Practices and Perceptions of UML Use in Open Source Projects

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Abstract*—*Context: **Open source is getting more and more collaborative with industry. At the same time, modeling is today playing a crucial role in development of, e.g., safety critical software.** ***Goal:*** **However, there is a lack of research about the use of modeling in open source. Our goal is to shed some light into the motivation and benefits of the use of modeling and its use within project teams.** ***Method:*** **In this study, we perform a survey among open source developers. We focus on projects that use the Unified Modeling Language (UML) as a representative for software modeling.** ***Results:*** **We receive 485 answers of contributors of 458 different open source projects.** ***Conclusion:*** **We found out that collaboration seems to be the most important motivation for using UML. It benefits new contributors and even contributors who do not create models. Teams use UML during communication and planning of joined implementation efforts.**

***Keywords*-UML; architecture documentation; OSS projects; GitHub; motivation; communication; effectiveness of UML**

I. Introduction

Open Source, which has its roots in the free software movement, started partially as a counter-movement to the software industry in the 80s and 90s [1]. Even though, there was a clear border between Open Source and industry, in the late 90s and early 2000s, the situation started to change. In those years, some industry started to early adopt the open source movement practices, collaborating with communities [3], or some companies were created around some communities [4]. Many projects created foundations to serve as an umbrella to collaborate and integrate software industry partners [5].

Thus, we have witnessed a process and technology transfer among open source software (OSS) and industry, that has made the line between both be vague nowadays. Notable contributions from OSS to industry have been technologies, such as git and GitHub, and community-managing practices, although the list of adoptions is much larger [6]. On the other hand, OSS has embraced practices from industry, such as (modern) code review practices and planning and requirements analysis mechanisms [7]. Companies with a large pool of developers try to have an "internal" OSS-like ecosystem, a concept coined as inner source [8]. Many OSS practices are commonly taught at universities and young graduates start their professional careers with experience in OSS, whether in languages (Python, Perl, Ruby...), products (JQuery, Hadoop...) and tools (GCC compiler tool chain, git and GitHub...) [9]. And the software industry is looking into popular Open Source repositories, such as GitHub, to find suitable candidates to fill open development positions [10].

In this regard, we have seen a clash of two worlds, resulting in new practices where industry sometimes has adopted elements from OSS and vice versa. As the trend seems to go on, we would like to draw attention on modeling, specifically on the use of Unified Modeling Language (UML) in OSS. UML has been around as a graphical language for modeling software systems for about 25 years. As far as it is known, UML is not yet frequently used in OSS projects, with a rather marginal use [11]. OSS is known to be programming-driven, with other tasks having room for further improvement [12]. However, modeling is used in major companies [14]. Modeling is, thus, an area where we can find a gap between OSS and industry. Given that the use of UML in OSS is not very well-known, we would like to shed some light into this issue with the aim of discovering how UML is used and whether it is considered useful. We hope that the results will help to understand whether the use of UML in open source helps these projects and whether industry working with open source projects should promote the UML use.

To this end, we used a technique, that we developed to find UML in GitHub projects [11]. The paper showed the feasibility of our approach and triggered us to come up with various research questions addressed in this paper. For this paper we scanned through the majority of non-forked GitHub projects (over 12 million of projects) and identified which of these projects use UML.

We performed a large scale survey directed at those projects that use UML, with focus on how the UML is used and how it impacts development activities. Contributions of this research are: i) the identification of a large set of open source projects that use UML and ii) insights from a large scale survey under developers of open source projects into use of UML. Amongst other insights, we found that UML is used to coordinate the development. Furthermore the use of UML seems to help new contributors to get started, while it does not seem to attract new contributors. The set of projects we identify are a valuable resource for future empirical studies regarding the UML.

The rest of this paper is constructed as follow: We formulate a number of research questions in Section II, then introduce related work (Section III) and describe our research method in Section IV. Section V presents our findings. We discuss the our findings, possible threats to validity and implications of our research in Section VI and giving conclusions in Section VII.

II. Research Question

To better understand the use of UML in OSS, we formulate the following 3 main research questions:

RQ1 *Why is UML used in OSS projects?*

To get an impression of the role of UML models in OSS we formulate following this first question.

- $SQ_{1.1}$ What are the motivations to use UML modeling?
- $SQ_{1.2}$ What are the reasons not to use UML in projects?

RQ2 *Is UML part of the interaction of (a team of) contributors?*

Teams and interaction between developers play an important role within todays software intensive industry [13]. Models are used as artifacts that are basis for planning and work coordination. However, it is an open question, whether UML models fulfill a similar role in OSS projects. We approach this question from three aspects: 1) the awareness within the project that UML models are available, 2) the use of UML during project planning and communication, and 3) the role of UML during joined implementation efforts. These three sub-research questions are structured:

- $SQ_{2.1}$ Are developers aware of the existence of UML in their projects?
- $SQ_{2.2}$ Are UML models used during communication and team decision making?
- $SQ_{2.3}$ Are modeled designs adopted afterward during the implementation phase by teams of OSS contributors?

