Feature Toggle Driven Development: Practices used by Practitioners

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Abstract  Background: Using feature toggles is a technique that allows developers to either turn a feature on or off with a variable in a conditional statement. Feature toggles are increasingly used by software companies to facilitate continuous integration and continuous delivery. However, using feature toggles inappropriately may cause problems, such as dead code and code complexity. For example, repurposing an old feature toggle which activated functionality that had been unused for 8 years caused Knight Capital Group, an American global financial services firm, to go bankrupt. The awareness of feature toggle industry practices can help practitioners use feature toggles since software practitioners usually prefer to learn through the experiences of other software practitioners.

Aim: The goal of this research project is to aid software practitioners in the use of feature toggles through an empirical study of feature toggle practice usage.

Method: We conducted a qualitative analysis of 109 Internet artifacts about feature toggles and also conducted a follow-up survey to find the frequency of usage of feature toggles in industry.

Results: We identified 17 practices in 4 categories: Management practices, Initialization practices, Implementation practices, and Clean-up practices. We observed that all of the survey’s respondents use a dedicated tool to create and manage feature toggles in their code. Using a maintenance tool, setting up the default value for feature toggles, and logging the changes made on feature toggles are common practices.
ture toggles are also frequently-observed practices in Internet artifacts. Conclusions: The feature toggle driven development practices discovered and enumerated in this work can raise the practitioners’ awareness of usage of feature toggles in industry and help the practitioners to better use feature toggles in their projects. The feature toggle practices discovered through this work can enable future quantitative analysis to mine code repositories to automatically identify feature toggle practices.

**Keywords** Continuous Integration · Continuous Delivery · Feature toggle · Practice

1 Introduction

In 2012, developers in Knight Capital Group, an American global financial services firm, updated their automated, high-speed, algorithmic router which inadvertently repurposed a feature toggle\(^1\), activating functionality which was unused for 8 years. Within 2 minutes, developers realized the deployed code behaved incorrectly but took 45 minutes to stop the system. During that time, Knight Capital lost nearly 400 million dollars, which caused the group to go bankrupt\(^2\). As illustrated, using feature toggles without following good practices can be detrimental to an organization.

Developers guard blocks of code with a variable as a feature toggle in conditional statements, and by changing the value of the variable, enable or disable that part of the code in the system’s execution. The value of the variable could be changed either in the code or remotely on the configuration server. The use of feature toggles is a technique often used in continuous integration (CI) and continuous delivery (CD) contexts, and allows teams to incrementally integrate and test a new feature even when the feature is not completely ready to be released\(^3\)\(^4\). Developers also use feature toggles for other purposes, such as, gradual roll out and performing experiments. However, feature toggles can turn into technical debt\(^5\). Using feature toggles adds more decision points to the code which adds more complexity. This increased complexity drives the need to remove toggles when their purpose is complete.

The identification and categorization of feature toggle practice\(^6\) used in industry can help software practitioners to use toggles more efficiently and to control the accumulation of technical debt. The goal of this research project is to aid software practitioners in the use of feature toggles through an empirical study of feature toggle practice usage. Software practitioners prefer to learn through the experiences of other software practitioners\(^6\). As such, our study obtains practice usage from practitioners.

We state the following research questions:

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\(^1\) Feature toggles are also called feature flags, feature bits, feature flippers and feature switches\(^3\).

\(^2\) A *practice* is a method used by team members repeatedly in similar situations during the software development. For example, unit testing is a practice that companies use to test a method.
RQ1 (Identification): What are the feature toggle practices that software practitioners use?
RQ2 (Frequency): How frequently are feature toggle practices used?

To answer the first research question, using a keyword search we collected 66 Internet artifacts about feature toggles, including 10 peer-reviewed papers, 41 blog posts and online articles, 15 videos. We used the open coding technique to perform qualitative analysis of these artifacts and identify practices. To answer the second research question, we then analyzed 69 company-specific Internet artifacts and conducted a follow-up survey to find the frequency of usage of these identified practices.

We summarize the contribution of this paper:
1. A list of 17 feature toggle practices in four categories used by practitioners; and
2. An analysis of the frequency of usage of feature toggle practices in industry.

The rest of the paper is organized as follows: in Section 2, we briefly describe the background of feature toggles and prior academic work related to our paper. In Section 3, we explain our research methodology. In Section 4, we report our findings. In Section 5, we discuss our findings. We enumerate the limitations of our study in Section 6. We conclude and describe future work on feature toggles in Section 7.

2 Background and Related Works

2.1 Background

Companies must deliver valuable software rapidly to be competitive. This expectation leads companies to use CI and CD to make development cycles shorter. CI is a practice of integrating and automatically building and testing software changes to the source repository after each commit. CD is a practice for keeping the software in a state such that it can be released to a production environment at any time. CI/CD refers to a combination of these two practices and enables delivering code changes frequently. Using feature toggles is one of the techniques that is used in numerous software companies who practice CI/CD.

Programming languages have long provided the language constructs to implement feature toggles. However, the first use of this language construct to support CI/CD was at Flickr in 2009. Figure 1 is an example of a feature toggle usage. In this example, use of a new search algorithm depends on the value of the useNewAlgorithm toggle. If the value of this toggle is true then the new search algorithm is used, otherwise search function calls the old search algorithm.

