Assessing Modeling Languages, metrics and tools

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Abstract. Any traditional engineering field has metrics to rigorously assess the quality of their products. From a long time ago, engineers know that the production process is not all; the output must comply with the rules and good-practices, must satisfy the requirements and must be competitive.
Professionals in the new field of software engineering started a few years ago to define metrics to appraise their product: individual programs and software systems.
This concern motivates the need to assess not only the outcome but also the process and tools employed in its development. In this context, assessing the quality of programming languages is a legitimate objective; in a similar way, it makes sense to be concerned will models and modeling approaches, as more and more people starts the software development process by a modeling phase.
In the paper we discuss the quality of modeling languages, introducing and motivating the topic, presenting metrics, and comparing tools.

Keywords: : Modeling Languages, Software/Language Quality, Software/Language Metrics, UML

1 Introduction

A model is a representation of reality aiming for the simplification of some complex object.

Models are built so that we can better understand the system being developed. They help us to visualize a system as it is or as we need it to be. Models allow us to specify the structure and behavior of a system, they provide the guidance lines/blueprints in constructing a system, and finally, models document the decision taken for a given system;

Some models are best described textually, other graphically. All interesting systems exhibit structures that transcend what can be represented in a programming language.

A modeling language is a language whose vocabulary and rules focus on the conceptual and physical representation of a system.

Specifying means building models that are precise, unambiguous and complete. The UML addresses the specification of all the important analysis, design and implementation decision.

That aside, when assessing a modeling language we might infer on its quality.

The software functionality, trustability, usability, efficiency, maintability and portability.

* Importância do uso de métricas num projecto: no que consistem, o que medem, o que ajudam a melhorar, etc. - esta parte liga-se com o que sugiro abaixo - sugiro partir de uma definição geral de métricas;

Nowadays, metrics become increasingly essential for Software Engineering: they are crucial for quality assessment and reengineering processes. In *Forward Engineering* they are used to measure the software quality and estimate cost and effort of software projects [FP98]. In the field of *Software Evolution*, they can be both used to identify stable or unstable parts of a system as to determine where refactoring can be or have been applied [DDN00]. They even can be used for assessing the quality and complexity of software systems in *Software Reengineering* or *Reverse Engineering* [CC90].

When focusing on the field of Object-Oriented (OO) systems, many metrics have been proposed for assessing the design of a software system. However, most of the existing approaches involve the analysis of the source code and cannot be applied in earlier stages of the development process. In fact, it is not always simple to apply the existing metrics in this earlier stages. As the Unified Modeling Language, proposed by Booch, Jacobson and Rumbaugh [BRJ05] has became a standard for expressing OO systems, apply metrics to these models enables an early estimate of development efforts, implementation time, complexity and cost of the system under development.

* Especificar o tipo de métricas sobre o qual nos vamos focar (UML) - o paragrafo acima ja fala 1pc, completar se tiverem+ideias

** estrutura do artigo - proposta a completar

In this paper, we will introduce and discuss the major existing metrics for UML models, and focus on present a set of tools designed for measure UML projects. In what follows, Section 2 is devoted to the metrics assessment process. In Section 3 we describe the principal measurements applicable to the most popular UML diagrams. Then, in Section 5 we present some tools designed for apply metrics to UML models and the results of applying them a real case-study. We conclude in Section 6 with a comparsion between the presented tools (.....).

2 Metrics Assessment

* Explicar aqui que as métricas não podem ser observadas, por si só, fora do contexto. Este problema prende-se essencialmente com o facto deste tipo de medições ser empírica, ou baseada em métodos empíricos.

> Effective management of any process requires quantification, measurement, and modeling. Software metrics provide a quantitative basis

> for the development and validation of models of the software development process. Metrics can be used to improve software productivity and quality. [Mil98]

* Explicar em maior detalhe o que se entendo como validação de métricas (Kaner e Walter Bond).

Fenton [Fen99] estimates that companies spend about 4% of the development budget in the establishment of metrics program, therefore, engineers should also certify and garantee that the applyed metrics actualy quantify, measure, and model the atributes of the sistem.

