

How Do Programmers Use Optional Typing? A Case Study

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Abstract

One of the most important things to be taken into account when choosing a programming language is its typing system, static or dynamic. This question has become increasingly more important due to the recent popularization of dynamic languages such as Ruby and JavaScript. This paper studies which are the most influencing factors for a programmer when choosing between typing systems. An analysis of the source code of over seven thousand projects written in Groovy, a programming language where one can mix static and dynamic typing freely, shows in which situations programmers prefer a typing system over the other. Results of this study suggest that the previous experience of the programmer, project size, complexity of modules, scope and visibility of statements are some of the most important factors in this decision.

Categories and Subject Descriptors D.2.3 [Software Engineering]: Coding Tools and Techniques

General Terms Experimentation, Language

Keywords Type systems, static analysis, Groovy and GitHub

1. Introduction

When choosing a programming language for a project, a developer considers several characteristics of that language. One of the most important is its typing system, which can be static or dynamic. The typing system determines when the type of a statement is defined [11]. Statically typed languages, such as Java and C#, require the type of a statement to be defined by the programmer, which can then be used by the compiler to check for any typing errors. On the other side, in dynamically typed languages, like Ruby and JavaScript, the definition of the type of a statement only happens during run time.

The discussion about what is the best typing system has become increasingly more important in recent years due to rapid popularization of dynamically typed languages. According to The TIOBE Programming Community Index [1], a well-known ranking that measures the popularity of programming languages, 27% of the programming languages in the industry are dynamically typed. In 2001, this number was only 17%. Among the 10 languages on top of the ranking, four are dynamically typed: JavaScript, Perl, Python

and PHP. In 1998, none of these languages was among the top 10 ranking.

Several factors may be considered when choosing between a dynamically or statically typed language. Since dynamically typed languages are simpler, they allow programmers to perform their tasks more quickly [11] and adapt to changing requirements [13]. Also, by removing the repetitive work of defining types, these languages allow their users to focus on the problem to be solved rather than spending time with the rules of the language [12].

Statically type languages also have their advantages. These allow compilers to look for type errors [9]. Typed declarations increase the maintainability of systems because they document the code, informing the programmer the nature of each variable [4, 10]. Systems built with these languages tend to be more efficient since they do not need to perform type checking during their execution [2, 5]. Finally, modern development environments, such as Eclipse and IDEA, are able to assist programmers with functionalities such as code completion based the information they get from statically typed declarations [3].

This paper presents a study aiming to understand which factors actually influence the decision of a developer for typing their declarations or not. This question was studied based on the analysis of a massive dataset with more than seven thousand projects. These projects were written in Groovy, a language with a hybrid typing system which allows developers to choose, for each statement, either to type or not. Through a static analysis of these projects, it was possible to understand when developers choose each type system and then extract what are the factors that influence this decision.

The remainder of this paper is organized as follows. Section 2 introduces the main concepts of the Groovy program language. Sections 3 and ?? describe the configuration of the study and its results. Section 6 discusses threatens to validity and section 7 shows related work. Finally, section 8 concludes this study and suggests future works.

2. The Groovy Language

Groovy is an object-oriented programming language designed to run on the Java Virtual Machine. Its adoption has grown remarkably over the last years, specially among Java developers who seek more dynamism without having to learn a completely new language. It builds upon the strengths of Java, but has additional features inspired by dynamic languages such as Python and Ruby. Groovy type system is flexible and allows programmers to optionally type their statements. This makes Groovy an ideal language for a case study about how programmers choose between using or not typing in their code.

Despite having been launched less than ten years ago, Groovy is already a very popular language. According to the TioBE Programming Index, Groovy is the 22st most popular language in the software industry [1], ahead of languages like Prolog, Haskell and Scala.

The syntax of the Groovy language is similar to Java's and most of Java syntax is also valid in Groovy. Like Java, Groovy code is compiled to bytecode, allowing it to seamlessly integrate with existing Java classes and libraries. These factors have attracted a large number of Java programmers who want to use Groovy's dynamic functionality without having to learn a completely different language or change the execution platform of their systems.

Groovy was designed to be more expressive and concise than Java. Below we show two implementations of a simple algorithm. Given a list of numbers, return a list containing only the even numbers of that list. Listing 1 shows the Java implementation while Listing 2 shows the Groovy counterpart.

Since Groovy has more expressiveness, it is able to reduce much of the boilerplate required in Java. Consider Listing 2. Note that Groovy offers a native syntax for lists (lines 3, 6 and 14) and operator overloading (line 6). Semicolons are optional, except when there are multiple statements in the same line. When the keyword *return* is omitted (line 10), the last expression evaluated with a method is returned. Also, parenthesis in method calls can often be omitted (line 16). In addition to that, Groovy implicitly imports frequently used classes, like those of the *java.util* package, and methods, like *System.out.println* (line 16).

Listing 1 A simple algorithm written in Java

```

1  import java.util.ArrayList;
2  import java.util.List;
3
4  public class JavaFilter {
5      List<Integer> evenNumbers(List<Integer>
6          list) {
7          List<Integer> result = new ArrayList<
8              Integer>();
9          for(int item : list) {
10             if(item % 2 == 0) {
11                 result.add(item);
12             }
13         }
14         return result;
15     }
16
17     public static void main(String[] args) {
18         List<Integer> list = new ArrayList<
19             Integer>();
20         list.add(1);
21         list.add(2);
22         list.add(3);
23         list.add(4);
24
25         List<Integer> result = new JavaFilter().
26             evenNumbers(list);
27         System.out.println(result);
28     }
29 }
```

Groovy's design was influenced by dynamic features of programming languages such as Ruby and Python. Listing 3 shows how these features can be used to rewrite the same algorithm presented in Listing 1 in a single line of code. First, notice that the code shown in Listing 3 is a script, rather than a class file. It makes use of a closure to allow a programmer to define a filter logic. This closure is passed down to the *findAll* method, which will apply this closure to every element of the list in order to decide if that element should be returned or not. Closures are one of the most important

Listing 2 A simple algorithm written in Groovy

```

1  class GroovyFilter {
2      List<Integer> evenNumbers(List<Integer>
3          list) {
4          List<Integer> result = []
5          for(int item : list) {
6              if(item % 2 == 0) {
7                  result << item
8              }
9          }
10         result
11     }
12
13     public static void main(String[] args) {
14         List<Integer> list = [1, 2, 3, 4]
15         List<Integer> result = new GroovyFilter
16             ().evenNumbers(list)
17         println result
18     }
19 }
```

features of Groovy compared to Java. They allow a functional programming style of code, which is both expressive and powerful.

