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Fakultät für Informatik
Der Technischen Universität München

Bachelor's Thesis in Wirtschaftsinformatik

Patterns and Reference Models – Two Sides of the Same Coin?
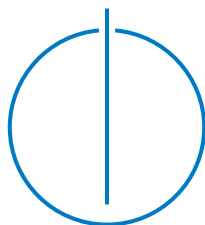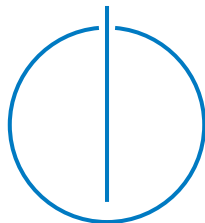
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Patterns and Reference Models – Two Sides of the Same Coin?

Patterns und Referenzmodelle – Zwei Seiten einer Medaille?

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Abstract

This thesis is motivated by the question if there is any difference between the concept of reference models and the concept of patterns. This question is of particular interest as there is no common understanding of both concepts and their differentiation. In recent years different authors seek to identify patterns and reference models as synonyms. Other authors understand the concepts as distinct but target the same aim of presenting re-usable solutions for common problems in given contexts. Firstly, we collect definitions of patterns and reference models from literature and put them in comparison. From this relevant characteristics of the respective concepts are elicited. In a second step we raise hypotheses based on the characteristics. These characteristics are further used to create a comparison matrix and a questionnaire. We send the questionnaire to persons who work with patterns and reference models to find out how they evaluate the characteristics.Furthermore, we prepare our comparison by revisiting selected patterns and reference models and subsequently discuss and juxtapose their characteristics. Thereby we analyze patterns and reference models from three perspectives, the literature, the opinion of professionals and the documented instances. The results of the analysis show whether there is a clear distinction between both concepts or not. In particular we discuss which hypotheses can be confirmed or refuted.

Zusammenfassung

Diese Arbeit ist durch die Frage motiviert, ob es Unterscheide zwischen dem Konzept des Referenzmodells und dem Konzept des Pattern gibt. Diese ist deshalb von Interesse, da für beide Konzepte ein allgemeines Verständis fehlt und sie auch nicht klar von einander unterschieden werden können. In den letzten Jahren tendieren einige Autoren dazu Pattern und Referenzmodelle als gleichbedeutend anzusehen, wohingegen Andere in ihnen unterschiedliche Konzepte sehen, die allerdings daselbe Ziel haben. Dieses Ziel ist die Darstellung wiederverwendbarer Lösungen für bekannte Probleme in einem bestimmten Kontext. Um beide Konzepte vergleichen zu können, sammeln wir in einem ersten Schritt Definitionen von Pattern und Referenzmodellen. Aus diesen Definitionen extrahieren wir Eigenschaften die jeweils charakteristisch für Referenzmodelle und Pattern sind. Auf diesen Charakteristika besieren unsere Hypothesen bezüglich der Verbindung zwischen Pattern und Referenzmodellen. In einem zweiten Schritt entwickeln wir eine Vergleichsmatrix und einen Fragebogen . Mit der Vergleichsmatrix untersuchen wir einzelne Instanzen der beiden Konzepte. Den Fagebogen haben wir an Personen verschickt, die sich beruflich entweder mit Pattern oder Referenzmodellen beschäftigen, um ihre subjektive Einschätzung zu erhalten, was für beide Konzepte characteristisch ist. Somit untersuchen wir Pattern und Referenzmodelle von drei verschiedenen Standpunkten, die Definitionen in der Literatur, die Meinung von Personen, die sich beruflich mit den Konzepten beschäftigen und die tatsächlichen Modelle. Anhand dieser Analysen diskutieren wir, welche Hypothesen akzeptiert werden können oder zurückgewiesen werden müssen.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Motivation

The re-use of artifacts is an important topic in various disciplines. In the scope of software development re-usable artifacts are called "components" in almost every discipline of computer science and information systems. In addition to the well known components other types of re-usable artifacts exist in these disciplines. The term *reference model* names a prominent type of artifact in information systems. Such reference models enable the re-use of information models by abstracting them. The idea of generating abstract artifacts to use them in various contexts came up in information systems in the nineties and became popular. In software engineering further types of re-usable artifacts are denoted as *patterns*. The idea of patterns originates in architecture where Christopher Alexander – as described in [Al77] – uses them "to provide a complete working alternative to [the] present ideas about architecture, building and planning". His intention is showing possible solutions to problems which appear over and over again without restricting the user too much. Eighteen years later the idea of patterns has been adapted by the software engineering community [Ga94]. The article "patterns in business and information systems engineering" [Wi09] discusses the role of patterns on the information systems discipline, two of its co-authors, Fettke and Loos, suspect a relationship between the two concepts. In particular, they assume that the original ideas of patterns and reference models have been different but have approached each other in the recent years. This thesis investigates this idea and seeks to answer the question if patterns and reference models are formally two separate concepts whose characteristics have mixed up together over the time.

1.2 Research question

According to Fettke and Loos in [Wi09] patterns and reference models have different origins. Nevertheless, both artifacts represent the same central idea. Patterns as well as reference models provide abstracted solutions for problems. Thus, these solutions can be applied more than once. The central question this thesis will answer is why these solutions are named differently. The goal is to get a consistent understanding of the conceptions and to show the separating characteristics, if there are any. We address this problem from three different angles as shown in Figure 1.1. In the first step, we collect various definitions of both concepts. We analyze how the various characteristics describe the conception of patterns and reference models. Based on this, we create a questionnaire to find out how persons who are either familiar with patterns or reference models classify them. In the third step, we analyze how objects which have either been named pattern or reference model fit to the characteristics we found in the definitions.
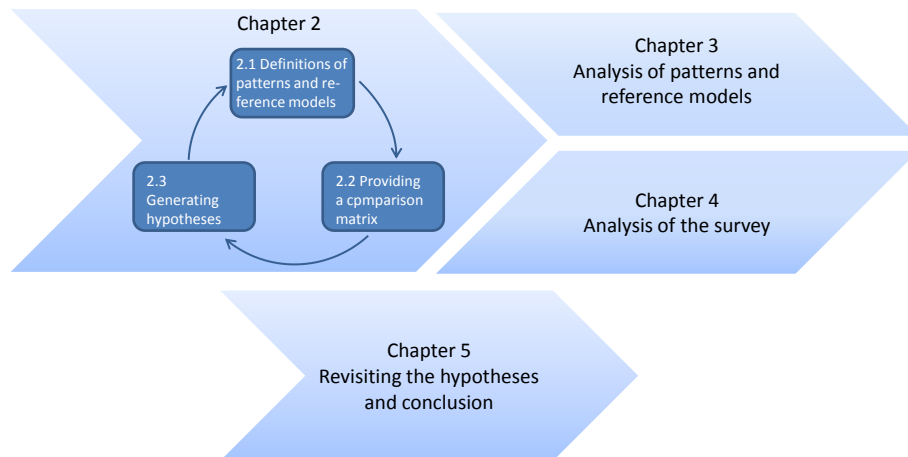

Figure 1.1: Structure of the Thesis

1.3 Structure of the thesis

This thesis focuses on addressing a terminological question. Therefore, it is beneficial to apply a *hermeneutic* research method. This method, according to Gadamer [Ga90], iteratively develops an understanding of existing (scientific)

literature by re-reading the provided definitions and terms, and interpreting them against the evolving knowledge background. Hermeneutic text comprehension is in particular applied in **Chapter 2** to get an understanding of the terms "pattern" and "reference model", and to elicit relevant characteristics thereof. In a first step we collect definitions of both terms from various sources and dates in Section 2.1. From this collection the relevant characteristics of the artifacts are identified. These characteristics are used in a second step to elicit a comparison matrix. In Section 2.3 our theories and hypotheses are introduced. These three sections are mutually dependent as shown in Figure 1.1.

In **Chapter 3** we introduce prominent representatives of patterns and reference models. We describe their intention, their format and other characteristics. Thereby, we concentrate on the characteristics, defined in Chapter 2. Using the comparison matrix, we analyze if these characteristics are mentioned in the respective instances or if they are neglected. By a statistical analysis we identify dependences between the characteristics.

In contrast to an objective analysis of the characteristics of reference models and patterns in Chapter 3, **Chapter 4** shows subjective views. We ask in a questionnaire people who are familiar with either patterns or reference models for their opinion. This survey is created based on the comparison matrix. Considering that we want to get the participants' opinion we extend the possible answers. To get a feeling why authors name their ideas reference models or patterns we add questions about their background.

In **Chapter 5** we go back to the hypotheses. The results of the analysis show whether there is a clear distinction between both concepts or not. In particular we discuss which of the hypotheses can be confirmed or refuted. Therefore we use the knowledge we gained in the previous chapter. Finally we give an outlook on future research directions.

1.4 Research method

The core of this work is to compare patterns with reference models to get an overview how they are related to each other. To analyze if two terms are equal

or not it is necessary to go deeper into the structure of terminology. This is the field of Semiotic which "is the theory of signs, their syntax, semantics and pragmatics" [Kl]. Its goal is to find out the relations between the signs, the ideas which are referred by the signs and the object in the real world. To analyze the relations of two terms, we have to discuss the structure of the terminology first. Therefore, we introduce an extension of the Framework of Information System Concepts (FRISCO) tetrahedron of Falkenberg et al. [Fa98] as shown in Figure 1.2. The tetrahedron itself extends the semiotic triangle to a tetrahedron by placing the actor in the center of the relations of conception, symbol and referent.
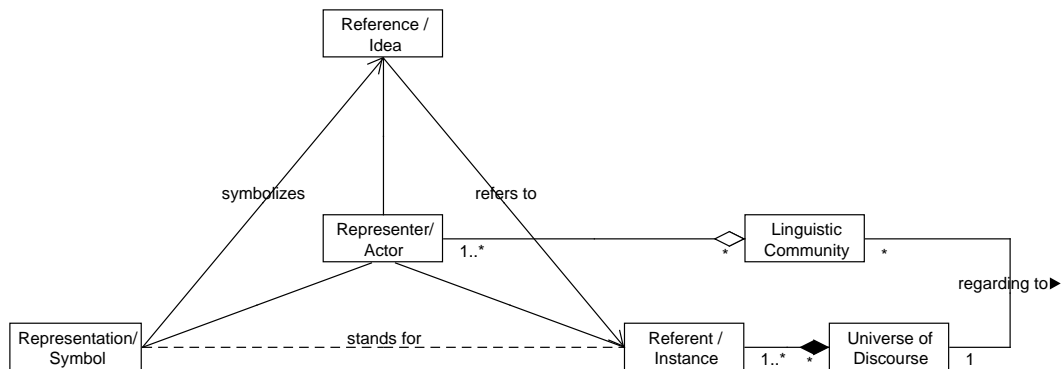
Figure 1.2: Semiotic Diagram

The left corner is the *representation* of a term. The representation or *symbol* is a physical or symbolic entity. This entity can be represented by spoken or written language, but according to Kamlah and Lorenzen in [KL67] gestures and events can also be a representation. The top of the outer triangle is called reference, idea, thought, conception depending on the author. We decided to use the terms *reference* and *idea*. It reflects the content or the sense of the referent in a mental and abstract way. It contains the meaning or intention and all characteristics of the referent. The *referent* or *instance* is "the counterpart or effect [of the reference] in the real world" [HVS00]. It represents the physical entities, actions and processes. The referent is represented by the symbol and reflects all characteristics of the idea. Falkenberg at al. integrated the actor into the semiotic triangle in the FRISCO tetrahedron. Actors can either be persons who communicate the concept to others or "interpret some representation and construct a conception of it" [HVS00]. Furthermore, actors initiate

the connection between the three corners of the triangle. They link the symbol to the connection and transfer them to the referent. Hereby actors form a linguistic community. According to Schweda in [Sc11] "a linguistic community is a group of people that in respect to a certain universe of discourse agree on assigning the same linguistic terms to the same objects of discourse".

Therefore, we extended the FRISCO tetrahedron by the *linguistic community* as the group an actor is part of and by the *universe of discourse*. Persons in the same universe of discourse have the same understanding of the referent, its representation and reference. Two individuals are in the same linguistic community if they refer to all objects in the universe of discourse the same idea. But a linguistic community is not a static group it is rather a group which increases steadily by communicating concepts to individuals who are not yet in the community.

In a first step we assume that these artifacts belong to two different linguistic communities. Before we can compare the conception we have to extend the communities to a common understanding. Therefore we use two techniques. On the one hand the extensional view on the other hand the predicate view. The extension view is a part-whole relation between the conception and its instances. "This means that a concept[ion] is defined by its corresponding individuals in relation to the possible worlds in the universe of discourse" as described in [Sc11]. In line with Guizzardi's postulate 4.1 [Gu05] we assume that "each individual must be an instance of a [conception]". Therefore we use instances of patterns and reference models to analyze their manifestations. On the other hand we use in our thesis the predicate view. Thereby we split the conception into its characteristics. In line with Guarino and Welty, "two things can be the same because they have some parts or qualities in common, or because they are related in the same way to something else" [GW00]. The parts or qualities of patterns and reference models are their characteristics. Moreover, all of those characteristics have to identify the conception distinctly, so it is possible to differentiate between different conceptions.