> (...) if a project or company is managed according to the results of measurements, and those metrics are inadequately validated, insuficiently understood, and not tightly linked to the attributes they are intended to measure, measurement distortions and dysfunctional should be commonplace. [KB04]

3 Applying Metrics To UML Models

–esta intro ficará para depois de termos as subsec prontas As métricas para avaliação de software estão bem mais desenvolvidas que as métricas para linguagens de modelação. É então interessante ter em conta o estudo já realizado sobre métricas para avaliação de código, como é o caso das CK Metrics, como ponto de partida para métricas de modelação.

-Junção da Sec.1 do artigo dos Pedros e Ulisses com Sec.3 do artigo do Ismael e Daniela.

* Explicar que as métricas sobre UML derivam directamente do OO.

* Falar em CK metrics e falar apenas nos tipos de CK metrics mais importantes.

* Relacionar as tabelas do paper do Ismael e Daniela com os tipos de CK metrics.

3.1 CK Metrics

One of the most popular suites of OO metrics was proposed by Chidamber and Kemerer [CK94]. They were proposed to capture different aspects of object-oriented designs, including complexity, coupling and cohesion, and were posteriorly adapted for modeling languages as we can see in [MP06].

This suite is composed by six metrics: Weighted Methods Per Class (WMC), Depth of Inheritance Tree (DIT), Number of Children (NOC), Coupling between Object Classes (CBO), Response For a Class (RFC), e Lack of Cohesion in Methods (LCOM). We detail bellow each metric and its features.

Weighted methods per class (WMC): This metric regards to the complexity of a class's methods, being equal to the sum of the complexities of those methods defined. There two kinds of WMC metrics:

- $WMC1_1$ can be obtained from a class diagram of a *UML* model. It is computed by identifying the class and counting the number of methods in that class, which means that, in this case, the WMC metric considers a method as a unity.
- WMC_{cc} is also computed by identifying the class and counting the number of methods, but each method is not a unity, is the result of a McCabe Cyclomatic Complexity of it. Another difference is that this kind of WMC cannot be computed only with information of diagrams class, needing information of other kinds of diagrams, like sequence or activity.

Depth of inheritance tree (DIT): This is metric is equal to the maximum length from the class to the root of the inheritance, which could be defined as the depth of the class. It is computed by taking the union of all the class diagrams in a *UML* model and traversing the inheritance hierarchy of the class.

Number of children (NOC): This metric represents the number of childs and descendants of a certain class. Can be obtained gathering all diagrams class, in a *UML* modulation, and checking all the inheritance relations of the class.

Coupling between object classes: Two classes are related if the method of a class uses a instance variable or method of another class. Counting the number of classes to which the class are related and counting all kind of references of the attributes and parameters of the methods of the class, an estimate of this metric's value can be obtained from the class diagrams. Though, it is possible to calcute a more precise value if the behavioural diagrams are taken into account, since the usage of instance variable and invocation methods are additional information.

Response for a class (RFC) - This metric is the number of methods that can be invoked by an object of a given class. It can be obtained from a class diagram and, also, by behaviour diagrams (e.g. sequece diagrams), which can inform of several methods of other classes that are invoked by each of the class's methods.

Lack of cohesion in methods (LCOM)- Is the metric that measure the number of sets of instance variables accessed by every pair of methods, of a given class, that has a non-empty intersection. With the intention of computing a value for this metric, it is essential the information of the usage instance variables by the methods of a class, i.e., it is needed a sequence diagram (a class diagram does not have information about the usage).

The set of metrics that were here defined can be found and cited in several papers (probably the most famous [MP06]). They are currently the most studied and used to evaluate *UML*models.

3.2 Use Case Metrics

The Use Cases Diagrams are graphical representations of entities which interact with the system under development - the *actors*, and operations that the system must perform for them. They define a sequence of actions which illustrate a specific way of using the system.

This diagrams are functional specifications, collected at the beginning of a system development process. They are crucial to an early estimate of the system complexity and its development efforts.

— Falta incluir algumas métricas sobre UC e referenciar alguns trabalhos na área;

— Falta Introduzir textualmente o trabalho d Marchesi para contextualizar a tabela;

Marchesi Metrics

Metric	**Description**
NA	Number of actors of the system.
UC1	Number of Use Cases in the system.
UC2	Number of communications among UC and Actors
UC3	Number of communications among UC and Actores without redundancies
UC4	Global complexity of the system

Table 1. Use Case Metrics proposed by Michele Marchesi

3.3 Class Diagram Metrics

These diagrams are used to describe the types of objects in a system and their relationships. They describe the structure of a system by showing the system classes, their attributes, methods and the relationships between them. Their quality have a huge impact on the final quality of the software under development, as they describe the general model of the system information.

