TEDDY: AN AUTOMATED TOOL FOR DETECTION AND SUGGESTION OF PYTHONIC IDIOM USAGE

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ABSTRACT

In the present day, software development has been one of the main focuses for Thailand 4.0 with the aim to integrate Technology and Industrialization. In this field, many programming languages are being used and each language has its unique format called coding idioms. For example, in Java, some of the coding idioms are not applicable to Python programming. When programmers switch between many programming languages, there might be some unfamiliarity that cause the produced program to drop in quality, or difficult to read and understand.

With the problems stated above, we had the idea of creating a software, named "Teddy", that helps in checking the quality during development of Python programs. Teddy helps programmers detect coding idioms within their source codes and report the usage of those idiomatic code snippets. Teddy is designed to offer two modes of operation - prevention and detection mode. The prevention mode supports real-time idiomatic code detection during code review time in pull requests, while the detection mode runs a thorough scan of idiomatic and non-idiomatic code over historical commits.

A series of tests and evaluation has been performed, using real software projects to assess the performance level of the implemented tool. It has been found that Teddy has high precision for detecting idiomatic and non-idiomatic Python code usage. The visualization can provide developers insightful information regarding the evolution of idiomatic and non-idiomatic Python code in their project. This will eventually allow the programmers understand more about idiomatic Python usage and also help naive programmers in their learning of Python language.

KEYWORDS: PYTHON, CODING IDIOMS, AUTOMATED ANALYSIS
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บทคัดย่อ

ปัจจุบันการเขียนซอฟต์แวร์เป็นหนึ่งในการตอบรับนโยบาย Thailand 4.0 ที่มีเป้าหมายในการพัฒนาประเทศโดยการประยุกต์ใช้เทคโนโลยีกับธุรกิจและอุตสาหกรรมภาคส่วนต่าง ๆ ของชาติ ซึ่งมีภาษาที่ใช้ในการเขียนซอฟต์แวร์ต่าง ๆ อยู่หลายภาษา แต่ละภาษานั้นจะมีรูปแบบการเขียนที่แตกต่างกันเรียกว่า สำนวนรหัส หรือ coding idiom ซึ่งบางครั้งสำนวนรหัสบางชุดจะมีรูปแบบเฉพาะตัวของแต่ละภาษาโปรแกรม ยกตัวอย่างเช่นการเขียนซอฟต์แวร์ด้วยภาษาโปรแกรมเชิงวัตถุ ในภาษาจาวาอาจมีสำนวนรหัสบางรูปแบบที่ไม่เหมาะสมสำหรับการใช้กับการเขียนซอฟต์แวร์ในภาษาไพธอน ด้วยความรู้ที่จำกัดของผู้พัฒนาโปรแกรมหรือผู้ที่กำลังเรียนรู้ภาษาโปรแกรมใหม่อาจจะทำให้เกิดความผิดพลาดของผู้พัฒนาซอฟต์แวร์หรือจากการไม่คุ้นชินในการเปลี่ยนจากภาษาโปรแกรมหนึ่งไปอีกภาษาหนึ่ง จุดบกพร่องจากการเขียนโปรแกรมดังกล่าวส่งผลให้ซอฟต์แวร์นั้นขาดสเถียรภาพและถูกลดทอนในด้านประสิทธิภาพ รวมถึงในด้านความปลอดภัยของการปฏิบัติการของซอฟต์แวร์นั้น ๆ

จากปัญหาที่ได้กล่าวมาข้างต้น ทางทีมพัฒนาจึงมีความต้องการที่จะสร้างเครื่องมือในการช่วยเหลือการตรวจสอบและประเมินคุณภาพการเขียนโปรแกรมด้วยภาษาไพธอนพร้อมทั้งแนะนำรูปแบบที่เหมาะสมโดยอัตโนมัติ ซอฟต์แวร์ดังกล่าวมีชื่อว่า Teddy โดย Teddy นั้นจะสามารถช่วยให้ผู้เขียนซอฟต์แวร์ด้วยภาษาไพธอนสามารถตรวจสอบเพื่อค้นหาปัญหาจากการเขียนโปรแกรมและนำเสนอตัวอย่างที่ถูกต้องให้นักพัฒนาโปรแกรมเข้าใจรูปแบบการเขียนที่ถูกวิธี ทำให้การเขียนซอฟต์แวร์นั้นเป็นไปได้อย่างมีประสิทธิภาพมากขึ้น โดย Teddy นั้นได้ถูกออกแบบให้มีระบบการทำงานแบ่งเป็น 2 แบบ ได้แก่ แบบที่ 1 (แบบป้องกัน - prevention mode) ในรูปแบบการทำงานนั้น Teddy จะทำการหาการใช้ coding idiom ในเวลาจริงจาก pull request ที่เกิดขึ้นใหม่ และแบบที่ 2 (แบบตรวจจับ - detection mode) จะทำการค้นหาการใช้ coding idiom จากทุกเวอร์ชั่นตั้งแต่อดีตจนถึงล่าสุดของซอฟแวร์โปรเจคดังกล่าว

เพื่อทำการทดสอบและประเมินประสิทธิภาพของเครื่องมือที่ได้พัฒนา ได้มีการใช้โปรเจคซอฟแวร์จริงในการวัดระดับการทำงาน จากผลการทดสอบนั้นพบว่า Teddy สามารถตรวจจับการใช้ coding idiom ด้วยความแม่นยำที่สูง แผนภาพที่ถูกสร้างขึ้นจากเครื่องมือนั้นจะช่วยให้ผู้พัฒนาทราบถึงข้อมูลเชิงลึกเกี่ยวกับการพัฒนาของโค้ดภาษาไพธอนทั้งแบบ idiomatic และ non-idiomatic ภายในโปรเจคนั้น ๆ โดยที่ผู้พัฒนาเองก็จะสามารถเข้าใจเกี่ยวกับ idiom ภาษาไพธอนให้ดียิ่งขึ้นและยังช่วยในการเรียนรู้เกี่ยวกับภาษาไพธอนอีกด้วย ยวกับภาษาไพธอน

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CHAPTER 1
INTRODUCTION

This chapter introduces the overview of this senior project report. It includes the motivation of the project, the problem statements we tackle, the objectives of the project, the scope of the project, and the project's users respectively. Lastly, the report structure is laid out for which each chapter contains the corresponding contents.

1.1 Motivation

Nowadays, Python is one of the most commonly used programming languages worldwide [2]. The Python developers include those who are already settled in the community, the new ones who just start learning how to program, and the experienced ones from other languages that are transitioning to Python. Each of them have different styles of writing code.

The programmers who are strongly familiar with Python write code in a so-called "Pythonic" way, which is a well-accepted way of writing and proved to be readable and efficient. The naive programmers who just start writing programs may write in the most simple ways as possible. The proficient programmers, who are transitioning from other languages to Python, have a chance of using writing styles that are practical in their old programming language syntax, but unorthodox in Python language.

When programmers write programs in Python language and do not adopt idiomatic Python way of writing, it *may* cause the program to be inefficient or difficult to read by the Python community. One example of such usage is `f = open('file.txt')` and `f.close()` as displayed in Figure 1.1. These statements within the program can cause problems when programmers forget the to add in `f.close()`. On the contrary, the proper Pythonic idiom for this scenario would be `with open() as f:` instead, which would make the program lose performance [3].

In the software development cycle, using Pythonic way of writing code within the development phase gives the code reviewers a better understanding of the program and

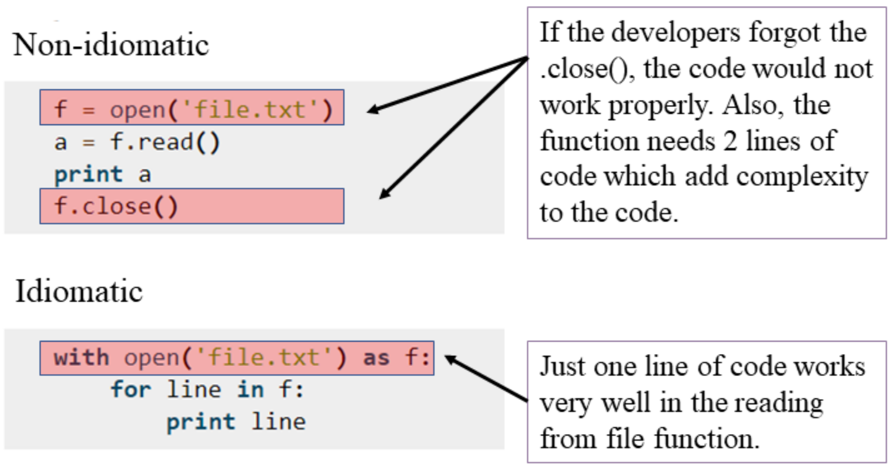

Figure 1.1: Comparison between Idiomatic and Non-idiomatic Python coding style in with open case study

a smoother work flow. This is in regards that experienced reviewers would have a better understanding if the codes provided are Pythonic. If there is a software program which can assist the use of Idiomatic Python coding style, the number of higher-readable Python code should be produced and also the effort of the Python code reviewers are reduced.

With the reasoning above, we have had the idea of creating "Teddy" as a software that would help in the detection and prevention of misusing idiomatic Python coding styles in software. The users of the software would be able to check their code quality in terms of idomatic coding style. The tool also helps the new programmers to learn and understand what their flaws are when using Python as a programming language. We, as the developers of Teddy, believe that Teddy can enhance the standards for Python language and give the developers in Thailand more understanding of Python, which is a worldwide and one of the most widely-used programming languages.

1.2 Problem Statement

This project tackles the following problems in nowadays software development:

1. There are only a few studies on Pythonic idioms during the evolution of a software project.

2. Many naive Python programmers and transitioned experienced programmers from other languages to Python are not aware of idiomatic Python coding style. They also do not know when and how to use them in their day-to-day programming

tasks.

3. The manual process of source code reviews by experts takes a lot of time and becomes a tedious routinely tasks.

While coding with Python, many programmers are not aware of idiomatic Python coding style, where it is actually considered to be a significant factor to the readability and efficiency of the program. The unawareness can potentially lead to certain problems such as unnecessary computational resource consumption, and functional flaws in the software program. By having a software that can guide the use of idiomatic coding style, source codes will be using the same format and give other developers the same understanding of the code written.

1.3 Objective of project

This project aims to create a software to satisfy the following objectives.

1. To create a software program that can detect idiomatic Python code with high accuracy.
2. To analyze source codes retrieved from an online source called GitHub and provide real-time results on idiomatic and non-idiomatic code statements.
3. To visualize the detected idiomatic Python code usage with a friendly graphical user interface.

1.4 Scope of the project

The scope of this work is as follow:

1. The proposed tool and techniques allow the users to detect Python idioms within the source codes automatically.
2. The proposed tool allows the users to see information from GitHub through the software user interface.
3. The proposed tool is able to be integrated with GitHub and provide a full analysis report.

4. The proposed tool is designed to work with Python source files only.
5. The proposed tool relies on GitHub API, and hence it only supports GitHub as the data source.

1.5 Target Users

The project provides numerous benefits within the programming field. Thus, our target users consist of programmers varying in their field of work. Our project would also provide benefits in the educational field. The tool would allow teachers and students to gain benefits in understanding idiomatic Python coding style. By giving an accurate, fast and automated code review, programmers would be able to obtain a preliminary review on their codes before sending it to a reviewer. Teachers would be able to have students use the tool to gain a better understanding in the usage of idiomatic coding sytle in Python.

1.6 Report Structure

This document consists of six chapters in total. Chapter 1 is this Introduction chapter. It includes the motivation, problem statement, objective, scope and target users of our project, and the report structure. Next, Chapter 2 discusses the background concepts, related works, and tools and methods involved in this project. Chapter 3 then explains the design aspects of our works, with the system architecture, use case diagram and data flow diagram. Chapter 4 is the detail of our implementation, followed by Chapter 5 being the result of testing and evaluation. Lastly, Chapter 6 summarizes and conclude the work on this project.

CHAPTER 2
BACKGROUND

With this project aiming to create a software for detecting and analyzing the usage of idiomatic Python coding style, the understanding of related fundamental concepts is important. This chapter discusses the key topics related to the project, which include definitions and keywords, fundamentals, related work, and tools and methods.

2.1 Definition and Keywords

1. *Software Program*: A software program refers to a set of computer instructions that is designed to carry out certain tasks, which may or may not receive input or interact with human as the user of the program.

2. *Source Code*: Source code refers to a sequence of valid textual commands that can be compiled or assembled into an executable software program. Source code is written using a human-readable programming language.

3. *Idiomatic Coding Style or Coding Idiom*: Coding idiom is the way to express or write the programming code differently from the traditional syntax of the language and let this methodology produces its own particular function. Like human language, the real context of a certain phrase cannot be interpreted directly by individual words. For example, in English, “a piece of cake” means something that is very easy which cannot be translated directly as an actual piece of cake. The explanation also works for coding idioms, sometimes what may have written code to perform a specific function in a short style that is allowed by the programming language syntax. For example, in C, to write increment of a variable, the developer can declare the statement `i=i+1` which can be written in idiomatic C code as `i++`.

4. *Idiomatic Python (IP) Code*: Python code written to execute particular function by following the principles of Python language that are well-accepted in the com-

munity [4].

5. *Non-Idiomatic Python (NIP) Code*: Python code to perform a specific function that is syntactically correct but do not follow the idiomatic way of writing.

6. *Online Repository (or Repository)*: An online repository refers to a website which provide online storage, sharing and managing of source codes as a service. GitHub is a famous example of online repository hosting website with its built-in `git` version control system.

2.2 Fundamentals

This section explains the concepts and background knowledge in relation to the project.

2.2.1 Python Programming Language

Python is a high-level programming language first appeared in 1990 [5]. It is widely used in many fields of information technology research, such as deep learning, distributed computing, multimedia processing etc. In last 10 years, Python has been one of 10 most popular programming languages in the world, now ranked at number 2 [6]. Python language is an open-source code with its set of comprehensive libraries and add-on packages that facilitate different operations for different applications.

Python is practical with many programming paradigms - procedural, object-oriented, and functional. The design of Python syntax commands focuses on the inclusion of "significant white space". Unlike other languages where the presence of white space is ignored or looked over, white space such as indentation signifies a grouping of code, called a block, that is executed within an encapsulating declaration - function, conditional, iteration.

2.2.2 Pythonic Idioms or Idiomatic Python Code

The word Pythonic is defined as an idea or piece of code which closely follows the most common idioms of the Python language [4], rather than implementing code using concepts common to other languages while the term idiom, in general, means groups of words or phrases that have particular meaning that cannot be directly translate from each word. When putting everything together, we can assume that Pythonic idiom is the way to write a set of code to execute particular function by following the principle of Python language. The example of comparison between idiomatic Python code and non-idiomatic is shown in Figure 1.1 as `with open` is one of the most popular idiom used referenced from the study of Alexandru et al. [7]. As it is stated in the paper, top 3 most used Pythonic idioms from 1000 GitHub repository are `list` comprehension with the usage of 866 repositories, `with` statement with the usage of 848 repositories, and `decorator` with the usage of 765 repositories.