Feature toggles have been categorized into four types in software systems.
function Search()
{
    var useNewAlgorithm = false;
    if (useNewAlgorithm) {
        return newSearchAlgorithm();
    } else {
        return oldSearchAlgorithm();
    }
}

Fig. 1 An example of a feature toggle

- **Release toggles**: Release toggles are used to add new features to the software to enable trunk-based development. In trunk-based development, all the developers commit changes to one shared branch instead of having multiple branches. Using release toggles in trunk-based development supports CI/CD for partially-completed features.
- **Experiment toggles**: Experiment toggles are used to perform experimentation on the software, such as is done by Microsoft [12] [13], to evaluate new features changes and their influence on user-observable behavior.
- **Ops toggles**: Ops toggles are used to control the operational aspect of the system behavior. When a new feature is released, system operators can disable the feature quickly if it performs unexpectedly.
- **Permission toggles**: Permission toggles are used to provide the appropriate functionality to a user, e.g. special features for premium or paid users.

As feature toggles have gotten more popular, tools have been developed to help developers use toggles more efficiently. For example, the LaunchDarkly feature management platform helps practitioners to create new feature toggles, change their status, track their changes, and control their life cycle. Feature toggle libraries in programming languages, such as Java, JavaScript, Ruby, Python, and PHP, can also be used to manage feature toggles. These libraries can be added to the code to aid in the creation, management, and use of feature toggles.

2.2 Related Work

Rahman et al. [14] performed a qualitative analysis of Internet artifacts and conducted follow-up inquiries to study continuous deployment practices used by 19 software companies. They reported 11 continuous deployment practices used by these 19 software companies. Using feature toggles is one of these 11 practices that is used by 13 of the companies. In addition, at the Continuous Deployment Summit [4] 2015, researchers and practitioners from 10 companies shared their best practices and challenges. Parnin et al. [4] disseminated 10 best

[3] [https://launchdarkly.com/]
practices from the Summit, including the use of feature toggles to implement Dark Launches.\footnote{“Dark launching” is a practice in which code is incrementally deployed into production but remains invisible to users.}

To understand the drawbacks, strengths, and cost of using feature toggles in practice, Rahman et al.\cite{rahman2015feature} performed a thematic analysis of videos and blog posts created by release engineers. They reported the purpose of using feature toggles: rapid release, trunk-based development, and A/B testing. They provided a number of design and test rules to use feature toggles, such as isolating feature toggles to avoid toggle dependencies; having the quality expectation for feature toggles as other parts of the code; and combinatorial feature testing. To identify feature toggle practices, we used a subset of these videos and blog posts\cite{rahman2015feature} and a large number of additional artifacts including more videos, blog posts, and peer-reviewed papers. In our study, we focused on identification of feature toggle practices and the usage of them in industry which is different than their paper’s purpose.

Rahman et al.\cite{rahman2015feature} also performed a quantitative analysis of feature toggle usage across 39 releases of Google Chrome from 2010 to 2015 and mined a spreadsheet used by Google developers for feature toggle maintenance. They quantified the prevalence of three major types of feature toggles used in Chrome: development toggles (33%), long-term business toggles (33%), and release toggles (34%). We mentioned four suggested types for feature toggles in section 2.1. Among three feature toggle types in Chrome, release toggles are mapped to release toggles in suggested types, long-term business toggles are mapped to permission toggles and development toggles do not map to any suggested categories directly. Development toggles are used for testing and debugging but none of the suggested types point to this usage. Release toggles should be short-lived toggles but Rahman et al. observed that 53% of the release toggles exist for more than 10 releases in Chrome. They classified unused but existing release toggles in the code as technical debt.

Rahman et al.\cite{rahman2015architectural} extracted four architectural representations of Google Chrome: 1) conceptual architecture; 2) concrete architecture; 3) browser reference architecture; and 4) feature toggle architecture. Using the extracted feature toggle architecture, developers can find out which feature effects which module and which module is affected by which feature. The researchers showed how developers can get a new viewpoint into the feature architecture of the system using the extracted feature toggle architecture. Their result raise awareness of the impact of using feature toggles on the modular architecture of the system.

None of this related work on feature toggles focus on identifying the feature toggle practices used in industry and their usage frequency. We fill this gap in this paper.
3 Research Methodology

We describe the steps of our methodology to answer the research questions. Our methodology has six steps, as shown in Figure 2. Each of these steps will be explained in detail in the following sub-sections.

3.1 Step One: Searching Initial Artifacts

The first step in our research methodology is to use a keyword search in the Google search engine to identify Internet artifacts about feature toggles. We used the following search terms: feature toggle; feature flag; feature switch; feature flipper; and feature bit. These search terms were obtained from Fowler’s blog post [1]. We reviewed the search results, and then we selected those links that were related to the use of feature toggles in software development. In the selected links, we used snowballing approach [16]. We clicked on links and the references to other feature toggle resources found in these links, and we read the articles or watched the videos. Searching for initial artifacts was done in two periods of times: May 2018 and June 2019. Some collected artifacts in Step One were company-specific artifacts. Company-specific artifacts were often written by a release manager or developer, referencing feature toggle usage at a specified company. We used these company-specific artifacts in Step Four in addition to Step Two.