Listing 3 A class written in Groovy

```
println([1, 2, 3, 4].findAll {it % 2 == 0})
```

Metaprogramming is another dynamic feature present in Groovy. Listing 4 shows how to add a method to an existing class dynamically. By adding the method *evenNumbers()* to the *List* class, it is possible to achieve higher expressiveness. This is specially useful when implementing Domain Specific Languages [19].

Listing 4 An example of metaprogramming in Groovy

```

1  List.metaClass.evenNumbers = {
2      delegate.findAll {it % 2 == 0}
3  }
4  println([1, 2, 3, 4].evenNumbers())
```

When Groovy 1.0 was first launched, in 2007, it was a purely dynamically typed language. However, it allowed programmers to optionally type their statements. Examples of typed and untyped declarations combined flexibly in the same file are shown on Listing 5.

This kind of typing should not be confused with static typing since Groovy compiler will not use these type annotations to look for errors. For example, the snippet of code shown in Listing 6 compiles without any errors. During runtime, the *string* variable will reference an instance of the *Integer* class. However, an exception will be thrown when we try to invoke the method *toUpperCase* since the *Integer* class does not have this method.

Since version 2.0, Groovy allows programmers to explicitly activate static typing with the usage of the *@TypeChecked* annotation. This makes Groovy a gradually typed language [14–18]. In this mode, the Groovy compiler will look for type errors and fail if it finds any.

Listing 7 shows an example of static typing in Groovy. Trying to compile the class *TypeCheckedGroovyClass* will produce an

Listing 5 Groovy is a dynamic language

```
1 class DynamicTyping {
2     private String typedField
3     private untypedField
4
5     DynamicTyping(typedParam) {}
6
7     def untypedMethod(untypedParam, int
8         typedParam) {
9         def untypedVariable = 1.0
10        return untypedVariable
11    }
12    int typedMethod() {
13        String typedVariable = ""
14        return typedVariable
15    }
16 }
```

Listing 6 A class written in Groovy

```
String string = new Integer(1)
string.toUpperCase()
```

error since the method *sum* is supposed to receive two parameters with the type *int*, but is called with two parameters of the type *String*.

Listing 7 A class written in Groovy

```
1 @TypeChecked
2 class TypeCheckedGroovyClass {
3
4     static int sum(int a, int b) {
5         a + b
6     }
7
8     public static void main(String[] args) {
9         println sum("1", "2")
10    }
11 }
```

The *@TypeChecked* annotation is reasonably recent and most Groovy programmers still do not use it. Typing annotations on the other side are very popular. Although they do not provide static type checking, they are capable of documenting the code and aiding in the integration with development tools.

3. Setudy Settings

In this paper, we want to understand what are the factors that have an actual influence over the decision of a developer to type their declarations or not. In order to answer that question, we analyzed a series of Groovy projects. Groovy allows programmers to choose whether to type or not each of their statements. By finding out when programmers choose to use types or not, we can infer what is the factor that has influenced such choice.

A case study is the best approach to analyze this question since it provides us with actual data from programmers in their regular activities. In order to obtain reliable results, however, we need a

large number of projects. Fortunately, it was possible to retrieve a massive dataset with more than 7 thousand projects from GitHub, a popular source control service. A static code analyzer was developed to analyze typing usage in these projects and these results were analyzed in conjunction with other data about these projects such as the project size and the programmers background.

In the remainder of this section, we formalize the research questions in subsection 3.1. The Data Collection procedure is described in subsection 3.2 while the dataset itself is discussed in subsection 3.3. Finally, we discuss the static code analyzer and the analysis procedure in subsection 3.4.

3.1 Research Questoins

In this study, we want to understand, from a practical point of view, what are the factors that influence programmers on the choice for using or not types in a programming language with optional typing. Based on the known facts about statically and dynamically typed languages, we propose the following questions, which we will try to answer by analyzing the source code of a series of Groovy projects:

- **Question Q1: Do programmers use types to implicitly document their code?** By typing their statements, developers are telling other developers about the nature of those statements. This increases the readability and, hence, the maintainability of their code. If we are able to observe a higher usage of types in statements that usually require more documentation, then we can assume that these developers indeed consider types as a means to document their code.
- **Question Q2: Are untyped declarations preferred when readability or stability are not a concern?** Besides readability, typing also contributes to stability. It reduces the risk of unexpected effects of modifications increasing the maintainability of the software system [28]. Our hypothesis is that, where these aren't important factors, typing becomes less necessary and developers will prefer the flexibility and objectivity offered by dynamic typing.
- **Question Q3: Does the previous experience of programmers with other languages influence their choice for typing their statements?** We believe that programmers used to a statically typed language will keep using types since they are used to it.

3.2 Data Collection Procedure

The projects used in this study were obtained from GitHub, a popular source control service based on Git. For each project, it was necessary to retrieve its source code, its metadata, and the metadata of all developers involved in that project. GitHub does not offer a listing of all hosted projects, but it offers two search mechanisms, a REST API and a web based search page. Unfortunately GitHub's API is too limited for our requirements. It imposes a limit of one thousand results and does not allow filtering projects by their programming language.