2 Characteristics of patterns and reference models

This chapter creates the basis for further analyses in Chapters 3 and 4. Therefore, we separate it into three sections which depend on each other as presented in Figure 1.1. Similar to the hermeneutic cycle one step can not be made without having at least an idea of the two others. While analyzing one of the sections the two others can and will progress on the side. Hence, we can start by introducing our hypotheses or our comparison matrix as well as by analyzing definitions of patterns and reference models. The most comprehensible start is to introduce the idea of both artifacts by their definitions. Thereby, a good overview of their characteristics is given. Then we deduce the characteristics for the comparison matrix, before we introduce our hypotheses.

2.1 Definitions

This section contains the first step towards answering our research question as introduced in Section 1.2. We collect definitions of patterns and reference models. On the basis of these definitions catchwords which are characteristic for the particular conception are evolved. Thereby, we use *the hermeneutic circle*. This circle describes a method of understanding a text and is separated into four phases. At the beginning the reader has some knowledge and prejudice about the issue. This status is called preconception. While reading the reader's preconception and the meaning of the text merge. In a third step the reader's knowledge increases and corrects the understanding of the issue. In the end the reader has a deeper understanding of the issue and can use this as preconception for further reading. We analyze the following definitions in this way. We start with our knowledge about patterns and reference models as preconception. By reading the first definition our knowledge enhances. We

add the meaning of the definition to our preconception and continue with the next definition. In each definition the most important phrases are underlined. Out of these phrases we generate catchwords and explain their meaning in connection with each definition. In Section 2.1.3 we re-visualize the occurrence of the characteristics in Tables 2.2 and 2.3.

2.1.1 Definitions of patterns and pattern languages

Below we compare seven different definitions of patterns sorted by the year they have been published. Phrases which are characteristic for patterns are underlined and connected to a footnote. In the footnote the catchword which represents the phrase is mentioned. After each definition the catchwords whose occur for the first time are explained in detail. Subsequent to the definitions we compare three various formats, which are often used for patterns, among each other. These formats are the Alexandrian format introduced in [Al77], the GoF-format which has been used the first time by Gamma et al. [Ga94] and the canonical format which has been picked up by Meszaros and Doble [MD97].

2.1.1.1 A pattern language (Alexander, 1977)

In his book Alexander describes architectural elements. These elements can be used as blueprints for future projects. He names these elements patterns. The book is directed to people who just want to improve their gardens or a single room as well as to architects and landscape gardeners who change the whole cityscape by their work. Alexander defines the intention and the structure of his patterns in [Al77] on pages X to XII as follows:

> Each pattern describes a problem[1] which occurs over and over again in our environment, and then describes the core of the solution[2] to that problem, in such a way that you can use this solution[3] to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice[4].

---

[1] problem
[2] solution
[3] re-usable
[4] adaptable

For convenience and clarity, each pattern has the same format[5]. First, there is a picture [...]. Second, [...] each pattern has an introductory paragraph, which sets the context for the pattern[6] [...]. Then there are three diamonds to mark the beginning of the problem. After the diamonds there is a headline [...]. This headline gives the essence of the problem in one or two sentences. After the headline comes the body of the problem. [...] It describes the empirical background, the the evidence for its validity, the range of different ways the pattern can be manifested [...]. Then [...] is the solution [...] which describes the field of physical and social relationships [...] in the stated context. The solution, is always stated in form of an instruction - so that you know exactly what you need to do, to build the pattern. Then [...] there is a diagram, which shows the solution in form of a diagram [...].

After the diagram, another three diamonds, to show that the main body of the pattern is finished. And finally [...] there is a paragraph which ties the pattern to all those smaller patterns in the language, which are needed to complete this pattern, to embellish it, to fill it out.

There are two essential purposes behind this format[7]. First, to present each pattern connected to other patterns[8], [...], as a language, within which you can create an infinite variety of combinations. Second, to present the problem and solution of each pattern in such a way that you can judge it for yourself, and modify it, without losing the essence that is central to it.

Alexander defines a pattern as a possibility to describe a **solution** to a common **problem** in a **context** in such a way that the solution is **re-usable** i.e. that the pattern presents the solution in a way that it is **adaptable** to each concrete use case. Furthermore each of his patterns has these contents: a picture, a context, a headline, the empirical background, the solution, a

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[5]structured format

[6]context

[7]structured format

[8]combination

diagram, and a paragraph which connects the pattern with smaller patterns i.e. Alexander shows a **combination**-possibility for patterns. Subsequently we call the demand for a certain format **structured format**. Therefore, we assume that **problem**, **solution**, **context**, **re-usable**, **structure format**, **adaptable** and **combination** are catchwords which characterize patterns in Alexander's opinion.

2.1.1.2 Design Patterns – Elements of Reusable Object-Oriented Software (Gamma, Helm, Johnson and Vlissides, 1994)

Gamma, Helm, Johnson and Vlissides have written one of the most important books for the pattern community. The authors are often referred as the Gang of Four or GoF. They introduce in their book simple solutions to recurrent programming problems. These solutions have been improved over the time and try to offer a high degree of flexibility and re-usability. These solutions are not static in their description, but are continuously revised. In [Ga94] they give the following definition of patterns based on the essential constituents at page 3:

In general a pattern has <u>four essential elements</u>[9]:

- <u>the pattern name</u> is a handle we can use to describe a design problem, its solutions, and consequences in a word or two.

- <u>the problem</u>[10] describes when to apply the pattern. It explains the problem and its context.

- <u>the solution</u>[11] describes the elements that make up design, their relationships, responsibilities, and collaborations. The solution doesn't describe a particular concrete design or implementation, because a pattern is like a template that can be applied in many different situations. Instead, the pattern provides an abstract description of a design problem and how a general arrangement of elements solves it.

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[9]structured format
[10]problem
[11]solution

- the consequences are the result and trade-offs of applying the pattern. [...] they are critical for evaluating the design alternatives and for understanding the costs and benefits of applying the pattern.

[...]For this book we have concentrated on patterns at a certain level of abstraction. Design patterns are not about designs such as linked lists and hash tables that can be encoded in classes and reused as is[12]. Nor are they complex, domain-specific designs for an entire application or subsystem. The design patterns in this book are descriptions of communicating objects and classes that are customized to solve a general design [problem][13] in particular context[14].

Gamma et al. use for their description of patterns a template to capture the mandatory elements pattern name, problem, solution and consequences which they describe on pages 6f.

- **pattern name and classification:** The pattern's name conveys the essence of the pattern succinctly. A good name is vital, because it will become part of your design vocabulary.[...]

- **intent**[15]**:** A short statement that answers the following questions: What does the design pattern do? What is its rationale and intent? What particular design issue or problem does it address?

- **also known as:** Other well-known names for the pattern, if any.

- **motivation:** A scenario that illustrates a design problem and how the class and object structures in the pattern solve the problem. The scenario will help you understand the more abstract description of the pattern that follows.

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[12]re-usable, adaptable
[13]problem
[14]context
[15]problem

- **applicability**[16]: What are the situations in which the design pattern can be applied? What are the examples of poor designs that the pattern can address? How can you recognize these situations?

- **structure**[17]: A graphical representation of the classes in the pattern using a notation based on the Object Modeling Technique (OMT).

- **participants**[18]: Theses classes and/or objects participating in the design pattern and their responsibilities.

- **collaborations**[19]: How participants collaborate to carry out their responsibilities.

- **consequences:** How does the pattern support its objectives? What are the trade-offs and results of using the pattern? What aspect of system structure does it let you vary independently?

- **implementation:** What pitfalls, hints, or techniques should you be aware of when implementing the pattern? Are there language-specific issues?

- **sample code:** Code fragments that illustrate how you might implement the pattern in C++ or Smalltalk.

- **known** uses[20]: Examples of the pattern found in real systems. We include at least two examples from different domains.

- **related** patterns[21]: What design patterns are closely related to this one? What are the important differences? With which other patterns should this one be used?

---

[16]context
[17]solution
[18]solution
[19]solution
[20]practice-proven
[21]combination

The Gang of Four disassociates itself from having created a pattern language in terms of Alexander, but Gamma et al., too, express that there is a possibility to combine patterns. Furthermore, Gamma et al. describe that patterns are not about designs that can be "reused as is". According to [Ga94] patterns are intended to be **re-used**. This is done not by copy-paste, but instead by adapting the solution to the concrete problem before re-using it. Furthermore they claim that patterns "solve a [problem] in a particular context". They also present the situation in which the pattern can be applied for each pattern in the paragraph "applications". This situation-description we call **context**. Summarizing we found the subsequent characteristics in [Ga94]: **solution**, **problem**, **context**, **structured format**, **re-usable**, **adaptable**, **practice-proven** and **combination**.

2.1.1.3 Design Patterns for Object-Oriented Software Development (Pree, 1994)

In his book, Pree develops a method to communicated complex object-oriented designs. The design of frameworks is captured and separated by several patterns. These patterns can be used to project the design. In [Pr95] Pree defines on pages 60f patterns as follows.:

> In general, patterns help to reduce the complexity in many real-life situations. For example, in some situations the sequence of actions is crucial in order to accomplish a certain task. Instead of having to choose from an almost infinite number of possible combinations of actions, patterns allow the solution of problems[22] by providing time-tested combinations that work. [...] Programmers tend to create parts of program by imitating[23], though not directly copying, parts of programs written by other, more advanced programmers. This imitation involves noticing the pattern of some other code and adapting[24] it to the program at hand. Such imitation is as old as programming.

---

[22]solution
[23]re-usable, practice-proven
[24]adaptable

The design pattern concept can be viewed as an abstraction of this imitation activity. In other words, design patterns constitute a set of rules describing how to accomplish certain tasks in the realm of software development. As a consequence, books on algorithms also fall into the category of general design patterns. For example, sorting algorithms describe how to sort elements in an efficient way depending on various contexts[25].

Referencing Pree "patterns allow the solution of problems", thus, our catchwords **problem** and **solution** occur again. This solution has to be time-tested. Hence, Pree describes that patterns base on imitating solutions. Considering both the time-tested and the imitating aspect we get the often quoted characteristic of **practice-proven**. As Pree relates the pattern - like Alexander and Gamma et al. did before – to a **context** and defines them as a part of a program which bases on imitating an existing code fragment, it has to be adapted before it can be used. For [Pr95] pattern has a **re-usable** and **adapting** character, too. All in all we found these characteristics: **problem**, **solution**, **context**, **re-usable**, **adapting** and **practice-proven**.

2.1.1.4 Analysis Patterns – Reusable Object Models (Fowler, 1997)

The intention of this book is to document conceptual structures of business processes. Thereby, Martin Fowler concentrates on the resulting model instead of focusing on the process of modeling. Therefore, he separates the patterns which he describes into two classes and defines them as follows (cf. [Fo97] page 8):

> [A] pattern is an idea that has been useful[26] in one practical context[27] and will probably be useful in others[28].I use the term *idea* to bring out the fact that a pattern can be anything. [...]. The phrase *practical context* reflects the fact that patterns are developed out of the practical experience of a real project. It is often said that patterns

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[25]context
[26]practice-proven
[27]practice-proven, context
[28]re-usable, context

are discovered rather than invented. This is true in the sense that models turn unto patterns only when it is realized that they may have a common usefulness. A particular project comes first, and not all ideas of a particular project are patterns; patterns are those things that developers think may be *useful in other contexts*. Ideally this comes from actually using them elsewhere, but it may just reflect the opinion of the original developers. The patterns in this book fall into two categories:

- Analysis patterns are groups of concepts that represent a common construction in business modeling. It may be relevant to only one domain, or it may span many domains. Analysis patterns form the heart of this book.

- Supporting patterns are patterns in themselves and are valuable on their own. They have a special role in this book, however: They describe how to take the analysis patterns and apply them, to make them real.

In contrast to the previous authors Fowler uses the term 'idea' instead of solution or problem "to bring out the fact that a pattern can be anything". Like Pree he emphasizes that patterns are **practice-proven**. He describes this fact more concrete: "patterns are developed out of the practical experience of a real project". Thus, we summarize that patterns are **practice-proven**, **re-usable** and have a **context**.