3.2 Step Two: Identification of Practices and Categories

The Internet artifacts found in Step One was used for the process of identifying feature toggle practices. We analyzed the artifacts using an open coding technique, a technique to analyze textual data by labeling (coding) concepts and identifying categories based on similarity and dissimilarity of codes [7]. First, we took notes from non-textual resources, such as videos. Then, we labeled (coded) the suggested recommendations, experiences, and implementation details about using feature toggles mentioned by practitioners in the textual artifacts and in the notes of non-textual artifacts.
Fig. 3 An example of using the open coding technique.

After the identification of practices, we observed similarities and dissimilarities between practices. We put practices with similarities into one category based on an open coding technique and found four categories. We give an example of using open coding with a sample of our data in Figure 3. In this figure, three paragraphs from three artifacts are shown and labels are assigned to them. The labels of two first paragraphs are pointed to the same concept so we grouped them as “Limit the number of feature toggles”. The last label is changed to “Create a cleanup branch” practice. The similarity between these two extracted practices is pointing to cleaning up feature toggles, so the two practices are grouped as “Clean-up practices”. The result of this step is the answer to the first research question (RQ1-Identification).

3.3 Step Three: Searching Company-specific Internet Artifacts

Some artifacts collected in Step One were company-specific artifacts. Additionally, some artifacts contain a list of companies which use feature toggles. From these artifacts, we obtained a list of companies which use feature toggles in their development cycle. Additional searches were conducted to collect more artifacts related to feature toggle from these specific companies. We used the search strings in the following format: “[company name] [feature toggle term]” where company name represents the name of the company; and feature toggle term is a search term for “feature toggle,” as defined in Step One. For each combination of company name and feature toggle term, a search string was applied to collect as many artifacts as possible. These strings were searched by using both the Google search engine and search feature found within a company’s blog. If a company uses a feature toggle management system named by an artifact, we also used that system’s name instead of “feature toggle term” in a search string. For example, Facebook uses Gatekeeper for feature toggle management [17]. We used Gatekeeper instead of “feature toggle term” as well as search terms for feature toggle in the search for Facebook.
3.4 Step Four: Extraction of Practice Usage from Company-specific Artifacts

In this step, we used company-specific Internet artifacts collected in Step One and Step Three. We analyzed each artifact to determine which practices identified in Step Two are used by the companies as mentioned in the artifacts. If a practice was not clearly mentioned, a second person analyzed the artifact and then we made a decision if the company used the practice or not.

Step Three and Step Four were performed iteratively and repeatedly if new artifacts for a company were found in Step Four.

3.5 Step Five: Follow-up Survey

After extracting practice usage by the companies, we observed that our result is not complete. For instance, some of the identified feature toggle practices do not mentioned in any of the company-specific artifacts so we conducted a follow-up survey to obtain more information about feature toggle practice usage.

Contact information of company employees was gathered by collecting social media accounts and email addresses of named individuals associated with company-specific artifacts found in Steps One and Three. We also found contact information of managers/developers in companies that we knew they are using feature toggles while doing Step One, even though we did not find company-specific artifacts for them in Step Three. We requested each practitioner to complete the survey. We contacted the practitioners by email where email was available and by social media if email addresses were not found.

The survey has 11 questions and is presented in the Appendix. On average, each practitioner needed approximately 5 minutes to answer all questions. To design the survey’s questions, we used Likert scale options [18] for 12 practices that Likert scale options can be used. We provided five options in the survey for each practice to specify how much the survey respondents use the practice: Always, Mostly, About half of the time, Rarely, and Never. For the remaining practices, we provided different options we identified for each practice.

3.6 Step Six: Analysis of Usage Frequency of Practices

We analyzed the information from Step Four (analyzing company-specific artifacts) and Step Five (survey) to find the frequency of usage of each identified practice in the industry to answer RQ2. We integrated the result of Step Four and Step Five and report the frequency of usage of feature toggle practices.

4 Results

In this section, we present the result of the research methodology. Section [4.1] provides the answer to RQ1 and Section [4.2] provides the answer to RQ2.
4.1 Feature Toggles Practices

We found 66 Internet artifacts in Step One. From these, we identified and categorized 17 practices in Step Two. We found four categories of practices: Management practices, Initialization practices, Implementation practices, and Clean-up practices. We describe the 17 practices in their categories as follows:

4.1.1 Management practices (6)

Management practices are practices that are performed by development team members to make decisions about how to use feature toggles before starting and during usage.

- Use management systems: Management systems help companies to create, use, and change the value of feature toggles in a centralized system. As we mentioned, adding feature toggles adds to the complexity of the code and managing a number of feature toggles could be challenging. Using feature toggle management systems help to overcome the technical debt and manage the added complexity [19]. The management systems are connected to the code, and the changes impact the running system immediately. Feature toggle management systems can have a dashboard that helps team members to see the list of feature toggles and their current values. Team members can add new feature toggles or change the values of the toggles if they have the permission. These management systems can be open-source or closed-source. Organizations may create their own feature toggle management system. For example, Facebook uses Gatekeeper to manage the usage of feature toggles [17]. Alternatively, companies can manage feature toggles using existing management systems, such as LaunchDarkly and Split [5]. As an example, Behalf [6] and CircleCI [7], two of the 38 companies for which we found their artifacts, use the LaunchDarkly feature toggle management system. Envoy [8] uses Split’s feature toggle management system.

