relations appear in the form of motivations of design decisions: the architecture of one layer is motivated by goals at a higher layer that it helps to bring about. Therefore, to find guidelines for architecture design decisions, we have traced back all design decisions.

In both governmental cases, we found that design decisions at the application layer are motivated differently compared to design decisions at the software platform and physical network layers, and the difference itself is similar in both cases. (In the third case, no such difference has been found. We expect that the architecture studied in this case was too small.)

Case study A was carried out in a large organization, employing thousands of persons in the IT department alone. In this organization, architecture at the application level and at the infrastructure (software platform and physical network) level are each a responsibility of a different subdepartment. They motivated their designs as follows:

- Design decisions at the *application level* could be traced back via business processes to the business strategy of the organization. In terms of the strategic alignment perspectives distinguished by Henderson and Venkatraman (see Table 1), we interpret this as *strategy execution*.

- Compared to the architecture at the application level, the architecture at the *infrastructure level* is much more motivated by goals and contingencies not related to the business mission of the organization. A factor influencing the design of the infrastructure-level architecture is for example developments in the IT market, i.e. the state of the art in packaged standard software platforms. Several goals in the design of this architecture were mentioned that are not derived from the business strategy, e.g. a goal to use open standards as much as possible. In terms of alignment perspectives, this is *service level*.

In case study B, we identified a similar difference between design decisions at the application level and the infrastructure level:

- The architecture at the business processes layer and application layer is motivated extensively and explicitly in terms of how these architectures contribute to the business mission of the organization studied. The line of reasoning in the project documentation started with the mission of the organization studied. This mission was refined into a set of "service delivery principles", which do not contain any IT-related terms. The service delivery principles were refined themselves in numerous "consequences", most of them referring to processes and management information, and a few of them referring to properties of the IT needed. In term of alignment perspectives, this is a form of *strategy execution*.

- The architecture at the software platform and physical network infrastructure is for a large part motivated by reference to other projects that were carried out concurrently (but by other teams). The design choices and their motivations from these projects were not available to us. However, the documentation of the project studied describes a number of advantages of the architectures designed by the other projects. These advantages do not refer to the business mission of the organization studied, but to its relation with software vendors (the architecture is as open and modular as possible to avoid vendor lock-in). Thus, the architecture at this level seems to be motivated by the relative position of the IT department in the value chain. In terms of alignment perspectives, this is *service level*.

In both cases, we have observed that the design of the architecture of the infrastructure level is motivated in a different way than the architecture at the application level, and that the infrastructure level architecture is much less motivated by the business processes it supports (indirectly via the application level). This may be due to the fact that an infrastructure is never designed for one specific group of users, of which the requirements can be fully determined. To the contrary, we argue that an IT infrastructure is designed for a large part without knowing the requirements of its users. This has important consequences, e.g. application designers need to be aware of the fact that the infrastructure is largely without their design charter. They should view their task as aligning the needs of end users with the infrastructure services provided [12].

Given these findings, we state the following hypotheses:

H1 The IT infrastructure of a large organization is designed at a time when most of its users are not known. The design of the infrastructure is therefore not motivated by user needs, but by the IT strategy of the organization.

H2 Alignment at the application level is motivated both by end user needs and by the features of the currently available infrastructure.

Space restrictions prevent us from presenting more of our intermediate results on the architecture process, on the structure of design organizations anmd on specific architecture guidelines used in the observed processes.

5 Discussion

We have presented a framework for architecture alignment that can be positioned between approaches for software architecture (that concern software artefacts only) and strategic alignment.

This framework is used to facilitate case study research to find alignment patterns used in practice. Our first results indicate that our approach might yield an operationalization of an strategic architecture alignment model. Moreover, we have found a difference between how architectures are designed at the application level and the infrastructure level, which we think is significant for practical alignment models. Generalizations such as the two hypothesis listed above can be used by designers to guide their architecture decisions.

In future research, we will first apply our framework to more case studies. This should result in more and more precise hypotheses. After that, we will validate our hypotheses by structured surveys. The ultimate goal of this research is to find guidelines that will assist the practicing architect in aligning architectures at all levels.

Acknowledgements

The authors wish to thank the organizations that have provided access to their architecture project documentation. The GRAAL project is jointly funded by Telematica Instituut and CTIT.

References

[1] L. Bass, P. Clements, R. Kazman, and K. Bass. *Software Architecture in Practice*. SEI Series in Software Engineering. Addison-Wesley, 1998.

[2] J. C. Henderson and N. Venkatraman. Strategic alignment: Leveraging information technology for transforming organisations. *IBM Systems Journal*, 32(1):4–16, 1993.

[3] C. Hofmeister, R. Nord, and D. Soni. *Applied Software Architecture*. Addison-Wesley, 2000.

[4] R. Kazman, M. Klein, and P. Clements. ATAM: Method for architecture evaluation. Technical Report CMU/SEI-2000-TR-004, Carnegie Mellon Software Engineering Institute, 2000.

[5] A. Kleppe, J. Warmer, and W. Bast. *MDA Explained. The Model Driven Architecture: Practice and Promise*. Object Technology Series. Addison-Wesley, 2003.