Measures like the *Number of Attributes in the Class* (NAC), the *Number of Operations in the Class* (NOC), *Number of Inherited Attributes* (NIA), *Number of descents/ancestors od a Class*(NDC/NAC), or even the *Number of Interfaces Implemented* (NII) are used both for indicate the system complexity and as a index of quality.

— Citar mais trabalhos sobre DC com+exemplos de métricas

— Falta Introduzir textualmente o trabalho d Marchesi nesta área para contextualizar as tabelas;

3.4 Other Metrics

– estou a incluir aqui as métricas q temos no nosso artigo, + notas sobre o trabalho d Michele Marchesi

– conforme fique no final, pensei em incluir+algumas notas sobre outros trabalhos q fui encontrando, mas ficaria para dp da deadline desta semana, p o

Marchesi Metrics

Metric	Description
NC	Number of Classes
CL1	Weighted Number of responsibilities of a Class
CL2	Weighted Number of Dependencies of a Class
CL3	Depth of inheritance tree
CL4	Number of immediate subclasses of a given class
CL5	Number of distinct class

Table 2. Marchesi Class Diagram Metrics

Marchesi Metrics

Metric	Description
NP	Number of Packages.
PK1	Number of Classes
PK2	Weighted Number of responsibilities of a Class
PK3	Overall Coupling among Packages

Table 3. Marchesi Package Metrics

resto ser revisto entretanto e vermos se ainda há espaço.

— Falta para além de traduzir, contextualizar 1pc+

No caso dos Diagramas de Estado, estes são utilizados para descrever o comportamento de um objecto. Um estado representa uma situação de um objecto que se prolonga durante um determinado intervalo de tempo, durante o qual não sofre estímulos de objectos exteriores nem há qualquer alteração em nenhum dos seus atributos.

Métricas de Estados

Métrica	Descrição
TEffects	The number of transitions with an effect in the state machine.
TGuard	The number of transitions with a guard in the state machine.
TTrigger	The number of triggers of the transitions of the state machine.
States	The number of states in the state machine.

Table 4. Exemplos de Métricas sobre Diagramas de Estados

As métricas associadas a este tipo de diagrama encontram-se associadas à complexidade e dimensão do problema [**?**]. Na Tabela 4 podemos observar alguns exemplos de atributos que podemos medir com o uso de métricas sobre este tipo de diagramas. Outras métricas bastante comuns para este tipo de modelo contabilizam, por exemplo, o número de transições entre estados ou até o número de actividades definidas em cada estado.

Os Diagramas de Actividade descrevem fluxos de trabalho e são ainda úteis para detalhar operações de uma classe (incluindo comportamentos que possuam processamento paralelo).

Métricas de Actividade

Métrica	Descrição
Actions	The number of actions of the activity.
ObjectNodes	The number of object nodes of the activity.
Pins	The number of pins on nodes of the activity.
Guards	The number of guards defined on object and control flows of the activity.

Table 5. Exemplos de Métricas sobre Diagramas de Actividade

Como podemos observar pelos exemplos da Tabela 5, existem também diversas métricas sobre Diagramas de Actividade. Para além destas, podem ainda ser medidos atributos representativos do número de grupos ou regiões de actividade num diagrama, o número de fluxos de objectos, ou até o número de excepções de cada diagrama.

4 Case Study

–Apresentação de um Exemplo a ser analisado por cada uma das ferramentas: encontrar um projecto (idealmente open source) que tivesse disponível os diagramas UML (não apenas diagramas de classes, para os programas que conseguem processar mais que estes)

5 Tools for UML Metrics Specification

Nowadays, the most popular UML tools for software application development are Visual Paradigm for UML[1] and Poseidon for UML[2]. They enable a visual environment to model software, which reduces the complexity of software design. However, they not support metrics specification - it is required to use other tools, designed for this task. In the next subsections, we will introduce the leading systems on the quantitative analysis of UML models structural properties, and put them to test for explore their features with a real case-study.