- Use maintenance tool: Through the use of a maintenance tool, practitioners record the feature toggle’s information e.g. the owner of the feature toggle; the current value (on, off); the current status (to remove, untriaged, keep, removed); and the time of its creation. The main difference between a maintenance tool and a management system is that the maintenance tool has no connection to the code. Developers need to keep code changes and data on the maintenance tool consistent and up-to-date manually. However, the management system and code are connected, and changes in one of them are reflected on the other. Also, the management system can incorporate a maintenance tool.

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[5] https://www.split.io/
[6] https://www.behalf.com/
[7] https://circleci.com/
[8] https://envoy.com/
The data in the maintenance tool are useful, for example, if a toggle is always on or always off for a long period of time, the team should consider removing it. As an example, Google has a spreadsheet with a list of feature toggles, the owner, toggles’ status, and notes about toggles which used in the Chrome project [20].

- **Log changes**: The log changes practice involves tracking changes that are made on feature toggles. By logging, the information of who changes which toggle and when is recorded [21]. This recorded information could help practitioners to keep track of changes of feature toggles in their lifetime. For example, Split’s feature toggle management system has the ability to log changes of the feature toggles [22].

- **Determine applicability of feature toggle**: Before the design and implementation of a feature toggle, the development team should determine if a feature toggle should be used in the existing situation or not. Using feature toggles adds more decision points to the code which adds more complexity to the code and requires attention to remove toggles when the initial use is completed. Using this practice can limit the number of feature toggles in a code base. Feature toggles are useful, but they are not essential for some situations. For instance, a developer can integrate the functionality into the trunk branch of a product without a user interface (UI) element such that the partially-developed code can be tested through the application programming interface (API) without the feature being accessible to a user. When the feature is completed, the UI element could be added and rolled out to the user instead of initially adding the UI element and wrapping it in a feature toggle [1]. Different companies have different approaches to making decisions. For example, all new features in GoPro have feature toggles [9]. However, practitioners in Finn.no, a largest online marketplace in Norway, avoid using feature toggles if they do not need the toggle [23].

- **Give access to team members**: Through this practice, permission to change values of feature toggles is granted to team members in addition to developers using the feature toggle management system. Using this practice prevents feature toggle management bottleneck. If all team members, such as Q&A team members, have access to feature toggles, they can change a toggle status in case of a problem [24]. For example, Instagram gives access to their feature management system to the product managers and sales team so they can add someone to a white list of getting a specific feature [24].

- **Group the feature toggles**: This practice points to make groups of similar feature toggles. Grouping the feature toggles can be used for different purposes. For example, grouping helps to give different teams or team members access to groups of toggles [21]. Also, related toggles could be grouped in the same group to simplify their management [25], such as toggles related to one part of an application can be grouped to turn on or off at the same

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9 https://bit.ly/2ISi1ye
time. Practitioners in GoPro have a two-level toggle hierarchy: simple feature toggles and higher level feature toggles.

4.1.2 Initialization practices (3)

Initialization practices are used to make decisions about the design of the feature toggle before their creation.

- **Set up the default values**: Default values for each feature toggle are determined in the case that the assigned value cannot be found or does not exist. Using this practice mitigates unwanted behavior of the feature toggle. For example, at Lyris, the absence of the feature toggle value in the code means that the toggle is off.

- **Use naming convention**: With this practice, naming conventions for feature toggles are established, particularly to make the intention of the toggle self-documented. Having the naming convention has several benefits. First, understanding the purpose of using the toggle is useful, i.e. if the owner of the code is changed, the new owner can understand the usage of the toggle easily if the name of the toggle reflects its usage. For instance, “ct.enable_flex_cache_inspector” is one of the toggles used in Lyris and the purpose of using the toggle is clear based on its name. Second, it is less likely to have multiple toggles with same names in the code even by different teams by following naming conventions. Third, adding the type of the toggle as a prefix in its name can help with the management of the toggles. For instance, if the feature toggle is a short-lived toggle, like release toggles, the developer will get a signal from the name of the toggle that the first intention of using the toggle was a short-term use and will plan to remove it. In InVision, long-lived toggles have “OPERATIONS-” prefix. Developers in this company also add the JIRA ticket number to the name of the feature toggle to make the purpose of using the toggle and responsible team to remove the toggle clear. If a “RAIN-123-release-the-kraken” is a name of the toggle, it is clear that the toggle is related to JIRA ticket RAIN-123 and the responsible team to clean-up the feature toggle is the Rainbow team.

- **Determine the type of the toggle**: With this practice, the type of the toggle is specified using the toggle types mentioned in Section. Permission toggles and ops toggles are long-lived toggles based on their usage purpose in the code. Release toggles and experiment toggles are short-lived toggles. The implementation and management of each type of the four toggle types are different. The developer should know the type of the toggle before designing and implementing the toggle. The developer can manage the quality of toggle’s implementation and plan to remove the toggle on time based on the type of the toggle. In addition, the first step to control the number of feature toggles in the code is to identify short-lived toggles which should be removed faster than others.
4.1.3 Implementation practices (3)

Implementation practices are related to implementation details of feature toggles.

