

# API Evolution: A Study of Software Releases and Change Trends

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## ABSTRACT

As software evolves over the lifetime of a project, changes to software such as methods or classes occur, which can have ripple effects throughout the rest of the system causing relationships to be re-engineered and causing instability. However, projects are sometimes deemed stable at certain release points by projects owners or maintainers. We know that studying a release history of a project can give clues as to a project's history, release process, and how processes change, but can it shed light on what causes a project to be released and deemed stable? This paper presents our findings from studying source code change trends surrounding 109 major release points of 10 open source projects. We found 9 large source code change trends at these release points that can be used to determine if a project is likely near a major release point and thus deemed stable.

## Keywords

Change trends, software repositories, software releases

## 1. INTRODUCTION

Release points are a vital milestone of software projects. From major releases of a Waterfall based project to iterations of an Agile development, releases form an interesting single point of a project's development history. Third party users of a system often only see a product at a release point either major or minor, and expect the system to come with a sense of reliability and stability at this point. However, the decision as to when a project is ready for public usage as to its reliability, quality and stability can be a difficult decision to make for most project owners or maintainers.

While measuring software quality has had a major focus in software engineering research for many years [1] [10] [12], the sub study of software stability and its implications on quality and reliability remains a difficult subject to understand. The decision of what makes a project stable and ready for a release often comes down to the release manager or maintainer of a project and is often a reflection of

the open source community which surrounds the project [4]. Code churn is an often looked to statistically for stability but can be grossly misleading in terms of pre-release and post-release defects [8], with some exceptions [14]. Creating an approach to determining software stability and release preparedness is still a large open area of interest in software engineering research.

In this paper, we perform analysis of software change trends, specifically those trends around major releases. Change trends are trends which indicate a likelihood for a change type to occur around a certain event. Change trends have been used to detect stability in core architecture [16] as well as evolving dependencies [2]. With the power of major release points in open source projects as a starting point for project stability and the understanding that change trends can be leveraged to detect stability and the evolution of source code, the question we investigate in this paper is: *"What trends exist in source code changes surrounding major releases of open source projects as a notion towards a project stability measure?"*. By answering this question, we hope to provide the ability to determine a project's stability and perhaps reliability based on its current change trends. We also look to provide researchers with the ability to perform further analysis of projects in regards to software quality with the findings of this paper.

In this paper, we perform a case study of 10 open source projects in order to study their source code change trends surrounding major release points throughout their history. We studied 26 change trends quantitatively and 4 change trends qualitatively, and identified a core group of 9 change trends which occur prominently at major release points of the projects studied. These 9 change trends can be used to determine if a project is likely near a major release point or can be deemed stable.

## 2. RELATED WORK

While very little has been published about release quality studies and stability, there have been a few studies which attempt to address the issues directly or indirectly. Wu et al. [17] performed a case study of SoftPM, a widely adopted project management tool, to explore the relationships of pre-release and post-release failures at major releases. Wu et al. found that the ratio of post-release failures to pre-release failures is significantly low and can be used to show reliability and stability. Hindle et al. [11] performed a case study on MySQL which observed a project's behavior around major and minor release by monitoring artifact check-ins and changes. They found that there are temporary stoppages

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for source revisions around releases, indicating that a temporary freeze is taking place for developers and that last minute fixes and manual testing may be performed. Zaidman et al. [18], in comparison, studied the co-evolution of production and test code with inspections and analysis at major and minor releases, showing how test and production code can evolve at different rates and times. These results show that production and test code should be handled as different cases for a stability measure around major releases.

The study of open source projects revolving around release points has become more accessible by the work of Tsay et al [15]. Tsay et al. created a resource of historical release dates for open source software projects to be used for future studies by other researchers.

In terms of software stability, development techniques have been proposed to increase software stability. Fayad [6] [5] suggests that “business objects” (BOs) do not change in nature and that they are inherently stable. These objects only need to change to accommodate external modules at the interface. Some studies such as Chow et al. [3] have investigated the stability of changes to interfaces which are considered a good indication of stability. Mockus et al. [13] used major and minor release points to compare industry process quality to customer-perceived quality of the software project. Mockus et al. found that defect density is lowest at major releases but at the same time software quality is at its lowest all when compared to minor releases. The low software quality here relates to end-user errors of installations and configurations. Wermelinger et al. [16] showed that stable core architectures can be detected by using source code changes. Finally, Fayad et al. [7] have investigated the Software Stability Model (SSM) for Software Product Lines to show that the SSM’s impact on architecture and design of a software product can help improve the life of the product line and make it more adaptable and applicable.

