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SEA: An UML Profile for Software Evolution Analysis in Design Phase

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ABSTRACT

Software evolution is one of the software process activities that occupies a major percentage of software development cost. Since requirements change continually and new technologies emerge, software should be adapted to satisfy these new changes to continue to survive. Despite software evolution being performed after software validation and deployment, software developers should predict at earlier stages how software would evolve in the future to avoid surprises. Although many works focus on how to enhance the program structure to facilitate maintenance tasks, only few works treat software evolution in earlier phases of software development process. In this direction, we propose an UML profile that permits to tackle software maintenance issues at the early phases of software development process. The proposed approach helps software developers to predict in design phase the kind of maintenance tasks that could occur in the future.

1 Introduction

According to [1], software evolves and changes continually in order to support new emerging technologies and satisfy customers and business needs. Some studies estimate that software evolution could reach more that 60% of software development total cost [2]. This issue pushes software engineering community to focus on how optimizing software evolution cost.

In fact, software maintenance cost varies depend on the kind of maintenance tasks that will be performed. For example, if the source code to be maintained is crosscutting among software modules, maintenance tasks performed on that source code are as well, the thing that could generate an extra cost. But, if the source code to be maintained is encapsulated in a single module, software maintenance applied to that source code is modular (less time and less cost).

Duality among crosscutting maintenance and modular maintenance motivates the community to provide solutions to keep software maintenance being modular. For example, some design patterns [3] and some program structuring/decomposition [4]–[8] facilitate software reuse and maintenance. But, even though some solutions could assure modular software maintenance, the challenge still existing since software maintenance could be modular for the same program with respect to a given architecture/structure but not with respect to another. A such problem is known as tyranny of decomposition or expression problem [9] (see Sect. 3 for more details). To resolve this problem, many works ([10]–[14]) tried to attenuate the effect of tyranny of decomposition on software maintenance but results still relative and they treat this issue only in source code level.

In this paper, we illustrate how software developers could tackle software maintenance issues at the design phase of software development process. The early treatment and analysis of software maintenance tasks that could occur later permits to get a clear overview about how the program will evolve in the future. The main goal is to specify from the beginning the program structure that is more adaptable for future maintenance tasks. This could be realized by: first, identifying what kind of maintenance tasks is more probable to occur and then recommending the program architecture that is more adaptable to this kind of maintenance tasks. To concertize our approach, we define an UML profile that helps software developers to analyze and predict the kind of future software maintenance tasks that could occur.

The rest of this paper is organized as follows: first, we explore some related works (Sect. 2). Then, we give some explanations about tyranny of program decomposition problem. We show also how this problem affects modular maintenance (Sect. 3). Next, we present how we have defined *SEA* UML profile (Sect. 4). After that,

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we show how we validated *SEA* by applying some stereotypes in a real case study (Sect. 5). Finally, we resume our contributions and we propose some future works (Sect. 6).

2 Related work

In fact, this paper is an extension of the paper [15] (presented in the International Conference on Computer and Information Sciences (ICCIS) in 2019). In [15], the approach consists of proposing an UML profile called *MODEM* used to model maintenance tasks in design phase. This profile provides some UML stereotypes that permits to software developers to model and analyse maintenance tasks before occurring. The extension we propose in this work consists of adding more details and semantics to the previous work. We have modified some stereotypes, added new stereotypes and added tagged values in order to better analyse and predict in design phase future maintenance tasks that could occur. Further more, comparing to the previous work, we validate the extended UML profile by apply it to a real case study.

In [16], the author proposed a process of eight steps helping to supervise maintenance tasks that could occur later. Their approach simulates communications between stakeholders in order to design maintenance tasks, apply them and test software again before delivering the final version. In [17], the author proposed also an approach that aims to treat maintenance tasks in early phases of software development. They propose a software maintenance life cycle model that relies on a process of four steps. During this process, stakeholders interact between each other to study and analyze maintenance tasks to do in order to guarantee a consistent planning for performing maintenance tasks. The process is incremental and iterative and it stops when maintenance tasks analysis proves that software maintenance requests percentage becomes under a given threshold.

Although these works show a relevant contribution in planning maintenance tasks at earlier stages of software development, both of them involve different stakeholders to express needed maintenance tasks which could disturb software development process. In addition, maintenance issue is not expressed explicitly in models as we propose in our approach.

In [18], the author proposed an UML profile that permits to support requirements evolution. Their method is tool supported and consists of extending requirements engineering process by making it supporting requirements evolution. Although this approach facilitates requirements changes management, it still limited to specification phase. In our work, we focus more on design phase because we treat a problem which is related to software architecture rather than software requirements.