- **Type of assigned values:** In the implementation of feature toggles, companies use three different ways to assign values to toggles. One way is to assign a string to feature toggles as their values. For example, one of the feature toggles in Google Chrome project is `kDisableFlash3d[] = “disable-flash-3d”`. If the value of the feature toggle is set then the toggle is enabled [3]. The second way to assign values is to assign boolean values to feature toggles. When the value is true the toggle is enabled and when value is false the toggle is disabled [30]. The third way is to assign multivariate values such as when the toggle is to capture user experiences. As an example, Rollout provides multivariate toggles, for instance a toggle can accept “Red”, “Blue” and “Yellow” as its value.

- **Ways of accessing the values:** We identified three ways development teams access the values of feature toggles. First, the feature toggles could be primitive variables, hard-coded into the program. The values can be accessed directly, such as our example is Figure 1. Second, toggles could be objects and the object has a method to determine the value of the toggle (e.g. `myToggle.isActive()`). We found a number of implemented libraries in GitHub which use this approach, such as rollout. Third, toggles could be accessed through a manager object. Managers map key/value pairs to return the value. LaunchDarkly uses this approach in their implementations.

- **Store type:** The list of feature toggles and their values can be stored in one of two ways: file storage and database storage. In file storage, the values of feature toggles are stored in one or multiple configuration files, such as what Google does in the Chrome project [3]. In database storage, the values of feature toggles are stored in databases, such as Redis [30] or SQL [31]. Dropbox uses both configuration files and database. A JSON file called `stormcrow_config.json` is shared between all the production servers and contains the value of feature toggles. If this JSON file is not found for any reason, the feature toggle management system Stormcrow has the ability to access to the database directly [32]. In addition, some companies “use a third party service” to fetch values of the feature toggle. For example, if they use a feature management system, they fetch the values of feature toggles from the management system.

4.1.4 Clean-up practices (5)

Following the clean-up practices helps practitioners to remove their feature toggles on time and manage the complexity of using feature toggles.

The five following practices are clean-up practices:

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10 https://rollout.io/
11 https://github.com/fetlife/rollout
– Add expiration date: Using this practice helps practitioners to remember when to remove a toggle, using one of the following three processes:
  – Time bombs: If the toggle exists after its expiration date, a test fails or the application does not start, which causes a developer to remove the toggle [11, 33, 29]. The expiration date is the latest possible date which the developers should remove the toggle from the code.
  – Automatic reminders: Add automatic reminders to remind developers the deadline for removing feature toggles [33]. For example, Slack has an archival system. When developers want to add a new feature toggle, they have to specify the date they plan to delete the toggle. If the toggle is not deleted by the specified date, the developer will get an alert [12].
  – Use cards/tasks/stories for removing toggles: Add tasks/stories/cards for removing toggles to a Kanban board (or any other tool that the team uses) [33] or to developers task backlog [11, 29]. For example, developers at Lyris create user stories for removing toggles [26].

– Track unused toggles: With this practice, dead code and unused feature toggles are removed. When a toggle is always on or always off, it should be removed. Based on the logging system or maintenance tool, the status of toggles could be monitored. Developers can use this data to find when the toggle is safe to remove [21].

– Limit the number of feature toggles: Using this practice the number of alive feature toggles at a time are limited to control the number of toggles. An alive feature toggle is a toggle which exists in the code whether it is on or off. By this limitation, practitioners have to remove an unused toggle to be able to add a new toggle if the number of existing toggles meets the limitation [11, 29, 34]. If short-lived toggles are identified using the “Determine the type of the toggle” practice, developers have a candidate list of toggles to be removed.

– Create a cleanup branch: This is the practice of creating a branch to delete the toggle and submitting a pull request for the branch at the same time as adding a new feature toggle to prevent forgetting the deletion of the toggles [27].

– Change a feature toggle to a configuration setting: This is the practice of keeping feature toggles in the code with changed functionality. The feature toggle can be changed to admin or user configuration settings. Using this practice prevents creation of dead code [35]. As an example, suppose a feature toggle is used for running experiments to see which color is better for the “buy” button in an e-commerce application. The experimental results show that the users are happiest when they can control the color of the button. Instead of deleting the feature toggle, it will be changed to a user configuration setting.

12 https://bit.ly/2W4bQUK
4.2 Usage of Practices in Industry

In Step One, 26 artifacts were company-specific artifacts. In Step Three and Step Four, we found 43 additional company-specific artifacts. In total, 69 company-specific artifacts from 38 companies were collected. The overlap between initial Internet artifacts and company-specific artifacts is shown in Figure 4. In Step Four, we analyzed these 69 company-specific Internet artifacts to find which companies use the identified practices. The list of companies and detailed information about their practice usage is shown in Table 2 in the Appendix.

In Step Five, we conducted a survey to gather additional information about the usage of feature toggles practices in industry. We had company-specific Internet artifacts of 38 companies. Of these 38 companies, we sent out the survey to 36 companies for which we had the contact information for release engineers and/or developers. In addition to these companies, we identify a list of 20 companies which use feature toggles in their companies. These companies are mentioned in Internet artifacts as the example of companies which are using feature toggles but we cannot find company-specific artifacts related to their practice usage. We found contact information for release engineers and/or developers in 9 of these companies and send the link of the survey to them. In total, we sent the survey to 45 companies. We got 17 responses for a response rate to the survey of 38%. These 17 responses are from at least 14 companies because three respondents did not mention their companies’ name.