2.1.1.5 Meta Patterns: A Pattern Language for Pattern Writing (Meszaros and Doble, 1997)

In [MD97] Meszaros and Doble present a recipe for writers, how they can write a pattern, or, if they already did, what they could improve. Their paper does not give a definite definition of what patterns are, nevertheless we found some features which are central for a pattern.

Essentially a pattern is a "Solution[29] to a Problem[30] in a Context[31]" [MD97] (cf. page 2). Thereby, a recurring solution is shared that "it may be reused"[32] (cf. page 4). In order patterns should be remembered they need evocative names, that conjecture up images or metaphor names (cf. page 16) as well as some "mandatory elements"[33] which unify the structure of the patterns. These elements are enumerated on pages 6 to 8:

- Pattern Name: A name by which this problem/solution can be referenced.

- Problem: The specific problem that needs to be solved. Use *Context-Free Problem* to ensure that the problem is kept separate from the constraints on the solution.

- Solution: The proposed solution to the problem. Note that many problems may have more than one solution, and the "goodness" of a solution to a problem is affected by the context in which the problem occurs. Each solution takes certain **forces** into account. It optimizes some at the expense of others. It may totally ignore some **forces** if the context implies they are lower in priority.[...]

- Context: The circumstances in which the problem is being solved imposes constraints on the solution. The **context** is often described via a "situation" rather than stated explicitly. Sometimes, the context is described in terms of the *Patterns* that have already been applied. The relative importance of the **forces** (those that need to be optimized at the expense of others) is determined by the **Context**

- Forces: The often contradictory considerations that must be taken into account when choosing a solution to a problem.

---

[29]solution
[30]problem
[31]context
[32]re-usable
[33]structured format

The relative importance of the **forces** (those that need to be optimized at the expense of others) is implied by the **context**.

[Furthermore,] optional elements [may be used]:

- Resulting context: The context that we find ourselves in after the *Pattern* has been applied. It can include one or more new problems to solve. This sets us up for applying more *Patterns*, possibly the next *Pattern*(s) in a language.

- Related Patterns: Other *Patterns* that may be of interest to the reader. [Such as]

  - Other solutions to the same problem,

  - More general or (possibly domain) specific variation of the *Pattern*,

  - *Patterns* that solve some of the problems in the resulting context [...].

- Examples: Concrete examples that illustrate the *Pattern*.

- Code Samples: Sample code showing how to implement the *Pattern*.

- Rational: An explication of why this solution is most appropriate for the states problem within this context.

- Aliases: Other names by which this *Pattern* might be known.

- Acknowledgments: You should acknowledge anyone who contributed significantly to the development of the *Pattern Language* or the techniques described in it. [...]

[In addition, there are some points which pattern writers should consider. At first they should] clearly identify a primary target audience with whom [they] would like to communicate the solution. [Secondly the pattern should be] single pass readable [because] a simple message is more likely to be understood correctly. [Last but not least the writers should] use terminology that is tailored

> to the audience. [They should] use only those terms with which
> the typical member of the audience could reasonably be expected
> to be comfortable. [Furthermore, for diagrams,] notations that are
> likely be familiar to the target audience [should be used].
>
> [But in their opinion] <u>patterns [can be] related to each other</u>[34] by
> virtue of solving the same problems or parts of a solution to a larger
> partitioned problem. [This is called] pattern language. [There the
> writer have to] ensure that each Pattern could conceivable be used
> alone or with a limited number of Patterns from the language.

In the first quoted sentence they combine the three most most frequently mentioned characteristics: **solution**, **problem**, **context** and by sharing the solution the pattern become **re-usable**. Like some of the authors before Meszaros and Doble propose some mandatory elements: pattern name, problem, solution, context and forces so patterns get a **structured format**. With the opinion that patterns can be related to each other they tie on Alexanders idea of a language. We call this idea **combination**. The fact that a pattern has to be **adapted** to the respective case can be shown on the intention by writing their pattern.

> this pattern language describes and demonstrates a collection of
> writing <u>practices that have been observed</u>[35] to be particularly effective. The language is targeted at both novice and experienced
> pattern writers: novices may choose to treat these patterns as
> <u>suggestions to be tried</u> and to be adopted where they help, experts
> can use these <u>patterns as a form of checklist</u>[36], helping them keep
> in mind some of the issues and forces in effective pattern writing.

All in all, Meszaros and Doble collect techniques and hints for writing a good pattern, but each of this ideas has to be modified by the writers. Summarizing Meszaros and Doble highlight the same aspects in patterns as Alexander: **solution**, **problem** and **context**, **structure format**, **re-usable**, **adaptable**, **practice-proven** and **combination**.

---

[34]combination
[35]practice-proven
[36]adaptable

17

2.1.1.6 Reference modeling for business systems analysis (Fettke and Loos, 2007)

This book includes essays of several authors and research groups. These have been aggregated with the intention to cover as many as possible aspects of reference modeling as possible. Thereby, the Fettke and Loos mention the term patterns and give on page 4 a short definition taking up the position of reference modelers.

> Within computer science, the meaning of the term "design pattern" is similar to the meaning of "reference model". Design patterns are "proven solutions[37] to recurring design problems"[38] (Coplien, 2000, p. 1604). This idea is pursued with reference models, too. However, design patterns are normally finely granulated, reusable[39] artifacts that are mostly use for designing an information system[40]. The main idea of business patterns or analysis patterns is quite similar to the concept of reference modeling.

In the community of reference modeling the rule of three, containing **problem**, **context** and **solution**, can be identified. Furthermore, a pattern as well as a reference model has to be **re-usable**.

2.1.1.7 A Pattern-based Approach to Enterprise Architecture Management (Ernst, 2010)

In his doctoral thesis Ernst investigates methods how patterns can be used for Enterprise Architecture Management (EAM). By the help of patterns the disadvantages of existing methods to support the EAM should be avoided. Thereby, he compresses some definitions of patterns and defines patterns and their counterpart anti-patterns as follows (cf. pages 51-52).

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[37]solution
[38]problem
[39]re-usable
[40]context

> **Pattern:** A pattern is a general, reusable[41] solution[42] to a common problem[43] in a given context[44]. [...]

> **Anti Pattern:** An anti pattern documents a solution to a recurring problem in a specific context, which has proven not to work in practice.

In his very short definition of patterns Ernst mentions only the three main components **solution**, **problem** and **context**. By the help of his definitions of anti-patterns we can maintain that a solution has proven to work in practice before it becomes a pattern. Thus, the pattern has been **practice-proven**.

Comparison of the three different formats Before we continue with the definitions of reference models we compare the different formats found in the definitions, namely the "Alexandrian format", the "GoF format" and the "canonical format". Later format is an extension of the mandatory elements introduced by Meszaros and Doble [MD97]. In the canonical format these mandatory and optional elements are mixed together (see Table 2.1).

Both the GoF format and the canonical format capture all elements of the Alexandrian format, rename them and add some new elements. The additional elements are 'consequences', 'implementation' and 'sample code'. The equivalent of the implementation and the sample code would be in Alexander's description an architectural model. This model could not be presented in a book, so he confine himself to depict pictures how the result can look like. This is motivation and example at the same time.

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[41]re-usable
[42]solution
[43]problem
[44]context

Alexandrian format	GoF format	Canonical format	Comparison
picture	motivation	motivation	The picture shows a possible result and the motivation describes a possible application. In the canonical format the motivation is optional
introduction	applicability	context / applicability / preconditions / forces	All these terms contain the context of the respective pattern
body of the problem	intent	problem / intent	
headline	pattern name and classification	name	The pattern name tries to summarize the essence as Alexander does in the headline
range of manifestation	known uses	examples / known uses	Alexander shows the range of manifestations of his patterns. The GoF shows in known uses the range of their patterns, too
solution in form of instructions & diagram	structure& participants & collaborations	solution	Gamma et al. split the paragraph including their solution into three parts to reach more clarity
paragraph which ties the pattern to all those smaller patterns	related patterns	related patterns	The GoF and the canonical format do not describe a pattern language from Alexander's point of view. For example, they do not give a sequence as Alexander does
	also known as / consequences / implementation / sample code	resulting context / consequences / rational	There are no equivalents in [Al77]

Table 2.1: Comparison of the formats for structuring patterns

2.1.2 Definitions of reference models

In this paragraph we consider definitions of reference models. If we have not been able to quote the definition in English, we translated the quote. The characteristics and catchwords are marked then in the English parts to ensure consistency concerning Section 2.1.1.

2.1.2.1 Komplexitätsmanagement in Prozessmodellen: Methodenspezifische Gestaltungsempfehlungen für die Informationsmodellierung (Rosemann, 1996)

Rosemann deals in [Ro96] with the principle of correct modeling. Thereby he introduces a framework and gives recommendations for process modeling. In [Ro96] reference models are defined as follows on page 36.

> Referenzmodelle zeichnen sich im Vergleich zu unternehmensspezifischen Modellen durch einen höheren Anspruch an <u>Allgemeingültigkeit</u> (z.B. <u>für eine ganze Branche</u>) aus, den sie durch die <u>Abstraktion von einzelnen unternehmensspezifischen Modellen</u> (induktive Erstellung: empirisch-deskriptiver Ansatz) und unter Einbeziehung <u>theoriebasierter</u> <u>Erkenntnisse</u> (deduktive Erstellung: analytisch-präskriptiver Ansatz) erzielen.

Reference models raise a higher claim of <u>universality</u>[45] (e.g. for a <u>whole branch</u>[46]) than enterprise-specific models. They reach this aim by <u>abstracting individual</u> <u>enterprise specific models</u>[47] (inductive generation: empirical-descriptive approach) and by integrating <u>theory-based knowledge</u>[48] (deductive generation: analytical-prescriptive approach).

According to Rosemanns's understanding reference models have to be **universal**. By this term he figures out that reference models are no "enterprise specific models" but branch-wide applications. Thus, he considers additional

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[45]universal
[46]branch-related
[47]practice-proven
[48]theory-based

a reference model as **branch-related**. Then he shows up that a reference
model can either be **practice-proven** or **theory-based**. Therefore, refer-
ence models have – according to Rosemann – these characteristics: **universal**,
branch-related, **practice-proven** and **theory-based**.

2.1.2.2 ARIS-House of Business Engineering (Scheer, 1997)

The essay "ARIS-House of Business Engineering" by Scheer is part of a con-
ference which deals with the state of development and the perspectives of
reference modeling. Scheer introduces a process-oriented framework for the
realization of reference models. In this context he defines the term reference
model (cf. page 4):

> Unter einem Referenzmodell wird ein Modell verstanden, das als
> Ausgangspunkt für die Entwicklung auf konkrete Aufgabenstellungen
> bezogener Problemlösungen dienen kann.

> Je nachdem, welche Aufgabenstellung mit dem Einsatz von Ref-
> erenzmodellen bearbeitet wird, können beispielsweise branchen-
> spezifische Referenzmodelle, softwarespezifische Referenzmodelle oder
> Vorgehens-Referenzmodelle unterschieden werden.

A reference model is seen as model which can be used as basis to develop[49]
problem solutions[50] referring to concrete tasks[51].

According to which problem should be handled by the use of reference models
there can be differentiated between e.g. branch-related reference models[52],
software-specific reference models or process-reference models.

Scheer defines a reference model in [Sc97b] as a concept that is - in our words-
a **solution** to a **problem** which can be **branch-related**. This resembles to a
great extent the definition of the term pattern.

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[49]basis to derive models
[50]problem
[51]re-usable, adaptable
[52]branch-related

2.1.2.3 Prozeßorientiertes Management mit SAP R/3 (Donath, 1999)

Donath gives in [Do99] an introduction of SAP R/3 and how to use it. Thereby, he addresses planning, optimization and organization of enterprise processes. These processes are considering the supply chain. He contributes his experiences in form of case studies. On pages 31f he gives the following definition:

> Ein Referenzmodell ist eine Spezifikation eines Metamodells für einen bestimmten Diskursbereich (Referenz = Bezug). Es ist ein verallgemeinertes, semantisches Modell für eine bestimmte Branche. [...] Das Referenzmodell ist auf Wiederverwendung (über eine eventuelle Anpassung an spezielle Bedingungen) ausgerichtet.

A reference model is a specification of a meta model for a certain area of discussion[53] (reference = base). It is a generalized[54] semantic model for a certain industry[55]. [...] The reference model is oriented on re-usability[56] (eventually by modifying [57] it to specific conditions).

As previously described by Rosemann, Donath considers **universal**ity or in his own words generalization and branch-relation as characteristic for reference models. He adds that a reference model is based on a **problem** and oriented on **re-usability** by **adapting** it. All in all we found these catchwords in his definition: **problem**, **universal**, **re-usable**, **adaptable** and **branch-related**.