Some other works like [19]–[22] focus on analyzing and expressing design patterns explicitly at early phases of software development by defining the appropriate UML profiles. These works aim to enhance design patterns implementation comprehension for programmers since design pattern does not appear explicitly on source code. These works focus more on improving software comprehension rather than treating software evolution issue.

Some other works such as [13] and [23] treat maintenance issues in implementation phase by providing reversible transformations among dual design patterns (composite and visitor) in order to keep maintenance tasks modular. In [24], the author proposed also a relevant approach that treats software maintenance issue in source code level. Their approach consists first of exploring the best machine learning techniques used for predicting software maintenance and then improving their performance. Although these works show important contributions in treating software maintenance issues, they still limited to implementation phase while we focus more on tackling this issue in earlier software process activities.

3 Background

We present in this section an overview about potential challenges that software evolution could face. One of the issues that could affect software evolution is tyranny of decomposition or expression problem [9]. In fact, although software modularity enhances program structure and facilitates software maintenance, a modular program structure could be biased to one kind of modular maintenance and not to another. A maintenance task is called modular when changes are mostly encapsulated in one module. Contrary to this, if changes touches many modules at the same time, the maintenance task is called crosscutting.

For example, Figure 1 illustrates a program composed of two classes *Circle* and *Rectangle* that extend an abstract class *Shape*. The program contains also two methods *print()* and *show()* which represent the business code of the program. The structure of the program is a base form of Composite design pattern in which each data type is encapsulated in a module. A such program structure decomposes the program with respect to data-types axis.

The decomposition of the program (Figure 1) permits to perform modular maintenance with respect to data-types. For instance, if we add a new shape (a Triangle for example) to the hierarchy of shapes shown in Figure 1, we first create a new class, then, we redefine the code of methods *print()* and *show()* only in this new class. In this case, the maintenance task is modular (low cost). But, if we add a new feature to the program (for example a method *color()*), we have to implement it in all classes which causes a crosscutting maintenance (extra cost). We deduce that the architecture of the program shown in Figure 1 allows a modular maintenance with respect to data-types and not with respect to functions (methods). Hence, the program structure is dominated by the data-types decomposition axis (a tyranny of decomposition according to data-types).

Another axis of decomposition of the program described above is illustrated in Figure 2. This program represents the Visitor design pattern implementation of the program shown in Figure 1. The Visitor pattern encapsulates each business code in a single module: the business code *print* is encapsulated in module/class *Print* and the business code *show* is encapsulated in module/class *Show*. This program structure decomposes the program with respect to functions which permits to add a new function without touching other modules: for example if we add a feature *color* to the program, we add a new class in which we implement this new feature for all shapes. Thus, Visitor design pattern permits to perform modular maintenance with respect to functions since it provides a functions decomposition axis.

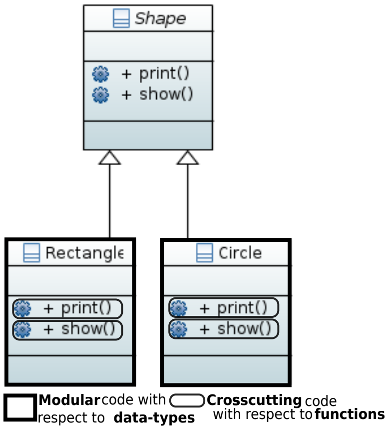


Figure 1: Decomposition axis of a simple variety of Composite design pattern.

But, if we add a new shape to the program shown in Figure 2, many modules would be changed since the new shape should be visited by both *print* and *show* business codes. In this case, the program maintenance is crosscutting. We say that the program structure is dominated by functions decomposition axis (a tyranny of decomposition according to functions).

The above two examples explain well the problem of tyranny of decomposition. A such issue still always a main problem that affects software evolution. In this work, we aim to contribute in attenuating tyranny of program decomposition effect on software maintenance. Our target is to help software developers in analyzing and predicting in earlier phases of software development the kind of maintenance tasks that could occur later and in recommending the right architecture (decomposition axis) of the program that could keep maintenance being modular.

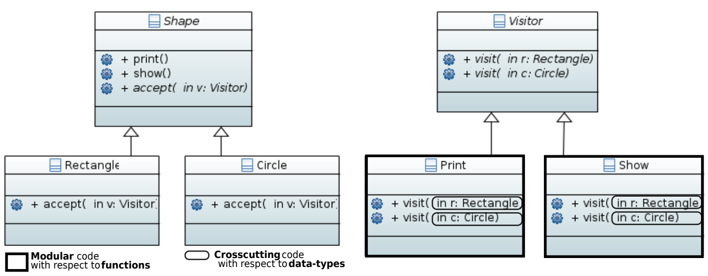


Figure 2: Visitor structure corresponding to the program shown in Figure1.