2.2.3 Code Clones

Code clone refers to a code fragment - a sequence of source codes - being similar to another code fragment by some given definition. The two similar code fragments then form a "clone pair". Clones occur as the result of programmers reusing or reproducing source codes from external sources, and apply those codes to their own programs [8].

Four different types of clones have been defined, in other words the definitions of how two code fragments are regarded as similar. Type-1 clones are identical code fragments which different are only in white spaces, layouts and comments. Type-2 clones extends from the Type-1 plus additional variation in identifiers, literals, and types. Type-3 takes into account Type-1 and Type-2 with added, changed, or removed statements. Lastly, Type-4 are syntactically different code fragments which yield the same computational results.

Consequential issues may follow code cloning without caution and knowledge about the duplicated solutions. Often the original code fragment contains flaw or errors. Once the buggy source code is duplicated, so are the errors and bugs inside. The widely spread errors are now difficult to contain or correct, even when the original copy gets rid of the mistake. Another problem of code cloning is that the copied codes may violate the copyright or license of the program. As the result code clone detection and prevention now plays significant role in quality control of software development.

The process of code clone detection follows a sequence of steps. Pre-processing is the first step for which any uninterested code segments would be removed, and definition of comparison unit is set. Next, the transformation step, is when the pre-processed codes are converted into some intermediate representation other than the original textual format, including extraction and normalization. The transformed code is then fed into a comparison algorithm as for the match detection step. After this, the list of resulting clone pairs is formatted to align with original textual code, passed through post-processing and filtering by manual analysis or automated heuristics, and aggregation that combines clone pairs into clone classes.

Of all the clone detection tools, many techniques and technical approaches are implemented. Four outlining groups of approaches are

1. *Textual*: The source codes undergo little to no transformation before the actual comparison takes place. Often the raw source codes are used directly to find clone pairs.

2. *Lexical*: Also known as“token-based technique”, the comparing source codes are converted into “tokens” first, using tokenizer and normalizer modules. Then the identical sub-sequence of tokens are scanned where matching units are returned as clones. This technique is more sensitive to minors changes in white spaces and formatting.

3. *Syntactic*: A parser is used to convert source codes into parse tree, or “abstract syntax trees” (ASTs). The generated trees are then processed to search for clones by either 1) tree matching (finding similar sub-trees) or 2) structural metrics (comparison of metric vectors).

4. *Semantic*: For the semantic approach, the source code is represented as a program dependency graph (PDG). The nodes suggest expression or statement, while edges are control and data dependencies. Discovery of clones is by looking for “isomorphic sub-graphs” - sub-graphs containing the same number of nodes connected in the same way - from two comparing PDGs.

In Listing 2.1 is a snippet of Java code, bubble sort implementation. From the raw source code, demonstration of its abstraction as others forms are shown. Figure 2.1 depicts the program dependency graph representation, where each node is connected by two types of dependency edge - data and control. From Figure 2.2, the source code is converted into an abstract syntax tree.

Listing 2.1: Java implementation of bubble sort algorithm

```
public int[] BubbleSort(int[] ar) {
        int temp;
        for (int i = ar.length-1; i > 0; i--) {
                for (int j = 0; j < i; j++) {
                        if (ar[j] > ar[j+1]) {
                                temp = ar[j];
                                ar[j] = ar[j+1];
                                ar[j+1] = temp;
                        }
                }
        }
        return ar;
}
```

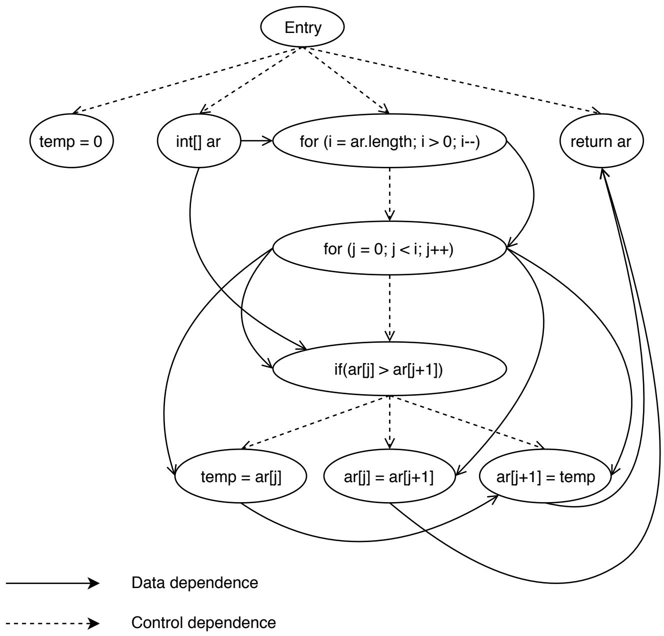

Figure 2.1: Program dependency graph representation of Java bubble sort code

In addition to above, some clone detection tools utilize characteristics of two or more approaches mentioned, which is considered to be a hybrid combination. However such trend is rather unpopular.

Since our work is centered around IP detection, therefore it is logically relevant that the code clone detection pipeline is borrowed, then appropriately adopted into the detection of coding idioms.

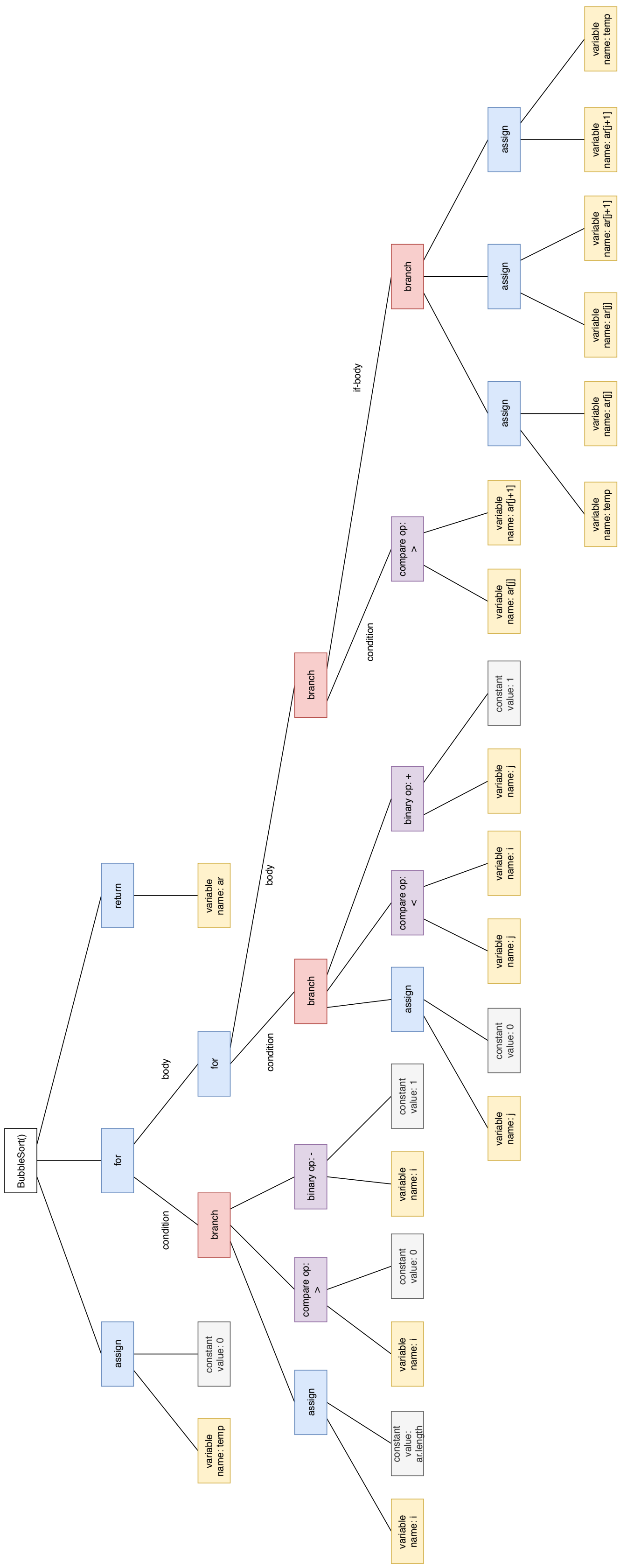

Figure 2.2: Abstract syntax tree representation of Java bubble sort code

2.3 Related Work

This section discusses the works closely related to the research of this project.

2.3.1 On the Usage of Pythonic Idioms

Pythonic way of coding is not yet particularly defined. In the book "Zen of Python" by Tim Peters [9], it is mentioned as the obvious way to do the preferable coding style. On the other hand, in the paper Usage of Pythonic Idioms stated that Pythonic is the idiomatic style for developing Python [7]. The researcher divided the experiment into two parts: interviewing Python developers on understanding the concept of IP and the usage of IP over 1000 GitHub repository.

The result of the second part of the approach shows the popularity and improvement of performance or readability of idioms used in the selected 1000 projects. The researcher of the paper listed and classified the idioms that are used in those 1000 projects and also make the collection in the website [10]. The information would be the foundation for our tool to detect the usage of IP in the searched projects.

2.3.2 Diggit: An Automated Code Review Tool

Code reviewing can be seen as a common practice in many software development teams, this would also include the reviewing from communities as well. Code reviewing thus became a core practice within the software development cycle. With code reviewing becoming apparent, sometimes there are problems when many codes are being edited in different areas. Developers would use online version control services such as GitHub to control these problems.

Although GitHub can be seen as an answer to the coding review problems with a large number of contributors, the problem of verifying and going through the edits made still be considered tedious. Thus the solution that Diggit used is to have the GitHub Bot communicate directly with GitHub to gain access to changes or interactions made to the codes that are hosted on the GitHub service which allows the manipulation and viewing from an automated system.

With help from the GitHub API, Diggit created a system that has a version control system in which it checks using association rules when activities have been made on the

GitHub repository [11]. It then helps in the phase where code reviewers check on the edits made within the code and make the process faster. Our project would be using the same method as Diggit, which is using an automated system to interact with a GitHub repository during a pull request and access the information within the pull request.

2.3.3 Toxic Code Snippets on Stack Overflow

With software development being used in many fields, and with the more programmers starting to be reliant on the usage of online platforms, such as Stack Overflow [12]. The code snippets that are found on such platforms are considered by many to be usable, but in reality there are many flaws, outdated methods or even licensing problems contained within the snippets [13]. These outdated or codes with flaws can then be classified as toxic code snippets which are generally unwanted within the source codes.

Toxic code snippets are commonly seen posted in online forums, mostly in the commonly used platform Stack Overflow. With the most of these snippets not coming directly from Stack Overflow, but copied from other locations such as an open source software [13]. Even when there are many toxic code snippets located in Stack Overflow and it is considered to be dangerous to use, users themselves acknowledge it's existence and are aware of these snippets [13].

In the research of Toxic code snippets on Stack Overflow, focuses on the usage of codes that are considered to be harmful, while bearing some similarities to our project that focus on the usage of harmful codes within Python.

2.4 Tools and Methods

2.4.1 GitHub

GitHub [14] is an online platform which allows its users to be able to interact with it's online storage called a repository. The repositories are used to store source codes. Users is able to view, edit and give contributions to those repositories as a community. With over 40 million developers [15] on GitHub in the statistics collected on September 30, 2019 and the increasing trend of creating new repositories with 44 percent [16] more than year 2018 totaling in over 100 million repositories as of August 2019 [15], thus we choose GitHub to be our main repository.

With GitHub having it's own version control system called `git` and introduced it during the time when source code version control was not known and used. GitHub started to attract attention when the system allowed users to be able to work remotely and have a version control system in which allows ease of access to the developers.

2.4.2 Probot

Probot [17] is a framework created to help give users flexible access to the usage of GitHub Apps by using Node.js. The framework aims to help users in using GitHub Apps by handling hard to understand webhooks and GitHub's tedious authentication system. With an understandable and easy to write style of coding it allows users to gain an understanding relatively fast.

2.4.3 Smee.io

Smee.io [18] is a webhook service provider, which was created by the Probot development team to allow users to create webhooks connecting to GitHub and sends those information back to the users. A webhook is an access point which allows other systems to receive certain information from another through HTTP access. Smee.io can be used in a scenario such as when a system requests to gain access to information on pull requests from GitHub. The system would connect to the Smee.io webhook, which monitors the activity on GitHub and relays information to the system.

2.4.4 Elasticsearch

Elasticsearch [19] is a distributed, RESTful search and analytics engine, and a data storage itself, that relies on Apache Lucene infrastructure and library [20]. The exchange of user's queries and results is through REST API commands. It provides the schema-less JSON document formatting for the retrieved documents, through HTTP web service.

Inside Elasticsearch, data is stored as JSON documents. Documents which are related to each other are grouped as an "index". First, the raw data is parsed, normalized and pre-formatted prior to being indexed. Its ultilization of "full-text search" using "inverted-index" - a data structure where for every unique word there is a corresponding list of documents where the word appears in. And because Elasticsearch simultaneously updates the inverted-index as new documents are being indexed, therefore the searchable delay after indexing is very small, almost in real-time.

2.4.5 Version Control System

A version control system (VCS) is software tool capable of managing changes, usually done by a team of programmers, to the source code over time [21]. A VCS has the ability to keep track modifications, compare two versions of the same pieces code from two different times, and revert or merge versions of source code. A series of versions, where one is the result of modifying a preceding version, forms what is called a branch.

Master Branch

Master branch is the permanent primary branch for every source code whom a version control system is applied to. Source code with VCS is required to have at least this one branch. The master branch represents the root mainstream, where every version has passed testing, and all the source codes are in stable, ready-to-deploy state. Version updates on this branch should be not frequent as the experimental or testing stage will occur in developing branch(s).

Developing Branch

Developing branch is a secondary branch that diverts from a pre-existing root branch, tracking version changes within its own branch independent from the root branch. The purpose of it is to “containerize” a developing or ongoing activity from the more stabilized branches, or other unrelated branches. Once the development or changes of a developing branch ended, the final content can then be merged into the root branch or master branch, through a “pull request”.

2.4.6 Siamese

Developed by Ragkhitwetsagul C. and Krinke J., “Siamese” is a code clone search tool with high degree of scalability via multiple code representation [1]. The tool is written in Java and supports clone detection of Java and Python languages. It works with Elasticsearch 2.2.0 to index and retrieve source codes needed to perform clone detection process. Siamese is capable of detecting Type-1, Type-2, Type-3 and Type-4 by transforming raw source code into intermediate representation format as tokens, using parser, normalizer and tokenizer for respective programming language. The tool does not provide a graphic interface and can only be controlled via command-line interface. Figure 2.3 depicts the architecture of Siamese program, incorporating the small steps from indexing and retrieval, to outputting the results of clone search.