2.1.2.4 Referenzmodell für die Simulation in Produktion und Logistik (Wenzel, 2001)

The book [We00b] deals with reference models linked to the simulation of production and logistics. Reference models are used to derive cost efficient models for simulation. This book concerns itself only with the modeling process and the wish to simplify this process by using reference models. Wenzel [We00b] introduces on page 2 the subsequent definition of reference models.

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[53]problem
[54]universal
[55]branch-related
[56]re-usable
[57]adaptable

> Ein Referenzmodell umfasst eine systematische und allgemeingültige
> Beschreibung eines definierten Bereichs der Realität mit den für
> eine vorgegebene Aufgabenstellung relevanten charakteristischen
> Eigenschaften und legt das zugehörige Modellierungskonzept fest.

A reference model includes a systematic and universal[58] description of a defined
area of the reality [59]has the relevant characteristic properties for the given
tasks[60] and defines the belonging modeling concept.

Therefore, Wenzel, too, associates **universal**ity and a **problem** with the term
reference model.

2.1.2.5 Referenzmodellierung: Gestaltung und Verteilung von Konstruktionsprozessen (vom Brocke, 2003)

In his doctoral thesis [VB03] vom Brocke addresses the question why informa-
tion systems are so often build up from nothing. Thus eventual advantages
are not exploit and incompatibility between systems inside and outside an or-
ganization can arise. We examine vom Brocke's definition of reference models
on page 58:

> Ein Referenzmodell (ausführlich: Referenz-Informationsmodell) ist
> ein Informationsmodell das Menschen zur Unterstützung der Kon-
> struktion von Anwendungsmodellen entwickeln oder nutzen, wobei
> die Beziehung zwischen Referenz- und Anwendungsmodellen dadurch
> gekennzeichnet ist, dass Gegenstand oder Inhalt des Referenzmodells
> bei der Konstruktion des Gegenstands oder Inhalts des Anwen-
> dungsmodells wieder verwendet wird.

This definition has been translated in [FL07] as follows:

> A reference model ... is an information model that people develop
> or use[61] for supporting the construction of application models,
> though the relationship between the reference and application model

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[58]universal
[59]re-usable
[60]problem
[61]basis to derive a model

can be characterized by the fact that <u>object or content of the</u> <u>reference model</u>[62] is <u>reused</u>[63] by the construction of the object or content of the application model.

In his definition vom Brocke describes a reference model as a **re-usable basis to derive models**.

2.1.2.6 Wirtschaftsinformatik-Lexikon Auflage 7 (Heinrich, Heinzl and Roithmayr, 2004)

The lexicon [HHR04] gives definitions of terms which are important for the field of information systems. A definition of reference models is among those as well:

> **Referenzmodell**: Ein →Modell, das einen gewollten oder geplanten →Zustand eines →Systems abbildet, an dem sein gegenwärtiger Zustand beurteilt werden kann [...] oder ein Modell, das als <u>Vorbild zur Ableitung</u> eines spezifischen Modells verwendet wird. Mit Referenz wird eine <u>Empfehlung zur Nutzung</u> oder Verwendung ausgedrückt. Je nach Gegenstand des Modells werden verschiedene Typen von R.en verwendet [...]. Ein R., das Bausteine zur Konstruktion von R.e zur Verfügung stellt wird als Meta-R. bez. Unterliegt dem R. keine →<u>Theorie</u> , sondern lediglich <u>praktische</u> <u>Erfahrung</u>, wird dies als →best practice bez.

> **best practice**: Ein als <u>nachahmenswert</u>, weil als am besten geeignet angesehenes <u>Vorgehen</u> bei der Durchführung <u>einer</u> →Aufgabe . Dabei handelt es sich i.d.R. nicht um wissenschaftliche Erkenntnis, sondern um <u>praktische Erfahrung</u>.

Reference model: A model which describes a wanted or planed state of a system, to evaluate the the current state [...] or a model which is used as <u>basis to drive a specific model</u>[64]. By reference a <u>recommendation for usage or</u> <u>utilization</u>[65] is expressed. Depending on the object of the model various types

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[62]problem
[63]re-used
[64]basis to derive models
[65]re-usable

of reference models are used. A reference model which is provides modules for the construction of reference models defined as meta reference model. If a reference model does not have a underlying theory[66] but only practical experience[67] it is named as best practice.

best practice: An exemplary[68], because as most qualified considered procedure[69] by handling a task[70]. Thereby, it is ordinarily no scientific knowledge but practical experience[71].

In this lexicon a reference model is described as a **re-usable basis to derive models**. It can be **theory-based** as well as **practice-proven**. Furthermore, it is a **solution** related to a **problem**. Thus, this definition includes many characteristics we also found in patterns: **re-usable**, **practice-proven** as well as **theory-based**, **problem** and **solution** and **basis to derive models**.

2.1.2.7 Business process reference models: survey and classification (Fettke, Loos and Zwicker 2005)

The aim of the "Workshop on Business Process Reference Models" (BPRM 2005) was to clarify the purpose and advantages of reference models. In their contribution to this workshop Fettke, Loos and Zwicker "analyze [...] and describe similarities and differences between the [...] reference models" (cf. [FLZ05] pages 8ff).

> It is a conceptual framework and may be used as a blueprint[72] for information systems construction. To use a particular reference mode, it must be adapted to the requirements of a particular enterprise.

However, in [FL07] Fettke and Loos indicate the fact that "the term [reference model] is used to designate different objects". Fettke and Loos point out the

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[66]theory-based
[67]practice-proven
[68]re-usable
[69]solution
[70]problem
[71]practice-proven
[72]basis to derive models, re-usable

same characteristics as vom Brocke does. In their opinion a reference model is the **basis to derive models** and therefore, it is **re-usable**.

2.1.2.8 Adaptive Referenzmodellierung – Methodische Konzepte und Anwendung wiederverwendungsorientierter Informationsmodelle (Delfmann2006)

In his doctoral thesis Delfmann formulates the basic concepts for the construction of reference model languages. For this purpose he goes into detail with the term reference model. Thereby, he starts with the primary meaning of reference and also comments the often mentioned characteristics like universality and branch-relation (cf. pages 45f):

> Etymologisch bedeutet *Referenz* "Empfehlung" oder "Bezugnahme". Ein Refernzmodell ist demnach ein Modell mit Empfehlungscharakter bzw. ein Modell, auf das Bezug genommen wird.[...] In der Literatur werden weitere charakteristische Merkmale für Referenzmodelle diskutiert. Dies sind u.a. *Allgemeingültigkeit, Branchenbezug, Vollständigkeit* und *Adaptierbarkeit* [...] Zusammenfassend wird hier unter einem Informationsmodell ein *Referenzmodell* verstanden, sofern es mit der Intention konstruiert wird, für verschiedene Anwendungskontexte *wiederverwendet* zu werden. Seine Eignung für eine Wiederverwendung kann letztlich erst dann beurteilt werden, wenn es tatsächlich wiederverwendet *wird*, bzw. falls dem Anwender die Inhalte des Referenzmodells bereits im Vorfeld bekannt sind. Das Referenzmodell ist *adaptiv*, wenn es auf Grundlage einer Sprache konstruiert ist, die explizite *methodische Konzepte zur Modellierung* bereitstellt, und wenn diese Konzepte mit der Intention, die Wiederverwendung zu vereinfachen, bei der Konstruktion angewendet werden.

Etymological 'Referenz' means "recommendation" as well as reference. According to this a reference model is a model with recommendation character or a model which is referenced. [...] In literature some more characteristics of reference models are discussed. These include universality, industry relation,

completeness and adaptability. [...] All in all in this text information model is regarded as reference model as far as it has been constructed with the <u>intention of re-use</u>[73] for various application contexts. In the end its suitability for re-use can not be evaluated until it is re-used indeed, or if the users knows the contents of the reference model beforehand. The reference model is adaptive, if it is based on a language which provides explicit methodical concepts for modeling and if these concepts has been used by the construction with the intention to simplify the re-use.

In his dissertation Delfmann criticizes the common characteristic like universality, industry relation, completeness and adaptability. He considers them as optional and not necessary. In his opinion a reference model is constructed - but there is no statement if it is theory-based or tested - to be reused. Thus, we can summarize that it has to be **re-usable**.

2.1.3 Summary of relevant characteristics

From the definitions analyzed above we can derive a set of common characteristics for patterns and reference models. By reference to Tables 2.2 and 2.3 we visualize which characteristics are mentioned in which definition.

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[73]re-usable

Characteristic	problem	practice-proven	re-usable	adapta-ble	context	struc-tured format	combi-nation	solution
Alexander [Al77]	X		X	X	X	X	X	X
Gamma et al. [Ga94]	X	X	X	X	X	X	X	X
Pree [Pr95]	X	X	X	X	X			X
Fowler [Fo97]		X	X		X			
Meszaros & Doble [MD97]	X	X	X		X	X	X	X
Fettke & Loos [FL07]	X		X		X			X
Ernst [Er10]	X	X	X		X			X

Table 2.2: Summary of pattern characteristics

Characteristic	basis to derive models	re-usable	practice-proven	problem	univer-sal	theory-based	branch-related	solution
Rosemann [Ro96]	X		X	X	X	X	X	
Scheer [Sc97b]		X		X			X	X
Donath [Do99]				X	X		X	
Wenzel [We00b]		X		X	X			
vom Brocke [VB03]	X	X		X				
Heinrich [HHR04]	X	X	X					
Fettke et Loos [FLZ05]	X	X				X		X
Delfmann [De06]		X						

Table 2.3: Summary of reference model characteristics

29

2.2 A comparison matrix of pattern and reference model characteristics

In this section the meaning of each catchword is explained in detail in preparation for the comparison matrix. Each characteristic is described with a brief definition. Previously, we adjust the catchwords, found in the definitions. Some of them are mentioned in both conceptions as re-usable and practice-proven. Others just appear in the definitions of pattern or reference model e.g. theory-based and structured format. To detach the catchwords from the concepts and to reach a more common understanding we have renamed some of those. Without any modification we adopt the catchwords 're-usable', 'practice-proven', 'theory-based' and 'universal'. The remaining ones have to be generalized or defined more precisely. First of all we adapt the rule of three containing 'problem', 'solution' and 'context' because these catchwords are too one-sided to the conception of pattern. These are modified into 'problem specific', 'provides a solution' and 'constrained in their applicability'. The catchword 'basis to derive models' is generated from the definitions of reference models. The authors mentioned that the model has to be modified before it can be used. This fact is mirrored for patterns by 'adaptable'. Thus, we combine these under the therm 'adaptable'. In Section 2.1 we named the fact that a format is used more than once for an instance of a conception 'structured format' but this catchword does not fit totally the essence of the definition, so we renamed it into 'documented in a defined format'. A second case whereby the catchword does not completely fit the meaning behind is 'combination' which is better expressed by 'linked to others'.

For those characteristics we list the definitions mirroring our understanding of those. In the course of this, we defined the characteristics independent of the conceptions. This is important to reach a common understanding of the terms. Subsequent we itemize the catchwords and their definitions.

- **re-usable**: capable of being used again

- **practice-proven**: an idea which has turned out to work good in practice

- **theory-based**: derived from theoretical knowledge

- **adaptable**: can be tailored to a particular situation or application context

- **documented in a defined format**: the document is presented in a identifiable structure, which is used more than once by different authors

- **constrained in their applicability**: applies in a specific context or is given in particular circumstances

- **universal**: applicable or common to all members of a group or set of (world-)wide scope or applicability

- **branch-related**: linked to a specific industry domain

- **problem-specific**: applies to a dedicated problem

- **provides a solution**: gives a description how to solve a problem

- **linked to others**: can / must be connected with other patterns / reference models; uses other patterns / reference models

To classify the instances of reference models and patterns in an objective way we have decided to use a three-step scale aligned with the Likert scale. This scale shows the level of agreement or disagreement on a series of statements. The idea behind this scale is that a statement is the refused more often, if the statement differs from the personal opinion. It is considered symmetric because there are equal amounts of positive and negative positions and a neutral position. Our position are: 'true', 'no statement' and 'the opposite is true'. Whereas, the scale of our survey which mirrors the subjective opinions of persons about pattern and reference model has five steps. It ranges from strongly agree and neutral to strongly disagree. Table 2.4 shows the objective classification scale for the comparison of the instances, whereas, Table 2.5 shows the subjective scale of the survey.