In order to retrieve a expressive dataset, it was necessary to write a bot to interact with GitHub's webpage and search for projects. Some special care was necessary to make this strategy work. Because the number of results is limited to 1 thousand projects, we had to segment the queries. Multiple requests were made. Each request asked for the name of all projects created on a given month and results were combined. Another problem faced was that GitHub denies excessive requests from the same client. By adding a 10 seconds delay between requests, it was possible to overcome this limitation.

With the name of all projects in hands, it was then possible to use GitHub's REST API to query for the metadata of all projects. Since the metadata of a project also contains the id of the develop-

ers of that project, it was possible to obtain the metadata of those developers using GitHub's REST API.

3.3 Dataset

Our dataset consists of 7268 obtained from GitHub. These projects add to a total of 9.8 million lines of code and approximately 169 thousand Groovy files. There are about 412 thousand declarations considering variables, methods and fields. Projects have between 1 LoC and 150 KLoC. The age of a project, defined as the time between the the first and last commits, varies form 1 day to 5 years. The distribution of the size and age of the projects are shown in Figures 1 and 2 respectively.

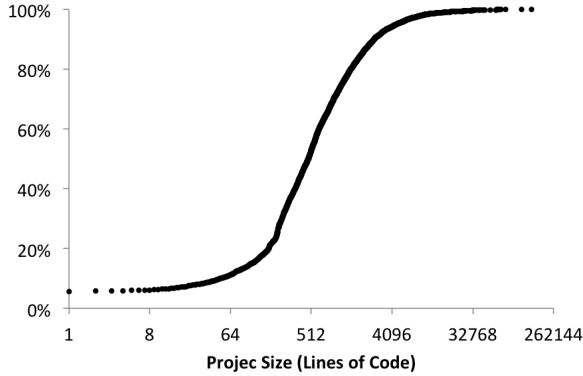


Figure 1. Cumulative Distribution of the Size of the Projects

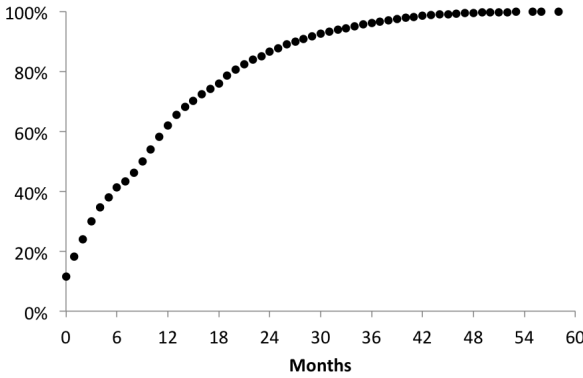


Figure 2. Cumulative Distribution of the Age of the Projects

The projects in our dataset were developed by 4481 prople. While most projects were developed by a single programmer (Table 1), there are projects with up to 58 developers. These developers have different backgrounds. Figure 3 shows what are the other languages used by these developers in other GitHub projects. Java is the most popular among them. More than 50% of the developers of projects in our dataset also have Java projects on GitHub. Figure 4 shows the background of these developers in terms of the type system of the other languages they have used.

3.4 Analysis

In order to understand where programmers use types, a static code analyzer was built. It is based on the Groovy metaprogramming library, which is capable of compiling Groovy files and generate an abstract syntax tree (AST) for them. This static code analyzer can analyze the following types of declarations:

Table 1. Distribution of the Number of Developers

Number of Developers	Fraction of Projects
1	84%
2	9%
3	3%
4 or more	4%

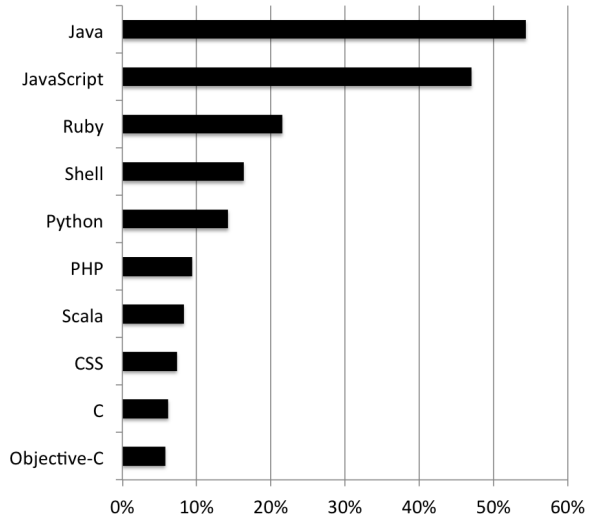


Figure 3. Usage of other languages by Groovy developers on GitHub

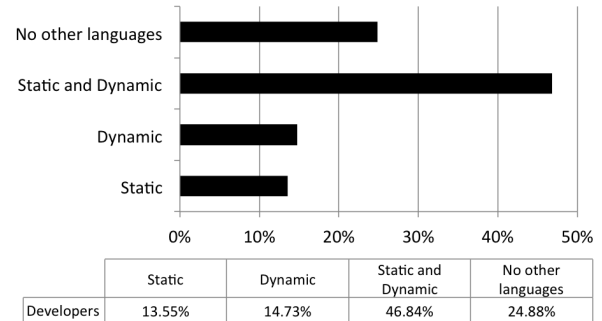


Figure 4. Type System of other languages used by programmers

- Return Methods
- Method Parameters
- Constructor Parameters
- Fields
- Local Variables

In addition to that, it can answer the following questions for each statement

- What is the typing system of the statement?
- Is the statement part of a script or a class?
- Is the statement part of a test class?
- What is the visibility of the statement? (except for local variables)

We opted for not compiling projects. This would require us to resolve all dependencies, which many times is impossible. This is even harder when we consider the dimension of our dataset. Instead, we generated the AST for each file using the *CONVERSION* phase of the Groovy compiler. At this phase, the compiler hasn't tried to resolve any dependencies yet, but it is capable of generating an AST with sufficient information to determine the type system of each statement. This makes it possible to analyze each Groovy file separately without having to compile the whole project.