4 SEA specification

4.1 Overview

Many works have treated software evolution issue at the implementation phase. In this work, we tackle this issue in design phase of software development process. Since UML (Unified Modeling Language) [25] does not provide customized semantic constructs related to software maintenance, we propose an UML profile [26] that supports analyzing and predicting maintenance tasks that could occur in the future.

The UML profile we propose is called *SEA* (in short *SEA* for *S*oftware *E*volution *A*nalysis) (see Fig. 3) . *SEA* is defined in Papyrus [27] EMF-based editor and it provides the following features:

- tracing software evolution history by adding some information to each software version. This feature could help to get an overview about maintenance tasks characteristics, the thing that could provide some recommendations about choosing the right program structure.
- studying and deciding which parts of a given software are more stable than others. This feature could help to predict at earlier phases the program structure evolution.
- expressing explicitly some semantic terms related to software maintenance in class diagrams such as data-type module, function module, composite design pattern...etc. This feature enhances software comprehension and helps to identify the decomposition axis of a given software.

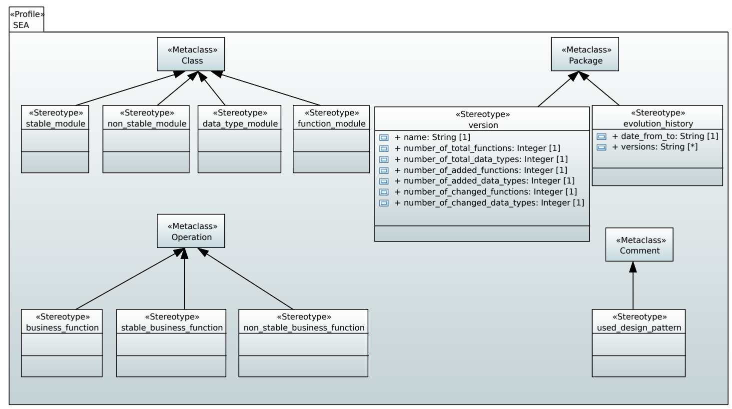


Figure 3: *SEA*: an UML profile for analyzing software evolution.

4.2 Stereotypes for analyzing software modularity

Marking modular and crosscutting software parts. Modularity in software architecture helps to optimize software maintenance cost. It permits also to encapsulate concerns and minimize crosscutting concerns effect. Thus, expressing modularity concepts explicitly in models and diagrams helps software developers to explore at early stages of software development the decomposition axis that is dominant. This helps to recommend the right kind of future maintenance tasks that are modular and to avoid those which are crosscutting. In this direction, *SEA* permits to mark explicitly in class diagram which elements represent modular concerns and which elements represent crosscutting concerns.

Until now, *SEA* supports two concerns (or two decomposition axes): data-types concern and functions concern. In this context, we propose the following stereotypes:

- <<*data_type_module*>>: it extends the meta class *Class* and it is used to precise classes that belong to data-types concern when software architecture is built according to Composite design pattern.
- <<*function_module*>>: it extends the meta class *Class* and it is used to precise classes that belong to functions concern

and that encapsulate program business code when software architecture is built according to Visitor design pattern.

- <<*business_function*>>: it extends the meta class *Operation* and it is used to mark methods that contain program business code. It could be used especially in Composite pattern structure to show that business code is crosscutting among different modules. This feature helps software developers to be aware of the cost of maintenance tasks performed with respect to functions.

Fig 4 shows an example of how to precise explicitly modules/classes that belong to the concern data-types by applying <<data_type_module>> to class diagram. In the example, we see explicitly that classes *Rectangle* and *Circle* are marked as data-type modules. In the same example, methods *print()* and *show()* are marked explicitly as business code. This shows visually that business code is crosscutting among program modules which gives an indication that maintenance tasks performed with respect to functions are costly.

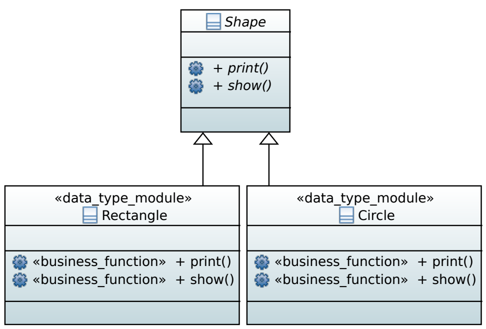


Figure 4: Use of *SEA* in marking modular data-types concern.