Characteristics	true	no statement	the opposite is true
re-usable			
practice-proven			
theory-based			
adaptable			
documented in a defined format			
universal			
branch-related			
problem-specific			
provides a solution			
linked to others			

Table 2.4: Objective classification scale

Characteristics	strongly agree	agree	neutral	disagree	strongly disagree
re-usable					
practice-proven					
theory-based					
adaptable					
documented in a defined format					
universal					
branch-related					
problem-specific					
provides a solution					
linked to others					

Table 2.5: Subjective classification scale

2.3 Hypotheses on patterns and reference models

Hypotheses can be generated via two different approaches. The inductive approach abstracts a hypothesis from a collection of facts, whereas, the deductive approach starts with a general position or theory and then generates specific implications or hypotheses. By analyzing the definitions we form a view on patterns and reference models. Thereby, some hypotheses base on the definitions of Section 2.1, whereas, other hypotheses base on considerations which influences may affect the decision towards naming an artifact pattern or reference model. Our initial hypothesis is the statement in [Wi09], co-authored by Fettke and Loos, "that there is no strict differentiation between patterns and reference models anymore". We divided this statement into two hypotheses.

- **H01**: There is no strict differentiation between patterns and reference models.

- **H02**: The relation between both conceptions has changed over the years.

The hypotheses **H03** to **H07** are elicited form the definitions and the catchwords contained in them. Thereby, we concentrate on those characteristics which appear only in the one of these conceptions. The hypotheses are:

- **H03**: Reference models are used alone whereas patterns are often used or can be used in combination or related to other patterns.

- **H04**: Reference models relate to a branch whereas patterns are branch neutral.

- **H05**: Patterns describe the context in which they can be applied.

- **H06**: Patterns describe observed solutions that have been proven to work in practice.

- **H07**: Patterns have a structured format whereas reference models are not presented in a recurring format.

The last block of hypotheses is based on the consideration which influences may have impact on the naming, i.e. what is the reason that someone uses a pattern instead a reference model and, more important, what is the reason that some authors name an artifact pattern instead of reference model or in reverse. This is the intention behind the hypotheses **H08** to **H11**:

- **H08**: It depends on the country whether a concept is named as pattern or reference model.

- **H09**: It depends on the educational background whether a concept is named as pattern or reference model.

- **H10**: A person with an academic background trends to name concepts as reference models whereas a practitioner tends to name them as patterns.

- **H11**: A person with an academic background trends to use reference models whereas a practitioner prefers patterns.

3 Comparison of selected patterns and reference models

This chapter captures the results of Chapter 2 and based on it we analyze instances of patterns and reference models. For this purpose the objective classification scale (cf. Table 2.4). We distinguish three different manifestations. The authors can mention the characteristic explicit, they can make no statement about the respective characteristic or they mention that the opposite is true. In the thesis we analyze the patterns and reference models listed in Tables 3.1 and 3.2.

3.1 Selected patterns and reference models revisited

In the following we briefly summarize key characteristics of selected patterns and reference models. Thereby, we prepare our considerations on the elicited characteristics.

Composite (Gamma, Helm, Johnson and Vlissides, 1994) 'Design Patterns: Elements of Reusable Object-Oriented Software' is probably one of the most common books about patterns. Thereby, Gamma et al. analyze various problems which can occur while object-oriented programming and describe solutions that have been tested. Thereby, they separate the patterns into three classes. The 'Creational Patterns', the 'Structural Patterns' and the 'Behavioral Patterns'. The first class of patterns describes the creation of objects by hiding the creational process. As a result the systems is independent form the creation, the composition and the representation of its objects. The second

class of patterns, the 'Structural Patterns', deals with generating larger structures. Therefore, interfaces and hierarchies are very important. Especially the 'Composite Pattern', presented in this group, is explained in detail. The last and largest group covers 'Behavioral Patterns'. These patterns especially pay attention to the interaction of the objects. The 'Observer', for example, describes how one class can be informed about changes in an other class or the 'Visitor' handles changes at one point of the system that affects many other parts of it.

Because all patterns in [Ga94] are structured in a similar way, the manifestations of the characteristics are described by reference to the 'Composite' pattern. This pattern is part of the 'Structural Patterns'. The intent of this pattern is to structure objects in part-whole hierarchies, as this pattern is useful if the objects have a hierarchical structure or if they are needed to be treated uniformly. To organize this hierarchy the pattern contains three classes: the *component*, the *composite* and the *leaf*. The client communicates with the component via an interface to interact with the objects of the structure. The component forwards the request of the client. If the receiver is a leaf, the request is handled instantly. If the receiver is a composite, the request is forwarded to its child-components. For each pattern Gamma et al. describe when to apply the respective pattern, what problem it solves and how this is done. Thus, each of these patterns is **problem-specific**, **constrained in its applicability** and **provides a solution**. A goal of the authors is to describe the patterns in a way that once a pattern has been understood by the reader it can be used again without thinking about the conception. The intention to describe re-usable patterns is accommodated by presenting for each pattern 'known uses' in which the respective pattern has been applied. Thus, patterns which are based on programming experiences are **re-usable** and **practice-proven**. Gamma et al. never mention whether their pattern are **theory-based** or not. Furthermore, the motivation gives a short example of how to use the pattern. These examples show more than one thing. Firstly, the example presents that the pattern has to be **adapted** by adding methods and adapting classes to the respective situation. Secondly, the variety of the motivations demonstrate the **universal** character of the patterns. The third fact the motivation points out is that the patters are not **branch-related**. Each of the examples of use is independent from a branch. The motivation of

Gamma, Helm, Johnson and Vlissides	*Design Patterns – Builder, Singleton, Composite, Observer, Visitor, Adapter* [Ga94]
Taylor	*Patterns for Productivity* [Ta98]
Anderson	*A Collection of History Patterns* [An98]
Charlston	*Essence Pattern* [Ca98]
Switzer	*Courier Pattern* [Sw98]
Harrison and Brown	*A Secret Partner Pattern* [HB02]
Rising, King, May and Sanchez	*Patterns for Building a beautiful Company* [Ri02]
Byun, Sanders and Chung	*A Pattern Language for Communication Protocols* [BSC02]
Zhen and Shao	*A Pattern Language for Developing Web based Multi Source Data Acquisition Application* [ZS02]
Saadawi	*Universal E-Catalog Pattern* [Sa06]
Fernandez and Pernul	*Patterns for Session-Based Access Control* [FP06]
Grofu, Smith, Guerra and Odeyemi	*Web Content Management Patterns* [Gr06]
Morrison and Fernandez	*The Credential Pattern* [MF06]
Saúde, Victório and Coutinho	*Persistent State Pattern* [SVC10]
Sahu, Fernandez, Cardei and Van Hilst	*A Pattern for a Sensor Node* [Sa10]
Günther and Fischer	*Metaprogramming in Ruby – A Pattern Catalog* [Sc10]

Table 3.1: Authors and analyzed patterns

the 'Composite' pattern e.g. is to implement a program which can be used to paint rectangles and lines. At the end of each description of the single pattern Gamma et al. list a number of related patterns. Moreover the patterns described in [Ga94] are referenced in more recent patterns. Of those pattern instances we have analyzed some are linked to at least one pattern presented by the GoF. In [ZS02], [Ca98], [An98], [Sw98], [FP06], [HB02] and [SVC10] patterns of Gamma et al. are referred.

Kruse	*Refenzmodellgestütztes Geschäftsprozeßmanagement: Ein Ansatz zur prozeßorientierten Gestaltung vertriebslogistischer Systeme* [Kr96]
ISO / IEC	*Open Systems Interconnection - Basic Reference Model: The Basic Model* [ISO96]
Remme	*Konstruktion von Geschäftsprozessen.: Ein modellgestützter Ansatz durch Montage generischer Prozeßpartikel* [Re97]
Scheer	*Wirtschaftsinformatik: Referenzmodelle für industrielle Geschäftsprozesse* [Sc97a]
Kees	*Ein Verfahren zur objectorientiereten Modellierung der Produktionsplanung und -steuerung* [Ke98]
Bauer	*Internet und WWW für Banken: Inhalte, Infrastrukturen und Erfolgsstrategien* [Ba98]
Curran and Keller	*SAP R/3 Business Blueprint : Business-Engineering mit den R/3-Referenzprozessen* [CK99]
Schlagheck	*Objektorientierte Referenzmodelle für das Prozess- und Projektcontrolling: Grundlagen – Konstruktion – Anwendungsmöglichkeiten* [Sc99]
Pumpe	*Ein Referenzmodell zur Planung und Steuerung der Abläufe in Seehafen-Containerterminals* [Pu00]
Wenzel	*Referenzmodelle für die Simulation in Produktion und Logistik* [We00a]
Krcmar, Dold, Fischer, Strobel and Seifert	*Informationssysteme für das Umweltmanagement: Das Referenzmodell ECO Integral* [Kr00]
Luxem	*Digital Commerce: Electronic Commerce mit digitalen Produkten* [Lu00]
Gerber and Mai	*Ein Referenzmodell für das Filialgeschäft von Banken als betriebliche Wissensplattform* [GM02]
Haas, Ahlemann and Hoppe	*Organisationale Integration von E-Learning in Unternehmen – ein Referenz-Informationsmodell* [HAH03]
Tzouvaras	*Referenzmodellierung für Buchverlage: Prozess- und Klassenmodelle für den Leistungsprozess* [Tz03]
Becker and Schütte	*Handelsinformationssysteme* [BS04]
Ahlemann	*Unternehmensweites Projektcontrolling: ein Referenzmodell für Software- und Organisationssysteme* [Ah06]
Bernus, Mertins and Schmidt	*Handbook on Architectures of Information Systems* [HRP06]
Poluha	*Anwendung des SCOR-Modells zur Analyse der Supply Chain: Explorative empirische Untersuchung aus Europa, Nordamerika und Asien* [Po06]

Table 3.2: Authors and analyzed reference models

A Pattern Language for Developing Web based Multi Source Data Acquisition Application (Zhen and Shao, 2002)   The content of this pattern language is described the best by authors in [ZS02]. "This pattern language in progress deals with developing web based multi source data acquisition applications. The data sources of the application may be of various types such as real-time database, relational database and other sources like dynamic web pages". This pattern is advantageous to companies which use various data sources across the value chain. The aim of this pattern is to optimize the presentation of data from different sources on one web page. Therefore, Zhen and Shao have presented four patterns as part of a pattern language at PLoP 2002. These four patterns are the *Display Component*, the *Configuration Client*, the *Remote Data Collector* and the *Configuration Database*. "The Display Component is a thin-client component, which is embedded in the web browser. The browser invokes the Display Component when the end-user opens the web page of the data acquisition system. The Configuration Client may be either a web based client or a normal desktop client. By using it, one can define and modify the displays for end users and the data sources for data acquisition" [ZS02]. The Remote Data Collector acquires and routes data from different data source. These sources are mainly real-time or relational databases and web pages, whereas other types of data sources are possible as well. The Configuration Database is a kind of relational database and stores the modified information of the Configuration Client.

All four patterns are presented in the GoF format. Thus, the authors **document the patterns in a defined format**. Consequently they follow the rule-of-three as well. Firstly, they describe the context and the forces which have impact on the patterns. The Display Component e.g. must be interactive and configurable. In addition different data sources have to be paid attention to. In context with data bases the integrity and consistency of the data is very important. The end-user must be able to change the data but the integrity and consistency of the data must be ensured. The **problem** is always phrased in one or two short questions. The problem covered by the pattern Configuration Client is characterized by the question "How to store configuration data of the data acquisition system correctly and easily?" and "What kind of solution can reduce the total cost of your application?" [ZS02].

The solution to the problem is separated into two parts: In the solution itself which contains a description of the components and their tasks and in the 'structure' picturing a class diagram of the connection of the single components and the methods and attributes they contain. Therefore, all patterns of this language are **constrained in its applicability**, **problem-specific** and **provide a solution**. Furthermore,Zhen ans Shao present for each pattern different other patterns from various sources used by and linked to the respective pattern. Thus these patterns are **linked to others**. Because of the fact that Zhen and Shao present for each pattern at least two 'Known Uses' the patterns are **practice-proven** and **re-usable**. Whether the patterns are **based on a theory** or not is never mentioned. Considering the fact that different kinds and amounts of data sources can be used as well as methods can be added, these patterns are **adaptable**. Nowadays, many companies use web-based applications regardless of their domain and various data sources. Hence, this pattern language is **not branch-related**. Because of the manifold possible applications and the general description these patterns are **universal**.

A Pattern for a Sensor Node (Sahu, Fernandez, Cardei and VanHilst, 2010) At PLoP 2010 Sahu et al. have presented 'a Pattern for a Sensor Node'. Sensors are used in many parts of our daily life. Mostly they are applied in situations, where men are unable to detect specific details or observe specific environment. A sensor measures a physical quantity and converts it into a signal. This signal can be read by a person or an instrument. If many sensors are connected in a network, a single sensor is a node in this network. These sensors must be able to communicate with each other as well as with other nodes – not only sensors – in the network. Therefore, Sahu et al. present a pattern that "is the first of a series for wireless sensor networks" [Sa10].