The downside of the approach described above is that we can't analyze Groovy code in conjunction with its dependencies. For example, it is impossible to answer if programmers tend to type code that interacts with other typed modules since we haven't resolved any dependencies to these modules. However, this was fundamental in order to execute a study with such an expressive dataset. Nevertheless, as we will see in the next section, we were still able to obtain detailed and relevant results using this strategy.

4. Results

In this section we present the results of the analysis of the declarations of the projects described in section ???. These results will be discussed in more details in section 5.

The analysis shows that 61% of the statements are typed, while only 39% of these are dynamically typed. This results considers all declarations of the 7268 projects in the dataset.

4.1 Declaration Type

Figure 5 shows the amount of typed and untyped declarations for each type of declaration. Untyped declarations are far more frequent in local variables that in other types of statements. Fields, method returns and parameters on the other side are mostly typed. In particular, constructor parameters are typed in more than 90% of the declarations.

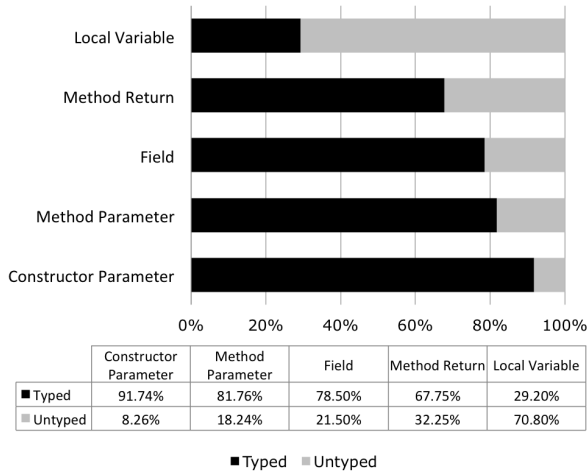


Figure 5. Type Systems by Declaration Type.

4.2 Visibility

In this section, we break down the results shown above by visibility. Figure 6 shows results for method returns. There is little difference in the usage of types on the declarations of the return of private and public methods, with 64.44% and 67.26% declarations typed respectively. On the other side, the return of protected methods, are almost always typed.

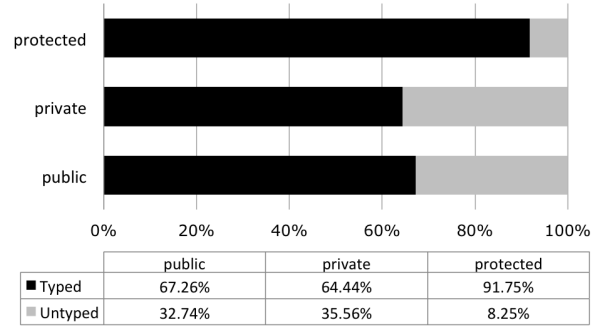


Figure 6. Method return declarations by visibility

Figure 7 shows the results of the analysis of method parameter declarations. Compared to the results for method returns shown in figure 6, declarations of public method parameters are typed more often. While public method returns have types in 67.26% of the times, public method parameters have more than 80% their declarations typed. The usage Parameters of constructors, shown in Figure 8, present a similar behavior to that of parameters of methods.

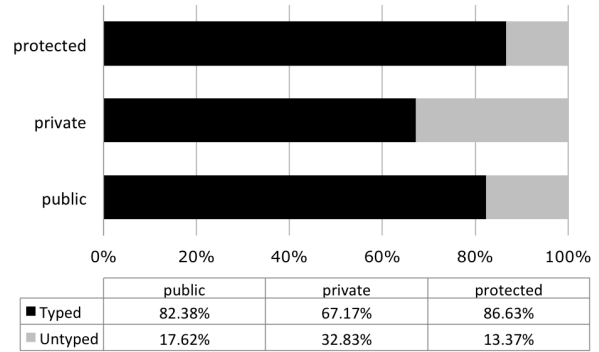


Figure 7. Method parameter declarations by visibility

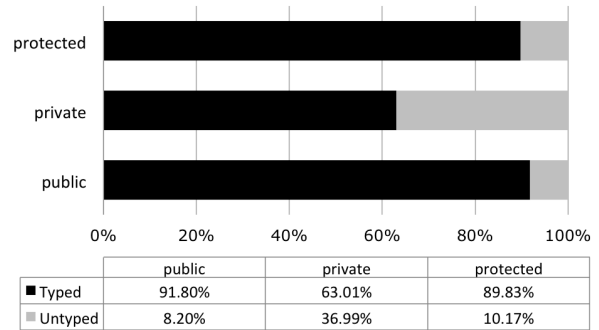


Figure 8. Constructor parameter declaration by visibility

Figure 9 shows the results for field declarations. Differently from previous analyzed declarations, protected fields are significantly less typed than public fields. While the first is typed in 88.8% of the cases, 80.5% of the latter are typed. Another difference is that private fields are slightly more typed than other private declarations. While this frequency is 72.4% for private fields, method

returns, method parameters and constructor parameters do not get typed more than 67% of the time.