As mentioned in Section 3, we used a Likert scale with five options for 12 of the 17 practices for which Likert scale options can be used. In our analysis, we grouped Always, Mostly and About half of the time responses and assumed the companies that selected these options use the practice. We also grouped Rarely and Never and assumed the company does not use the practice if the respondents selected one of these two options. The detailed result of the survey responses on questions with Likert scale options which are a subset of identified practices is shown in Figure 5. For the 5 remaining practices includ-
ing all 3 implementation practices and 2 management practices, we provided a list of appropriate options and the possibility to add another answer. For example, using Likert scale was not applicable for the “Use management systems” practice because a company either does or does not uses a management system.

We use results from analyzing company-specific artifacts and survey responses to answer our RQ2. The result of analysis of company-specific artifacts is shown in third column and the survey result is shown in the last column of Table 1. The frequency of usage of each practice in both company-specific Internet artifacts and survey result is shown in this table.

Table 1 Feature toggle practices and their usage in industry

| Category (mean of frequencies based on Internet artifacts, mean of frequencies based on survey) | Practice | Frequency from Internet artifacts (38 companies) | Frequency from survey (17 companies) |
|-----------------------------------------------|----------|--------------------------------------------------|-------------------------------------|
| Management (42%, 63%)                         | Use management systems | 32 (84%) | 17 (100%) |
|                                               | Use maintenance tool   | 25 (66%) | 6 (35%)   |
|                                               | Log changes            | 21 (55%) | 10 (59%)  |
|                                               | Determine applicability of feature toggle | 8 (21%) | 14 (82%) |
|                                               | Give access to team members | 7 (18%) | 12 (70%) |
|                                               | Group the feature toggles | 2 (5%)  | 5 (29%)  |
| Initialization (25%, 73%)                     | Set up the default values | 22 (58%) | 15 (88%) |
|                                               | Use naming convention | 5 (13%) | 12 (71%) |
|                                               | Determine the type of the toggle | 1 (3%) | 10 (59%) |
| Implementation (66%, 100%)                    | Type of assigned values (string, boolean, multivariate, more than one) | 32 (1 (3%), 7 (18%), 5 (13%), 19 (50%), 17 (1 (6%), 6 (35%), 9 (53%)) |
|                                               | Ways of accessing the values (primitive variable, objects, managers, more than one) | 28 (0 (0%), 0 (0%), 28 (74%), 5 (29%), 17 (2 (12%), 2 (12%), 8 (47%)) |
|                                               | Store type (file, database, both, third party service) | 15 (9 (24%), 4 (11%), 5 (5%), - ) | 17 (3 (18%), 2 (12%), 6 (35%), 3 (18%)) |
| Clean-up (4%, 38%)                            | Add expiration date (Time bombs, Automatic reminders, Use cards/tasks/stories for removing toggles) | 6 (0 (0%), 1 (3%), 5 (13%), 9 (0 (0%), 2 (12%), 7 (41%)) |
|                                               | Track unused toggles | 2 (5%) | 8 (47%) |
|                                               | Limit the number of feature toggles | 0 (0%) | 9 (53%) |
|                                               | Create a cleanup branch | 0 (0%) | 4 (24%) |
|                                               | Change a feature toggle to a configuration setting | 0 (0%) | 2 (12%) |
In this section, we provide the result of Step Six of the research methodology. Based on the survey responses, the companies have been using feature toggles for an average of 4.2 years. Among 17 respondents, 16 respondents use toggles to have gradual roll out. Fifteen respondents use toggles to support CI of partially completed features, and fourteen respondents use toggles to perform A/B testing. Twelve respondents use toggles to have dark launches.

In the following sub-sections, we provide analysis of the frequency of usage of feature toggle practices for each category based on company-specific artifacts and survey responses showed in Table 1.

5.1 Management practices

The most used practice in the management practice category is “Use management systems” based on both company-specific Internet artifacts and survey responses. As we mentioned before, management systems could have a maintenance tool inside so they may not use a separate maintenance tool when they have a management systems to manage their feature toggles.

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**Fig. 5** Frequency of using the subset of feature toggle practices with Likert scale based on the survey
The “Log changes” practice enables practitioners to follow “Track unused toggles” practice from clean-up category. If the company logs every change made on feature toggles, tracking unnecessary toggles will be easy.

For the “Determine the applicability of feature toggle” practice, three survey respondents stated that the feature toggle is always added when a new feature is added or any feature is changed. They do not have any decision making process for using feature toggles. In companies where a feature toggle is added for each new feature, there will eventually be a large number of feature toggles so management and deletion of the toggles are more critical to prevent increased code complexity and dead code.

5.2 Initialization practices

The most used practice in the initialization category based on both company-specific Internet artifacts and survey responses is “Set up the default values”. The “Use naming conventions” and “Determine the type of the toggle” are next in the rankings. The usage ranking of the practices in this category is same in both company-specific Internet artifacts and survey responses.

“Determine the type of the toggle” is a practice which helps practitioners to use “Limit the number of feature toggles” practice in the clean-up category more efficient. If the type of the toggles are pre-determined, the practitioners have a list of short-lived toggles as a suggested list of toggles to remove. Instead of checking all of the toggles, the short-lived toggles could be checked for removal.