### 3. METHODOLOGY

To answer our research question, we used the tool ChangeDistiller created by Fluri et al. [9]. This tool allows us to detect fine grained source code changes in Java projects. This tool works by building an abstract syntax tree of a file before and after a code change, then it tries to determine the smallest possible edit distance between the trees. This results in the source code change at a fine grained level performed in the commit.

We conducted a case study of 10 open source Java projects. These projects are: eclipse.jdt.core, eclipse.jdt.ui, eclipse.jetty.project, eclipse.mylyn.common, eclipse.mylyn.context, hibernate-orm, hibernate-ogm, hibernate-search, eclipse.maven.core, and eclipse.maven.surefire. These project were chosen because ChangeDistiller only works for Java source code and because of their high use amongst other Java projects and to study specific ecosystems of projects and their evolution trends.

For each of the projects, we obtained the software repository and used ChangeDistiller to iterate over every commit found in a project’s master branch. We stored 34 of ChangeDistiller’s built in source code change types for each commit. We noted how many of each change type was performed in each commit and stored that information in a PostgreSQL database. In order to filter and protect our results, we manually inspected the 10 Java projects studied in order to identify code built for test purposes. We separated

changes to this test code from all other code to ensure our results only focused on real implementation while allowing us to study changes to test based code separately.

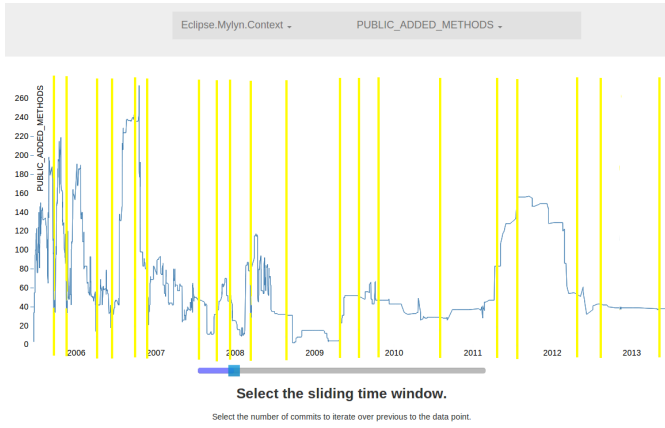
Next, we decided to examine software change trends surrounding releases of the project’s we had selected. Since releases have preconceived notions of software stability, we decided that by studying the change types surrounding these releases, we could get a better understanding of what types of source code changes or trends constitute software stability or maturity. In order to study the release points, we went to each of our 10 project’s web pages and looked through their release histories for major, minor, alpha, beta, and release candidate type releases. In total we identified 472 releases across our 10 studied projects.

Once the release dates were collected we set about analyzing out data by creating average change ratios surrounding the release dates of each project as a way to measure the trend of a particular change type at a release type. This change ratio simply compares the number of change events (of a given change type) before a release to after the release. Both of the before and after event totals are divided by the number of commits on their respective side of the release to account for activity. We implemented this algorithm through Equation 1.

Equation 1 works to create a change ratio by first creating a numerator by summing across all releases of a given release type a sum of a particular change type in commits ( $T_c$ ) from the release date ( $r$ ) to a given number of days after the release ( $d$ ) divided by the number of commits in this date range ( $|c|$ ). Next the denominator is created by summing across all release of a given release type a sum of that same particular change type in commits ( $T_c$ ) from a given number of days ( $d$ ) before the release date ( $r$ ) to the release date divided by the number of commits in this date range ( $|c|$ ). This numerator and denominator form the final change ratio. This equation gives us a ratio of a particular change type happening before and after a particular release. If the ratio is above 1 then that particular change type occurs more frequently after the release and if it is below 1 then it occurs more frequently before the release. For the purposes of our study, we set the number of days before and after the release ( $d$ ) to 60 as the projects studies had many months in between their major releases. This quantitative data formed much of the basis for the results to come in Section 4

$$\text{ChangeRatio} = \frac{\sum_{r_0}^{r_n} \sum_{c=r}^{r+d} T_c / |c|}{\sum_{r_0} \sum_{c=r}^{r-d} T_c / |c|} \quad (1)$$

We also created a web application for the visualization of the data called API Evolution (APIE). This visualizer allowed us to inspect a single project and a single change type metric at a time (see Figure 1) for qualitative analysis of software evolution trends. We used this tool to manually inspect 4 specific change type trends surround release dates. To do this, we aggregated change types across 50 commits, meaning that each point in the graph represented the date of a commit and the sum of the particular change type’s occurrences over the last 50 commits. This was used to smooth out the curves presented by the tool to allow easier manual inspection. This method however does not take activity into account as seen in Equation 1, so it represents the true activity and change types occurring. Manual inspections were



**Figure 1: A screen shot of the APIE visualizer showing project Eclipse.Mylyn.Context with change type PUBLIC\_ADDED\_METHODS being analyzed and showing major releases as vertical yellow lines.**

labeled into 4 categories: upward trending, local maximum, downward trending, and local minimum. Since the graphs were quite turbulent, best estimations were conducted by two judges at each release point to fit the graph into the aforementioned 4 slope categories. The two judges used 1.5 months before and after the release date as start and end points for the graph trend line.