RQ3 *What is impact/benefit of UML?* Much research was performed to identify benefits of UML usage in industry. However, it is not yet clear whether UML usage impacts or even benefits development in open source. Again, we consider three different perspectives: 1) the role of UML for novice contributors, 2) the impact of UML on the working routine, and 3) the impact of UML on the attractiveness of a project for potentially new contributors. The following sub-research questions are structured:

- $SQ_{3.1}$ Can UML models support new contributors?
- $SQ_{3.2}$ What are the impacts of using UML in OSS projects?
- $SQ_{3.3}$ Can UML models help to attract new contributors?

III. Related work

In the following we discuss related studies about UML or modeling in industry and open source.

A. Modeling in Industry

Modeling is widely studied in industry, for example in surveys such as the ones performed by Torchiano et al. [14], Gorschek et al. [15], or Forward et al. [16]. Torchiano et al. found that models help to improve design and documentation. However, they also found that model usage is connected to extra effort, especially due to a lack of supporting tooling. Forward et al. find that models are primarily used for design and documentation, while code generation is rather seldom. Gorschek et al. [15] focused on a different population, which are programmers, partially working in industry and open source. Within their sample design models are not use very extensively. However, models and UML are found to be used mainly for communication purposes. Further, they report on a higher use of models for less experienced programmers.

Besides these big surveys also case studies were performed in order to investigate the impact of the modeling/UML usage. For example, Baker et al. [17] found an increase of productivity when using UML in Motorola. Also Nugroho et al. [18] investigated an industrial case study and found that UML usage has the potential to reduce the defect density and, thus, increase the quality of software. Just as in the case described by Kuhn et al. [13], most of the case studies draw a picture of model use, where models are actually artifacts that are produced and consumed by different people.

B. Modeling in Open Source

Much less work has been done on UML use in open source software. One reason for this is the challenge to actually find cases that can be studied. For example, Badreddin et al. studied 20 projects, without finding UML and concluded that it is barely used in open source [19]. Similarly, Ding et al. [20] found only 19 projects with UML when manually studying 2000 open source projects. However, in our previous work [11] we presented an approach to solve the problem of finding projects with UML by mining GitHub for projects with UML.There are several investigations of single or very small numbers of cases of open source projects that use UML, e.g. by Yatani et al. [21], who found that models are used to describe system designs, but are rarely updated. Osman et al. [22] studied to what ration classes in the diagrams are implemented in the code. Finally, Kazman et al. [23] investigate the Hadoop Distributed File System to learn how documentation impacts communication and commit behavior in the open source system. There are some studies that approach model use in open source with a quantitative perspective, studying large numbers of projects. For example, to study the use of sketches, Chung et al. [24] collected insights from 230 persons contributing to 40 open source projects. Finally, Langer et al. [25] studied the lifespan of 121 enterprise architect models in open source projects.

However, to the best of our knowledge there is so far no quantitative study targeting the use of UML within the team communication and its effects.

IV. Research Methodology

In this section, we describe our study method in details. The overall process is shown in Fig. 1.

A. Data Collection

First step is to identify UML files in GitHub repositories. In our previous work, we were able to identify UML files in around 1.2 million GitHub repositories [11]. In this study, we extend the data collection work to the whole GitHub database using data collection method described in the paper. A number of changes had been made in order to adapt the big data retrieval. In this section, we briefly summarize the data collection steps and the changes that were made.

1) Obtaining the full list of GitHub projects: To obtain the list of projects, we used the data from the February 1st 2015 dump of GHTorrent [26]. From this dataset we could obtain a list of projects that were not deleted and non-forks. However, GHTorrent does not contain information on the files contained in the repositories. Hence, we ended up using GitHub API to obtain the list of files for a total number of 12 847 555 repositories. The result is a JSON file per repository with information on the files hosted in the *master* (or *default*) branch of the repository.

2) Identifying UML files: Next step was to identify UML files from the file list. Firstly, potential UML files were collected using several heuristic filters based on the creation and storage nature of UML files. After that, an automated process was applied to examine the existence of UML notation in the obtained files. A manual validation was made to consolidate the identification result. Details about the identification steps are described in Section 4 of the paper [11]. At the end of this step, we were able to identify 93 648 UML files from 24 797 repositories.

3) Extracting meta-data: For all projects that contain a UML file, development meta-data from the repositories has been retrieved. Therefore, we use `perceval`, an evolution of the well-known `CVSanalY` software [28], that allows to obtain these data in JSON files, making it possible to perform the process in parallel. It took the five instances of the tool over 4 weeks to complete this task. At the end, and after removing 240 JSON files that contained a 404 Not Found response, we had 24 125 JSON files that were parsed and normalized, and finally converted into SQL.

B. Filtering the obtained projects and contributors

In this phase, we aimed at mitigating a number of known threats to validity when mining GitHub database, i.e. sample/short-time projects [29] or identification of contributors [30]. Section IV-B1 and section IV-B2 show the criteria that we applied to filter out short-time projects and to merge duplicate contributors, respectively.