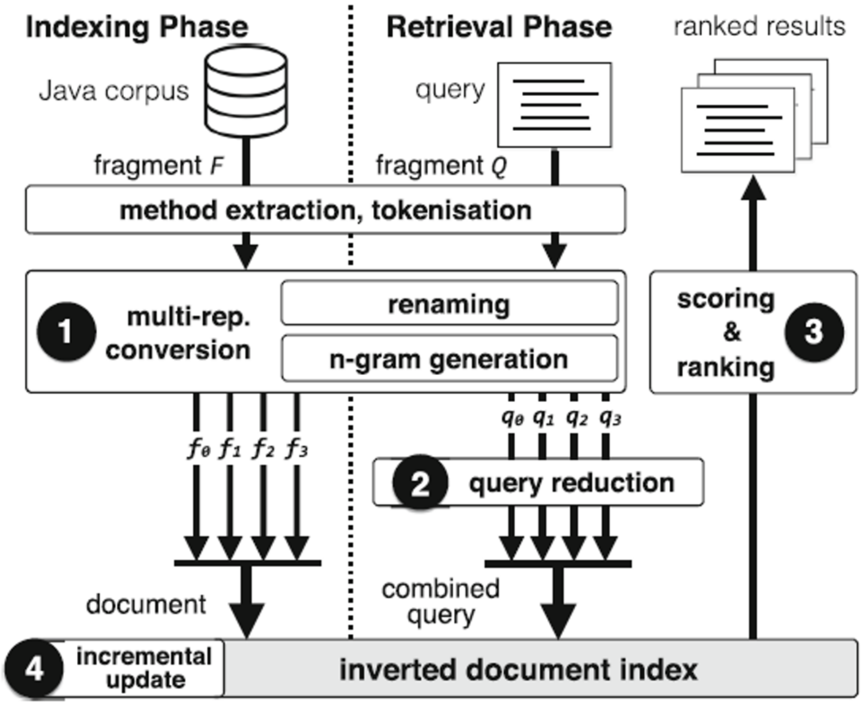

Figure 2.3: Siamese architecture [1]

CHAPTER 3
ANALYSIS AND DESIGN

This chapter covers the analysis and design which covers the explanation of system architecture, use case diagram, and data flow diagrams (level 0 and level 1).

3.1 System Architecture

The software aims achieve two different processes with similar tasks as seen in Figure 3.1. The tasks would be the ability to detect IP within a source code and analyze those within the source code with a database containing tokenized IP. While the main goal is the same, the two different process will act differently during the data collection and processing, with the first being Detection mode and the latter called Prevention mode.

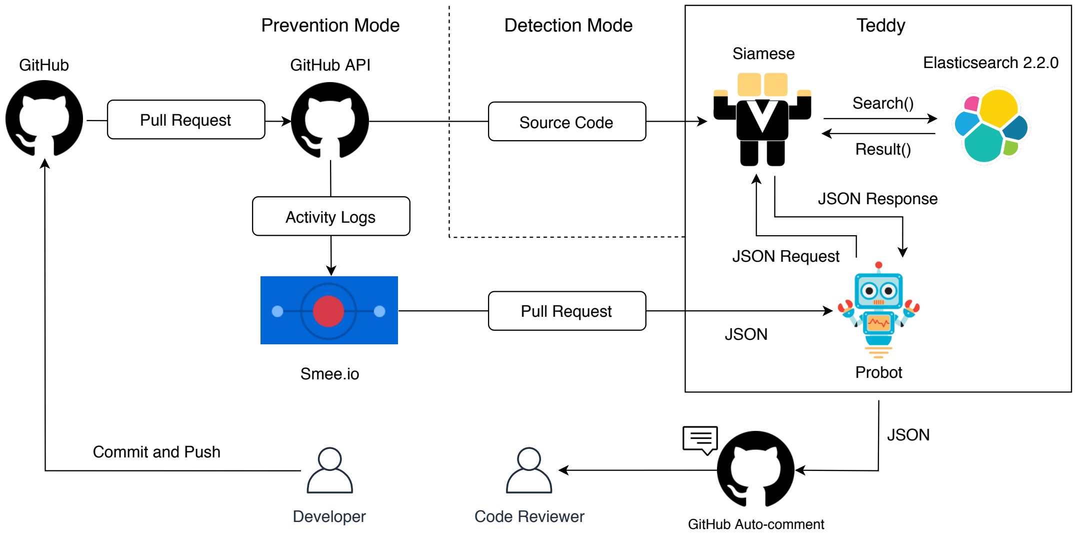

Figure 3.1: System Architecture of the project

3.1.1 Detection Mode

In detection mode, we will access the source code within a repository in GitHub and acquire the source code to run on our software. The source code will be sent directly to Teddy through Siamese to only send important IP for Teddy to analyze. After that it will be sent to a graphical user interface to show the users on what problems have been detected regarding IP.

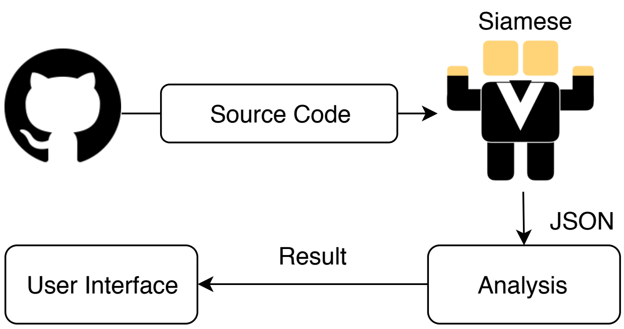

Figure 3.2: Simplified View of Detection Mode

3.1.2 Prevention Mode

In prevention mode, the software will be designed to be active at all times and run on a real-time analysis. The prevention mode is also divided into two major parts which are the communication part with GitHub and the analysis part.

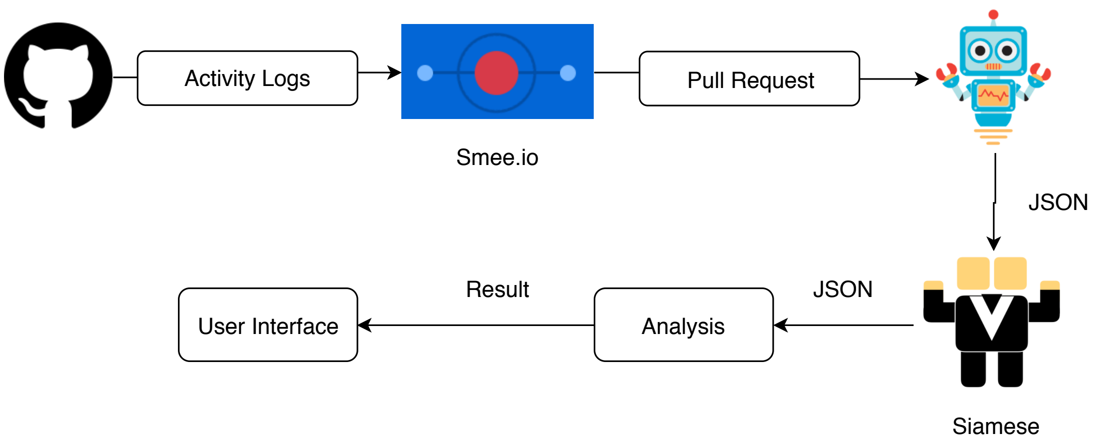

Figure 3.3: Simplified View of Prevention Mode

Communication with GitHub

In the first part will be the modules that works with external services outside of Teddy. Whenever GitHub has any activities there will be information sent to Smee.io, Teddy would target whenever there are information sent regarding pull requests and parse only the updated code snippets.

Analysis within Teddy

After the code snippets are extracted, Probot will send the code snippets as JSON files to Siamese. Siamese will then compare the code snippets and use it to obtain related tokenized Pythonic iddioms within the database. Finally at the Analysis and User Interface, users will be able to see the what parts of the snippets are Non-idiomatic Python code.

3.2 Use Case Diagram

In the use case diagram, Teddy interacts with three external actors and entities - GitHub, Developer, and Code Reviewer. There are three use cases.

First, Retrieving Source Code, is when the developer gets the wanted repository from GitHub (both for the prevention and protection mode). GitHub is the secondary actor that receives the request from Teddy, and in return gives back the clone (contents) of that repository.

Next, after Teddy complete its function of IP detection or prevention, both Developer and Reviewer can view its results. In detection mode, the developer and code reviewers see the result of Python idiom usage within the entire chunk of source codes. In Prevention Mode, on the other hand, Teddy uses code snippet inside the pull request as the input and analyze for idiom usage within the snippet. Then, developer and code reviewers can see the analysis result of the snippet done by Teddy.

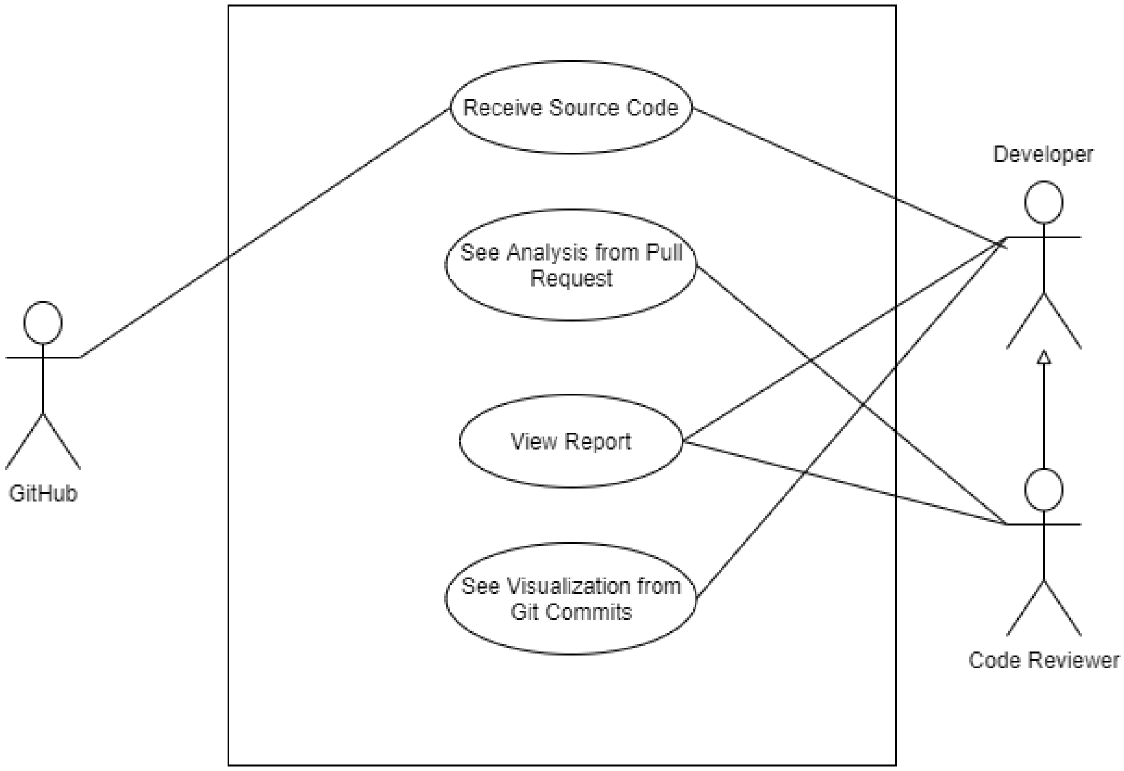

Figure 3.4: Use Case Diagram of Teddy System

3.3 Data Flow Diagram

3.3.1 Level 0

In prevention mode, Figure 3.5, the data comes from three external entity: GitHub which is the repository, Code Reviewer, and Developer of the project. Once the developer chooses the source code to be used in the tool,the request for source code will be sent to the repository, then the pull request log and the source code will be sent to the system. After the pull request is analyzed by the system, the pull request analysis will be sent to the code reviewer. Spontaneously, the pull request analysis and the source code will be used in the system to analyze the result. After the system gets all of the result, it will generate the report and sends the report to the code reviewer and the developer.

In detection mode, Figure 3.6, the external entities are only GitHub and Developer. Firstly, the developer would enter the GitHub URL to let Teddy send the URL to receive the repository. Then, Teddy extracts all of the commits to use in the last step. Finally, after getting the commits, Teddy would generate the visualization with IPs and

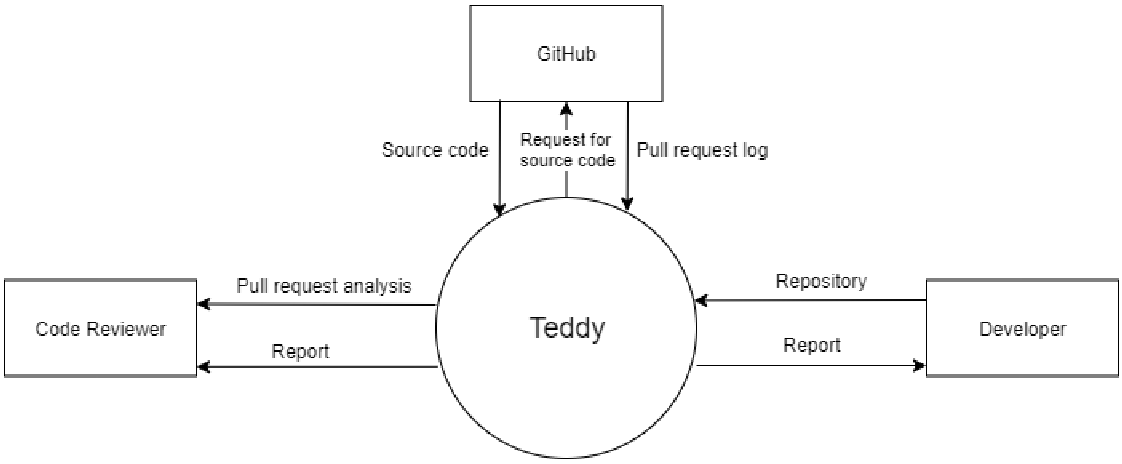

Figure 3.5: Data Flow Diagram Level 0 of Teddy System in Prevention Mode

NIPs and send them back to the developer.

3.3.2 Level 1

The inner part of prevention mode composes of four main processes: 1. Get source code from repository 2. Extract code snippet 3. Search idiom 4. Generate report. Firstly, for the get source code from repository process, the external entity would select the repository to be cloned in the system. The request for the source code would be sent out to the repository and the pull request log and source code will be sent back to the system. Then, they will be passed to the extract code snippet process which analyze the sent elements and deliver it as pull request analysis to the outside of the system. One more product of the process which is the JSON snippet, along with the source code, will be sent to the search idiom process which is done by the automated system. The system will send the JSON snippet as JSON query to search the idiom in the idiom database which will be resulted in the form of relevant JSON result. After the search, the result will be generated into the full detailed report and sent back to the external entity outside of the system.