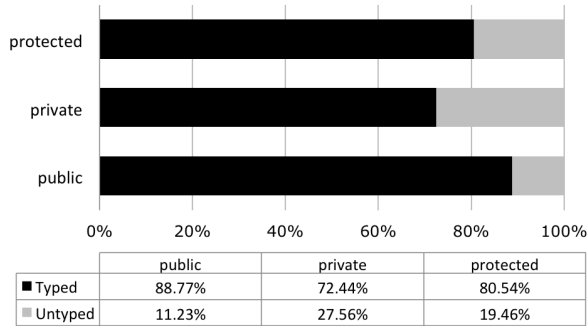


Figure 9. Field declaration by visibility

In summary, for all types of declarations, private declarations are less typed than the public and protected counterparts. Protected declarations, on the other side, are usually the most typed. The only exception to this are fields, where the usage of types in public declarations surpasses those of protected declarations by 8%.

4.3 Project Size

In this section we show how the use of types in declarations varies as projects grown in size. The project size is a simple metric to measure the complexity of a project. Usually, the larger the project, the greater the number of modules and and the need for maintenance [29].

Results are shown for public, private and protected declarations (Figures 10, 11, 12 respectively) and local variables (Figure 13). In these graphs, each bar shows the average usage of untyped declarations of projects grouped by their size. The boundaries of each group are defined under each bar. For example, a project with 1500 lines of code is in the fifth group, since 1500 lies within the interval [1024, 2048]. Notice that we are using a logarithm scale for the project size in these graphs.

Types are less used in public declarations as project size increases. While projects with less than 1024 lines of code have almost 40% of their declarations untyped, this number is less than 20% in projects with over 65536 lines of code. Figures 11 and 12 show that, different from public declarations, private and protected declarations have no apparent correlation with the project size.

Conversely, the use of untyped declarations in local variables increases with the project size. This is shown in figure 13. The average frequency of untyped local variable declarations in projects with less than 512 lines of code is less than 40%. On the other side, in projects with over 65536 lines of code, the average frequency for this type of declaration exceeds 70%.

4.4 Test Classes

In this section, we analyze how types are used in test classes. Table 14 shows that declarations in this type of code are 14% less typed when compared to declarations in other types of classes.

4.5 Scripts

In this section we analyze how types are used in script files. Differently from last section, Table ?? shows that there is no significant difference between declarations in this type of code and declarations in class files.

4.6 Programmers Background

Figure 16 shows how programmers use types in their statements according to the type system of the languages they have used on

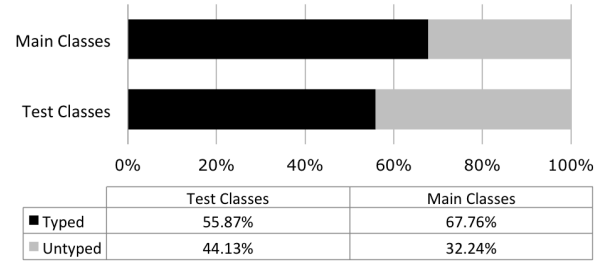


Figure 14. Declarations in test classes and main classes

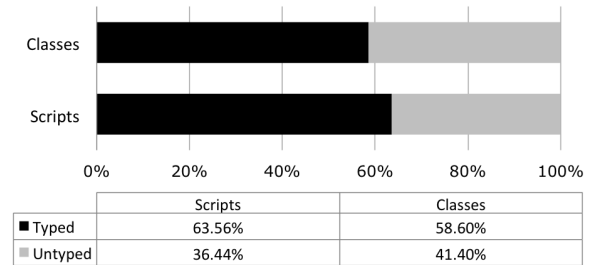


Figure 15. Declarations in scripts and classes

GitHub. Developers are distributed in three groups, those with only statically typed languages, those with only dynamically dynamic languages and those with both.

There is a clear distinction in the behavior of those whose all projects are written in statically typed languages. These programmers use types in about 28% of their statements compared to 40% of the other programmers. Notice that the behavior of those programmers with only dynamic languages on their portfolio is no different from those with statically and dynamically typed languages.

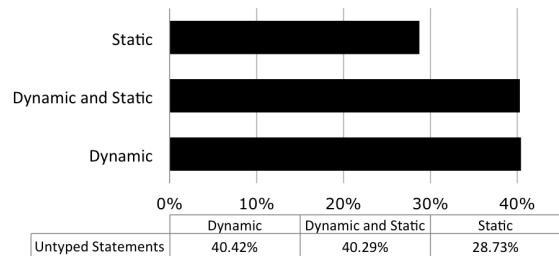


Figure 16. Programmers Background and Usage of Untyped Declarations

5. Discussion

In this section, we discuss the questions proposed in Section 3.1 based on the results above. We were able to find evidence to support an affirmative answer for all 3 questions. Section 5.1 shows that documentation is the main reason why Groovy developers use types, specially on the definition of their modules. An analysis of local variables, private statements and test classes in Section 5.2 supports the suspect that untyped declarations are used more frequently when readability or stability aren't a concern. Last, Section