1) Filtering short-time projects: For this paper we aim at projects that are interesting from an industry perspective. Thus, we focus on projects that are not short-term and that do not jut consist of a singe contributor. We define short-time projects as those projects that have: i) active time (time between the first and the latest commits) less then 6 months, OR ii) less than 2 contributors, OR iii) less than 10 commits. After classifying and filtering short-time projects, 4 650 UML-projects (out of 24 125, we use the term *UML project* to refer to GitHub projects that contain UML file(s)) and 2 701 (out of 17 101) non-UML projects met our requirements. The final list of the projects is shared in our replication package[1].

2) Merging duplicate contributors: One contributor can use different emails, user-name (for example, one changed his profile user-name or email during the project time). This might cause duplicate contributors, and as a consequence, projects with one contributor only could be classified as having more than one contributor [30]. We merge identities with different ids that have: i) same e-mail address, or the same full name -in the case of the full name; ii) names have to have at least two words or including a number if only a word, e.g., "arg123". This is a rather conservative approach, but it minimizes the number of false positives [30]. After running the script, the original 129 276 contributors result in 99 319 distinct ones.

C. Conducting survey

In the following we give a short overview about how we conducted the survey.

1) Participant: To ensure that be get a balanced picture, we had to consider the role that the different contributors play within the OSS projects with UML. Two dimensions of roles are important (each questioned person would fulfill a combination of roles in these two dimensions):

- Founder (F) vs. non-founder (NF)
- Non-UML Contributor (NUC) vs. first UML Contributor (1UC) & UML Contributor or updater (non-1st contributor) (UC)

Consequently, each interview participant fulfills one of the following 6 roles: F-1UC, F-NUC, F-UC, NF-1UC, NF-NUC, NF-UC. For each project, we randomly selected 3 contributors, to whom we sent the questionnaire. The selected 3 contributors had to fulfill one of the following 3 constellations of roles.

- F-NUC, NF-1UC, NF-UC
- F-1UC, NF-UC, NF-NUC
- F-UC, NF-1UC, NF-NUC

For some projects not all roles could be identified (e.g. there are not necessarily NUCs or UCs). In this case we contacted for respectively less contributors.

2) Questionnaire: The questionnaire is designed to meet the following requirements:

[1]The replication package for this paper can be found at http://oss.models-db.com/2017-icse-seip-uml/

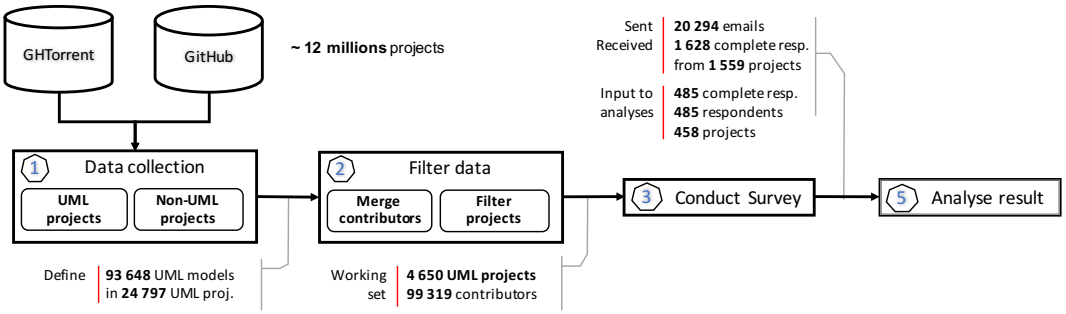


Figure 1: Overall process

Multiple roles: We distinguish for the roles, what questions they get, in order to facilitate different information needs. For example, we would ask NUCs whether they are aware that UML models exist in the project, while we would ask UCs, whether they think that NUCs are aware of it. Thus, depending on the role, participants received between 5 (NF-NUC) and 19 (F-1UC) questions.

Exploration: We use a funneling approach (from broad to narrow) when designing the survey. For example, if a UC uses a UML model for architecture/design purpose, we would ask if the model is adopted, and eventually, who implemented the model. Accordingly, the number of questions would not just be different between different roles, but also between respondents who have the same role. In addition, to gain more insights, we use a mix of close-ended and open-ended questions in the survey.

Personalized Contact: To ensure that participants know what projects and UML models we are referring to, we personalized the email with which we contacted potential participants by concretely referring to his/her GitHub identification, the name of project of interest and (if applicable) an URL to his (first) UML commit or to a UML file committed by someone else. By following the URL (e.g. https://github.com/rvs-fluid-it/wizard-in-a-box/blob/master/src/doc/wizard-in-a-box-design.png), participants could get further contextual information about the UML models, for example commit messages, commit date, etc.

We used Lime Survey tool [2] as the tool provide functionality to fulfill the survey requirement. Our Lime Survey server is hosted at http://survey.models-db.com/. Details about survey settings and email templates can be found in the replication package.

3) Sending out the survey: We sent 20 294 survey emails to OSS contributors in 6 days, from July 21 to July 26, 2016. More than 1 000 emails were not sent because of various problems, including out-dated emails, etc. We sent reminder emails after one week and finally closed the survey in August 4, 2016. Altogether, we received 2 230 responses, of them, 1 628 were completed. After filtering responses that belong to short-term projects, we gained 485 survey responses of respondents from 458 projects.