For detection mode, the inner part of the system consists of three main processes: 1. Get GitHub repository 2. Extract GitHub commits 3. Generate visualization. For the first step, the system would receive GitHub URL as an input from the external entity, then pass the URL to GitHub to access to GitHub repository. After that, the second procedure starts. The system would obtain commits from the repository and pass to the part that

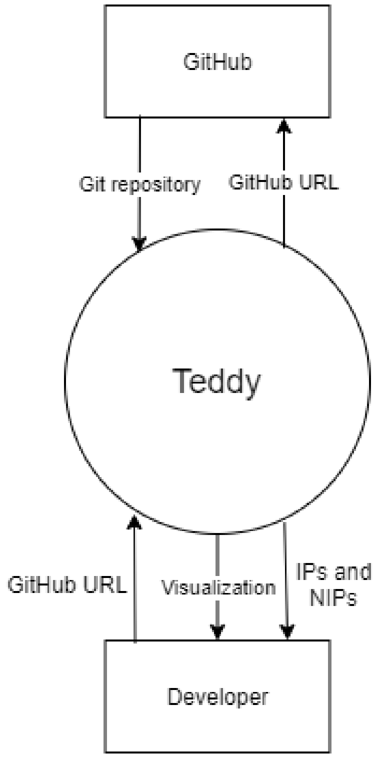

Figure 3.6: Data Flow Diagram Level 0 of Teddy System in Detection Mode

has responsibility on the visualization. Finally, the system will generate the visualization in the form of HTML page based on the information extracted from the commits.

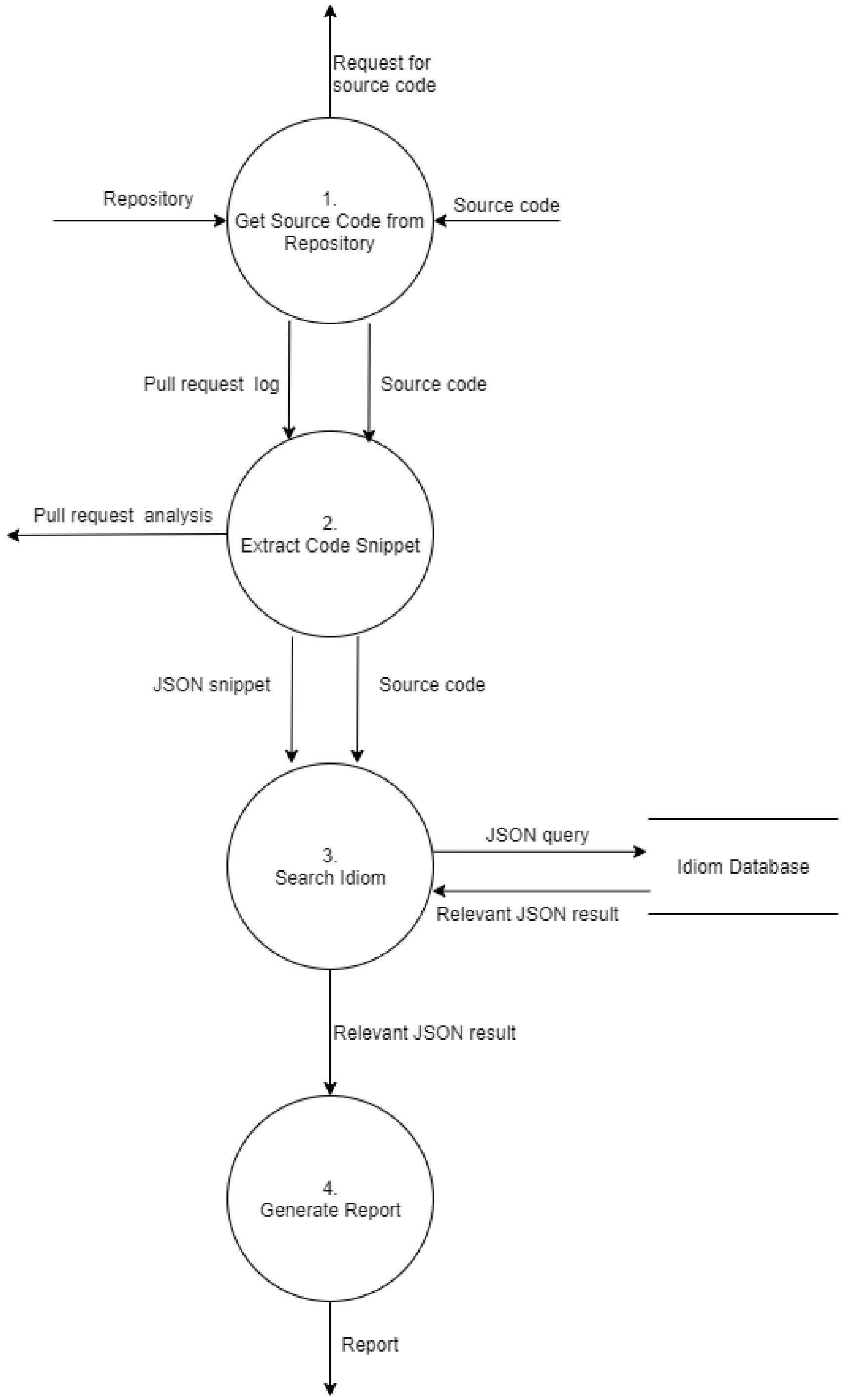

Figure 3.7: Data Flow Diagram Level 1 of Teddy System in Prevention Mode

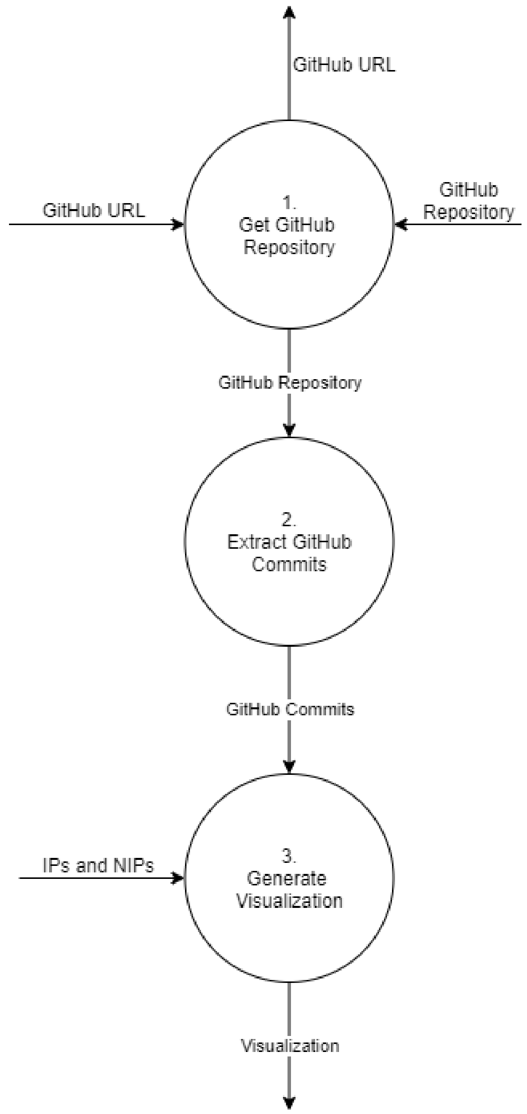

Figure 3.8: Data Flow Diagram Level 1 of Teddy System in Detection Mode

3.4 Comparison to Relevant Tools

As seen in Figure 3.9, we have compared Teddy against two other tools that achieve similar objectives. Our criteria that is used to compare and show distinct features include IP, automated review, GitHub integration, and a standalone user interface. The criteria were chosen based on the importance in regards to the objective of this project and the relevancy to the features that our tool can provide.

	Pythonic Idioms	Automated Review	GitHub Integration	Standalone UI
TEDDY	✓	✓	✓	✓
Diggit Automated Code Review Chatley R., Jones L., (2018)		✓	✓	
SMARTBEAR Collaborator https://smartbear.com		✓		✓

Figure 3.9: Feature Comparison Between Teddy and Other Relevant Tools

CHAPTER 4
IMPLEMENTATION

This chapter contains the implementation of this project which will be divided into four sections: IPs and NIPs preparation, the prevention mode, the detection mode, and the user interface.

4.1 IPs and NIPs Preparation

From the literature review, we decided to collect each type of idioms from the references that we have found. Then, we extract as many distinct coding patterns of both IPs ad NIPs as we can from examples that each source presents. After complete collecting, we rearrange the code patterns into separated different documents for each type of idiom to use later in pattern matching procedure with Siamese.

Table 4.1: Types of IPs and NIPs studied in this project

Type	Name	Description	Amount
IP	dictionary comprehension	Declaration of `dict` variable and assigning its elements in a single statement	7
IP	enumerate	for-loop iteration using `enumerate` function	8
IP	file reading statement	Using `with open() as ...` to open a file	5
IP	list comprehension	Declaration of `list` data type and assignment of elements in a single statement	7
IP	if statement	Using implicit truthfulness for `if` condition statement	11
IP	string formatting	Concatenation of multiple string formatting statements, use of `.format()` with placeholder(s) in a static string	3
IP	set	Using `set` data type to create a unique collection	4
IP	tuple	Unpacking data for multiple assignment at once	4
IP	variable swapping	Using tuple to swap values between two or more variables	4
IP	code formatting	Proper use of indentation for code blocks and writing one statement per one line	2
NIP	dictionary comprehension	Separate declaration and for-loop element assignment of a `dict` variable	6
NIP	enumerate	for-loop iteration without `enumerate`	6
NIP	file reading statement	File opening without using `with open() as ...`	5
NIP	list comprehension	Separate declaration and for-loop element assignment of a `list` variable	8
NIP	if statement	direct comparison of variable with `True`, `False`, or `None`	12
NIP	string formatting	Sequence of one string formatting commands per one line, using '+' to concatenate static string and variable(s) together, or using '%' as string variable placeholder	7
NIP	set	Using for-loop to create a unique collection of item	4
NIP	tuple	Explicitly assigning variables with elements in a collection	4
NIP	variable swapping	Using a temporary variable to swap two variables' values	4
NIP	code formatting	Using ';' to put more than one statement in a single line	2

4.2 Siamese Configurations

Siamese allows for flexible customization of its search configuration with many different parameters in the configuration. From the array of over 50 individual parameters available for adjusting, the following are key parameters that are major factor to the result of this study.

From Table 4.2, there are three key parameters included. They are originally designed to work with code clone detection, in which we have applied them to the NIP/IP detection in particular.Value assigned to each of them has significant effect to the outcome of IPs/NIPs search results. Details regarding how the configuration's values are set for Siamese to perform at the best possible degree is included in Chapter 5.

Table 4.2: Key parameters of Siamese configuration

Name	Description	Value Options
Clone similarity computation method	Used to select the method of computing the numerical similarity value between a query method and an index method	none, fuzzywuzzy, tokenratio
Multi-representation similarity threshold	The percentage value that represent the threshold of the computed clone similarity for four type of code representation (Type 1, Type 2, Type 3 and Type 4)	0% - 100%
Multi-representation n-gram size	The length of consecutive tokens that form into a tuples to generate multi-representation formats (Type 2, Type 3, and Type 4) of the original code	At least 1

4.3 Prevention Mode

Prevention mode, one of the core features of this project, allows users to be able to get instant feedback of IPs and NIPs found in their pull requests from an automated process. The process would involve the usages of GitHub's API and Bots to help show the results to the users.

4.3.1 Techniques and Tools Involved in the Implementation

1. GitHub API - An API provided by GitHub that is used to communicate and handle activities within GitHub, these API's can be used to read the activities in a repository and make changes within the GitHub repository.

2. Node,js - Used as a server handler for Teddy, Node will handle receiving activities from GitHub and sending it to Siamese, it would also handle the usage of GitHub's API.

3. Siamese - Handles the usage of IPs and NIPs. It would send suggestions back to NodeJs to be passed onto GitHub.

4.3.2 Implementation Detail

Prevention mode can be split into 4 major parts which has specific functions needed to make the whole pipeline working. First, whenever activities happen on GitHub a system has to be designed to intercept those activities and sent for analysis. The second part is designing a way for the activities to be accepted into our system and parse only certain parts of the activities which include the commit ID and the edits content. Next, the activities would be sent to Siamese in which Siamese would use the edits content to scan for IP and NIP code fragments, and retrieve recommendation data for each NIP fragment found. Lastly, the system would then send back a response containing the components, which are the File name and suggestions of Idiomatic Python back to GitHub.

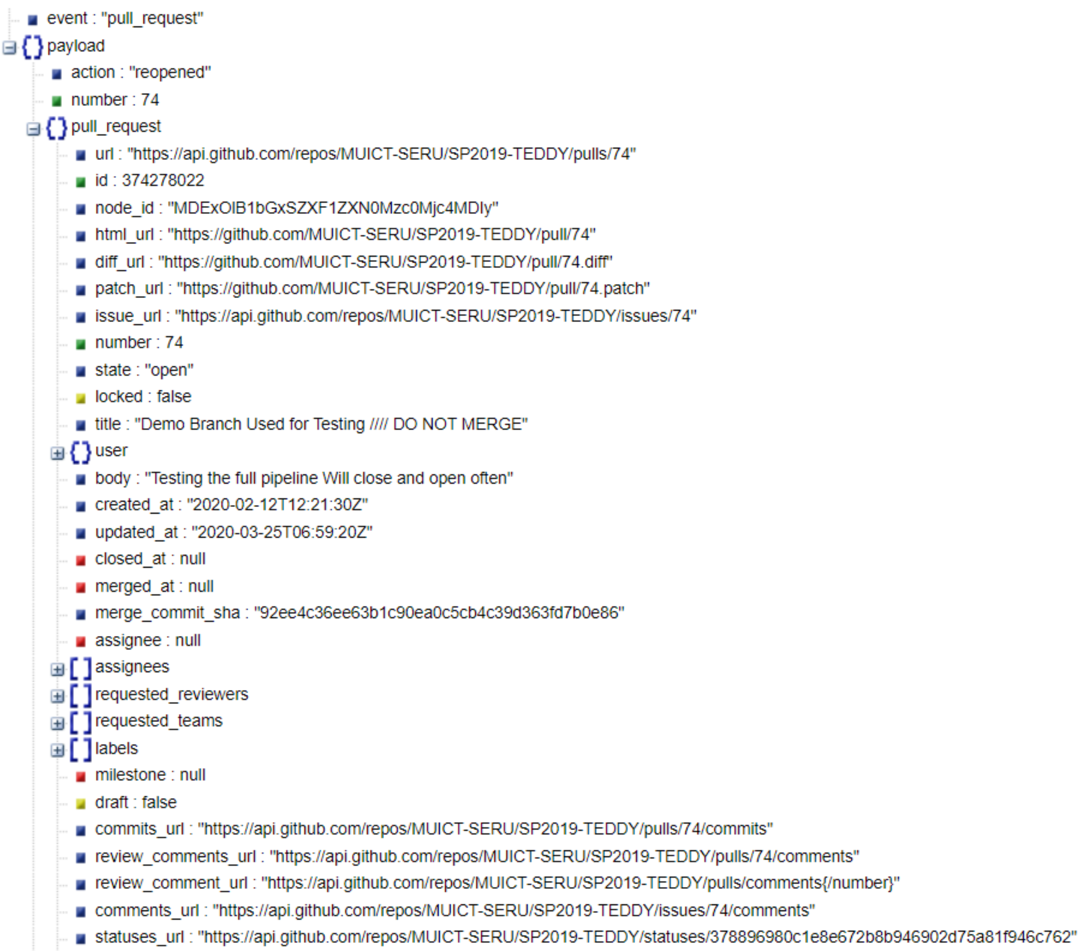

Figure 4.1: JSON Structure used by GitHub

```
{
  chunks: [
    {
      content: '@@ -0,0 +1,11 @@',
      changes: [Array],
      oldStart: 0,
      oldLines: 0,
      newStart: 1,
      newLines: 11
    }
  ],
  deletions: 0,
  additions: 11,
  from: '/dev/null',
  to: 'demo-files/python-file-4.py',
  new: true,
  index: [ '00000000..38f4ee39' ]
}
```


Figure 4.2: JSON Structure used by Teddy

Communication Between GitHub and Smee.io

In the first phase, we target information from GitHub, in which whenever an activity happens on GitHub there would be logs generated to keep track on what happens. GitHub allows the integration of Bots and Webhooks to interact with these information. Smee.io was chosen as the candidate to be the Webhook between our Probot and GitHub. Thus, Probot with Smee.io was used to receive important data from GitHub, such as the Repository, UserID, and PullRequestID. The data would then sent to Teddy as a JSON file with GitHub's generic structure.


```
15:52:11.152Z DEBUG github: GitHub request: POST /app/installations/:installation_id/access_tokens - 201 Created
  params: {
    "installation_id": 1552425,
    "baseUrl": "https://api.github.com",
    "request": {
      "timeout": 0
    }
  }
15:52:12.159Z DEBUG github: GitHub request: GET /installation/repositories - 200 OK (installation=1552425)
  params: {
    "per_page": 100,
    "baseUrl": "https://api.github.com",
    "request": {
      "timeout": 0
    }
  }
```


Figure 4.3: API response used by GitHub

Extracting data from Smee.io

Once the JSON has been received from Smee.io, Probot would comb through the JSON file and obtain necessary information, such as the commit id, files editted and edits made. The information would then be parsed to only contain certain information according to our JSON structure Figure 4.2. The JSON would then be sent off to Siamese for further processing.