5.3 Implementation practices

As shown in the first column of Table 1, the mean of usage frequencies of implementation practices is 66% based on company-specific Internet artifacts and 100% based on the survey. This category of practices is the most used practices in industry based on our result. When a company uses feature toggles, the development team implements the code of feature toggle including a mechanism to store the values of the toggle, select the type of the assigned value, and determine how to access the value.

For “Type of assigned values”, 50% of the companies use more than one identified way (string, boolean and multivariate) based on company-specific Internet artifacts; and based on the survey’s result, 53% of survey’s respondents use more than one way. For “Ways of accessing the values”, all of the companies that mentioned the way of accessing the values use “managers” based on company-specific artifacts, but 47% of the survey’s respondents use more than one of the identified ways.

For “Store type”, using a configuration file is more popular than using databases in the company-specific Internet artifacts; but the survey’s responses indicate that databases and a combination of configuration files and databases
are most used. We allowed respondents to add their own answer for this question, and three respondents mentioned “using a third party service”, such as get values from LaunchDarkly servers. However, we did not realize this option in analyzing company-specific artifacts. We added this new store type to Table 1 for the survey responses.

The difference between usage frequencies of practices based on the Internet artifacts and based on the survey’s responses shows that companies may change the implementation details of feature toggles over time and based on their experiences. Company-specific Internet artifacts mentioned the feature toggles implementation details in a time of publishing the artifacts, but the survey’s responses reflects the current implementation details.

5.4 Clean-up practices

An excess of toggles is one of the problems that the development team may face [3]. Sometimes an existing toggle that has not been used for a long time can cause severe damages. For example, the Knight Capital Group, as discussed in Section 1, went bankrupt due to the unintended activation of an old feature toggle. Companies may neglect clean-up activities. For example, Microsoft has no centralized process to clean-up the feature toggles; each team takes care of their feature toggles and decide when to remove them [12]. As discussed earlier, a negative consequence of using feature toggles is increased complexity and dead code, so removing unneeded toggles is necessary. However, based on the company-specific Internet artifacts and survey’s responses, the practices of the clean-up category are the least used category of practices. The mean of usage frequencies of clean-up practices are 4% based on company-specific artifacts and 38% based on the survey which is the lowest frequency category.

6 Limitations

In this section, the limitations of research are discussed.

6.1 Finding Internet artifacts

In Step One, we used a keyword search based upon five keywords to find Internet artifacts and selected links that were related to the use of feature toggles in software development from search results. We also followed links and references to other artifacts in selected links. We may have missed Internet artifacts related to feature toggles.

In Step Three, we searched for company-specific artifacts based the companies found in the initial Internet artifacts. Data from companies who have not shared their results on the Internet are not included in our study.
6.2 Identification of Practices and Categories

In Step Two, we did not use any automatic technique or tools to identify practices. We may have missed some practices which were mentioned implicitly in Internet artifacts.

Another limitation is lack of examples of using feature toggle practices. Practitioners mentioned most of the practices with no concrete example so we do not have enough examples to mention in the paper.

In addition, testing practices are not identified and mentioned in the list of practices. Testing of the system which has feature toggles has different aspects, such as unit testing of feature toggles, testing all combination of feature toggles enabling and disabling and testing dependent feature toggles. Another study should be conducted to cover testing concerns and practices when a development team use feature toggles.

6.3 Extraction of Practice Usage from Company-specific Artifacts

In Step Four, we reviewed company-specific artifacts to extract feature toggle practices usage. If the practice was not mentioned in the artifacts, we cannot conclude that the company does not use the practice. To overcome this limitation, we conducted the survey to gather more information about usage of feature toggle practices in companies.

6.4 Follow-up Survey

In Step Five, we found contact information of individuals associated with company-specific artifacts or who were release managers or developers of the companies. The contact information for some of the individuals could not be found or was old and out of date. To overcome this limitation, we found contact information of current development team members, such as release manager or developers of the companies, using company website or social media pages, such as LinkedIn. Additionally, the small sample size of the survey was a limitation.

7 Conclusion and Future Work

Feature toggles are a technique often used by companies who practice CI/CD to integrate partially-completed features into the code, conduct a gradual roll out, and/or to perform experiments. However, the development practices used by these organizations have not been enumerated in prior research. We performed qualitative analysis of 109 Internet artifacts. We identified 17 feature toggle practices in four categories: Management practices, Initialization practices, Implementation practices, and Clean-up practices. We also quantified
the frequency of usage of these identified practices in industry by analyzing company-specific Internet artifacts and conducting a survey.

The most popular practice in each category is consistent across the company-specific Internet artifacts and survey responses. We observed that all of the survey’s respondents “Use a management system” to create and manage feature toggles in their code. “Use maintenance tools”, “Set up the default values”, and “Log changes” are three additional most popular practices in industry based on company-specific artifacts. The least used category of practices is Clean-up practices, even though cleaning-up the feature toggles helps with managing the added complexity to the code and removing dead code. Inattention to removing feature toggles can cause severe problems, such as what happened to Knight Capital Group.

The feature toggle driven development practices discovered and enumerated in this work could raise practitioners’ awareness of feature toggle practices and their usage in industry. Using the result of this paper could help practitioners to use feature toggles in their projects better, which was the goal of doing this work. We got feedback from some of the respondents to the survey that the clean-up practices seem interesting, and they decided to use identified practices in their companies after participating in the survey.