[2]LimeSurvey homepage: https://www.limesurvey.org/

Table I: Number of emails sent, number of responses and number of responses after filtering by participant categories

	Founder			Non-Founder			SUM
	1UC	*NUC*	*UC*	*1UC*	*NUC*	*UC*	
Sent emails	4509	3891	713	6737	3221	1223	20294
#full resp.	373	293	68	564	210	120	1628
#inc. resp.	167	105	24	214	56	36	602
#fil. resp.	*84*	*79*	*27*	*176*	*80*	*39*	*485*
Percent(%)	17.3	16.3	5.6	36.3	16.5	8.0	100

D. Data Analysis

First, we take into account completed responses only. Second, we do not consider short-time projects.

Part of the questionnaire are free-text questions. We use these questions to learn about phenomena for which we do not know a fixed set of answers, yet. The goal of analyzing these data is to identify reoccurring themes. Therefore, we used a coding technique, following the constant comparison method as described by Seaman [31]. We decided to use an empty starting set of codes and develop them during the coding. For each of the question two of the authors coded the answers independently. In a second step we inspected the codes together to identify and if necessary resolve differences in the selected codes and application of the coding. Afterward, we went a second time through the data in order to ensure that the now fixed set of codes was assigned consistently. We did this i) to increase the quality of the coding and ii) to decrease the probability that we miss interesting aspects. As a final step we checked whether codes occurred for more than one project, in order to prioritize those themes that are of greater relevance.

Furthermore, we took those cases where we got multiple responses for the same project and aggregated them. This aggregation was done as follows: we interpret observation based questions (i.e. whether UML is used for communication) as reports about a project. Thus, aggregating a ”yes” and a ”no” answer for the same project to a ”yes” to indicate that there is a report about a phenomenon for that project. Similarly, we prioritized ”no” over ”I have no opinion”. ”I do” and ”I have seen other people doing” are merged to an ”I do”.

V. Results/Findings

A. Respondent Demographics

A total of 2 230 respondents from 91 countries began the survey, with 1 628 completed compulsory questions of the survey. After classifying survey responses by short-time projects, we ended up with 485 survey responses of respondents from 458 projects. Among 485 respondents, 190 (about 40%) are founders of an OSS project, 159 (32.8%%) are non-UML contributors (Table I). Regarding educational background (as shown in Fig. 2), 37.73% respondents had a Master's degree, 30.31% had a Bachelors, 16,29% had a Ph.D., and 11.75% were still in education. About 4% of the respondents identified as autodidacts. A vast majority of the respondents reported to be familiar with architecture documentation in different formats, leading by UML (90.31%), then auto-generated code documentation and software models in generic formats (78%) (Fig. 3). Only a half of them (45%) were familiar with architectural notations on white papers. There are programming languages where UML is more frequently found (Smalltalk, Java, C# and C++). On the other side, UML has not that much impact among the Objective-C and Ruby community.

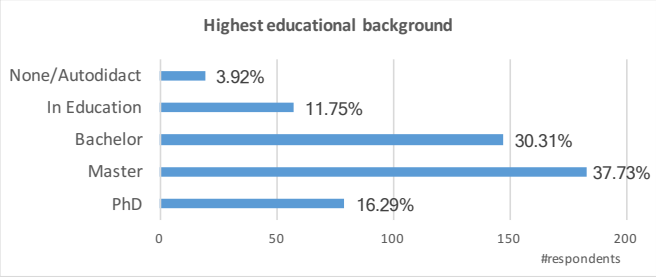


Figure 2: Distribution of respondents based on their highest educational background

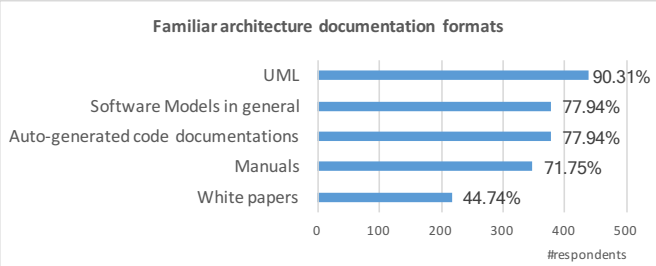


Figure 3: Architecture document formats that respondents were familiar with. The respondents could choose multiple formats

B. Why is UML used?

1) What are the motivations to use UML modeling?:

Fig. 4 shows the answers from 326 UCs (of 319 projects) about the *intent* of UML files they added/updated. Most of UML files served for design/architecture and documentation purposes, with 70% and 71% of votes, respectively. For about 18% of the projects software verification was mentioned as one of the main purposes. Refactoring and code generation less usual (in 14.11% and 12.85% of the projects).

Among 125 NUCs that claimed to be aware of the existence of UML models, 109 people (from 109 projects) reported to find UML helpful. Fig. 5 presents their answers. 79% of the respondents found UML useful for understanding the OSS systems. They also found UML models helpful as the models assisted in improving communication within the project, guiding implementation and managing quality of the project.