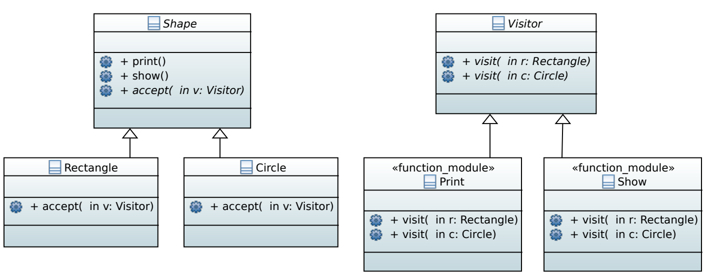


Figure 5: Use of *SEA* in marking modular functions concern.

Fig 5 shows how to use <<function_module>> stereotype to indicate that business code is encapsulated. This is used when the program is structured with respect to Visitor design pattern. We remark that classes *Show* and *Print* encapsulate respectively *show* and *print* business codes. The fact that these two classes are marked explicitly as functions indicates that software maintenance performed with respect to functions is not costly.

Precising modular program decomposition visually on diagrams helps to guide software developers to perform the right kind of maintenance that respects the existing concern. If they have to perform a crosscutting maintenance, they could be at least ready early to apply some tools or techniques that transform automatically the actual architecture to another one that supports modular maintenance (for example using reversible transformations among Composite and Visitor [13]).

Marking stable and changeable software parts. In order to predict future software evolution at early stages, one should predict which software parts tend to change sharply. For this purpose, we propose the following stereotypes:

- **stable_business_function vs non_stable_business_function**: these two stereotypes extend the meta class *Operation*. The former is used to mark functions/methods that would not be sharply changed. The latter marks probable functions that could change drastically in the future.

- **stable_module vs non_stable_module**: these two stereotypes extend the meta class *Class*. The former is used to mark classes/modules that would not be sharply changed, or will have small changes that do not influence the software architecture. The latter marks classes/modules that could radically change.

Fig. 6 shows how to apply stereotypes mentioned above to a class diagram. For example, after marking software parts as stable or non stable, one could identify which parts seems to be more stable than others. In case of finding that stable data-types modules number is greater than stable functions number, then, the decision could be biased to choose Visitor pattern as a future software architecture (since business code tend to change more than data-types).

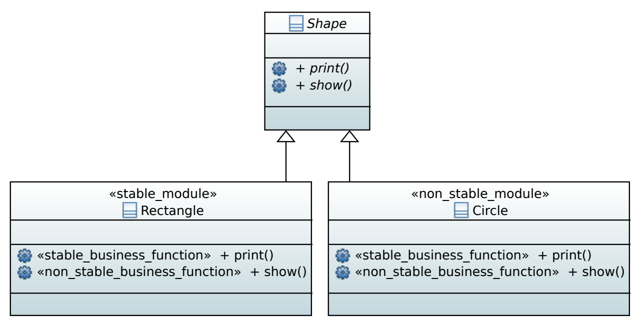


Figure 6: Use of *SEA* in marking changeable and stable software parts.

4.3 Stereotypes for software evolution history tracing

With time, software evolution could cause software architecture degeneration [28]. So, having a backup for each version is necessary and helps to get back to the non degenerated version. This is already existing by saving old versions. In our approach, we propose the stereotype <<evolution_history>> (extends meta-class *Package*) which permits to precise explicitly on a package including all software versions that this package contains software evolution history. The proposed stereotype provides two tagged values: <<date_from_to>> and <<versions>>. The former is used to indicate visually the period of time during which versions included in a package stereotyped <<evolution_history>> are built. The latter is used to list all versions that are built in the period of time indicated by <<date_from_to>>. These tagged values permit to add valuable visual data that could be used to assess the stability of software during a period of time.

Fig. 7 shows how to apply <<evolution_history>> stereotype: the package *software_X* (stereotyped <<evolution_history>>) includes three sub-packages that include respectively three versions of *software_X*.

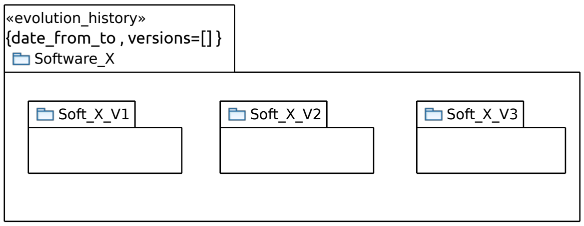


Figure 7: Tracing software evolution with <<evolution_history>> stereotype.