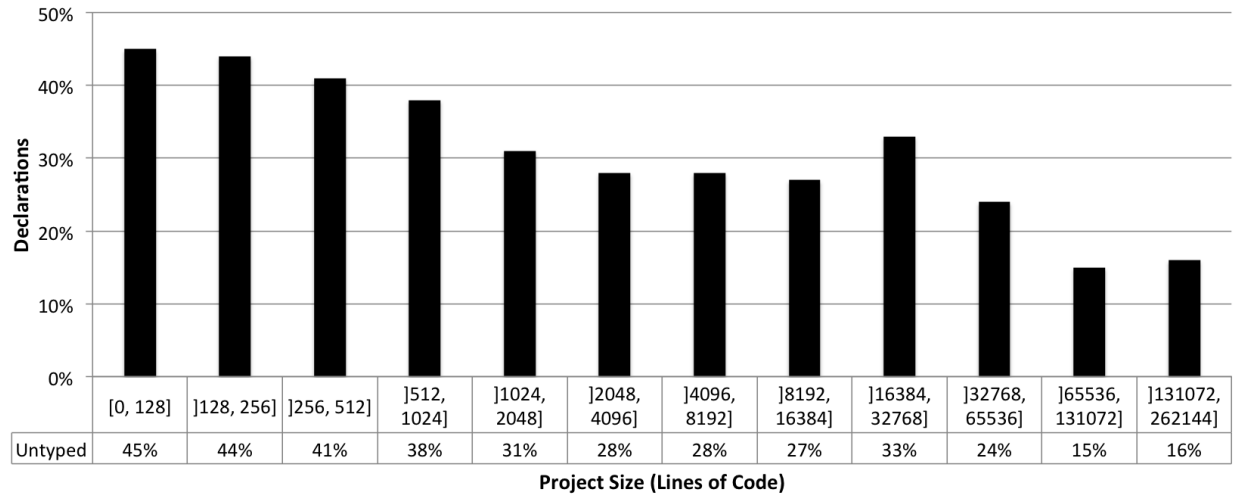


Figure 10. Untyped public declarations

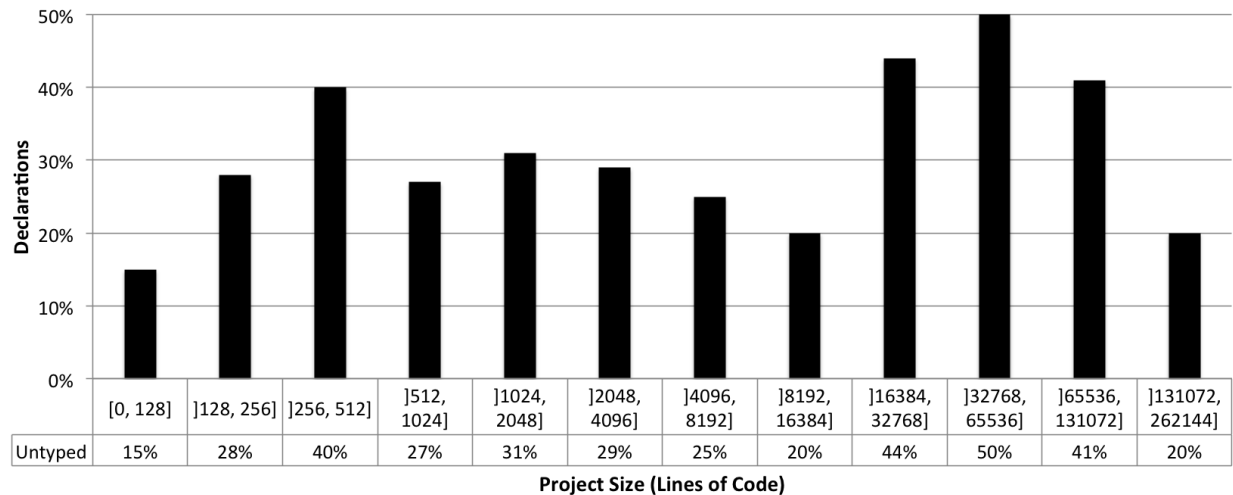


Figure 11. Untyped private declarations

5.3 shows how programmers with experience on statically typed languages use types more frequently than other programmers.

5.1 Types as implicit documentation

Well documented code plays an important role in making code more readable, hence improving the code overall maintainability [28]. By analyzing the results presented in Section 4, we were able to find evidence that this is an important factor considered by Groovy programmers.

Documentation is the main reason why Groovy programmers type their code. It is well known that the main advantages of using statically typed languages are implicit code documentation, static

type verification and execution performance. Groovy however is not a statically typed language, but a dynamically typed language with optional typing (we are not considering the `@TypeChecked` annotation in this study). This means that Groovy compiler can't verify types statically and that types still have to be checked during execution, which degrades runtime performance. Hence from the usual advantages of using a statically typed language, only code documentation holds true for Groovy. Considering the result shown on previous section, which shows that 60% of all declarations are typed, this means that code documentation is an important matter for Groovy developers.