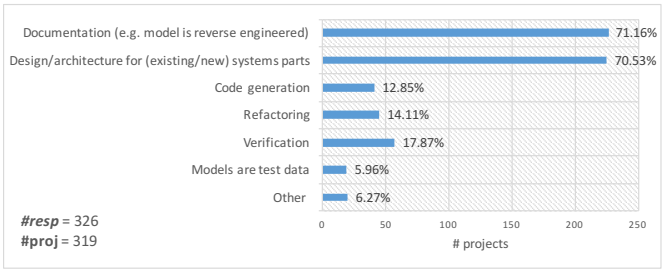


Figure 4: Intent of UML models that were added/updated

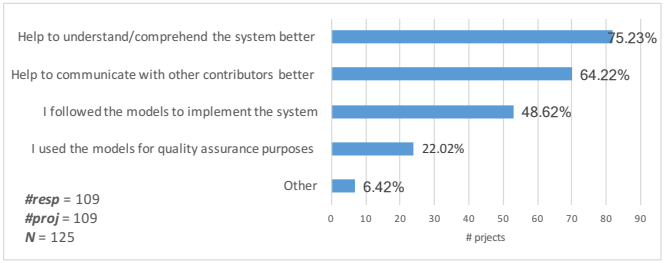
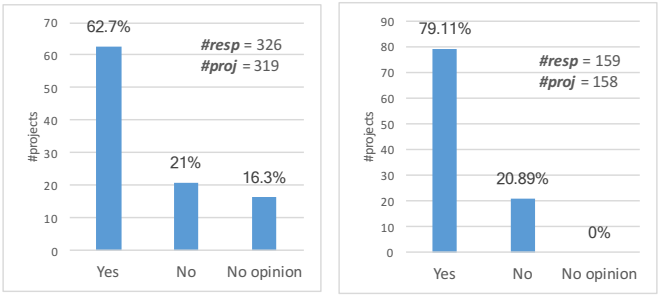


Figure 5: How did UML help non-UML contributors?

Results for $SQ_{1.1}$*: The majority of models are intended for creating software designs and documenting software systems. NUCs use benefit from UML models when it comes to understanding a system and communication.*

2) What are the reasons not to use UML in projects?: To complement our finding on the motivations to introduce/use UML, we asked those 16 NUCs, who did not find UML models useful, for the reasons why. Respondents in 6 projects actually didn't use the models, finding themselves not required to learn/use UML (e.g. *"there was no demand to do so"*). Interestingly, in no case license problems for modeling tools were a problem.

In 4 cases the UML files were outdated. Other reasons that were brought up in free-texts are: missing support for versioning models, a failed attempt to understand the models, a preference for other means of communication (face to face), a preference for other forms of modeling/sketching, a preference for reading code rather than spending time for UML models, and the dislike of UML (anti-UML attitude).



(a) Do UCs think that other contributors are aware of UML?

(b) Are NUCs aware of the existence of the UML models?

Figure 6: Developer's awareness about the existence of UML in their projects (by project)

Results for $SQ_{1.2}$*: Only a small number of respondents found UML not useful.*

C. Is UML part of the interaction of contributors?

1) Developer's awareness about the existence of UML in their projects:
To answer this question we first asked creators/maintainers of UML models whether they think that the models are known by developers of the projects (summarized in Fig. 6a). In 62.7% of 319 projects with responses, the UCs/1UCs believed that UML models are known by developers of the projects. Second, we asked NUCs of projects that use UML if they aware of the existence of UML models in their projects (Fig. 6b). Surprisingly, in the vast majority of the projects (80%) NUCs stated that they are aware of UML models.

To better understand the difference between the answers of UCs and NUCs, we looked in detail into the 24 projects for which we received responses from NUCs and UCs. In 10 out of 24 projects, NUCs and UCs differed. Interestingly, it is in 8 projects the case that UC(s) did not expect their UML to be known by other developers, while the NUCs were aware of it. It seems that model creators tend to underestimate the spread of their models.

Results for $SQ_{2.1}$*: A majority of non-UML contributors are aware of the UML models in their projects. This is even slightly more than expected by the authors of the models.*

2) Are UML models used during communication and team decision making?:
In a first step we asked founders and UCs whether UML models are considered in the communication between contributors. Fig. 7 summarizes the 405 individual responses from 388 projects. According to the responses, UML models were considered in communications in a large majority of the participated projects (60%).

As a step further, we asked whether UML models were used as a basis for architectural decision making or mentoring activities. Respondents from the majority of the projects recalled that they had used the UML models for making architecture decisions (58.7%) and explaining each other different aspects of the system (58.25%) (summarized in Fig. 8).