The identified feature toggle practices discovered through this work can enable future quantitative analysis to automatically identify practice use in code repositories. Additional future work involves the automatic identification of feature toggle bad smells in the code, such as unused feature toggles, nested feature toggles, and development of a tool to automatically refactor the code when bad smells are identified. Also, the quality of parts of the code which is activate or deactivate by feature toggles is one of the concerns mentioned by practitioners [26]. Studying the impact of using feature toggles on code quality, such as high cohesion and low coupling, could also be a future work.

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Appendix

The survey questions are as follows:

1. What is your company name?
2. How long has your team used feature toggles?
3. What feature toggle management system is used by your team? (Check all that apply). Options: Closed source custom system maintained by the company; Open source custom system maintained by the company; Third party (e.g. LaunchDarkly), Open source but not maintained by the company; None; Other.
4. For what purpose(s) does your team use feature toggles? (Check all that apply). Options: Support CI of partially-completed features; Dark launches; A/B testing; Gradual rollout; Other.
5. Does your team make decision about using feature toggles for each feature? Options: Yes. The team checks to find if using a feature toggle is necessary for the new feature; No. The feature toggle is always added when a new feature is added; Other.
6. How often does your team do the following management practices? Options: Always, Mostly, About half of the time, Rarely, and Never.
   - Using a maintenance tool (spreadsheet, etc) to manage data about feature toggles. (i.e. the owner of the toggle, the current value (on, off), the current status (to remove, keep) and the time of its creation).
   - Logging changes to toggle values/configurations (e.g. who changes which toggle and when, etc.).
   - Grouping toggles together in any way to simplify management or giving permissions (i.e. related toggles, other).
   - Allowing all team members (i.e. Q&A team) to have access to feature toggles and can make changes.
7. How often does your team do the following initialization practices? Options: Always, Mostly, About half of the time, Rarely and Never.
   - Determining the type (permission toggle, ops toggle, release toggle, experiment toggle, short-lived toggle, long-lived toggle) of the toggle at design step. (More information about types of toggles: [https://goo.gl/4okG5Y](https://goo.gl/4okG5Y))
   - Using naming conventions for toggles (similar to variable and function naming conventions).
   - Setting up a default value for toggle if toggle value is not found (i.e. toggle is off if its value is not found in the code).
8. How are the values of the toggles stored? (Check all that apply) Options: Configuration files; Databases; Other.
9. How are the values are assigned to the toggles in the system? (Check all that apply) Options: Assigned boolean values (True, False); Assigned multivariate values (e.g. Red, Yellow, Blue); Assigned string values (e.g. "disable-flash-3d", "enabled-flash-3d"); Other.
10. How does a developer access the toggle value in the code? (Check all that apply) Options: Value is accessed by checking a primitive data type (e.g.
enableMyFeature == true); Value is accessed through an object representing a toggle (e.g. MyFeature.isActive()); Value is accessed through a toggle manager/mapping from key to value (e.g. Dictionary); Other.

11. How often does your team do the following clean-up practices? Options: Always, Mostly, About half of the time, Rarely and Never.

– Limiting the number of existing toggles in the code.
– Build or test failing if a toggle is not deleted by a specified date (Time bomb).
– Automatic reminders near date to delete the toggle.
– Using tasks/stories/cards for removing toggles.
– Creating a clean-up branch for removing toggle points at the time of creation of the toggle.
– Tracking unused toggles for removal.
– Changing feature toggle to configuration setting to keep it in the code.
Table 2  38 Companies and their usage of identified practices from company-specific artifacts

| Company       | Use management systems | Use maintenance tool | Log changes | Give access to team members | Determine applicability of feature toggle | Group the feature toggles | Set up the default values | Use naming convention | Determine the type of the toggle | Type of assigned values | Ways of accessing the values | Track unused toggles | Add expiration date | Change a feature toggle to a configuration setting | Create a cleanup branch |
|---------------|------------------------|----------------------|-------------|-----------------------------|------------------------------------------|---------------------------|----------------------------|-------------------------|----------------------------------|------------------------|-----------------------------|---------------------|-----------------------|------------------------------------------------|------------------------|
| Airbnb        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Apiary        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| AppDirect     | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Behalf        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| CircleCI      | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Checkr        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| commercetools | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Domain        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Dropbox       | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Envoy         | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Etsy          | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Facebook      | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| FINN.no       | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Flickr        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| GoPro         | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Google Chrome | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| IBM           | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Instagram     | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| InVision      | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Librato       | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Lyris         | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Main Street Hub | ✓                    | ✓          | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Microsoft     | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Outbrain      | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Pinterest     | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Rally Software | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Reddit        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Slack         | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Soluto        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Surfline      | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| ThoughtWorks  | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| thredef      | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Travis-CI     | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Twilio        | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Upserve       | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Visa          | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| WePay         | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Wix           | ✓                      | ✓                    | ✓           |                             |                                          |                           |                            |                         |                                  |                        |                            |                    |                       |                                                             |                        |
| Total (38)    | 32                     | 25                    | 21          | 7                           | 8                                     | 2                         | 22                        | 5                         | 1                                 | 32                    | 28                         | 15                  | 2                     | 6                     | 0                     | 0                     |