The second stereotype that is related to software evolution history is the stereotype <<version>> which extends meta-class *Package*. It provides information about each version of a given software. It contains seven tagged values:

- *name*: version name
- *number_of_total_data_types*: total number of classes of current version
- *number_of_total_functions*: total number of methods of current version
- *number_of_added_data_types*: number of classes that have been added to the previous version to get the current version
- *number_of_added_functions*: number of methods that have been added to the previous version to get the current version
- *number_of_changed_data_types*: number of classes that have been changed to get the current version
- *number_of_changed_functions*: number of methods that have been changed to get the current version

Tagged values mentioned above permit to provide visual information about the behavior of software evolution. Getting a visual access to added classes and methods number during switching among software versions helps to get an overview about the recommended software architecture that could optimize maintenance cost. For example, if the percentage of *number_of_added_data_types* comparing to *number_of_total_data_types* is always greater than the percentage of *number_of_added_functions* comparing to *number_of_total_functions* and the current architecture is implemented with respect to Visitor pattern, then it will be better to switch the program structure into Composite pattern in order to keep maintenance modular with respect to data-types (see more details in Sect. 5).

Fig. 8 shows how to apply <<version>> stereotype: the package *soft_X_V1* (stereotyped <<version>>) shows the seven defined tagged values that permits to note helpful information about software evolution behavior related to *soft_X_V1*.

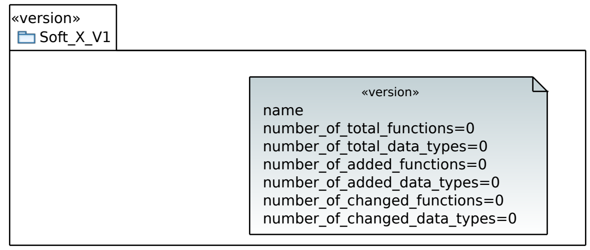


Figure 8: Adding helpful information to a software version by applying <<version>> stereotype.

4.4 Visualizing design patterns

Many programmers face some difficulties when implementing design patterns. Thus, visualizing in design phase some information about the design pattern that will be implemented later orients programmers early to cover any lack of knowledge about the indicated design pattern. In addition, marking design patterns explicitly on diagrams enhances software comprehension.

Marking information about chosen design patterns on diagrams could also assist used techniques in design pattern detection [29] and provide relevant data for data analysis and classification.

To reify this idea, we propose the stereotype <<used_design_pattern>> that extends the meta-class *Comment*. It could be associated to the package that includes the hole software project and indicates information about the chosen design patterns to implement. Provided information includes pattern name, pattern uses, modular maintenance tasks permitted, crosscutting maintenance tasks...etc. Fig. 9 shows how to apply <<used_design_pattern>> on comments.

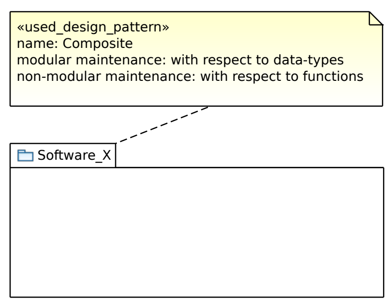


Figure 9: Use of *SEA* in visualizing information about chosen design patterns.

5 Application of *SEA* on a real software

5.1 An overview about JHotDraw evolutions

We study the utility of *SEA* in analyzing *JHotDraw* [30] evolutions. *JHotDraw* is a framework for two-dimensional graphics used for structured drawing editors. It is implemented in Java and it is based on Erich Gamma's *JHotDraw*, which is copyright 1996, 1997 by IFA Informatik and Erich Gamma [31].

We define the following metrics to use them in the rest of this section:

- V_i: a version *i* of *JHotDraw* where $1 <= i <= 13$ (we study here 13 versions of *JHotDraw*)

- CNV_i: classes number in version V_i
- MNV_i: methods number in version Vi
- ACV_1: added classes number to version $V1$ to obtain version V_i

  $ACV_1 = CNV_i - CNV_1$
- AMV_1: added methods number to version $V1$ to obtain version V_i

  $AMV_1 = MNV_i - MNV_1$
- ACV_{i-1}: added classes number to version $Vi - 1$ to obtain version V_i

  $ACV_{i-1} = CNV_i - CNV_{i-1}$
- AMV_{i-1}: added methods number to version $Vi - 1$ to obtain version V_i

  $AMV_{i-1} = MNVi - MNV_{i-1}$
- $RACV_1$: rate of added classes number to version $V1$ to obtain version V_i

  $RACV_1 = \frac{ACV_1}{CNV_1}$
- $RAMV_1$: rate of added methods number to version $V1$ to obtain version V_i

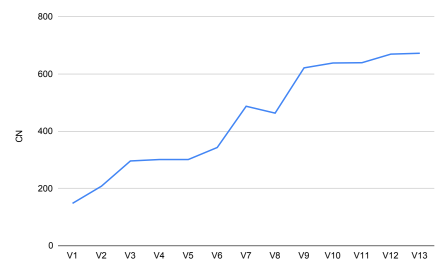
  $RAMV_1 = \frac{AMV_1}{MNV_1}$
- $RACV_{i-1}$: rate of added classes number to version $Vi - 1$ to obtain version V_i