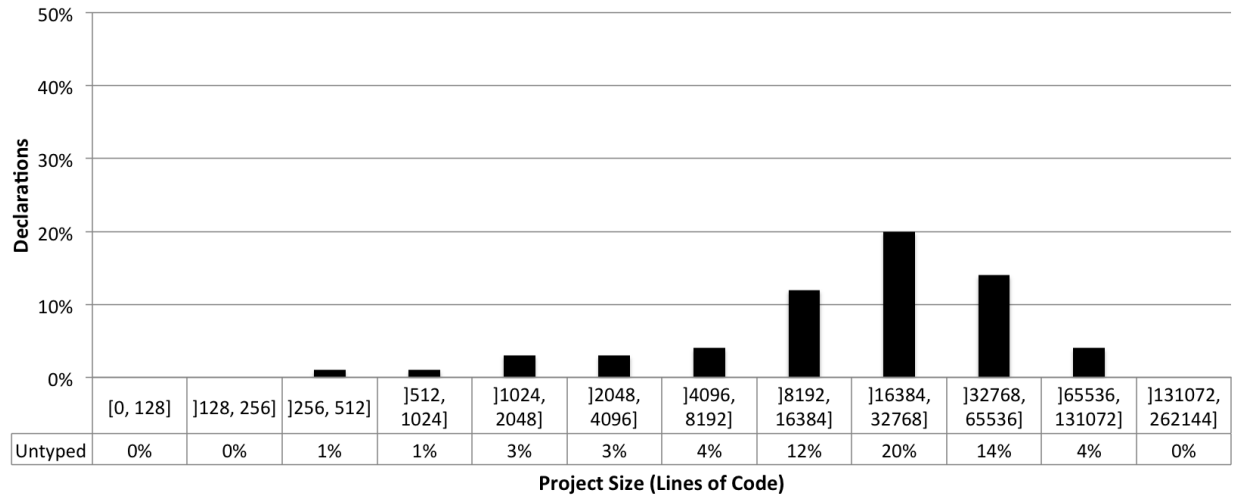


Figure 12. Untyped private declarations

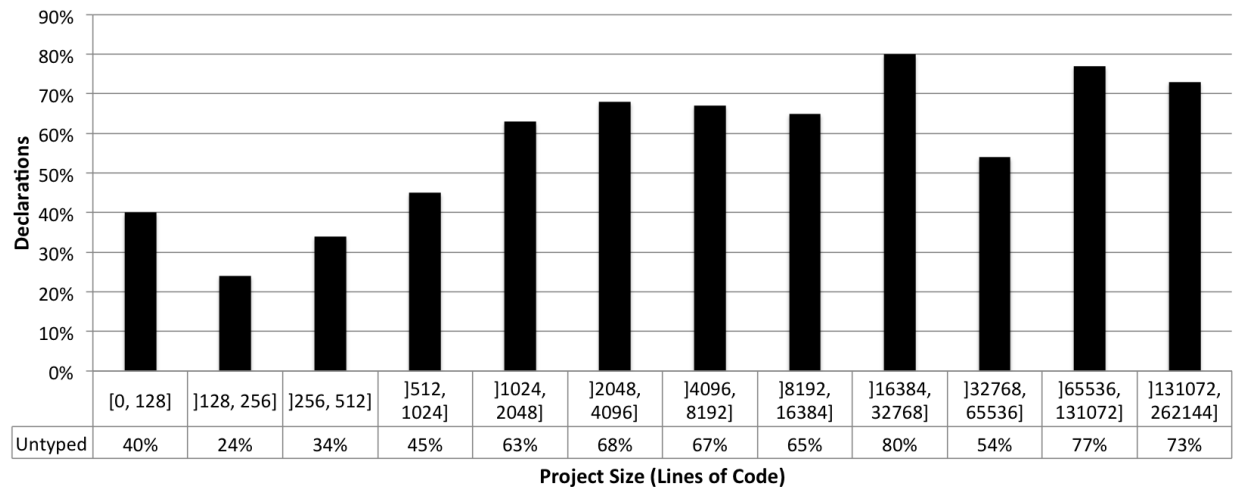


Figure 13. Untyped local variables

It is possible to observe an even higher usage of typing in the definition of modules. As mentioned in the literature [20–25], types greatly aid in the definition of the contract of a module. They restrict the pre and post conditions of methods and define the nature of the properties of that module. Clients of an well typed module will learn how to use it faster and make less mistakes since the contract of that module is clear to them.

Statements that define the interface of a module, i.e, fields, returns and parameters of methods and parameters of constructors, are more typed than the average. Consider Figure 5. While most of these elements are typed, only 30% of the local variables, which do not contribute to the definition of a module, are typed. On the

other side, parameters of constructors, which are some of the most important elements of a contract definition, are almost always typed

Section 4.2 further refines the results presented above. Figures 6, 7, 8 and 9 show how programmers type their declarations by visibility. These results contribute to the understanding that types are indeed considered more often on the definition of modules. First, notice that private statements are always less typed than their public and protected counterparts. Private statements are similar to local variables since they do not contribute to the interface of a module and are only accessible to the module where they were defined. In this case there is a smaller need for documentation and programmers do not feel as compelled to use types.

Public and protected elements define the interface of a method and thus are widely typed. In the case of parameters and returns of methods, the usage of types in statements with protected visibility surpasses that of statements with public visibility. In Groovy, protected declarations restrict access to internal elements of a class to its subclasses or other classes in the same package. It can be argued that the relationship between these classes is tightly coupled [27]. Apparently programmers understand that this type of contract is more delicate than others and that it should be well documented.

The usage of types in public declarations is heavily influenced by the project size. Figure 10 shows this clearly. In projects with more than 65KLoC, these untyped declarations are seen with less than half the frequency observed in the smallest projects. However, no particular pattern can be observed for private or protected declarations, represented by Figures 11 and 12.

Intuitively, the larger the project, the greater the difficulty of integration and the need for maintenance. This is more critical in public statements. Unlike private or protected statements, the number of modules to which a public statement is visible grows with the project size. This suggests that as projects grow, programmers will consider that the documentation of public elements is more important and will consider typing these declarations more often.

The project size has an opposite effect on the declarations of local variables. While public declarations get typed more often, the frequency of types in local variable declarations decreases. It is hard to tell the reason for this behavior. A possible explanation is that, as project grows, developers get more used to flexibility and objectivity of dynamic typing. They stop typing their declarations unless they understand they are really necessary.

5.2 Less typing when readability and stability aren't a concern

When readability or stability are not a concern, the advantages of typing become less apparent and programmers prefer the flexibility and objectivity of untyped declarations. This is what we found when we analyzed how typing is used in local variables, private statements and test classes. These are scenarios we consider readability and stability to be less relevant.

Most local variables are untyped. Figure 5 shows that less than 30% of these variables are declared with a type, a value significantly smaller than the overall result for all declaration types, 60%. It can be assumed that typing local variables does not aid in the readability of the code as much as in other types of declarations. The value of a local variable is defined very close to its declaration, usually in the same statement. This makes it easier for a reader to understand the nature of a given variable and even infer its type. Programmers can be more objective in this scenario and eliminate the repetitive work of typing their variables.

Local variables have a smaller scope and life cycle. They are only visible inside the block where they were instantiated and are destroyed once the execution of that block is over. Stability in this scenarios is not as critical making the flexibility of untyped declarations more apparent. For example, one can easily change the type of a local variable without having to worry about its use anywhere else.