The analysis of this patterns starts with the rule-of-three consisting of 'provides a solution', 'problem-specific' and 'constrained in their applicability'. The constraints are described in the paragraph *context*. Sahu et al. describe that physical environments may have to be recorded or monitored. These environments are sometimes in a way that persons can not stay there for a long time or the physical quantity can not discern by human. "This pattern can be

used to describe the nodes used in those environments or in similar situations, either as standalone units or as parts of a network" [Sa10]. Furthermore there are some forces which constrain the solution, as "forces about the function of the device", "forces about the use of the information collected" and "forces about the use of the devices" [Sa10]. The next paragraph deals with the *problem*. The basic problem is that the human presence would be a changing factor in environment or that "human monitoring is not a convenient or efficient alternative" [Sa10] to sensor monitoring. Based on this problem and the constraints the solution is generated. The processor handles the signals measured by the sensor. The sensor measurement is converted into a digital signal and then stored in the memory by the processor. The transceiver transmits the information wireless to its destination. For measuring, processing and transmitting the sensor need power provided by sources as batteries or solar cells. "When the sensor is part of a network the processor also keeps information about its neighboring nodes, decides the routing path and communicates the routing information to the other nodes" [Sa10]. Thus, this pattern is **constrained in its applicability**, **problem-specific** and **provides a solution**.

Furthermore Sahu et al. point out that this pattern has been already used. As a result this pattern is **practice-proven** and **re-usable**. Referring to the numerous examples in fields of application this pattern is not **branch-related** and it is **adaptable**. As a result of the various usages we can derive that this pattern is **universal**. Whether the pattern is **theory-based** or not is not mentioned in specification but the author emphasizes that this pattern **is linked to others**. While describing the pattern Sahu et al. orient themselves on the GoF format, resulting in the characteristic that it is **documented in a defined format**.

Konstruktion von Geschäftsprozessen (Remme, 1997) By the method which is introduced by Remme [Re97] general organizational knowledge is gathered and efficiently customized by a forming process. Especially the development of a systematic and reasonable process has been important to the author. Before a company can change, a sharp definite basic information has to be collected. On this information reasonable operations are applied step by step until the planned structure is achieved. The whole process is separated

into single operations which are named *process-particle*s. The whole reference model contains seven process-particles which build upon each other. These process-particles deal among others with *planning, storage, batch fabrication, sequencing, labor and location division* and *performance differentiation.*

His description of the particular process-particles is not confined to the structure and elements that are important in the respective step. Furthermore, he is endeavored to show the constraints and consequences of the particles. Only two of the seven particles do not have any constraints. These are the planning-particle and the performance differentiation-particle. All others **are constrained in their applicability**. Apart from that all seven particles are considered equal in their manifestations of the characteristics. All these process-particles are designed for solving concrete problems. They can be used together or alone depending on type and manner the company plans to change. Consequently these packages are **linked to each other**, **problem-specific** and **provide a solution**. Although, the author presents for each package an example of use he does not go into detail concerning his research method. It is never mentioned, if this reference model is based on theory or not, and, if these examples are real cases studies or contrived. Therefore, we can not draw any conclusions if the reference models are **theory-based** and **practice-proven**. We can not accept this assumption as well as we can not reject it.

Based on the examples of use we can accept two other characteristics for this reference model. We discern that the packages are **adaptable** and **re-usable**. Furthermore, we can derive from the comparison of the examples and the single process-packages that the basic model is usable in a **universal** way. Based on the intention to generate a model which can be used for changing structures in companies this model is **branch-neutral**. In contrast to other descriptions of reference models Remme uses in [Re97] a structured format. He uses this format is equal for all packages he describes. Starting with the definition of important terms for the representative package, he continues with showing the reference process. After that he explains the constraints and effects and concludes with an example of use. Although he does not refer to a format he uses this structure through his whole description, thus this reference model is **documented in a structured format**.

Referenzmodellierung für Buchverlage (Tzouvaras, 2003) The doctoral thesis [Tz03] develops a reference model for book-publishing houses. With this the author does not only acknowledge the changing competitive structures but also shows an openness to new technologies. His reference model is separated into four packages: the *Selection*, the *Configuration*, the *Distribution* and the *Book*. The package *selection* contains the program-planning of the publisher. Hence, the selection contains each book title which is distributed and planed by the publisher for a certain period of time (cf. [Tz03] page 136). The *Configuration* contains the editorial and technical work, separated into design and production of the book. Sales and marketing are covered by the package *Distribution*. Nowadays, the book data can be stored in a printed or digital form. This has to be considered in the reference model, as the packages exchange data and functions. The fourth package is the *Book*. This package plays a special role in the reference model. It is relevant for all other packages, thus the decoupling makes sense. As a result the complexity of the other packages is reduced and the packages can access the data form a central data base and the redundant storage is prevented.

Based on the evaluation of the reference model in [Tz03] we state that this reference model is **re-usable**. Moreover, the general models of the packages are **adapted to** the special needs of the company. This reference model is especially conceived for book-publishing houses, hence, it is **branch-related** and **constrained in its applicability**. As a result the description is **not universal**. Instead the reference model applies to a specific problem, the organization of a book-publishing house, and gives a description how to do so. Thereof, this model is **problem-specific** and **provides a solution**. The author does not mention if his reference model has to or can be used with other reference models as well as he does not refer to a format that has been used for other models. On the contrary he uses a format which is adapted to the special requirements of reference model. The model was developed based on concepts and models which come form information systems, business economics and media science. Via a theoretical-deductive method he generates recommendations, which are evaluated in case studies (cf. [Tz03]). Hence, this reference model is **theory-based** and **practice-proven**.

Unternehmensweites Projektcontrolling (Ahlemann, 2006) The reference model [Ah06] has been developed in the context of a doctoral thesis. It describes how projects have to be planed and realized in an enterprise in general. Therefore, Ahlemann divides the model into five parts. The fist one contains all cross-sectional aspects which link the other four parts and are important during the whole project as organizational structures, finance and strategic planning. The next section is about the *project initiation*. The section answers the question, how ideas can be generated and evaluated. The section *project preparation* contains the whole planning aspect as portfolio planning, project-organization and -planning. After finishing the planning, it must be realized and controlled. This is covered by the fourth section, the *project-realization and -control*. The last part of the reference model deals with the internal and external project close-out. The goal of the dissertation is to develop a conceptual reference model for a company-wide planning, control and coordination of projects.

This reference model is **theory-based** because the dissertation starts with the hypothesis that projects in different companies featuring similar structures. To evaluate this hypothesis the reference model was applied in different companies. Following to this context the properties **practice-proven** and **re-usable** are accurate. The reference model is structured in a defined format, which is introduced by vom Brocke in [VB03]. This format presents in a first step the method-oriented aspects and then the model-, organizational- and technology-oriented facets. The aim of Ahlemann is to present a model that includes all necessary tasks for project control, providing it in a clear way. For that reason his work is **universal**. Project control is an issue that is important for many branches. To generate a branch-neutral reference model and to present the model in a sufficient level of detail Ahlemann has decided to analyze just one organization form, the matrix project organization. Nevertheless the model is explicitly declared as **branch-neutral**. This work presents a closed subject and does not need other reference models to attain its full potential. Thus it is **not linked to other reference models**. Last but not least we elaborate on the rule-of-three, a solution to a problem in a given context. With the organization of a project Ahlemann describes a concrete solution to the problem, concerning the way of the project organization, in this special context, the

company must have a matrix organization of its projects. Thus, this reference model is **problem-specific**, it **provides a solution** and is **constrained in its applicability**.

3.2 Comparison of the characteristics

In general the analysis of the instances shows that patterns are more homogeneous than reference models. Most of the instances have the same manifestation of their characteristics. It is extremely rare that an instance of a pattern differs from the median in more than one characteristic. Below we discuss for each characteristic the evaluation of the instances in detail, featuring their differences and similarities.

re-usable: This property is an essential one for patterns as well as for reference models. Both concepts present solutions which should be used more than once. All definitions of patterns mention that patterns have to be re-usable. Within the definitions of reference models most definitions emphasize this aspect, too. Therefore, it is not surprising that this characteristic matches to all patterns and reference models we have evaluated. The analysis of the instances goes hand in hand with our expectations by the analysis of the definitions.

practice-proven: For patterns this property is an often mentioned one. According to Fowler in [Fo97] "[a] pattern in an idea that has been useful in one practical context and will probably be useful in others". Based on this definition and considering [Ga94], [Pr95] and [MD97] as well we expected that the instances of pattern are practice-proven and these expectations are fulfilled by the analysis of the instances. For reference models this characteristic is described in [Ro96] as one of two options to derive a reference model form specific models. Within the reference models this property is 'true' for 17 instances, an almost equal number of 15 instances have no position towards this property.

theory-based: Neither in the definitions nor in the description of patterns we have not found a statement if they are theory-based or not. The instances of reference models which have been developed in the context of a doctoral

thesis are manly theory-based e.g. [Kr96], [Ba98], [Lu00], [Tz03] or [Ah06]. But all in all the major part of them does not include a statement if they are theory-based or not. So the median of both is on 'no statement'.

adaptable: This property is named differently for patterns and for reference models. Patterns 'are not reused as is' (cf. [Ga94]), whereas reference models are used to derive models as mentioned in [Sc97b], [LS99], [VB03] and [HHR04]. In line with these definitions most of the instances, we have evaluated, have to be adapted to a specific situation.

universal: This catchword describes the fact that an artifact, reference model or pattern, can be applied by a group of people.According to the descriptions given in the instances, this means that the pattern resp. reference model is understood by all persons it is addressed to. Thereby, it is important that the constraints which apply are considered. Our analysis shows that the amount of patterns and reference models, which can be denoted 'universal', is equal. Thus, both, reference models and patterns, are described in a way that they are applicable.

branch-related: This property is often mentioned in context with reference models. In literature this subject is discussed very controversial. Delfmann opposes in [De06] against it, because in his opinion the possibilities to apply reference models is restricted. Appropriate to the diversification within the definitions the manifestations in the instances are not unambiguous, too. The majority rates for not branch-related, but some address a certain branch as the banking sector (cf. [Ba98]) or the logistic of ship containers (cf. [Pu00]). In contrast in definitions of patterns this property is never mentioned; furthermore, all authors of the instances describe the patterns in a 'branch-neutral' way.

constrained in their applicability: The distribution of this characteristic is similar to the distribution of 'practice-proven'. Almost every pattern contains a paragraph in which the context and the constraints are mentioned, whereas, within the description of reference models it differs between 'no statement' and the statement is 'true'.

problem-specific: 'Problem-specific' is a key characteristic of patterns. Together with context and solution this forms the rule-of-three. Thereby, a clear majority for this property has been expected. Each of the thirty-three analyzed patterns addressed a concrete problem. A large number of reference models addresses a concrete problem as well.

provides a solution: The last attribute of the rule-of-three is 'provides a solution'. Similarly to the two parts explained above all patterns contain an explicit a description of the solution they offer. Within the definitions of reference model this tendency has not been this clear as some authors mention this as characteristic but others does not.

linked to others: Some reference models are linked to others in the sense of Alexander. He has structured his patterns in [Al77] by their size. The most general or 'largest' patterns come above followed by 'smaller' or more specific patterns perfecting the large ones. Most of the evaluated reference models are structured in a similar way. First an overview of the model is presented, followed by an analysis of the different parts (cf. [Ah06], [HAH03] and [Re97]). Adapting these sections together they deliver the best result. In general patterns are aggregated to a 'pattern language' and present solutions which can be applied individually or combined, considering there is more than one problem to be solved. The quality of the solution does not decrease if patterns are used independently. As patterns can correlate to other patterns, which are not part of the language, reference models just refer to themselves.

documented in a defined format: There is only one out of the evaluated instances of patterns which has no defined structure. The general structure is based on the GoF format or the canonical format, being divided into context, problem, solution, known uses, consequences and related patterns. Besides these prevalent elements, optional ones like intent, forces, variants, examples, implementation exist as well. In contrast, reference models have mainly a structure which is unique for each instance. The only exception are books presenting a collection of reference models. These models are often linked to each other and are presented in the same format.

4 Analysis of the survey

Before we expand on the questionnaire, we want to thank all participants. You have helped us very much. Thanks to you we are able to analyze patterns and reference models from three perspectives. The survey we created is one of the two approaches we used to test our hypotheses which we introduced in Section 2.3. Thereby, we focus not only on the question how the participants evaluate the characteristics of Section 2.1 but we also want to find out reasons why they named an artifact pattern instead of reference model or in reverse. First we re-introduce the hypotheses we analyze with the help of this survey in Section 4.1. Then we amplify on the structure and the questions in Section 4.2. In Section 4.3 we finally analyze the given answers.