Siamese and Idiom Matching

A Spring Boot framework was integrated into Siamese which is originally a command line tool without any module to support HTTP requests. By having data model Java class files that replicate the structure of GitHub JSON object (Figure 4.1), SiameseX, as a Spring Boot Application, can handle an incoming HTTP POST request containing the commit content in JSON format. The structure of the received JSON and sample values of each field can be seen in Figure 4.2. Then, the values from `edit` attributes, where the actual code changes of the pull request's commits is located, are extracted and put together as a query that is used to match with IPs and NIPs within the search index, i.e., the idiom database. Inside the index contains 113 code snippets of different IP and NIP types, including the recommendation correcting pattern for each NIP. If there is a match between an NIP from the query and a NIP sample in the index, the corresponding correcting pattern for that NIP type is retrieved from the index and included as part of response's payload.

Response and Commenting on a Pull Request

SiameseX sends back a response containing the original pull request information it received with similar JSON structure and the added NIP correction recommendation patterns - an additional attribute added to the "chunk" structure inside the JSON object. Finally, Siamese sends the serialized form of JSON response object back to Probot. During this, Probot creates a direct connection to the GitHub API, then makes a comment and a pass-check directly to the pull request as in Figure 4.4.

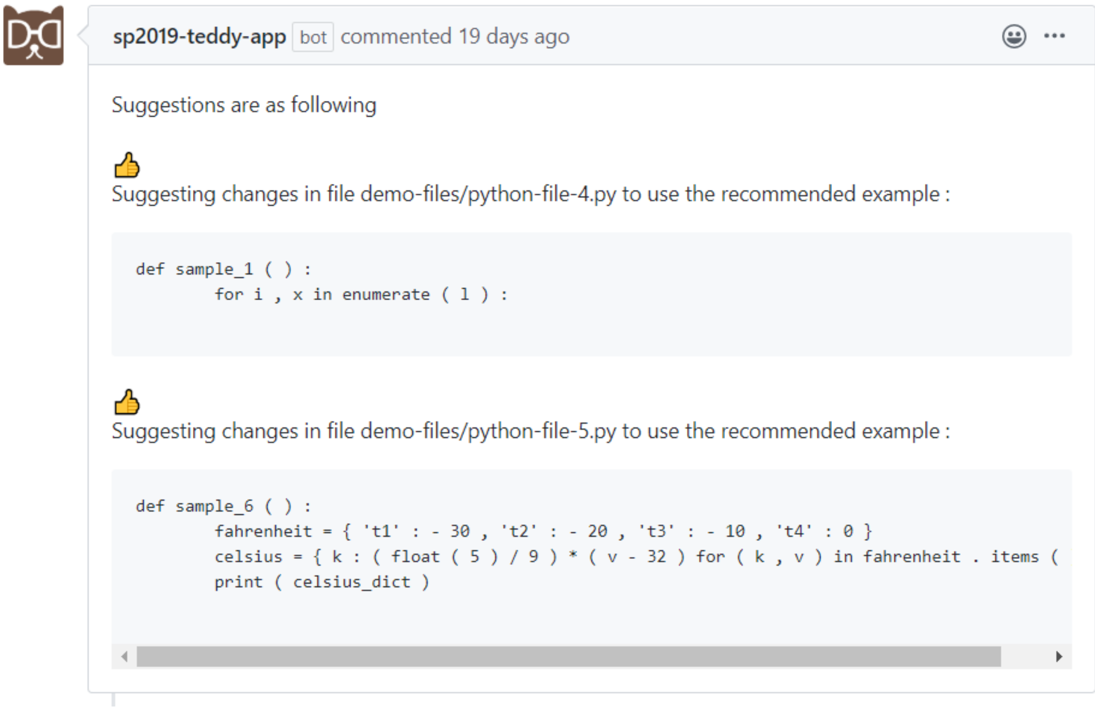

Figure 4.4: Teddy's automated comment into a GitHub pull request

4.3.3 Requirements

As many tools created, there are requirements that need to be met for the tool to operate and function properly. Here are the requirements needed for this tool to function.

1. A private/public GitHub Repository
2. The GitHub user called "TeddyMuict" must be added as a collaborator in the Repository
3. The GitHub Bot "Teddy" must be installed into the project.
4. The Bot "Teddy" must have permissions to comment on pull request.

4.4 Detection Mode

The detection mode works by providing a visualization of usage of IPs and NIPs across historical versions of source code of a GitHub repository. This is for the code developers to gain quick perception of how the software project has developed in terms of usage of IPs and NIPs, and make changes to their codes accordingly to improve code readability and performance.

4.4.1 Techniques and Tools Involved in the Implementation

Implementation of detection modes is done by incorporating a set of tools and techniques which are available, and adjust them to accommodate the application.

1. GNU Bash [22] - Because detection mode itself consists of several self-sustained modules and components with little to none built-in interactive functions to relay the data with other modules, bash script has been used in order to manage the sequence of modules' execution and direct the flow of data that occurs within the detection mode.

2. `git` vcs [23] - `git` version control system is needed as detection mode runs as offline program. Therefore, to be able to retrieve the online repository data from GitHub, `git` command lines are used for cloning and controlling versions of the software project.

3. Siamese [1] - Siamese is implemented as a search engine that looks for IPs and NIPs within the cloned software repository, and report the search results in form of `csv` files. Its query is a set of pre-selected IP and NIP sample code snippets.

4. Bokeh [24] - Bokeh, an interactive visualization library for Python, is used to produce the final visualization of IPs and NIPs in detection mode. The format is that of a `html` file.

4.4.2 Implementation Detail

As briefly mentioned earlier, GNU bash commands are necessary to connect the individual modules that makes up detection mode together, and direct the flow of data in proper manner. Thus all the commands to execute each module are written in the script.

First, a `git` command is executed to clone a selected repository (the URL must be provided as an argument when executing the script). The specified repository is then cloned and located at where the script is. Next, the script utilizes `git checkout` to revert the version of the repository to its first commit version as the iteration begins.

Next, for each commit version in the iteration, the script trigger the execution of `siamese.jar` which handles the indexing of the cloned repository (of that commit version) into the running Elasticsearch, and query that index with a prepared set of PIs and NIPs code snippets. Once Siamese completes the querying process, the search results is written into a `.csv` file.

After Siamese completes it process for one iteration of a commit version, the script instructs the version of the repository to be shifted to the next version. This step is repeated until Siamese finishes searching for the latest commit version of the cloned repository.

With one search result file generated for one commit version, the visualization module then takes all of the `.csv` files as input to further processing for the visualization. Finally, an interactive visualization plot of IPs and NIPs is produced and put in a local `.html` file.

4.4.3 IP and NIP Visualization

The visualization is done by contribution of the tool Python Bokeh 2.0.1 in the form of scatter plot represents the occurrences of both IP and NIP in each file in every commit in a Python project from GitHub.

The red legend is the representative of NIP while the green one is for IP. The different marker of the plot also used for identifying each type of idiom we have chosen to visualize which will be detailed as mapping between the markers and the idioms as in Table 4.3.

Figure 4.5 illustrates overview of the visualization of Teddy's detection mode. The x-axis represents the commit ID of the project while the y-axis represents the file name of each files including in the project. The green legend of the scatter plot illustrates the IP and the red legend is for NIP.

The zoomed version of the visualization is shown in Figure 4.6. From the figure, it can be seen that the scatter plot has different markers which represents each type of idioms. In our case study, we have the idiom in total for 10 types including: dictionary comprehension, enumerate, file reading statement, list comprehension, if statement, string formatting, code formatting, set, tuple, and variable swapping.

Table 4.3: Table showing mapping between the marker and type of IPs/NIPs

IPs/NIPs	Marker symbol
Dictionary Comprehension	○ (Circle)
Enumerate	△ (Triangle)
File Reading Statement	□ (Square)
List Comprehension	◇ (Diamond)
If Statement	⬡ (Hex)
String Formatting	∗ (Asterisk)
Code Formatting	⊗ (Circle Cross)
Set	× (Cross)
Tuple	▽ (Inverted Triangle)
Variable Swapping	⊠ (Square Cross)