  $RACV_{i-1} = \frac{ACV_{i-1}}{CNV_{i-1}}$
- $RAMV_{i-1}$: rate of added methods number to version $Vi - 1$ to obtain version V_i

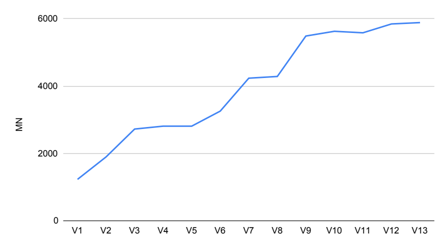
  $RAMV_{i-1} = \frac{AMV_{i-1}}{MNV_{i-1}}$

V_i	CNV_i	MNV_i
V_1	148	1229
V_2	208	1896
V_3	296	2723
V_4	301	2809
V_5	301	2809
V_6	343	2809
V_7	487	4234
V_8	463	4285
V_9	621	5486
V_{10}	638	5627
V_{11}	639	5582
V_{12}	669	5845
V_{13}	672	5885

(a) Classes number and Methods number of each version (data extracted from [32]).



(b) Evolution of *JHotDraw* classes number (CNV_i) during 11 years.



(c) Evolution of *JHotDraw* methods number (MNV_i) during 11 years.

Figure 10: Variations of classes number and method numbers during *JHotDraw* evolution.

The table shown in Fig. 10(a) illustrates *JHotDraw* evolution during 11 years. During this period of time, there were 13 versions of *JHotDraw* (5.2, 5.3, 5.4 b1, 5.4 b2, 6.0 b1, 7.0.8, 7.0.9, 7.1, 7.2, 7.3.1, 7.4.1, 7.5.1 and 7.6). We call here each version by V_i where $1 <= i <= 13$. The first column of the table mentions the version name (V_1, V_2,...,V_{13}), the second column mentions classes number in V_i (CNV_i) and the third column mentions methods number in V_i (MNV_i).

Like any software, *JHotDraw* is influenced by Lehman law [1] as shown by the shape of both curves of CNV_i progress (Fig. 10(b)) and MNV_i progress (Fig. 10(c)). We remark that classes number, which was 148 in V_1, increases to reach 672 in V_{13}, and methods number jumps from 1229 in V_1 to 5885 in V_{13}. Considering these evolutions, we apply some stereotypes of *SEA* profile to show its utility in analyzing software evolution during earlier stages of software process.

5.2 *Using* SEA *to trace* JHotDraw *evolutions*

To make *JHotDraw* evolutions easy to analyze in the design activity of software process, we apply stereotypes <<evolution_history>> and <<version>>. The former is applied to a package that includes all versions of JHotDRaw during 11 years and the latter is applied to each package that includes a version V_i of *JHotDraw*.

Application of <<evolution_history>> stereotype The target of applying <<evolution_history>> stereotype is to add information about the period of time in which *JHotDraw* versions are built and also about number and names of versions. This information is represented by defined tagged values that characterize the mentioned stereotype.

Fig. 11 shows how <<evolution_history>> stereotype and its tagged values are applied. By using this stereotype, software developers could create a package that includes all versions of *JHotDraw* and marks this package as a special package to trace *JHotDraw* evolutions history. In addition, they could note information such as "date_from_to=2000_to_2011" and list different versions that has been elaborated during this period.

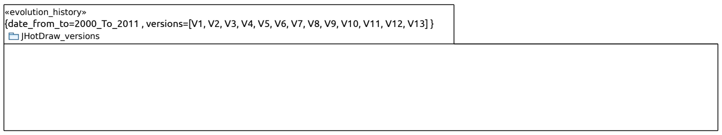


Figure 11: Application of <<evolution_history>> stereotype to JHotDRaw.

In fact, the expressiveness provided by the stereotype <<evolution_history>> permits to assess the stability of *JHotDraw*. The stereotype <<evolution_history>> provides information about the rate of versions number of *JHotDraw* by a given period of time (here 13 versions by 11 years) which could evaluate the impact of *JHotDraw* evolution on total development cost. It motivates also software developers to focus on studying the switch from V_i to V_{i+1} and deduce lessons for future evolutions.

Application of <<version>> stereotype As detailed in Sect. 4, the stereotype <<version>> has 7 tagged values. We consider here only *name*, *number_of_total_functions*, *number_of_total_data_types*, *number_of_added_functions* and *number_of_added_data_types*. For each version V_i of *JHotDraw*, software developers could apply the stereotype <<version>> to the package that contains V_i and they could assign a value to each tagged value. For example, Fig. 12 shows the main package that is stereotyped as <<evolution_history>> and inside of it the set of packages stereotyped as <<version>> that represent the 13 versions of *JHotDraw*.