We performed 1888 manual inspections across 10 projects, 472 release dates and 4 change types, and used this data to form the basis of our qualitative data. Quantitative data was used to compliment the quantitative ratios found from the previous methodology.

## 4. RESULTS

We focus our results on major releases of the 10 case study projects and select few of the calculated change ratios. There were 109 major releases across the 10 studied projects. All of the major findings as per values computed from Equation 1 for non test metrics can be seen in Table 1.

**Table 1: Implementation oriented change types and their normalized average change ratios at 60 days on each side of releases.**

Object	Added	Changed	Removed
Public Classes	1.14	0.86	1.16
Public Methods (Signature)	1.07	0.92	1.34
Public Methods (Bodies)	-	1.06	-
Private Classes	0.81	1.18	1.44
Private Methods (Signatures)	1.00	1.10	1.22
Private Methods (Bodies)	-	1.08	-
Files	1.12	0.96	1.14
Documentation	-	0.99	-

To study the most prevalent change trends, we set a ratio threshold of greater than 1.2, or less than 0.83 (20% greater trend of after the release date or 20% greater trend of before the release date) to indicate the greatest trends.

We found 4 major change trends occurring before major

releases: adding of private classes, changing of test method signatures, changing of documentation, and removal of test classes. We also found 5 major change trends occurring after major release: adding of test methods, changing of test classes, removal of public methods, removal of private classes, and removal of private methods.

Table 1 shows there are few change type trends around major releases which pass our threshold. We can see that both public and private methods being removed from a project is more likely to occur after a major release than after. Table 1 also shows significance in the changes to private classes. We see that private classes are added more (24%) before a major release and removed more after (44%) the release. All results in Table 1 could be used as identified trends of major software releases, while we have just highlighted the larger ratios which meet our threshold criteria in this paper.

Another interesting trend seen in Table 1 is that of changes to public objects. We can see for public classes and methods that 5 out of 7 ratios indicate changes occur to these objects after major release rather than before. We hypothesize that these changes to the public API after a major release come from newly reported bugs from end users as well as having old features being deprecated while adding new features to the project after the stable build had been released.

Our complementary qualitative results from manual graph inspections can be seen in Table 2. These results show that adding, changing signatures and bodies of, and removing public methods tend to all be at a local minimum of change type trends at major releases when activity is not taken into account. These results confirm previous results of low code churn as an indication of stability.

Lastly, we found that software changes related to testing can be an indicator of a major release points within the projects studied. The change ratios found can be seen in Table 3. As it can be seen, the four ratios which meet our threshold and are indicators of stability with regards to test based changes are: the changing of test classes, the removal of test classes, the adding of methods, and the changing of method signatures, and test classes being changed. Changes to documentation also meets our threshold and occurs more before a major release.

**Table 3: Test oriented change types and their normalized average change ratios at 60 days on each side of releases.**

Object	Added	Changed	Removed
Classes	1.07	1.21	0.76
Methods (Signatures)	1.23	0.83	1.01
Methods (Bodies)	-	0.90	-
Documentation	-	0.72	-

While all change ratios may need to be considered for continued analysis or a taxonomy of change trends, we have offered the strongest change trends in these results as a suggestion for future focus.

## 5. FUTURE WORK

We have planned further statistical tests of the change trends identified in this paper. We would like to determine if these patterns are unique to major releases versus other types of releases (minor, alpha, beta, release candidate) and to determine if these pattern are unique to releases alone or

**Table 2: Qualitative graph analysis results.**

Change Type	Upward Trend	Local Maximum	Downward Trend	Local Minimum
Added Public Methods	21.6%	17.2%	14.7%	33.6%
Changed Public Methods (Signature)	6.0%	19.8%	19.0%	39.7%
Changed Public Methods (Bodies)	9.2%	16.5%	26.6%	37.6%
Removed Public Methods	7.8%	16.4%	12.9%	41.4%

can be spotted throughout the history of a project.

If change trends are present in no other releases, some, all, or in non release history of the project, we will compare the history of the projects as to where these trends are found against preexisting software stability and quality metrics. We will use this data to create a new method of discovering when software can be considered stable in reference to the types of software changes being made.