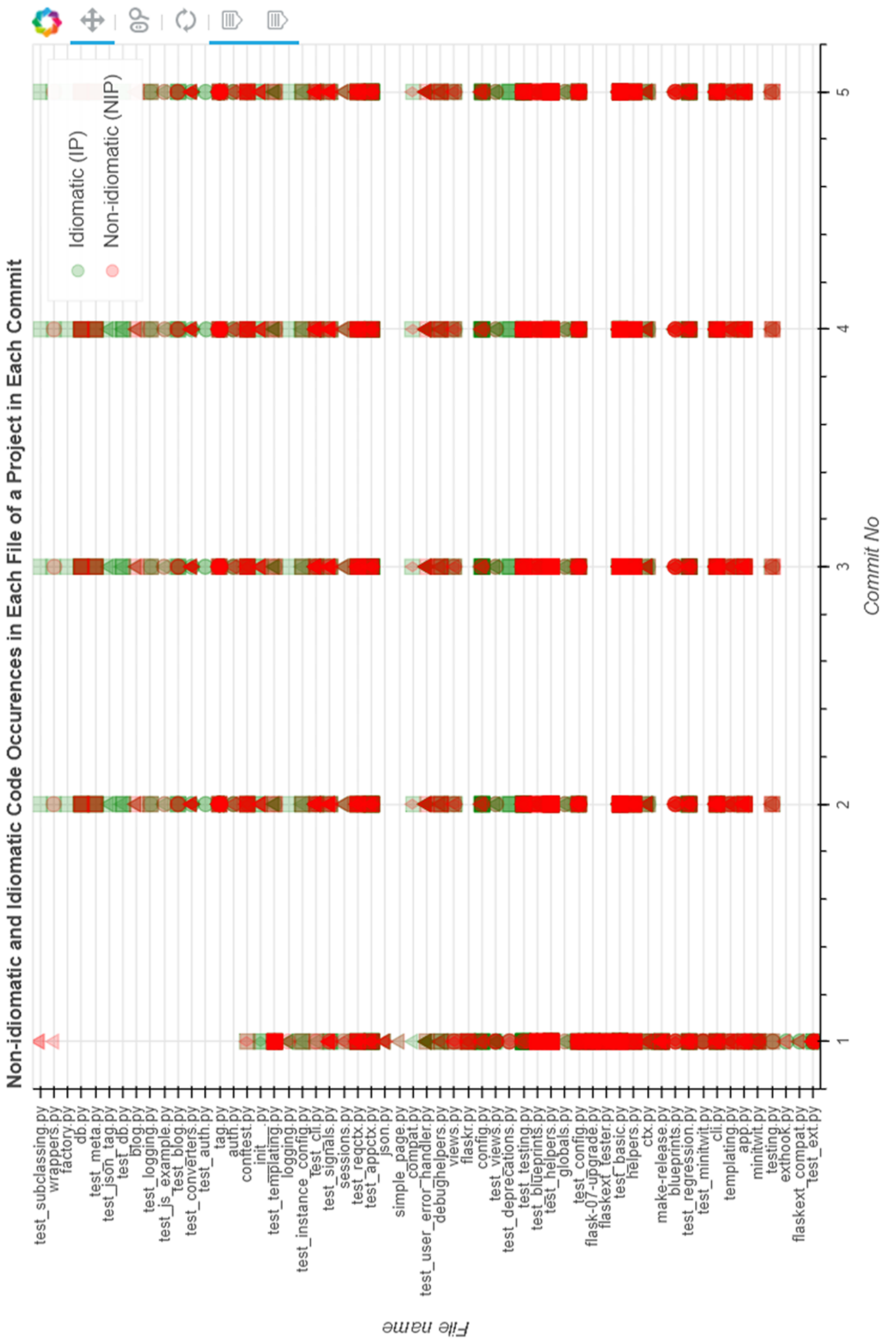

Figure 4.5: Overview of the sample visualization

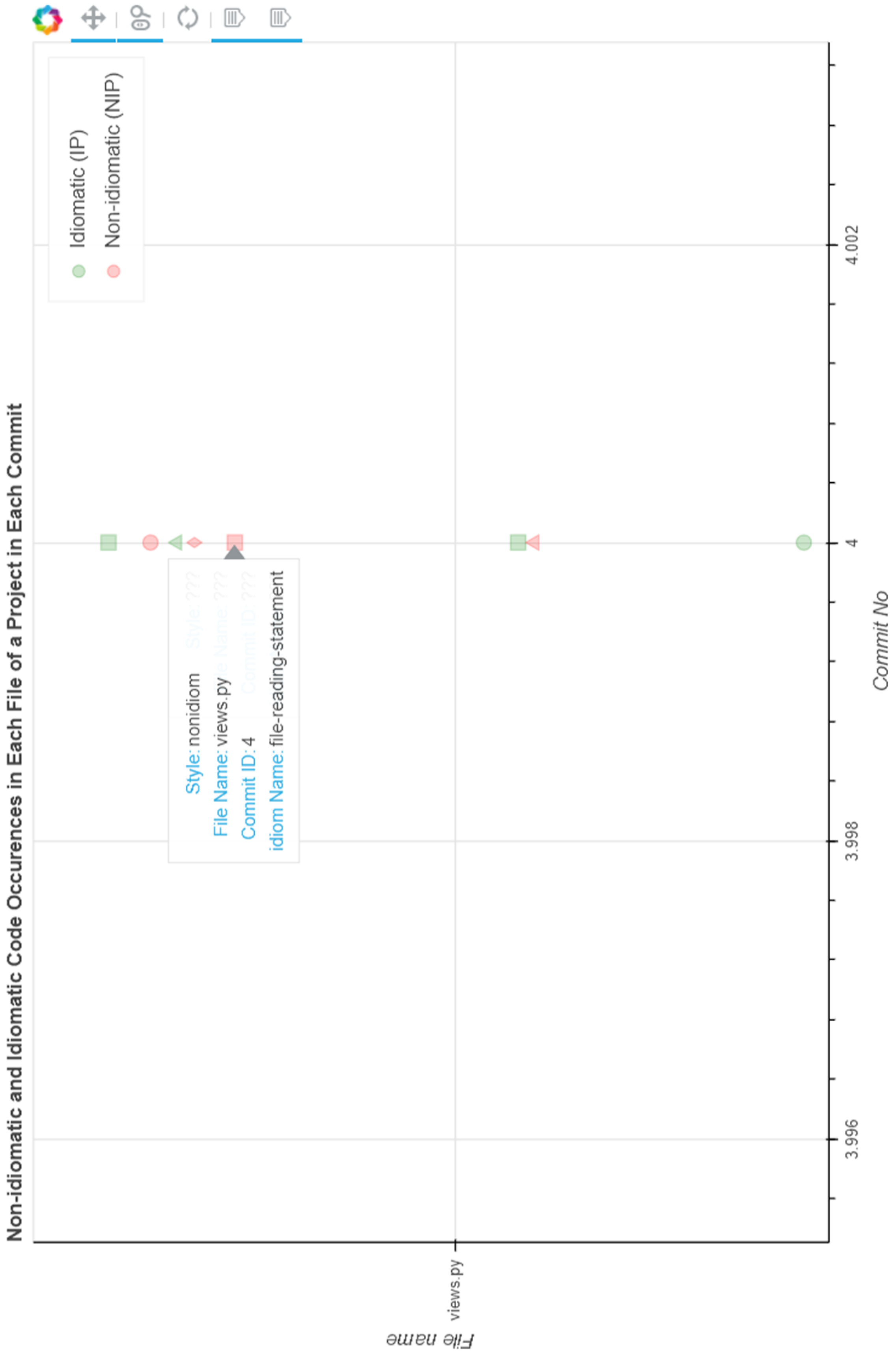

Figure 4.6: The zoomed view of the sample visualization

4.5 User Interface

Figure 4.7 shows the user interface which has been designed for minimal interaction with full usability, users will not have to navigate through settings as most of the process will be automated. The user interface will be divided into two sections, Detection and Prevention. In the Detection mode, users will simply have to put in the repository link and everything else will be automated as explained in Section 4.4, once the process is done, a new page would pop up showing the results. As for the Prevention mode, users will have to follow the instructions, which require them to allow "TeddyMuict" into their repository as a collaborator and Install "TeddyBot", the rest after that is automated and runs immediately when a pull request is created as explaiend in Section 4.3.

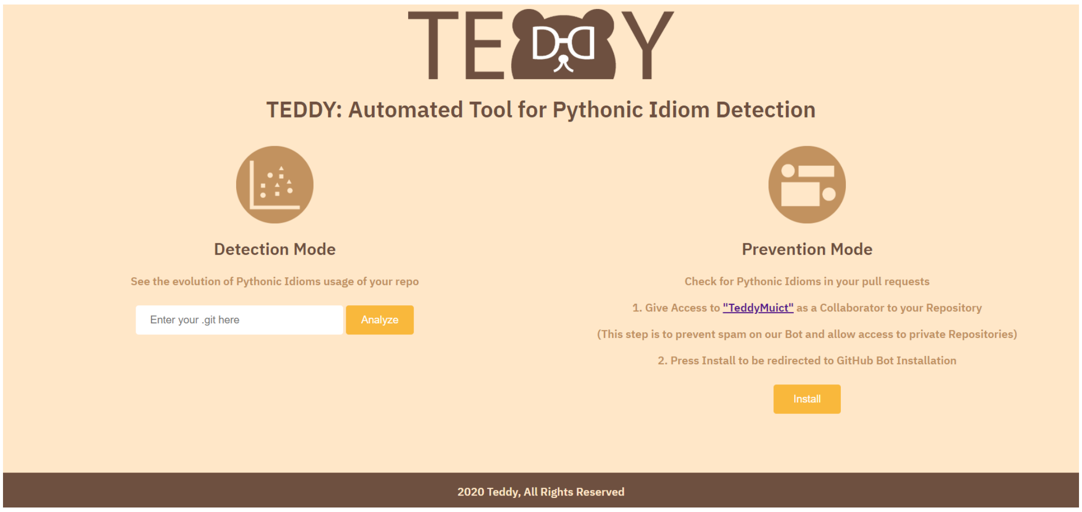

Figure 4.7: User Interface for Teddy Tool

CHAPTER 5
EVALUATION AND DISCUSSION

This chapter will focus on the Testing and User Evaluations of Teddy tool including the detection mode on synthetic dataset to evaluate its detection precision and recall, the detection mode on real software project (Flask), and the planned user study.

5.1 Detection Mode: Idiom Detection Accuracy

5.1.1 Methodology

Before Teddy could be run on a real software project, an evaluation experiment was conducted to verify its performance and make sure it can correctly return results as desired, or that there is any adjustments to be made if otherwise. A set of syntactic unbiased data set was created, with some objective error measures which are used to carry out the assessment.

Evaluation Dataset

To make a ground-truth data set for evaluation of Teddy, a collection of Python code has been prepared accordingly. In order to assure that there is no bias in the testing set, the prepared code has been from third-party sources - mainly the GitHub repository of Flask, Tensorflow and Manim.

Within the data set consists of three groups of Python code files, as shown in Table 5.1. The first group - the normal code - is the group of Python codes that do not pertain parts relevant to being classified as neither NIP nor IP. There are a total of 30 files for this group. The second group - the IP group - represents 20 snippets of IP code (one snippet per one file), each of which is sampled from the three open-source Python projects, as well as other online sources. And the third group - the NIP group - consists of 20 NIP code snippets (one snippet per one file) that are also picked from the similar sources as the IP group.

To be able to systematically extract IP and NIP snippets from hundreds of source code files, representative regular expressions are created for each of the IP and NIP type. Then, a tool called CCGrep [25] is employed to use those expressions as search inputs to obtain possible IP/NIP codes in the actual software repository files. The given results, however, has to undergo manual filter once more.

Among 20 IP and NIP code files, 2 samples for each of IP and NIP types are included. In total, with the normal codes, there are 70 Python files in this ground-truth testing data set.

Table 5.1: Table summarizing the contents inside evaluation data set

File group	Description	Number of files
Normal code	Python codes without any IP or NIP statements	30
IP code	Python codes with IP statements	20
NIP code	Python codes with NIP statements	20
Total		**70**

Experimental Framework

As detection mode aims to find and label different IP and NIP code snippets within historical versions of a software repository, the experiment has been designed to simulate one iteration of such scenario. A set of IP and NIP code snippets, 55 IP snippets and 58 NIP snippets, have been prepared and used to query for IP and NIP code inside the ground-truth data set.

The focus is to optimize and adjust the search parameters of Siamese search engine so that it can accurately find and match the IP and NIP codes in the query with those in the data set. The following error measures are used as assessing benchmarks for one particular parameter setting.

Error Measures

- Mean Average Precision (MAP) - The mean average precision is the mean value of average precision values over all the queries. The average precision is computed from different recall level, i.e., each time a relevant document is found. It is defined as

$$MAP(Q) = \frac{1}{|Q|}\sum_{j=1}^{|Q|}\frac{1}{|m_j|}\sum_{k=1}^{|m_j|} \mathit{Precision}(R_{jk}) \tag{5.1}$$

where Q is the set of the queries $\{q_1, q_2, ..., q_{|Q|}\}$, m_j is the set of relevant results for a query q_j, R_{jk} is the set of ranked retrieved items from the first-ranked item until a relevant document d_k, and *Precision*(X) is the function to compute normal precision for X.

- Query Recall (QR) - Query recall is the measure to evaluate how complete is the number of relevant items retrieved in respect to the subset of queries whose results are not empty (called "returned queries"). QR for a set of returned queries r is defined as:

$$QR = \frac{1}{|r|}\sum_{i=1}^{|r|}\frac{|RRI_i|}{|TRI_i|} \tag{5.2}$$

where RRI_i is the set of retrieved relevant items and TRI_i the set of all relevant items for the i-th returned query, respectively.

For this particular evaluation, the total number of relevant items (TRI_i) inside the data set is two for every IP/NIP query. Therefore, the possible values of recall for a single query can either be 0 ($|RRI_i| = 0$), 0.5 ($|RRI_i| = 1$), or 1 ($|RRI_i| = 2$). After summing all the recalls of every returned query, the final QR is then computed by averaging the summed amount by the number of returned queries $|r|$.

- Overall Recall (OR) - Overall recall is the measure to evaluate how complete is the number of relevant items retrieved in respect to the entire set of query R:

$$QR = \frac{1}{|R|}\sum_{i=1}^{|R|}\frac{|RRI_i|}{|TRI_i|} \tag{5.3}$$

where RRI_i is the set of retrieved relevant items and TRI_i the set of all relevant items for the i-th query, respectively.

In contrast to the error measure QR, OR also takes into account the queries which are not returned any result, in other words having empty list of results. For example, provided that there are a total of 113 individual IP and NIP snippet queries, if 88 of them are returned with non-empty list of results, the error measure QR is computed using the set of 88 returned queries while OR also considers the remaining 25 queries which have empty results.

- Mean Reciprocal Rank (MRR) - The mean reciprocal rank is the average of the reciprocal ranks of results for a sample of queries Q:

$$MRR = \frac{1}{|Q|} \sum_{i=1}^{|Q|} \frac{1}{rank_i} \tag{5.4}$$

where $rank_i$ refers to the rank position of the first relevant document for the i-th query. In our implementation, the reciprocal rank of a query (equivalent to a row in the `csv` output file) is the multiplicative inverse of the rank of the first true-positive match between the IP/NIP of the query and IP/NIP of the data set. The reciprocal rank of each individual row is added together and averaged by the number of rows in that file.

5.1.2 Results and Discussion

The results from running the experiment underwent thorough manual analysis and evaluation of the author, using the error measures previously mentioned. With a vast array of adjustable parameters in Siamese's search engine configuration, the margin of variance for error measures is from as low as 0.04 to the best case's of 1.

After several trial-and-errors with different settings over 40 variations, it has been observed and concluded that the following group of tests, in Figure 5.1, has the best overall results across the four error measures used.

From the table, only the similarity computation method and multi-representation similarity thresholds are the independent variables of interest while the other remaining settings are fixed as controlled variables. For each of 3 different multi-representation similarity threshold permutations - set1 (50-40-30-20), set2 (40-40-40-40), and set3 (0-0-0-0) - two sub-variations between clone similarity computation method of tokenratio and fuzzywuzzy were tested.

It can be observed that the two different clone similarity computation methods contribute to different aspects of the search quality. By taking a close look at QR and OR measures, the tests which applied fuzzywuzzy for clone similarity computation threshold have higher values comparing to their tokenratio counterpart in the same experiment set. They also have larger set of returned queries as well. In exchange for lower recall, the tests with tokenratio setting gain much higher MAP and MRR values comparing to those of fuzzywuzzy.

An unexpected finding was also made from set3 experiments. It is clear that despite all of multi-representation similarity threshold being set to zero (0-0-0-0), there are still some "unreturned" queries (query with empty result) with tokenratio as similarity threshold computing method, thus making the recall less than 1.

	Siamese Search Configuration Parameters										Error Measures Results				
	Clone similarity computation method	Multi-representation similarity threshold				N-Gram size for multi-			Query Reduction	Ranking Func.	Query Row Count	Mean Average Precision	Query Recall	Overall Recall	Avg. MRR
		T1	T2	T3	T4	T2	T3	T4							
best case											**113**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
set1	tokenratio	50	40	30	20	4	4	4	FALSE	tfidf	11	0.7273	0.4545	0.0442	0.7273
	fuzzywuzzy	50	40	30	20	4	4	4	FALSE	tfidf	93	0.4196	0.3763	0.3097	0.4343
set2	**tokenratio**	**40**	**40**	**40**	**40**	**4**	**4**	**4**	**FALSE**	**tfidf**	**9**	**0.8889**	**0.5000**	**0.0398**	**0.8333**
	fuzzywuzzy	40	40	40	40	4	4	4	FALSE	tfidf	110	0.3848	0.4682	0.4558	0.4066
set3	tokenratio	0	0	0	0	4	4	4	FALSE	tfidf	112	0.3476	0.8884	0.8805	0.4465
	fuzzywuzzy	0	0	0	0	4	4	4	FALSE	tfidf	113	0.3194	1.0000	1.0000	0.4414
set4	none	0	0	0	0	4	4	4	FALSE	tfidf	113	0.3175	1.0000	1.0000	0.4387

Figure 5.1: Table of Siamese's parameter tuning experiment and the resulting error measures

5.2 Detection Mode: Test on a Real Software Project

After an optimal setting for NIP and IP searching was discovered from the experiment, an actual software GitHub repository was run with Teddy's detection mode to inspect and verify the functionality. The selected repository was Flask, a lightweight Python WSGI web application framework. The repository's master branch was cloned and the tool iterated through its 3,887 commits (as of April 16, 2020) from first to last. Figure 5.2 shows the final visualization output of NIPs and IPs usage found in different version of the project.

From the figure, we can see that most of the files in the project use only IPs or NIPs in their code without changing in to it's counterpart all along the commits while few files use both styles. However, there is some file, for example `app.py`, that improve their style of writing at later commits which can be seen that the scatter plot starts to turn green in the later commits while on the other hand, `flask-07-upgrade.py` has trend of changing the code from IPs into NIPs.