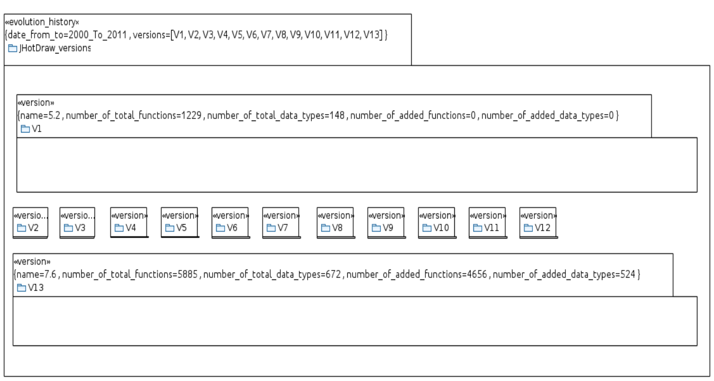


Figure 12: Application of <<version>> stereotype to JHotDRaw.

For each version V_i, we assume that software developers mark:

- name of the version (example: for version V_1, name is *5.2*)
- *number_of_total_data_types* (example: for version V_{13}, *number_of_total_data_types*= 672)
- *number_of_total_functions* (example: for version V_{13}, *number_of_total_functions*= 5885)
- *number_of_added_data_types* (example: for version V_{13}, *number_of_added_data_types*= 524)
- *number_of_added_functions* (example: for version V_{13}, *number_of_added_functions*= 4656)

5.3 *Utility of* SEA *in* JHotDraw *evolutions analysis*

As shown in the two last paragraphs, the application of stereotypes <<evolution_history>> and <<version>> adds explicit information about each version of *JHotDraw* (the thing that UML does not provide). This information makes packages that includes different versions being more expressive and informative about how *JHotDraw* (or any other software) evolves. This helps software developers to analyze easily the growth of *JHotDraw* at design phase and to take the right design decisions.

Let's assume a scenario in which a software developer analyzes information marked explicitly on packages that represents *JHotDraw* versions (each package is stereotyped as <<version>>):

***JHotDraw* evolution analysis scenario based on *SEA* application** We associate to each tagged value a metric from those presented above:

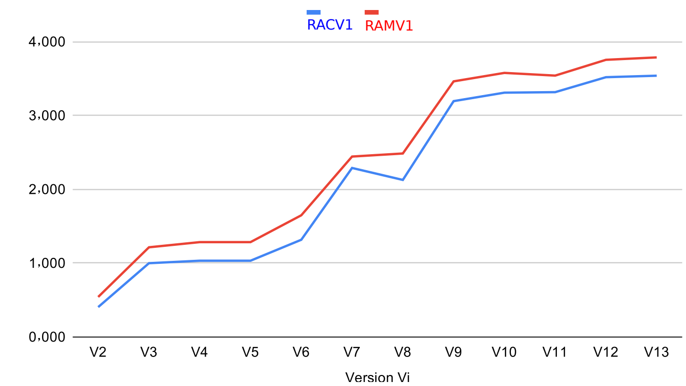
- *number_of_total_data_types* is represented by CNV_i
- *number_of_total_functions* is respresented by MNV_i
- *number_of_added_data_types* is represented by ACV_1
- *number_of_added_functions* is respresented by AMV_1

The table shown in Fig. 13(a) resumes values that are calculated basing on data collected from packages stereotyped as <<version>>. It shows variations of $RACV_1$ and $RAMV_1$ for each version V_i. The curve shown in Fig. 13(b) visualizes the progress of $RACV_1$ and $RAMV_1$ during 11 years. We remark that in all versions $RAMV_1$ is greater than $RACV_1$ which means that the percentage of added methods in each version comparing to initial number of methods in V_1 is greater than the percentage of added classes comparing to initial number of classes in V_1.

The fact that $RAMV_1$ is always greater than $RACV_1$ during 11 years of *JHotDraw* evolution indicates that maintenance tasks are applied more on methods. We could deduce in this case that software developers should recommend to use Visitor design pattern if it is not already used in *JHotDraw*.

V_i	$RACV_1$	$RAMV_1$
V_2	0.4	0.54
V_3	1	1.21
V_4	1.03	1.28
V_5	1.03	1.28
V_6	1.31	1.64
V_7	2.29	2.44
V_8	2.12	2.48
V_9	3.19	3.46
V_{10}	3.31	3.57
V_{11}	3.31	3.54
V_{12}	3.52	3.75
V_{13}	3.54	3.78

(a) Rates of added classes and methods number in a version Vi comparing to first version of JHoDraw $V1$.



(b) Rates evolution of added classes and methods number in a version V_i comparing to first version of JHoDraw V_1.