[6] A. Ligthart and J. Vis, editors. *Applicatieontwikkeling onder architectuur*. Ten Hagen en Stam, 2002. In Dutch.

[7] R. Maes. Reconsidering information management through a generic framework. PrimaVera Working Paper 99-15, University of Amsterdam, Department of Accountancy and Information Management, 1999.

[8] R. Maes, D. Rijsenbrij, O. Truijens, and H. Goedvolk. Redefining business – IT alignment through a unified framework. PrimaVera Working Paper 2000-19, University of Amsterdam, Department of Accountancy and Information Management, 2000.

[9] M. Shaw and D. Garlan. *Software Architecture: Perspective on an Emerging Discipline*. Prentice-Hall, 1996.

[10] W. van der Sanden and B. Sturm. *Informatie-architectuur: de infrastructurele benadering*. Panfox Holding, 1997. In Dutch.

[11] P. van Eck, H. Blanken, M. Fokkinga, P. Grefen, and R. Wieringa. A conceptual framework for architecture alignment guidelines. project GRAAL WP1 whitepaper. Technical report, Centre for Telematics and Information Technology, 2002.

[12] P. van Eck and R. Wieringa. Requirements engineering for service-oriented computing: A position paper. In J. Gordijn and M. Janssen, editors, *Proceedings of First International Workshop on e-Services, ICEC'03, Pittsburg, PA, USA*, pages 23–28, 2003.

[13] R. Wagter, M. van den Berg, J. Luijpers, and M. van Steenbergen. *DYA: snelheid en samenhang in business- en ICT-architectuur*. Uitgeverij Tutein Nolthenius, 2001. In Dutch.

[14] R. J. Wieringa, H. M. Blanken, M. M. Fokkinga, and P. W. P. J. Grefen. Aligning application architecture to the business context. In J. Eder and M. Missikoff, editors, *Advanced Information Systems Engineering. 15th International Conference, CAiSE 2003, Proceedings*, volume 2681 of *Lecture Notes in Computer Science*, pages 209–225. Springer-Verlag, 2003.

A Reinterpretation of the model by Maes et al. in GRAAL

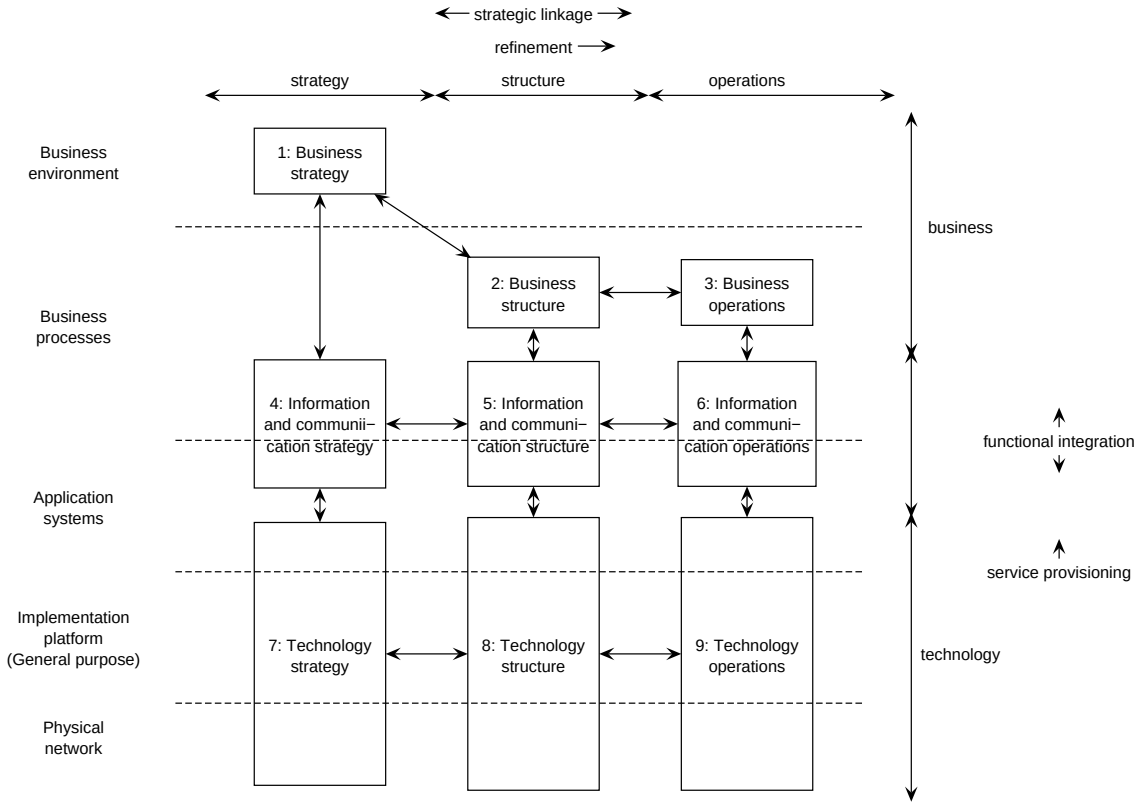

Fig. 6: The alignment model proposed by Maes et al. [8] in the GRAAL framework. The numbers refer to the numbers in Figure 2.