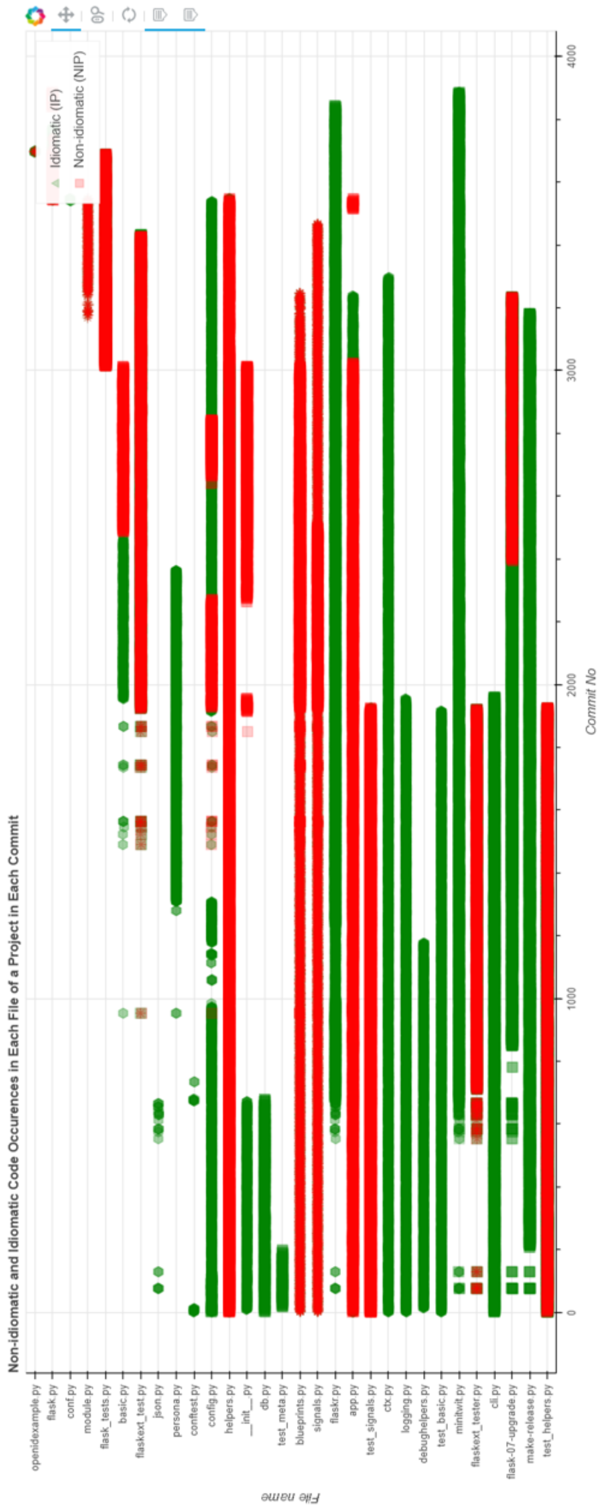

Figure 5.2: Visualization of IP and NIP usage in GitHub project Flask

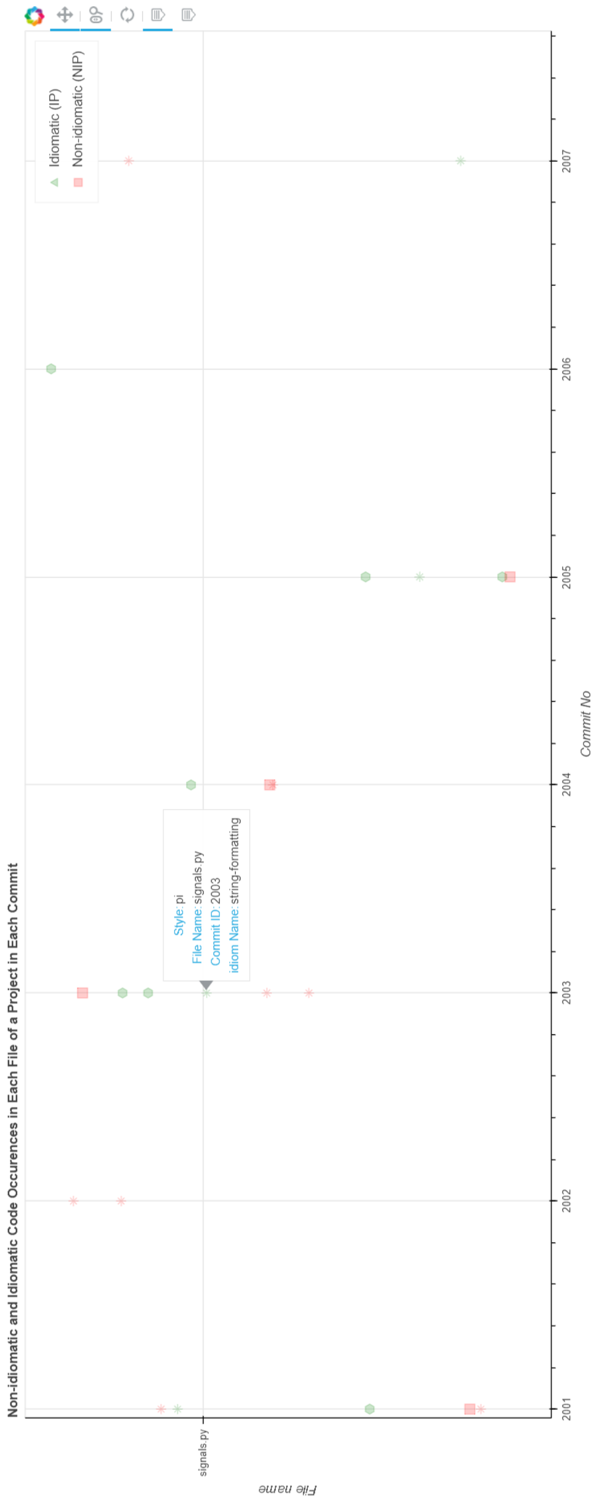

Figure 5.3: Zoomed Version of Visualization of IP and NIP usage in GitHub project Flask

5.3 Prevention Mode: User Study

A plan was made to conduct a user study on Teddy's prevention mode at Pronto Company with the target user in the sample size of 7 software developers. The research procedure starts with making the participants do the pre-test which involves their background knowledge of IPs and NIPs. Then, we, the researchers, would go in their company and set up the Teddy software for the participants. The participants would be given time to use the tool between 2 to 4 weeks to make sure they are familiar and keen enough to use the tool efficiently. At the end of the usage period, the participants have to do the test again (post-test). Moreover, we would interview them in additional to receive their comments about the tool.

Unfortunately, due to inconvenient situation that happened at the company, we were not able to deliver our tool and carry out the user study with the developers as planned. The cancellation of user study is also attributed to the situation of novel COVID-19 virus, making any other alternative means or options very unlikely to succeed. Thus, we did not include the user study result for the Teddy tool in this report

CHAPTER 6
CONCLUSION

This chapter will summarize the research and discuss the limitations, including the future directions of this project.

6.1 Conclusion

The main goal of this project is to give programmers a tool that can help them to analyze their code in a GitHub repository. We create an automated tool called Teddy that can detect the usage of idiomatic Python code during the development (code review time) and over historical commits. Teddy integrates several tools and techniques including GitHub integration (GitHub API, Probot, Smee.io), idiomatic code detection (SiameseX) and idiomatic code visulaization (Bokeh library).

The Teddy tool contains two modes of usage. The first mode is prevention mode, in which the tool works actively to give response to the user at real-time during pull requests. The other mode is detection mode, in which the tool gives feedback from going back to the start of the project and analyze the IPs and NIPs usage over all the projet's commits.

We evaluate the Teddy tool on synthetic idiomatic code dataset and a real software project. Using Mean Average Precision (MAP), Query Recall, Overall Recall, Mean Reciprocal Rank (MRR) to evaluate, we found that Teddy gives relatively high precision for idiomatic and non-idiomatic Python code detection. Moreover, the evaluation on Flask, a real Python project, shows that Teddy can visualize the usage of IPs and NIPs over 3,000 commits.

This Teddy tool is a valuable addition to nowadays modern software development and can be plugged-in to GitHub seamlessly. We hope that the tool will be useful for Thai programmers and other programmers around the world.

6.2 Problems and Limitations

For the prevention mode with the tool being able to handle a large number of incoming queries, the load time for handling multiple requests can be seen, as the tool can only handle 1 request at a time.

From using only one synthetic data set (due to time constraint in creating a ground-truth base from an actual soft repository) to test the tool, the level of performance, both precision and recall, is subject to vary for difference application on difference software projects. Also, regarding CCGrep, the tool offers little varieties of regular expression characters that used in the process of creating the synthetic testing data set, causing many of the sampled IPs and NIPs to be imprecise.

With the current performance of Teddy, despite its high precision, the tool is not able to identify the remaining PI and NPI code snippets as many, therefore resulting in very low recall. One possible explanation is that with the semantic nature of idiomatic Python codes, it is inefficient to capture the pattern with principle of code clone detection. The tool also has a problem when being left inactive for a while causing it to stop functioning until a request has been made several times. For the visualization, the limitation is that it is not flexible enough to manipulate the plot and the data in the plot. The plot can only handled by Java Script while the data is nearly impossible to adjust throughout the plot which means that the data must be ready and completed to be plotted.

6.3 Future Work

In the future we aim to have the tool be integrated into GitHub repositories without any problem regarding wait time and handling multiple queries. We also intend to expand the number of NIPs and IPs types to be included in Teddy's functionality to support wider scope of coding style and idioms. There are also many other unexplored minor settings of Siamese (and SiameseX) that remains potential key factors to the accuracy and recall of the search retrieval mechanism.

Since the unfortunate event of the company and COVID-19 prohibiting us from doing the user studies, our future work is to make it successfully tested with the expected target user groups in order to hear comments from real user experiences and get feedback to develop our tool to reach a higher level of efficiency.

Due to the limitation of pattern matching tool and time to study about each type of IPs and NPIs, we would like to expand our research coverage on this issue in future so that the tool can cover and detect more varieties and types of usage of Python idioms. In addition, we would like to try more flexible and adjustable visualization tool that would liberate the form of our visualization into more interactive way.

Moreover, if our tool can present the relationship between the appearing and disappearing Python codes in the project, it would be more beneficial for the user to track their usage of code.

APPENDIX A
IP CODE SNIPPETS

Listing A.1: List of IP dictionary comprehension code snippets

```
def i1():
    emails = {user.name: user.email for user in users if user.email}

def i2():
    dict_compr = {k: k**2 for k in range(10000)}

def i3():
    new_dict_comp = {n:n**2 for n in numbers if n%2 == 0}

def i4():
    dict1 = {'a': 1, 'b': 2, 'c': 3, 'd': 4, 'e': 5, 'f':6}
    dict1_tripleCond = {k:v for (k,v) in dict1.items() if v>2 if v%2 == 0
        ↪  if v%3 == 0}
    print(dict1_tripleCond)

def i5():
    nested_dict = {'first':{'a':1}, 'second':{'b':2}}
    float_dict = {outer_k: {float(inner_v) for (inner_k, inner_v) in
        ↪ outer_v.items()} for (outer_k, outer_v) in nested_dict.items()}
    print(float_dict)

def i6():
    # Initialize the `fahrenheit` dictionary
    fahrenheit = {'t1': -30,'t2': -20,'t3': -10,'t4': 0}
    # Get the corresponding `celsius` values and create the new
        ↪ dictionary
    celsius = {k:(float(5)/9)*(v-32) for (k,v) in fahrenheit.items()}
    print(celsius_dict)

def i7():
    mcase = {'a':10, 'b': 34, 'A': 7, 'Z':3}
    mcase_frequency = { k.lower() : mcase.get(k.lower(), 0) + mcase.get(k
        ↪ .upper(), 0) for k in mcase.keys() }
```

Listing A.2: List of IP `enumerate` code snippets

```
def i8():
    for i, x in enumerate(l):
        # ...

def i9():
    try:
        x = next(i for i, n in enumerate(l) if n > 0)
    except StopIteration:
        print('No positive numbers')
    else:
        print('The index of the first positive number is', x)

def i10():
    ls = list(range(10))
    for index, value in enumerate(ls):
      print(value, index)

def i11():
    a = [3, 4, 5]
    for i, item in enumerate(a):
        print i, item

def i12():
    for i, val in enumerate(array):
        #do stuff with i
        #do stuff with val

def i13():
    for index, element in enumerate(my_container):
        print (index, element)

def i14():
    my_list = ['apple', 'banana', 'grapes', 'pear']
    for c, value in enumerate(my_list, 1):
        print(c, value)

def i15():
    my_list = ['apple', 'banana', 'grapes', 'pear']
    counter_list = list(enumerate(my_list, 1))
    print(counter_list)
```

Listing A.3: List of IP file reading statement code snippets

```
def i16():
    with open('file.txt') as f:
        for line in f:
            print line

def i17():
    with open(path, "rb") as f:
        result = do_something_with(f)
        print("Got result: {}".format(result))

def i18():
    with open('file.ext') as f:
        contents = f.read()

def i19():
    with open("welcome.txt") as file:
        data = file.read()
        do something with data

def i20():
    with open(path_to_file, 'r') as file_handle:
        for line in file_handle:
            if raise_exception(line):
                print('No! An Exception!')
```

Listing A.4: List of IP list comprehension code snippets

```
def i21():
    result_list = [el for el in range(10000000)]

def i22():
        [print(i) for i in wordList]

def i23():
        new_list = [n**2 for n in numbers if n%2==0]

def i24():
        ls = [element for element in range(10) if not(element % 2)]
```

```
def i25():
        valedictorian = max([(student.gpa, student.name) for student in
            ↪ graduates])

def i26():
        a = [3, 4, 5]
        b = a
        a = [i + 3 for i in a]

def i27():
        return [[float(a_ij) for a_ij in a_i]
            for a_i in matrix_of_anything]
```

Listing A.5: List of IP `if` statement code snippets

```
def i28(countNotMax):
if countNotMax:
    # Some code here

def i29():
    if itemListEmpty():
        return "List is empty"

def i30(es):
    if !recreateIndex:
        es.connect()

def i31():
    if !gitHubRepo():
        for doc in index.getDoc:
            doc.setLicense(null)

def i32():
    num = input("Enter weight: ")
    if !num:
        print("No input found")
        else
            print("Processing your input")

def i33():
    name = 'Tom'
    is_generic_name = name in ('Tom','Dick','Harry')
```

```
def i34():
    num = 2
    prime_less_than_10 = num in (5,3,2,7)
    return prime_less_than_10

def i35():
    char = input("Enter a character A-Z")
    if char in ('A','E','I','O','U')
        print("Input is an vowel")

def i36():
    if itemListEmpty():
        return "List is empty"

def i37():
    if name:
        print(name)
        print(address)
        count++

def i38(sentence):
    if(sentence.endswith('?'))
        return 'Interrogative sentence'
        else
            return 'Informative sentence'
```

Listing A.6: List of IP string formatting code snippets

```
def i39(Store):
output = 'ID: {s.branch_ID}, City: {s.city}, Manager: {s.manager}'.format(s=
    ↪ Store)
return output

def i40(self, name, age, gender):
        self.name = name
        self.age = age
        self.gender = gender
    person = Person("John", 36, 'M')
    return 'Name: {p.name}\nAge: {p.age}\nGender: {p.gender}'.format(person=
        ↪ p1)

def i41():
    book_info = ' The Three Musketeers: Alexandre Dumas'
```

```
    formatted_book_info = book_info.strip().upper().replace(':', ' by').
        ↪ append(', ISBN:')
```