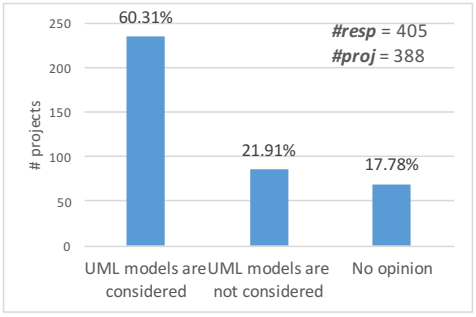


Figure 7: Are the UML model(s) considered in the communication between contributors? (per project)

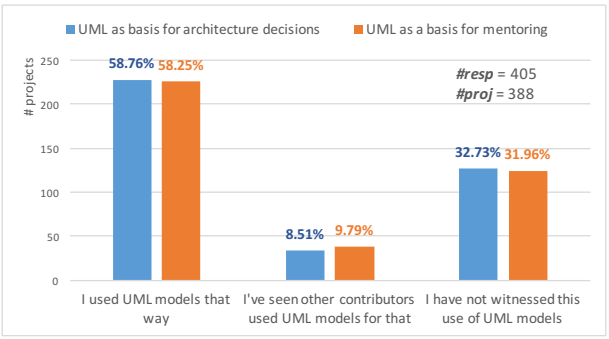


Figure 8: Is UML a basis for architectural decisions or mentoring activities? (per project)

Results for $SQ_{2.2}$*: UML models were considered as a mean of communication and as a basis for architectural decisions and for mentoring in a majority of projects.*

3) Are modeled designs adopted afterward during the implementation phase by teams of OSS contributors?:
For those projects that claimed to have design models, we asked the question "Was the UML models adopted during the implementation phase?". Fig. 9 summarizes for 225 projects the answers of the 231 respondents. In most cases UML models were adopted partly or completely during the implementation phase (about 92%).

If the answers was that UML models were at least partially adopted, we asked further questions to find out who and how many contributors implemented the modeled designs. Fig. 10 and Fig. 11 summarise the responses per project (based on 214 individual responses for 208 projects).

Creators of UML models are greatly involved in implementing the modeled designs (in 88.5% of the projects). Experienced contributors helped in 35.5% of the cases and novice contributors helped in around 13% of the cases.

In the majority of the projects (around 66%) more that 1 person participated in the implementation of previously

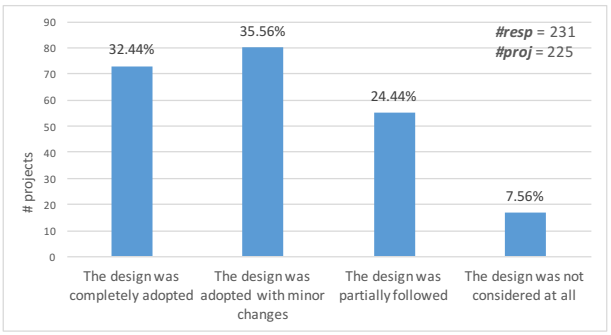


Figure 9: Was the UML models adopted during the implementation phase? (per project)

modeled designs. However, only 7% of the projects reported to have more than 5 contributors involved such joined implementation efforts.

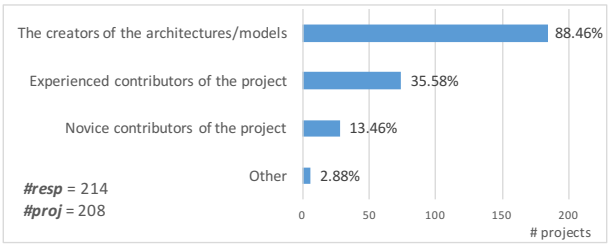


Figure 10: Who implemented the UML models? (by project)

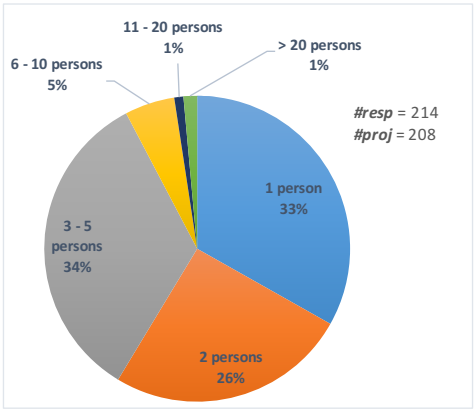


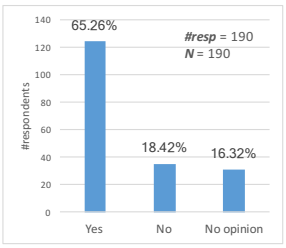
Figure 11: Number of contributors who implemented UML models in a project

Results for $SQ_{2.3}$*: Designs introduced with UML are in most cases adopted during implementation phase (fully or with slight changes). Most often these designs are implemented by groups of 2-5 persons.*

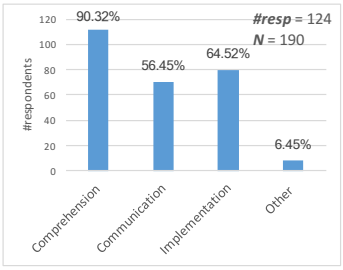
D. What is impact/benefit of UML?

1) Can UML models support new contributors?: We used two perspectives to approach the question whether UML models support new contributors.

First, we ask founders if they think that the UML models help new contributors to join their projects. We received



(a) Do UML models help new contributors?



(b) For what tasks do the models help?

Figure 12: Responses for the questions whether UML models help new contributors to join the project.