A similar conclusion can be derived for private statements. As shown in Figures 6, 7, 8 and 9, untyped declarations are much more common in in these statements than in their public or private counterparts. Private statements are usually more stable than others. Since they are only visible inside the class they were defined in, they can often be changed without having any unexpected effects outside that class. Also, since those statements are only referenced inside the class where they were defined, a reader can easily find those references and use them as a means to understand the code.

Another scenario with smaller need for readability and stability are test classes. These classes usually have simple relationships with the rest of the project, not having any clients and depending only on the classes under test. Test code is frequently considered a peripheral artifact of a software project and programmers usually do not worry about keeping the quality of such code [26].

Test classes are also typed less often than the usual. Figure ?? shows that declarations made inside the main classes of a project are typed in 68% of the cases. On the other side, only 56% of the test classes are typed.

A counter example to this analysis is the usage of types in scripts. It can also be said that readability and stability are not big concerns in scripts. These are pieces of code usually written to solve punctual problems. They do not establish complex relationships with other modules and aren't reused very often. Nevertheless, as shown in Table 15, there is no significant difference between the overall usage of types in scripts and classes.

5.3 Previous experience of programmers

Results indicate that the answer for Q3 is affirmative. The choice for using types on a language with optional typing, such a Groovy, is in fact influenced by the experience with other languages. Those developers who have only static languages on their GitHub portfolio will leave their statements untyped less often than other developers. Figure 16 shows that these developers have only 28.7% of their statements untyped compared to 40% of those developers with dynamic languages on their portfolio.

It is clear that the portfolio of a GitHub developer might not represent well his real experience with other programming languages. This developer might have projects hosted somewhere else or have projects in his portfolio that he has barely participated at. However, due to the scale of this study, it is difficult to collect more detailed metrics for every user.

6. Threats to Validity

In this section, we discuss potential threats to validity. As usual, we have arranged possible threats in two categories, internal and external validity [30]. The main threats to the internal validity of this work involve the fact that, in such a large scale case study, we can't analyze data into much detail. In Section 4.6 we consider that the GitHub portfolio of a programmer represents well his experience with other languages and type systems. However, these programmers might have projects hosted somewhere else or projects in his portfolio that he hasn't worked on. In Section 4.3, we consider that the project size is a metric capable of representing the complexity of a project well. This is not always true [29], but that was the most effective metric we could use without requiring projects to be compiled, which would drastically reduce our dataset.

There are other variables that can have influenced the programmers besides the ones considered in this study. Some frameworks require programmers to use typed or untyped declarations in some cases. For example, one of the ways a programmer can create a mock on Spock, a popular Groovy testing framework, requires programmers to type the mock declaration. Also, tool integration might encourage programmers to use types for functionalities such as code completion. In addition to that, the previous experience of programmers, which we have shown to have influence over programmers, might interfere with analysis of other influencing factors.

In order to overcome the threats shown above, as a future work, we are planning a controlled study. This will provide us with more detailed information, which we can use to complement the results of this case study.

The results presented in this study can not be generalized for every scenario. Depending on the context, each developer might

find different reasons to type or not their declarations. Also, since we only analyzed public projects, we can not say that our dataset can represent projects developed inside an organization, which are mostly private projects.

7. Related Work

This work is based on a series of studies that compare different typing strategies. Although we are not aware of any studies that analyze this question using a large scale case study as ours, we are aware of multiple controlled experiments with significant results.

In [7], the author compares the performance of two groups of students asked to develop two small systems. Both groups used a language developed by the author, Purity. The only difference in the language used by the two groups was the typing system. One group used a statically typed version of Purity while the other used a dynamically typed version of the same language. Results showed that the group using the dynamic version was significantly more productive than the other. Similarly to this work, the author was able to compare two typing strategies directly while isolating any external factors. However, it can be argued that these results may not represent well real life situations of the software industry. This was a short duration study where students were used as examples of developers with no interaction with other programmers. In our study, we try to get more relevant results when analyzing source code developed by programmers during their normal activities.

In a follow up study [8], the authors got to opposite conclusions. They compared the performance of two groups of developers in maintenance tasks. The first group used Java, a statically typed language, and the other used Groovy, but restricting developer to use only untyped declarations in order to simulate a dynamically typed version of Java. In this case, the group using the statically typed language, Java, was much more productive. This contradiction with a previous work reinforces the argument that the results of controlled studies aren't reliable enough for this type of study.

In experiments conducted in [6], the authors compare the performance of two groups working on small development tasks. One group used Ruby, a dynamically typed language, while the other used DRuby, a statically typed version of Ruby. Results showed that the DRuby compiler rarely managed to capture any errors that weren't already evident for programmers. Most subjects involved in the study had previous experience with Ruby, which suggests that programmers get used to the lack of typing in their declarations. We tried to investigate this phenomenon, by analyzing how programmers use types depending on their experience with other languages.

8. Conclusions and Future Work

In this study, we investigated, from a practical point of view, what are the most influential factors on the choice of a programmer for using or not types. Understanding these factors can help programmers choosing the most appropriate programming language for a given context. It's also a valuable information for programming language designers who can base their design on real user data. To answer this question, we conducted a large scale case study with more than 7 thousand software projects written in Groovy, a dynamically typed language with optional type annotations.

We found evidence that programmers use types as a means to implicitly document their code. This tends to grow in the presence of some factors, such as the statement visibility, the complexity of the contract defined by such statement and the size of the project where it is defined. Conversely, when readability or stability aren't a concern, the simplicity and flexibility of untyped declarations seems to be preferred, as seen on local variables, private statements

and test classes. Another important factor is the previous experience of programmers with a given type system.

In future works we wish to analyze the influence of static and dynamic type systems over the robustness of software systems. In particular, we want to understand whether the use of dynamic typing, which limits the compiler's ability to find type problems, has any correlation with the occurrence of defects in the system and if the use of automated testing is able to reduce this correlation.

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