Listing A.7: List of IP set code snippets

```
def i42():
student_nationality = ['Thai','Malaysian','Thai','Vietnamese','Vietnamese','
    ↪ Vietnamese','Singaporean','Laos','Cambodian','Cambodian','Chinese']
unique_nationality = set(student_nationality)

def i43():
    staff_name = ['Catherine','Bryan', 'Kevin', 'Frank', 'Emily', 'Steven', '
        ↪ George', 'Hallen', 'Sasha', 'Nathan', 'Edward', 'Phillip', '
        ↪ Scarlet', 'Robert']
    staff_year_of_birth = [1997, 1960, 1971, 1982, 1990, 1995, 1994, 1960,
        ↪ 1983, 1997, 1996, 1960, 1981, 1982]
    unique_year_of_birth = set(staff_year_of_birth)

def i44():
    max_temp = [35.6, 34.7, 34.7, 36.1, 36.4, 36.8, 36.2, 36.2, 35.1, 35.0]
    min_temp = [27.1, 27.0, 26.8, 26.8, 27.0, 27.5, 27.2, 27.2, 26.9, 26.7]
    unique_max_temp = set(max_temp)
    unique_min_temp = set(min_temp)

def i45():
    grade = ['A','B','B','B','C','D','F','C','C','D','A']
    unique_grade = set(grade)
```

Listing A.8: List of IP tuple code snippets

```
def i46():
    list_from_comma_separated_value_file = ['dog', 'Fido', 10]
    (animal, name, age) = list_from_comma_separated_value_file

def i47():
    catherine_info = ['Catherine', 1960, 'Australian', 'F', 165, 50, 'Trainee
        ↪ ']
    class Staff:
        name = ''
        year-of-birth = 0
        nationality = ''
```

```
        gender = ''
        height = 0
        weight = 0
        position = ''
    cat = Staff()
    (cat.name, cat.year-of-birth, cat.nationality, cat.gender, cat.height,
        ↪ cat.position) = catherine_info

def i48{):
    DOB_numbers = [11,27,1,9,1996]
    (h,m,D,M,Y) = DOB_numbers
    return '%i:%i %i-%i-%i' % (h,m,D,M,Y)

def i49():
    blood_groups = ['A','B','O','B']
    class Person:
        blood = 'X'
    p1,p2,p3,p4 = Person()
    (p1.blood,p2.blood,p3.blood,p4.blood) = blood_groups
```

Listing A.9: List of IP variable swapping code snippets

```
def i50():
seat_A1 = 'Mike Wazowski'
seat_A2 = 'James Sullivan'
(seat_A1, seat_A2) = (seat_A2, seat_A1)

def i51(var_A, var_B):
    (var_A, var_B) = (var_B, var_A)

def i52():
    english = 4.0
    math = 3.5
    (english, math) = (math, english)

def i53(arr):
    n = len(arr)
    for i in range(n):
        for j in range(0, n-i-1):
            if arr[j] > arr[j+1]:
                (arr[j], arr[j+1]) = (arr[j+1], arr[j])
```

Listing A.10: List of IP code formatting code snippets

```
def i54():
if file_name == "-":
    module = types.ModuleType("input_scenes")
    code = "from manimlib.imports import *\n\n" + sys.stdin.read()
    try:
        exec(code, module.__dict__)
        return module
    except Exception as e:
        print(f"Failed to render scene: {str(e)}")
        sys.exit(2)
else:
    module_name = file_name.replace(os.sep, ".").replace(".py", "")
    spec = importlib.util.spec_from_file_location(module_name, file_name)
    module = importlib.util.module_from_spec(spec)
    spec.loader.exec_module(module)
    return module

def i55():
    self.set_cairo_context_path(ctx, vmobject)
    self.apply_stroke(ctx, vmobject, background=True).apply_fill(ctx,
        ↪ vmobject).apply_stroke(ctx, vmobject)
    return self
```

APPENDIX B
NIP CODE SNIPPETS

Listing B.1: List of NIP dictionary comprehension code snippets

```
def n1():
    emails = {}
    for user in users:
      if user.email:
        emails[user.name] = user.email

def n2():
    d = {}
    for k in range(10000):
        d[k] = k**2

def n3():
    for n in numbers:
        if n%2==0:
            new_dict_for[n] = n**2

def n4():
    dict1_tripleCond = {}
    for (k,v) in dict1.items():
        if (v>=2 and v%2 == 0 and v%3 == 0):
                dict1_tripleCond[k] = v
    print(dict1_tripleCond)

def n5():
    nested_dict = {'first':{'a':1}, 'second':{'b':2}}
    for (outer_k, outer_v) in nested_dict.items():
        for (inner_k, inner_v) in outer_v.items():
            outer_v.update({inner_k: float(inner_v)})
    nested_dict.update({outer_k:outer_v})
    print(nested_dict)

def n6():
    fahrenheit = {'t1':-30, 't2':-20, 't3':-10, 't4':0}
```

```
    #Get the corresponding `celsius` values
    celsius = list(map(lambda x: (float(5)/9)*(x-32), fahrenheit.values()))
    #Create the `celsius` dictionary
    celsius_dict = dict(zip(fahrenheit.keys(), celsius))
    print(celsius_dict)
```

Listing B.2: List of NIP `enumerate` code snippets

```
def n7():
    for i in range(len(l)):
        x = l[i]
    try:
        x = next(i for i, n in enumerate(l) if n > 0)
    except StopIteration:
        print('No positive numbers')
    else:
        print('The index of the first positive number is', x)

def n8():
    x = next(n for n in l if n > 0)
    except StopIteration:
        print('No positive numbers')
    else:
        print('The first positive number is', x)

def n9():
    ls = list(range(10))
    index = 0
    while index < len(ls):
      print(ls[index], index)
      index += 1

def n10():
    # Add three to all list members.
    a = [3, 4, 5]
    b = a #a and b refer to the same list object
    for i in range(len(a)):
        a[i] += 3 #b[i] also changes

def n11():
    for i in range(len(array)):
        #do stuff with i
        #do stuff with array[i]
```

```
def n12():
    index = 0
    for element in my_container:
        print (index, element)
        index+=1
```

Listing B.3: List of NIP file reading statement code snippets

```
def n13():
    f = open('file.txt')
    a = f.read()
    print a
    f.close()

def n14():
    f = open(path, "rb")
    result = do_something_with(f)
    f.close()
    print("Got result: {}".format(result))

def n15():
    f = open('file.ext')
    try:
      contents = f.read()
    finally:
      f.close()

def n16():
    file = open("welcome.txt")
    data = file.read()
    print data
    file.close()

def n17():
    file_handle = open(path_to_file, 'r')
    for line in file_handle.readlines():
        if raise_exception(line):
            print('No! An Exception!')
```

Listing B.4: List of NIP list comprehension code snippets

```
def n18():
    result_list = []
    for el in range(10000000) :
        result_list.append(el)

def n19():
    for i in range(len(wordList)) :
        print(wordList[i])
        i += 1

def n20():
    ls = []
    for element in range(10):
        if not (element%2):
            ls.append(element)

def n21():
    new_list = []
    for n in numbers:
        if n%2==0:
            new_list.append(n**2)

def n22():
    list = [1, 3, 5, 7, 9]
    while i < length:
        print(list[i])
        i += 1

def n23():
    ls = list(filter(lambda element: not(element % 2), range(10)))

def n24():
    a = [3, 4, 5]
    b = a
    for i in range(len(a)):
        a[i] += 3

def n25(matrix_of_anything):
    n = len(matrix_of_anything)
    n_i = len(matrix_of_anything[0])
    new_matrix_of_floats = []
    for i in xrange(0, n):
        row = []
```

```
        for j in xrange(0, n_i):
            row.append(float(matrix_of_anything[i][j]))
        new_matrix_of_floats.append(row)
    return new_matrix_of_floats
```

Listing B.5: List of NIP `if` statement code snippets

```
def n26(countNotMax):
    if countNotMax == True:
        # Some code here

def n27():
    if itemListEmpty() == True:
        return "List is empty"

def n28(es):
    if recreateIndex == False:
        es.connect()

def n29():
    if gitHubRepo() == False:
        for doc in index.getDoc:
            doc.setLicense(null)

def n30():
    num = input("Enter weight: ")
    if num == None:
        print("No input found")
        else
        print("Processing your input")

def n31():
    name = 'Tom'
    if name == 'Tom' or name == 'Dick' or name == 'Harry':
         is_generic_name = True

def n32():
    num = 2
    if num = 5 or num = 3 or num = 2 or num = 7:
        prime_less_than_10 = True

def n33():
    char = input("Enter a character A-Z")
```

```
        if char = 'A' or char = 'E' or char = 'I' or char = 'O' or char = 'U':
            print("Input is an vowel")

    def n34():
        if itemListEmpty() == True: return "List is empty"

    def n35():
        if name: print(name); print(address); count++;

    def n36():
        if !gitHubRepo(): for doc in index.getDoc: doc.setLicense(null);

    def n37(sentence):
            if(sentence.endswith('?')) return 'Interrogative sentence'; else
                ↪ return 'Informative sentence';
```

Listing B.6: List of NIP string formatting code snippets

```
    def n38(Store):
    return 'ID: ' + Store.branch_ID + ' City: ' + Store.city + ' Manager: ' +
        ↪ Store.manager

    def n39(Store):
        return 'ID: %i City: %s Manager: %s' % (Store.branch_ID, Store.city,
            ↪ Store.Manager)

    def n40(self, name, age, gender):
            self.name = name
            self.age = age
            self.gender = gender
        person = Person("John", 36, 'M')
        return 'Name: ' + person.name + '\nAge: ' + person.age + '\nGender: ' +
            ↪ person.gender

    def n41(self, name, age, gender):
            self.name = name
            self.age = age
            self.gender = gender
        person = Person("John", 36, 'M')
        return 'Name: %s\nAge: %i\nGender: %c' % (person.name, person.age, person
            ↪ .gender)

    def n42():
```

```
    book_info = ' The Three Musketeers: Alexandre Dumas'
    formatted_book_info = book_info.strip()
    formatted_book_info = formatted_book_info.upper()
    formatted_book_info = formatted_book_info.replace(':', ' by')

def n43(sentence):
    output = sentence.capitalize()
    output = output.swapcase()
    output = output.replace('I\'m', 'I am')
    output = output.replace('You\'re','You are')
    output = output.replace('can\'t','cannot')
    return output

def n44(sentence):
    formatted = sentence.capitalize()
    formatted = output.swapcase()
    return formatted.endswith('.')
```

Listing B.7: List of NIP set code snippets

```
def n45():
student_nationality = ['Thai','Malaysian','Thai','Vietnamese','Vietnamese','
    ↪ Vietnamese','Singaporean','Laos','Cambodian','Cambodian','Chinese']
unique_nationality = []
for nationality in student_nationality:
    if nationality not in unique_nationality:
        unique_nationality.append(nationality)

def n46():
    staff_name = ['Catherine','Bryan', 'Kevin', 'Frank', 'Emily', 'Steven', '
        ↪ George', 'Hallen', 'Sasha', 'Nathan', 'Edward', 'Phillip', '
        ↪ Scarlet', 'Robert']
    staff_year_of_birth = [1997, 1960, 1971, 1982, 1990, 1995, 1994, 1960,
        ↪ 1983, 1997, 1996, 1960, 1981, 1982]
    unique_year_of_birth = []
    for year in staff_year_of_birth:
        if year not in unique_year_of_birth:
            unique_year_of_birth.append(year)

def n47():
    max_temp = [35.6, 34.7, 34.7, 36.1, 36.4, 36.8, 36.2, 36.2, 35.1, 35.0]
    min_temp = [27.1, 27.0, 26.8, 26.8, 27.0, 27.5, 27.2, 27.2, 26.9, 26.7]
    unique_max_temp = []
```

```
    unique_min_temp = []
    for temp in max_temp:
        if temp not in unique_max_temp:
            unique_max_temp.append(temp)
    for temp in min_temp:
        if temp not in unique_min_temp:
            unique_min_temp.append(temp)

def n48():
    grade = ['A','B','B','B','C','D','F','C','C','D','A']\
    student_placeholder = 'John Doe'
    unique_grade = []
    for g in grade:
        if g not in unique_grade:
            unique_grade.append(g)
```

Listing B.8: List of NIP tuple code snippets

```
def n49():
list_from_comma_separated_value_file = ['dog', 'Fido', 10]
animal = list_from_comma_separated_value_file[0]
name = list_from_comma_separated_value_file[1]
age = list_from_comma_separated_value_file[2]

def n50():
    catherine_info = ['Catherine', 1960, 'Australian', 'F', 165, 50, 'Trainee
        ↪ ']
    class Staff:
        name = ''
        year-of-birth = 0
        nationality = ''
        gender = ''
        height = 0
        weight = 0
        position = ''
    cat = Staff()
    cat.name = catherine_info[0]
    cat.year-of-birth = catherine_info[1]
    cat.nationality = catherine_info[2]
    cat.gender = catherine_info[3]
    cat.height = catherine_info[4]
    cat.weight = catherine_info[5]
    cat.position = catherine_info[6]
```

```
def n51():
    DOB_numbers = [11,27,1,9,1996]
    h = DOB_numbers[0]
    m = DOB_numbers[1]
    D = DOB_numbers[2]
    M = DOB_numbers[3]
    Y = DOB_numbers[4]
    return '%i:%i %i-%i-%i' % (h,m,D,M,Y)

def n52():
    blood_group = ['A','B','O','B']
    class Person:
        blood = 'X'
    p1 = Person()
    p1.blood = blood_group[0]
    p2 = Person()
    p2.blood = blood_group[1]
    p3 = Person()
    p3.blood = blood_group[2]
    p4 = Person()
    p4.blood = blood_group[3]
```

Listing B.9: List of NIP variable swapping code snippets

```
def n53():
seat_A1 = 'Mike Wazowski'
seat_A2 = 'James P. Sullivan'
temp = seat_A1
seat_A1 = seat_A2
seat_A2 = temp

def n54(numA, numB):
    temp = numA
    numA = numB
    numB = temp

def n55():
    english = 4.0
    math = 3.5
    temp = english
    english = math
    math = temp
```

```
def n56(arr):
    n = len(arr)
    for i in range(n):
        for j in range(0, n-i-1):
            if arr[j] > arr[j+1]:
                temp = arr[j]
                arr[j] = arr[j+1]
                arr[j+1] = temp
```

Listing B.10: List of NIP code formatting code snippets

```
def n57(file_name):
    if file_name == "-":
        module = types.ModuleType("input_scenes"); code = "from manimlib.
            ↪ imports import *\n\n" + sys.stdin.read()
        try:
            exec(code, module.__dict__); return module;
        except Exception as e:
            print(f"Failed to render scene: {str(e)}"); sys.exit(2);
    else:
        module_name = file_name.replace(os.sep, ".").replace(".py", ""); spec
            ↪  = importlib.util.spec_from_file_location(module_name,
            ↪ file_name); module = importlib.util.module_from_spec(spec);
        spec.loader.exec_module(module)
        return module

def n58(self, vmobject, ctx):
    self.set_cairo_context_path(ctx, vmobject); self.apply_stroke(ctx,
        ↪ vmobject, background=True); self.apply_fill(ctx, vmobject); self.
        ↪ apply_stroke(ctx, vmobject);
    return self
```

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