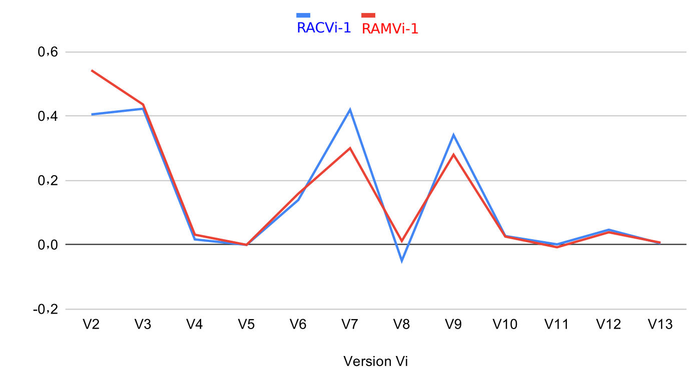
Figure 13: Study of Rates evolution of added classes and methods number in a version Vi comparing to first version of JHoDraw $V1$.

Let's now interpret evolutions from one version to its successor version. The table illustrated in Fig. 14(a) shows variations of $RACV_{i-1}$ and $RAMV_{i-1}$. We remark that $RACV$ of version V_2 is 0.4 and its $RAMV$ is about 0.54 which means that version V_2 of *JHotDraw* grows by 40% of V_1 classes number and 54% of V_1 methods number. Hence, maintenance tasks that switches V_1 to V_2 are applied more on methods (functions decomposition axis). This case occurs 5 times against 7 times in which maintenance tasks are applied more on classes (data-types decomposition axis). So, the switch from version to version shows that maintenance tasks change their behavior: they are applied 5 times with respect to functions decomposition axis against 7 times with respect to data-types decomposition axis. In this case, Composite design pattern seems to be the best choice for the future versions.

Lessons By analyzing *JHotDraw* evolutions as done above, we deduce that long-term evolution shows that Visitor design pattern is the best choice to optimize maintenance cost. But, variation in targeted decomposition axis due to the switch from version to version indicates that *JHotDraw* should change its architecture in order to keep maintenance being modular (software developers could use automatic reversible transformations among Composite and Visitor each time they remark that maintenance tasks would change behavior when switching from version to version).

V_i	$RACV_{i-1}$	$RAMV_{i-1}$
V_2	0.4	0.54
V_3	0.42	0.436
V_4	0.017	0.031
V_5	0.0	0.0
V_6	0.14	0.15
V_7	0.42	0.3
V_8	-0.049	0.012
V_9	0.34	0.28
V_{10}	0.027	0.025
V_{11}	0.002	-0.007
V_{12}	0.047	0.039
V_{13}	0.004	0.006

(a) Rates of added classes and methods number in a version V_i comparing to version V_{i-1}.



(b) Rates evolution of added classes and methods number in a version Vi comparing to version V_{i-1}.

Figure 14: Study of Rates evolution of added classes and methods number in a version Vi comparing to version V_{i-1}.

6 Conclusion and future work

We have defined an UML profile called *SEA* which could help software developers to analyze and predict maintenance tasks in early activities of software process. To reify our approach we defined some stereotypes that support treating maintenance issue in design phase of software development. *SEA* treats three main issues related to software evolution:

- Analyzing and predicting maintenance tasks by defining stereotypes that allow to trace software evolution history. They permit also to precise software parts that are more probable to change in the future and those which could stay stable. This feature helps to recommend the right software architecture that supports changes without extra cost.
- Marking explicitly on class diagrams software parts that are

encapsulated in modules and those that are crosscutting. For example, in Composite pattern, components classes represent data-types modules and methods/functions represent crosscutting concern. This feature permits to precise visually and easily modular concerns and crosscutting concerns, the thing that permits to identify quickly which kind of maintenance tasks is preferred.

- Visualizing in design phase design patterns that will be implemented later. This feature enhances software comprehension and helps to assimilate the chosen design pattern use and properties before implement it (sometimes programmers face difficulties to understand some design patterns). This could also give an overview about maintenance tasks that could be modular with respect to a given design pattern and those which could not. In the last case, software developers could use appropriate tools to switch program structure into another design pattern that is more convenient (such as automatic reversible transformation among Composite and Visitor [13]).

SEA is partially validated by apply it on *JHotDraw* evolution. This partial validation shows that it is possible to analyze software evolution history and predict the kind of maintenance tasks that could occur in the future. Our approach validation still partial until applying all *SEA* stereotypes to *JHotDraw* and also to other case studies. As a future work, we look for developing an algorithm based on supervised data analysis and classification to exploit data provided by *SEA* in models and diagrams to predict automatically future maintenance tasks kind.

Conflict of Interest The authors declare no conflict of interest.

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