4.1 Hypotheses covered by the survey

In Section 2.3 we introduce eleven hypotheses regarding the relationship between patterns and reference models. Most of them can be answered by analyzing the instances of both artifacts but others can only be answered by authors who have at least documented a pattern or a reference model by themselves. This includes hypothesis **H08** to **H11** which try to answer the question why a person names an idea a 'pattern' or a 'reference model'. We aim to find any factors influencing a person besides the documented idea. Furthermore, this survey has an impact on hypothesis **H03** to **H07**. These hypotheses strengthen the characteristics and make the assertion that a characteristic is especially present in one of both concepts. Thus, this survey covers the subjective view of people who are familiar with these concepts of characteristics we have found in literature. By analyzing the different instances we can only provide an objective presentation of how the concepts are documented. These

people, however, have generated an individual understanding of what is characteristic for patterns and reference models. This understanding founds on working with these concepts. Most participants have documented a pattern or reference model on their own yet. So we can assume that all participants have developed an idea what the terms pattern and reference model.

4.2 Structure of the survey

The survey is divided into three parts. During the first part background information about the participant as the country of origin, their profession and education and the period of time they have been familiar with pattern and reference models is gathered. Thereby, we want to get a better understanding who answered our questionnaire. Moreover, these questions help us to confirm or refute the different hypotheses dealing with the reason why an idea is named 'pattern' or 'reference model'.

The first question asks for the country the participant works in. In this case there is no use to aggregate single countries into groups. A grouping aspect is considered conveniently, when asking the participants about their educational background. We have decided to differentiate two main groups: information systems and information technology. For those who do not feel comfortable with the one or the other group, a blank text field is offered for an individual answer. The current professional occupation of the people is divided into 'academic', 'practitioner', 'scientific position in an enterprise (research & development)' and a blank text. The last two questions in this part concern since when the participants are familiar with patterns and reference models. Thereby, we differentiate four groups 'less than a year', '1 to 4 years', '5 to 10 years' and 'more than 10 years'.

The second and third part are almost identical. The second part the participants' opinion concerning patterns is collected, whereas, the third part concerns reference models. These parts have three mandatory and two optional questions. Firstly, we ask if they have ever written a pattern respectively documented a reference model and after that they have ever used a pattern / a

reference model. The next question is the most important one in this questionnaire. In this one we want to find out which property they see as characteristic for which concept. Therefore, we use Table 2.5. The participants have been able to mark the level they agree or disagree to the statement 'patterns / reference models are...'. For example they can answer the statement 'reference models are... re-usable' by highlighting 'strongly agree', 'agree', 'neutral', 'disagree' and 'strongly disagree'. In case they (strongly) agree the statement 'patterns / reference models are documented in a defined format' a hidden question appears, asking for the elements the format has. The last question we ask should serve to find out if the participants see a property which we have forgotten.

In Chapter 1.4 we have mentioned that patterns and reference models provide two different semiotic tetrahedrons for the moment. To compare the answers of our participants, we have to ensure that the understanding of the characteristics is the same as ours. Therefore, we provide a definition and at least one example for each characteristic. These appear by moving the mouse over the (i)-icon behind the characteristic. Thus, the participants were able to decide on their own if they want to read an explanation. Thereby, we ensure that the given answers base on the same understanding of the various views on patterns and reference models. For further reference we list the concrete questions and a token by which the question is referenced further on.

I Introduction

- **Q02**: Where (country) do you currently work?

- **Q03 / Q04**: What is your educational background?

- **Q05 / Q06**: Which of the following describes your current professional occupation best?

- **Q07 / Q08**: I am familiar with pattern / reference models since ...

II Patterns / III Reference Models

- **Q09 / Q14**: Did you ever write down a pattern / document a reference model yourself?

- **Q10 / Q15**: Did you ever use a pattern / reference model?

- **Q11 / Q16**: Pattern / Reference models are...

- **Q12 / Q17**: In your opinion, the defined format of a pattern / reference model contains these elements:

- **Q13 / Q18**: I think these items are also characteristics for patterns / reference models

4.3 Analysis of the answers

After the detailed explanation the structure of the questionnaire, the given answers are analyzed in this section. All in all 33 participants have answered the survey completely. The first block, the "Introduction" containing Q02-Q08, collects the background information of the participants.

Q02 asks for the country the participants currently work in. 15 participants are from Germany. The rest is spread through Europe and the USA. We have participants from Austria, Belgium, Italy, the Netherlands and the UK., but also from Estonia, Hungary and Lichtenstein. Almost the half of our participants has their educational background in the information systems. Twelve participants have made their education in information technology. The educational background of the remaining five ranges from Education to Mathematics, Supply Chain Management and Cognitive Science. The major part – 23 participants – is working in the academic world. Five refer oneself as practitioner and four are in an enterprise on a scientific position. The remaining one is an entrepreneur and researcher. Q07 and Q08 ask for how long the participants have been familiar with patterns and reference models. All of the participants are familiar with patterns for more than a year, whereas, 5 participants have little or no experience with reference models. Most of the participants have worked with patterns for almost the same period of time as they have worked with reference models. Those who are familiar with reference models for more than ten years are familiar with patterns for the same period as presented in Table 4.1. As a result, the knowledge about patterns and reference models is considered be equal.

		Reference models			
		<1 year	1-5 years	5-10 years	>10 years
Patterns	**<1 year**	0	0	0	0
	1-5 years	0	4	3	0
	5-10 years	4	2	9	0
	>10 years	1	1	1	8

Table 4.1: Familiarity with patterns and reference models

The second and third part are analyzed together, because, the second block contains the same questions about patterns as the third does about reference models. Five participants have neither written a pattern nor a reference model, but all participants have at least used one of their artifacts. The majority uses both, patterns and reference models as Table 4.2 shows. Whereby, 24 participants have written a pattern, only 16 have written a reference model (cf. Table 4.3). As a consequence the inhibition level for writing a pattern is perhaps lower than documenting a reference model or the effort is lower for patterns. In the definitions we have not found any hint that the size is characteristic either for reference models or patterns. In Q10 and Q15 the participants are asked to give their subjective opinion about the importance of the single criteria found in the definitions. Below we compare the answers for each characteristic.

		Reference models	
		no	yes
Patterns	**no**	0	3
	yes	8	22

Table 4.2: Usage of patterns and reference models

		Reference models	
		no	yes
Patterns	**no**	5	4
	yes	12	12

Table 4.3: Distribution of written patterns and reference models

re-usable: According to the definitions patterns as well as reference models are documented with the intention to be re-used. Based on the results of the definitions we expect that both statements are approved to. Indeed, for patterns the participants strongly agreed that the characteristic is applicable. For reference models the median agrees with this statement. 16 participants strongly agree and ten agree with the statement for reference models, so there is a very positive view on this statement. From our sight the one person who has strongly disagreed for patterns and the two who have done the same for reference models are unexpected answers.

practice-proven: Concepts which have been tested in real life are 'practice -proven'. This characteristic is mainly attributed to patterns. Thus, this reflects the expected answer. For reference models the definitions have a neutral manifestation. But our participants accepted this property for patterns as well as for reference models. Whereas, the acceptance for patterns increases from 'neutral' to 'strongly agree', the rate of answers in this scope is constant for reference models. So this result is not achieved by accident or an uneven distribution. The majority argue in favor of this property and only a small group of four people disagrees for reference models and two for patterns with this characteristic.

theory-based: An artifact is generated in a similar way as hypotheses, wherefore inductive or deductive methods can be used. A deductive method describes that a pattern or reference model is derived from a general theory. Patterns, moreover, are developed by identifying similarities in some solutions. Subsequently these solutions have to be connected and improved as described in [Ga94] and [MD97]. Thereof, we expected a 'disagreement' on the pattern-side. But the pattern community which answered our questionnaire was as neutral as the reference model community. In general, the number of participants who (strongly) agreed to this statement was equal for patterns and reference models.

adaptable: The property 'adaptable' is mentioned in the definitions of patterns by Alexander [Al77], Gamma et al [Ga94]. and Pree [Pr95]. In the definitions of reference models it is named 'basis to derive a model' and is in the eyes of most authors characteristic for reference models. Based on the definitions

we expect that the statement 'patterns / reference models are adaptable' will be agreed to by both groups. But the participants only agreed for patterns to this statement. On the statement 'reference models are adaptable' they have a neutral view. If we take a closer look on the single answers we see that a small part disagrees with the statement. The rest can be differentiated into two groups. Twelve people have a neutral view on this statement and 16 (strongly) agree with the statement. So it is a very narrow decision of 17 to 16 towards the neural statement but with a emphasis towards an agreement.

universal: This property is a controversially discussed characteristic in the reference model community. Whereas, this is a part of the definition in [Ro96], Delfmann refuses this characteristic in [De06]. Nonetheless we expected a disagreement on the pattern-side, because this property is never mentioned in a definition for patterns. Thus, an agreement by the reference model community has been awaited. But both communities have a neutral view on this characteristic in the evaluation of the questionnaire. In detail the pattern community is rather constant distributed between 'disagree', 'neutral' and 'agree'. The majority is indifferent between these manifestations. But for reference models the majority is concentrated on 'disagree' and 'neutral'. So the pattern community have a more positive position to the characteristic 'universal' than the reference model community, whereby, this characteristic is introduced by definitions of reference models.

branch-related: This characteristic is detected in the definitions of reference models. In literature it is controversially discussed, but nevertheless some authors have mentioned it. Our analysis of the definitions expects an agreement of the reference model community, as there is no indication in the definitions that this property has some importance for patterns. All the more it is interesting that thirteen persons (strongly) agree with the statement 'patterns are branch-related', whereas only nine (strongly) disagree with this statement. For reference models the majority (strongly) agrees with this statement as expected.

constrained in their applicability: This property is part of the three-part-rule which is cited by almost every definition we have analyzed. Hence, we have expected a strong agreement on pattern side and a disagreement in the view

of the reference model community. The answers concerning reference models as well as patterns can be separated into two groups. Persons who (strongly) disagree or are neutral and persons who (strongly) agree. For patterns there are 15 persons in the first group and 18 in the second and for reference models there are 17 in the first group and 16 out of 33 in the second. So the size of groups is almost identical. This is surprising whereas the context is a very popular characteristic for patterns and is never mentioned in one of the definitions of reference models.

problem specific: As well as 'constrained in their applicability' this property is part of the three-part-rule. As this rule is mentioned in almost every definition we expected our participants to 'strongly agree' to this characteristic for patterns and 'agree' to it for reference models. Indeed 16 of the participants have (strongly) agreed that this statement is true for reference models. For patterns 18 have (strongly) agreed. Nevertheless, the agreement for this property is not as strong by the participants as by the definitions.

provides a solution: This property is the third part of the three-part-rule and like 'constrained in their applicability' and 'problem-specific' the majority agrees to this statement for patterns. But in contrast to 'problem specific' the number of participants who strongly agree is almost the same as the rest. We have a ratio of 16 who 'strongly agree' to 17 answers that range form 'disagree' to 'agree'. So this result is far closer to our expectations than the results of the two others. In the definitions of reference models only two authors mention explicitly that a reference model is a solution (cf. [HHR04] and [Sc97b]), but our participants 'agree' that 'reference models provide a solution'.

documented in a defined format: Similarly to the 'adaptable' property this characteristics fit to our expectancies concerning patterns. A format which does not just fit to a single pattern but is used for more than one pattern was mentioned by three authors. In the definition of the reference models the format is never mentioned, therefore, we expect rather a disagreement concerning this statement. For patterns this characteristic has a straight increase of agreement from strongly disagree to strongly agree resulting to a median at 'agree'. The answers concerning the reference model are perfectly symmetric distributed around the 'neutral' answer. Ten people agree with the statement

and also ten people disagree. The rest gives a neutral answer. This distribution is unexpected as we have not found any indication in the definitions. Therefore, we expected a negative result or disagreement rather than a neutral position.

linked to others: For patterns this property is mentioned by Alexander [Al77], Gamma et al [Ga94]. and Meszaros and Doble [MD97]. Patterns are more or less mandatory connected to each other. No definition of reference models mentions this characteristic. Similarly to the result of 'documented in a defined format' the number of persons with the same view of patterns increases straight from strongly disagree to strongly agree. Whereas the answers concerning reference models have a broad area of approval in the middle sector. Fourteen of thirty three preferred a neutral answer. Twelve disagreed and only seven participants say that a reference model can be linked to other reference models. All in all this mirrors rather disapproval than support.