One of the tools that we are going to address is SDMetrics[3], a design measurement tool for UML models. Although its core is open source and available under the GNU Affero General Public License, SDMetrics GUI it is not freely distributed. In order to explore all the system features, SDMetrics staff gently provided us an Academic License which we sincerely would like to thank.

The core functionalities of SDMetrics include:

– the configurable XMI parser for XMI1.0/1.1/1.2/2.0/2.1 input files;

[1] Available at `http://www.visual-paradigm.com/product/vpuml/`
[2] Available at `http://www.gentleware.com/products.html`
[3] SDMetrics can be found at `http://www.sdmetrics.com/`

– the metrics engine to calculate the user-defined design metrics;

– the rule engine to check the user-defined design rules.

The other tool we put to test is the Sparx System Enterprise Architect[4], a team-based modeling environment. It embraces the full product development lifecycle, supporting both software design, requirements management, and metrics calculation for Use Case Diagrams. Thus, it allow to estimate the complexity of the project in a earlier stage, as well as the complexity associated with each actor of the system.

The case-study used to explore this tools is the modelation made for a project of a subject during our graduation. The subject name was Software Systems Development and it's project was *GCS - Gere Com Saber*, in english, Manages With Knowledge.
In the project, GCS is a company which doesn't provide services, but on the other hand, to meet it's clients needs, it has a wide range of suppliers, that GCS subcontracts, who are responsible for the service execution. Multiple suppliers can supply the same service and each service can be delivered in different ways. Each service can then be composed of multiple activities. As an example, there could be a service called *Shirts til 10Kg* and inside this service there could be activities such as *wash, iron, sewing buttons, etc.*
Each activitie of a given service as a stipulated price, and can be hired by a client.
The goal of the project was to model and implement a management software, with the same name as the company, that would help the completion of all the tasks inherent to the company.

As an example of the UML diagrams used on the test, we will display one image of the general Usecase diagram and an excerpt of the class diagram.