190 responses from 84 F-1UCs, 79 F-NUCs and 27 F-UCs. For those who agreed, we further asked with what tasks the models help. Fig. 12 shows the responses in detail. 124 out of 190 respondents (65.26%) agreed that UML models can help new contributors when joining the projects. They expected the models to assist new contributors in comprehending the system (90%), during implementation phases (65%), and when communicating with other contributors (56.5%).

Second, we asked each contributor what software artifacts he/she used when they got started with the project. 485 contributors answered this question. Despite the fact that most of respondents were familiar with architectural documents (as shown in Section V-A) , source code still remains their first choice to start working with an OSS project (81%) - see Fig. 13. Remarkably, UML and software models in general were reported to be starting points for 55% and 43.5% of the respondents, respectively. This is more than the proportion of contributors who started using wikis, issues, manuals, and auto-generated code documentations. This conforms the answers given by the founders about new contributors.

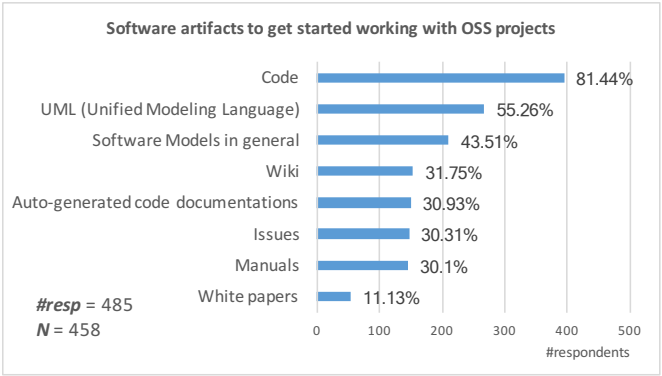
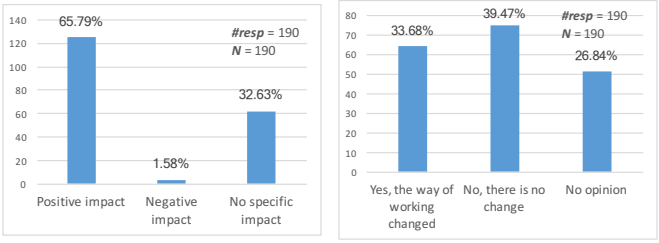


Figure 13: Software artifacts used by the respondents to get started working with their OSS project (multiple choices were allowed).

Results for $SQ_{3.1}$*: The results suggest that UML is helpful for new contributors to get up to speed.*



(a) Overall impact

(b) Impacts on working routine

Figure 14: Impacts of introducing UML into OSS projects

2) What are the impacts of using UML in OSS projects?:

Because of their overview about the projects, we asked founders for their impression about the impacts of introducing UML to their project. Fig. 14a and Fig. 14b summarize the 190 answers for the two questions. A majority of respondents (65.79%) reported positive impacts, while only a few founders (<2%) encountered negative impacts. Only, 34% of the founders saw changes in the way the contributors worked after UML was introduced.

To find out more about the changes, we asked those who observed changes to describe the way the working routine had changed. We received 31 responses to the open ended question. Comments positive to UML can be summarized in following groups: i) Hiding complexity/improved overview (mentioned **18** times); ii) Improved of communication/ reduced ambiguity (6 times); iii) Prevention of sub-standard implementations (5 times); iv) Improved scoping and partitioning of work (3 times); v) Improved/easier to implement designs (9 times); vi) Improved quality assurance (1 time); vii) Reduced architecture degradation (1 time).

We also received two answers describing negative changes, complaining about more work and the need for developers to learn the UML notation.

Results for $SQ_{3.2}$*: One third of respondents reported changes of the working routine due to UML, mainly in planning phase, development process and in communication. Most reported changes can be considered positive.*

3) Can UML models help to attract new contributors?: We ask founders if they think that UML models helps to attract new contributors to join their projects. 190 founders answered this question. Fig. 12 shows the responses in detail. Only a few of the respondents (21.58%) believe that UML models can attract new contributors, while most of them think UML is not an attractive factor (47.37%).

We asked those who think UML models attract new contributors for reasons behind their thoughts. We received only 25 answers, including following arguments: a) UML models makes the project and its goals become easier to understand (mentioned 13 times), b) the potential of UML to help new contributors (by code comprehension) (7 times), c) visual documentation is considered attractive (3 times), and d) UML can support communication between old and new members (2 times).

It is worth mentioning that two of the projects have been based on executable UML diagrams (xtUML), therefore the diagrams were considered a magnet to the contributors.

However, two of the respondents put their previous answer that UML is an attracting factor in perspective, mentioning additional factors, such as the personality, the quality of the model, and complexity of the project, e.g. *"I feel that it depends on two things: how perceptive the contributors are, and how elegantly and interesting the models was structured"* .

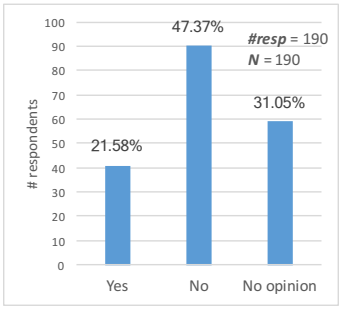


Figure 15: Do UML models attract new contributors to join the project?