## 6. CONCLUSIONS

This paper has presented some initial indications as to how software stability may be found, based on major release stabilities, by analyzing source code change type trends both before and after major software releases.

The 4 change trends found in this paper occurring before major releases are: added private classes, changed test method signatures, changed documentation, and removed test classes. The 5 change trends found in this paper occurring after major release are: added test methods, changed test classes, removed public methods, removed private classes, and removed private methods.

The source code change trends found in this paper, in combination with future work and analysis, will allow for the detection of stable code points throughout a software projects life time.

## 7. REFERENCES

- [1] J. B. Bowen. Are current approaches sufficient for measuring software quality? In *Proceedings of the software quality assurance workshop on Functional and performance issues*, pages 148–155, New York, NY, USA, 1978. ACM.
- [2] J. Businge, A. Serebrenik, and M. van den Brand. An empirical study of the evolution of eclipse third-party plug-ins. In *Proceedings of the Joint ERCIM Workshop on Software Evolution (EVOL) and International Workshop on Principles of Software Evolution (IWPSE)*, IWPSE-EVOL '10, pages 63–72, New York, NY, USA, 2010. ACM.
- [3] J. Chow and E. Tempero. Stability of java interfaces: a preliminary investigation. In *Proceedings of the 2nd International Workshop on Emerging Trends in Software Metrics*, WETSoM '11, pages 38–44, New York, NY, USA, 2011. ACM.
- [4] M. Conway. How do committees invent. *Datamation*, 14(4):28–31, 1968.
- [5] M. Fayad. Accomplishing software stability. *Commun. ACM*, 45(1):111–115, Jan. 2002.
- [6] M. E. Fayad and A. Altman. Thinking objectively: an introduction to software stability. *Commun. ACM*, 44(9):95–, Sept. 2001.
- [7] M. E. Fayad and S. K. Singh. Software stability model: software product line engineering overhauled. In *Proceedings of the 2010 Workshop on Knowledge-Oriented Product Line Engineering*, KOPLE '10, pages 4:1–4:4, New York, NY, USA, 2010. ACM.
- [8] N. E. Fenton and N. Ohlsson. Quantitative analysis of faults and failures in a complex software system. *IEEE Trans. Softw. Eng.*, 26(8):797–814, Aug. 2000.
- [9] B. Fluri, M. Wuersch, M. Pinzger, and H. Gall. Change distilling: Tree differencing for fine-grained source code change extraction. *IEEE Trans. Softw. Eng.*, 33(11):725–743, Nov. 2007.
- [10] R. B. Grady. Practical results from measuring software quality. *Commun. ACM*, 36(11):62–68, Nov. 1993.
- [11] A. Hindle, M. W. Godfrey, and R. C. Holt. Release pattern discovery via partitioning: Methodology and case study. In *Proceedings of the Fourth International Workshop on Mining Software Repositories*, MSR '07, pages 19–, Washington, DC, USA, 2007. IEEE Computer Society.
- [12] ISO/IEC. *ISO/IEC 9126. Software engineering – Product quality*. ISO/IEC, 2001.
- [13] A. Mockus and D. Weiss. Interval quality: relating customer-perceived quality to process quality. In *Proceedings of the 30th international conference on Software engineering*, ICSE '08, pages 723–732, New York, NY, USA, 2008. ACM.
- [14] N. Nagappan and T. Ball. Use of relative code churn measures to predict system defect density. In *Proceedings of the 27th international conference on Software engineering*, ICSE '05, pages 284–292, New York, NY, USA, 2005. ACM.
- [15] J. Tsay, H. K. Wright, and D. E. Perry. Experiences mining open source release histories. In *Proceedings of the 2011 International Conference on Software and Systems Process*, ICSSP '11, pages 208–212, New York, NY, USA, 2011. ACM.
- [16] M. Wermelinger and Y. Yu. Analyzing the evolution of eclipse plugins. In *Proceedings of the 2008 international working conference on Mining software repositories*, MSR '08, pages 133–136, New York, NY, USA, 2008. ACM.
- [17] S. Wu, Q. Wang, and Y. Yang. Quantitative analysis of faults and failures with multiple releases of softpm. In *Proceedings of the Second ACM-IEEE international symposium on Empirical software engineering and measurement*, ESEM '08, pages 198–205, New York, NY, USA, 2008. ACM.
- [18] A. Zaidman, B. Rompaey, A. Deursen, and S. Demeyer. Studying the co-evolution of production and test code in open source and industrial developer test processes through repository mining. *Empirical Softw. Engg.*, 16(3):325–364, June 2011.