5 Revisiting the hypotheses and conclusion

In this section we revisit the hypotheses of Section 2.3. Further, we conclude the thesis with some reflections on the findings and present an outlook to future research in the field.
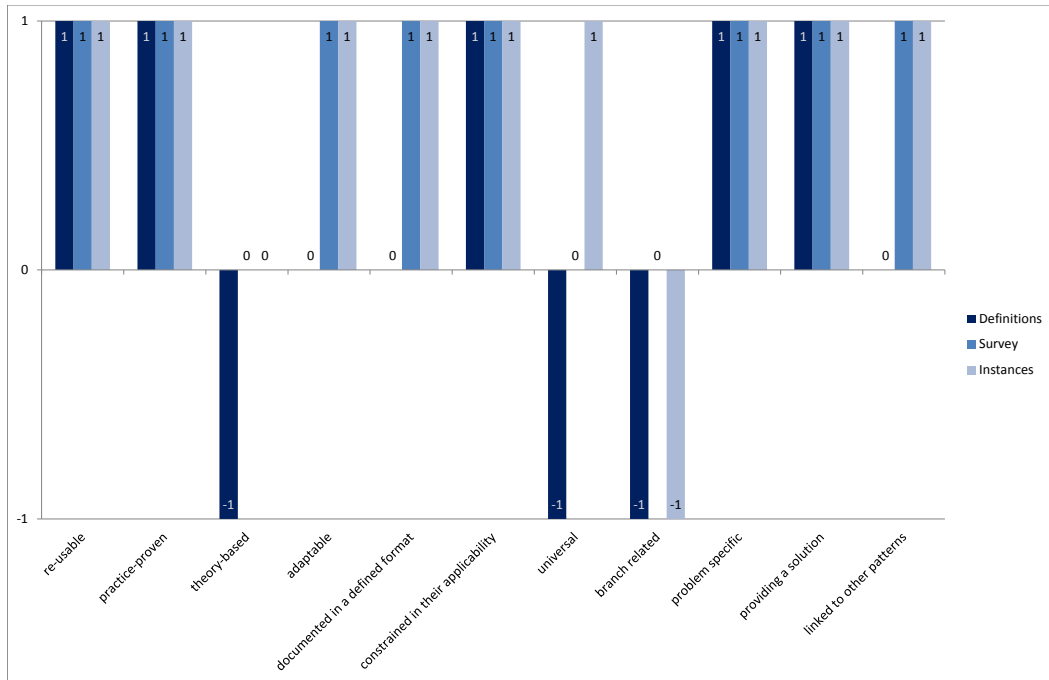
5.1 Revisiting the hypotheses

Because the hypotheses **H01** and **H02** are the initial hypotheses and base on the results of the others we deal with them at the end of this section. For confirming or refuting them we first take a look at the descriptions of the answers of the survey and the distribution of the instances. For the hypotheses H03 to H07 we compare these with the definitions.
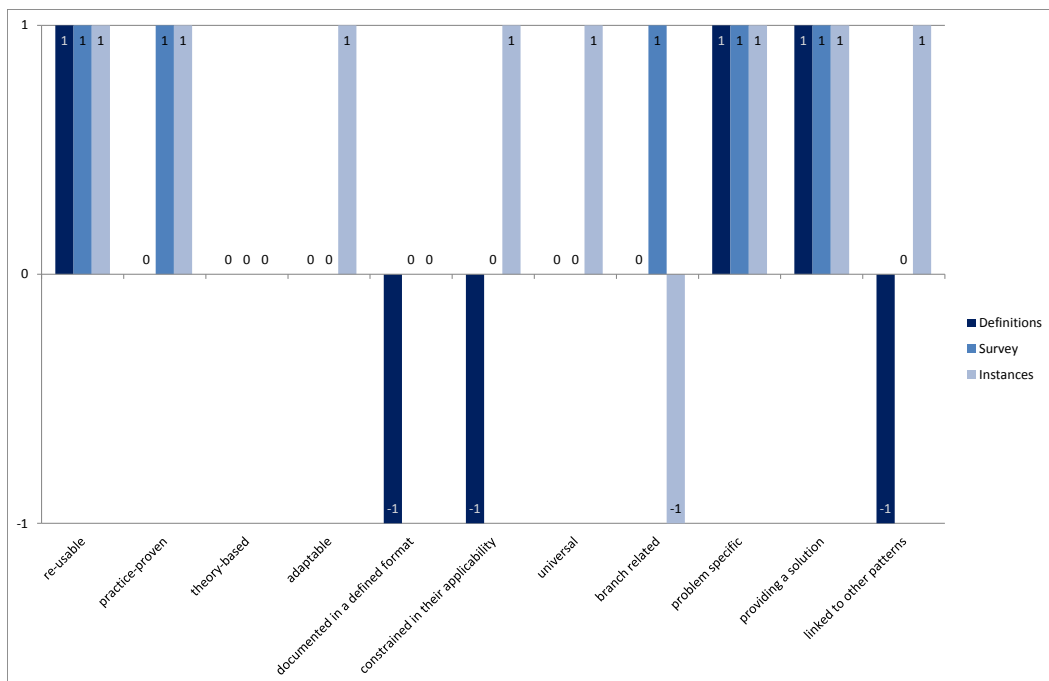
The first group of hypotheses comprises the characteristics we have analyzed in the previous chapters. In this chapter we meet the manifestations again. Thereby, we confine on those characteristics which are important for the hypotheses. In Figure 5.1 the manifestations of the characteristics for patterns and reference models are presented.

Thereby, we can derive for patterns and reference models that the tendency of 're-usable', 'practice-proven', 'adaptable', 'problem-specific' and 'provides a solution' is positive. Additionally, reference models are considered to be 'universal'. This characteristic is neutral for patterns. Whereas, reference models have a neutral manifestation on 'theory-based', 'branch-related', 'constrained in their applicability' and 'linked to others'. In our analysis patterns are not 'branch-related' and 'theory-based', although they are 'constrained in their applicability' and 'linked to other patterns'. Reference models and patterns

(a) Analysis Pattern

(b) Analysis Reference model

Figure 5.1: Summary of the analysis

differ from each other the most regarding the characteristic 'is documented in a defined format'. Patterns fulfill this characteristic whereas reference models do not. This leads us to the hypotheses. The hypothesis H06 that patterns are practice-proven and reference models not must be refuted. Reference models may be more often related to a branch, but there is neither an obligation nor significant frequency. It is true that reference model instances, we have evaluated, have been more often branch related than the pattern instances thus, we can not accept this hypothesis because the participants of the survey declare themselves against this characteristic for reference models. H03 and H05 have to be refuted, too. The possibilities for combining reference models may be more restricted but many of the analyzed instances can be used in parts and as a whole e.g. [Re97], [Sc97a], [We00a], [Kr00] and [Tz03]. The fact that reference models are 'constraint in their applicability' can not be denied. Some authors as Remme in [Re97] explicitly mention the constraints or implicit for example by presenting a reference model which is branch-related. The only hypothesis the characteristics differ clearly is H07. Patterns are mainly presented in the GoF or canonical format. Whereas reference models can be presented in a more general format as Ahlemann does, the most reference models are presented in their own format. This is also shown by the answers of the questions Q12 and Q17. Whereas, for patterns the participants of the survey enumerate the elements of the GoF and the canonical format, for reference models the format is more free.

Whereas **H03** to **H07** can also be analyzed by studying instances of patterns and reference models, **H08** to **H11** can only be analyzed by questioning people who use and document these concepts. By the help of the questions **Q02** to **Q10** and **Q14** / **Q15** we are able to verify hypothesis **H08** to **H11**. In this section each hypothesis is regarded separately, analyzing the data to confirm or refute the hypothesis.

For answering the hypothesis **H08** we combine the answers of **Q02** and **Q09** / **Q14**. 24 participants out of 33 indicated that they already have documented a pattern, whereas only 17 of them state that they have written a reference model. Comparing the amount of pattern writers and reference model authors sorted by the country there is no clear tendency to a specific country. Most of out participants are from Germany, but we have also received answers from

all over Europe and the USA. Having received only one or two answers from some countries as Estonia or the Netherlands we can not accept the hypothesis, therefore, we have not enough participants form the single countries.

The hypothesis **H09** is covered by the answers of **Q03** / **Q04** and **Q09** / **Q14**. We divided the educational background into three parts, information systems, information technology and other. 16 participants state that they have an information systems background and the background of 12 participants is in information technology. The remaining five participants have different backgrounds, as mathematics, supply chain management, media science, computer science and education. People whose background is in the IT tend to write down either only patterns or patterns and reference models than to document just reference models as do people with other backgrounds. At least a quarter of the participants with an informations systems background documented only reference models, whereas, two participants with IS background have written down only patterns. But the major part has documented patterns as well as reference models.

Our hypothesis **H10** states that it depends on the profession of a person whether a person names a concept reference model or pattern. The working environment can be divided into at last four sections. The major part works in an academic environment. Four refer to oneself as practitioner and five people work in a scientific position in an enterprise. Only one person claims oneself to be an entrepreneur and researcher. Nevertheless the distribution within the different occupation groups is approximately considered to be identical. 39% of the participants with an academic profession and 40% working in a practical working environment documented patterns as well as reference models.

The next hypothesis **H11** is closely connected to the previous one. Analyzing the interdependence between profession and documentation of a pattern / reference model, this hypothesis takes a closer look at the dependency between professional occupation and the usage of patterns and reference models. Each of our participants has already used at least a pattern or a reference model. Based on the dataset we neither can determine that one occupational field is the only one which uses patterns or reference models nor state that e.g. academic people use extremely often patterns.

In general we have to refute all hypotheses concerning the question why people name their artifacts pattern or reference model, because many of our participants have documented both. Therefore, the decision to name an artifact pattern or reference model is not dependent on the background of the author. Thus, there must be other criteria influencing the decision.

This leads us to the starting hypotheses **H01** and **H02** generated by Fettke and Loos in [Wi09]. They recommend that "reference models and patterns represent two forms of the same idea [and] to no longer make a distinction between both approaches in future". Within the instances of the pattern we have analyzed the manifestations are constant over the time. A few of them differ a little form the median, but generally there is no change of the point of view between Gamma et al. until the last year's PLoP Conference. The analyzed instances of reference models show less constancy as none of them matches to the median perfectly. But, despite the fact that reference models are less consistent than patterns, there is no direction of development identifiable over the years. All in all our analysis has shown that the concepts of patterns and reference models are very similar. The only clear difference we have found in the definitions, the questionnaire and the instances regards the format. Pattern are mostly structured in the GoF Format, whereas reference models are more flexible. But there is no reason why patterns can not be presented in an other structure (cf. [Ri02]) or why a reference model can not be documented in a recurring format. In our opinion the format is no sufficient reason to distinct both concepts.

5.2 Conclusion and Outlook

The goal of this thesis is to evaluate the hypotheses by Fettke and Loos in [Wi09]. We choose three approaches to elicit these hypotheses. Firstly we analyze various definitions of patterns and reference models from different authors to find the characteristics of both concepts. Thereout, we generate a comparison matrix and eleven hypotheses. To evaluate these hypotheses we created a questionnaire. This questionnaire has been answered by persons who are familiar with at least one of both concepts. In parallel, we analyzed

instances of patterns and reference models. Thus we regard on the hypotheses considering theses aspects: the definitions in literature, the subjective view of professionals and the instances of the concepts. The only characteristic we have found in literature differing both concepts clearly is the format the instances are presented in. By analyzing the questionnaire the fact that many participants document reference models as well as patterns attract our attention. Analyzing this we came to the conclusion that not the author is the reason why an artifact is named pattern or reference model. By analyzing the instances a characteristic which is never mentioned in the definitions appeared. Patterns and reference models can be assigned to different topics. Many reference models deal with business issues e.g. how to organize enterprises, processes or supply chains. Particularly common in this field is the business blueprint by SAP (c.f. [CK99]) or the ARIS House by Scheer (cf. [Sc97a]). Patterns predominantly deal with software problems as implementing a network of sensor nodes (cf. [Sa10]) or 'Metaprogramming in Ruby' by Günther and Fischer in [GF10]. But there are also some patterns which consider e.g. with 'building a beautiful company' (cf. [Ri02]). Indeed the authors do not go into detail on the organizational processes but point out mistakes in personal management and how to avoid them. An other point is the fact that many reference models are separated into sections. These sections can be applied alone or together. Thus, a reference models occurs to us like a pattern language.

From these points of view, that patterns and reference models deal with different subjects and a reference model can be compared to a pattern language, a renewed analysis of the literature and potentially a second questionnaire would be of interest. There would be some interesting points of view for further research concerning these facts. These issues emerge while writing this thesis and could not be evaluated. To analyze patterns and reference models considering these facts could lead to a new understanding of their relationship.

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