Results for $SQ_{3.3}$*: Only few founders think UML models attract new contributors to join the projects.*

VI. Discussions

In the following we discuss our insights in context of related works and implications of our results. Furthermore, we discuss threats to validity.

A. Comparison to Insights to Related Works

In this section, the observations are compared with findings from related works.

Communication: First of all, the observation that UML is used for communication purposes within OSS fits to observations that were already made about the use of documentation by Kazman et al. [23] and sketches Chung et al. [24]. Furthermore, the results fit to the insight of Gorschek et al. [15], who also observed a use for communication within industrial and open source programmers.

New contributors: The observation that new contributors seem to benefit form the use of UML confirms the first anecdotal evidence that Chung et al. [24] collected. Again, Gorschek et al. [15] found similar tendencies in their survey, where the use of models was found to be higher for novices.

Design and documentation: We could uncover one main similarity in the use of UML in OSS and industry. First, we observed that UML is mainly used for design and documentation, and less for code generation within open

source. Similar observations were made for industrial usage by Torchiano et al. [14] and Forward et al. [16].

Role splits: However, we also found a hint to a contrast in the UML usage. While we observed that the architectures defined within UML models are often implemented by multiple persons, as it happens within industry, we also observed that in the most cases all of these contributors participated in the model creation. This seems to be a contrast to the practice in many industrial cases, where the people creating the models are not necessarily the persons who create the code, as, e.g., observed by Kuhn et al. [13].

Finally, we made two observations that should be further studied also in industry. *Passive benefits:* This is on the one hand the observation that many persons who do not create UML, consider its existence in the project nonetheless as beneficial. *Partial adoption:* Furthermore, we found that many models are only partially adopted during the implementation. It would be interesting to see whether this is conform or in contrast to industrial practice.

B. Implications

In most investigated aspects the answers given by NUCs showed a slight tendency to be more positive about UML than the answers of UML contributors. Thus, it seems that models have an impact on teams that affects not just the models creators positively. We hope that OSS contributors feel motivated by these results to contributing models. Furthermore, it seems that the usage of UML helps new contributors to get productive. This might be seen as an incentive for the UML introduction.

Finally, the observed contrast that most people implementing a models also participated in its creation, might be an interesting option for industrial practice, too. Especially, when agile practices are applied.

C. Threats to Validity

In the following, we discuss internal and external threats to validity of our study as introduced by Wohlin et al. [32].

Internal validity: Some threats that are generic to research that bases on GitHub, as discussed by Kalliamvakou et.al. [29], concern our study, too: First, a large amount of GitHub projects are not software development projects or have very few commits, only. Furthermore most GitHub projects are inactive (Kalliamvakou et al. guess that the amount of active projects is around 22%). To mitigate the impact of these threats on our study, we filtered the projects based on the number of commits and size. Since such filters are always just heuristics, it is probable that some of the remaining projects still are toy or educational projects. However, we consider the remaining threat acceptable, since we can assume that the vast majority of the here studied projects are real software development projects.

We focus on projects that do use UML only, to ensure that questioned developers have the experience of working in a project with UML. To ensure nonetheless that persons that prefer to not use UML are not underrepresented, we send the questionnaire not just to persons who manipulated UML, but also to contributors who did not change or introduce UML files (NUCs). Therefore, we believe that our results still provide valuable insights.

External validity: Our study focuses strongly on open source projects. While we do not expect a direct generalizability of our results to closed source projects, we expect them to be mostly generalizable to open source projects. We did not limit the domain. However, there might be a bias towards the domain that comes with the usage of UML. Since we study the impact of UML, when it is used, we consider our results valuable despite the possible bias in studies domains. Finally, we only have a look at UML models that are stored within specific formats. Of course, it would be better to have a look at all possible representations of UML models that exist. However, the selected set of formats is with the standards (.uml and .xmi) and image files already broad and allows a first valuable insight.

VII. Conclusion and Future work

In this paper we study the use of UML in open source, in order to identify commonalities and differences to the use of UML in industry. Therefore, we performed a survey with contributors from 458 GitHub projects that include UML files. Our study delivers some first insights that might help companies to decide whether to promote UML usage in open source projects. In favor of UML are the observations that UML actually helps new contributors and is generally perceived as supportive. However, UML does not seem to have the potential to attract new contributors. Further, we found that the UML use in open source projects is partially similar to the industrial use. However, there are also differences that should be considered, when joining industrial projects with open source efforts. For example, the fact that there seems to be barely a split of roles between model creator and person implementing the modeled system. Furthermore, we found that many modeled designs are only partially followed during implementation.

Future works: We only use a part of survey responses in this study (ignoring responses of short-time projects). In future, we plan to compare, whether the results for these projects are different from the ones we found. Furthermore, we plan to use meta data to investigate, whether different aspects such as size, active time, and the number of contributors of a project affect the model use and perceptions of developers within the projects.

Acknowledgment

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