[4] `http://www.sparxsystems.com.au`

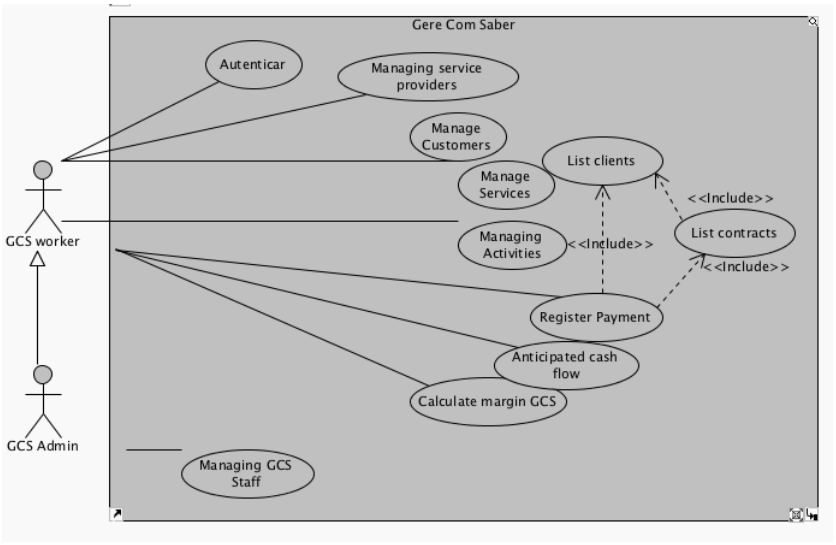

Fig. 1. The general Usecase of the modelation

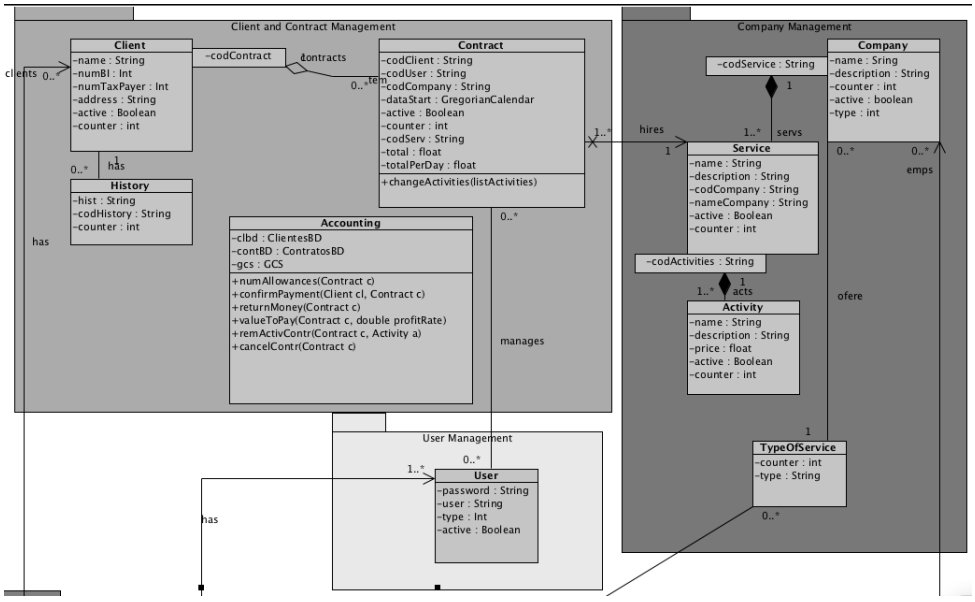

Fig. 2. Excerpt of the Class diagram

5.1 SDMetrics

SDMetrics is a very complete design measurement tool, analysing a wide range of UML diagrams, including Class, Usecase, Activity and Statemachine diagrams. For each type of diagram, this tool generates several metrics.
For example, **NumAttr** metric, one of the metrics that has already been adressed in this paper, is calculated from Class diagrams. Other one is **ExtPts**, wich is calculated from Usecase diagrams, and gives us the number of extension points of a given use case.

SDMetrics is written in java, and provides us a graphical user interface. The type of source files it receives to analyse are *XMI*[5] files, most modeling tools support project exportation in XMI.
This tool allows us to access the results from different views. We will approach the ones that seem the most important:

- **Metric Data Tables** provides a table that matches each UML model element analysed (table line) to it's value for each metric (table column);
- **Histograms** provides a graphical distribution for each design metric;
- **Design Comparison** provides us a mean to compare the structural properties of two *UML* designs. It is very useful to compare the same design in different iterations of the development, or to compare an alternative design to the current one.
- **Rule Checker** design rules and heuristics detect potencial problems in the UML design such as:
  - incomplete design such as unnamed classes, states without transitions;
  - violation of naming conventions for classes, attributes, operations, packages;
  - etc.
- **Catalog** this view provides us with the definitions of the metrics, design rules, and relation matrices for the current data set, and provides literature references and a glossary for them.

Not a view, but one of the most advanced features in this software is the possibility of defining Custom Design Metrics and Rules. The new metrics are defined in a XML file, with a very particular format, the *SDMetricsML* (SDMetrics Markup Language).
The SDMetrics tool doesn't provide a direct notion of good/bad quality of the design model. Despite that, on the SDMetrics website we can find several indications of how to interpret each output.

Results

[5] *XMI* (**X**ML **M**etadata **I**nterchange) is an *OMG* (Object Management Group) standard to generate XML-based representations of UML and other OO data models.

5.2 Sparx Systems Enterprise Architect

Sparx Systems Enterprise Architect is another tool that provides modeling of UML diagrams. It supports mind map diagrams and project management, to provide full traceability from requirements specification to deployment end implementation. This tool also provides also some metrics evaluation to compute the complexity of a project only based on Use Case diagrams.

To perform this evaluation, the user needs to provide a level of implementation complexity to each interaction with authors. This task can be done when defining the Use Case descriptions or when performing the metrics evaluation.

To evaluate the metrics, Enterprise Architect have a wizard, that gives also other options to do the complexity analysis. This options manipulates the Technical complexity and also Environment complexity and be used to adapt the evaluation and perform a better result on estimation.

Also can be filtered the Use Cases used in evaluation. To filter can be used manual selection or regular expressions over use case name. This kind of filtering ables the project to be distributed and evaluated individually.

The final result presented is the maximum number of working hours needed to perform the implementation.

Results

5.3 IBM Rational

–Permite modelação + aplicação de métricas

Results

6 Conclusion

Comparação entre as diversas ferramentas.

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