Project Number. GFP1405

DESIGN PATTERN GENERATOR FOR PYTHON

A Major Qualifying Project Report:

submitted to the faculty of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by:

Robert Mullins

Alfred Scott

Date: April 25, 2015

Approved:

Professor Gary F. Pollice, Major Advisor

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Abstract

Design patterns are important techniques that programmers can use to solve common problems and make their code more robust. The goal of this project is to provide a tool that supports inserting design patterns into existing code. We manipulate abstract syntax trees to achieve this goal. We created a graphical user interface that lets users generate different design patterns. We provide instructions on how to extend our program by adding more design patterns.

Acknowledgements

We would like to thank Gary Pollice, our project advisor. He provided us with the idea for our project as well as invaluable insight on to how to approach the many problems we faced.

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1. Introduction

A design pattern is a proven solution for a general problem. By utilizing design patterns, one's code often becomes more organized, readable, and expandable [19]. For these reasons, it is import for programmers to structure their code with design patterns in mind. Our goal is to design a tool that allows for the insertion of design patterns into existing code for the purpose of teaching good coding practices. Due to the fact that design patterns can only be applied under certain conditions, our tool also has the side effect of educating the programmer as to when patterns can be used.

Our project required us to select a suitable implementation language and an appropriate set of patterns to implement. Python is a popular programming language for beginners due to its readable syntax and ease of use [22]. The patterns we selected were ones that work well with Python, are useful for beginners to know, and have a standard structure regardless of code context. We decided to implement the class adapter, observer, abstract factory, and class decorator design patterns.

Our method of generating patterns utilized abstract syntax trees generated by Python. An abstract syntax tree (AST) is a tree representation of the abstract syntactic structure of source code. Each node of this tree can be anything from a main function to a single string. With the help of standard and third party libraries, we were able successfully apply design patterns to existing code. We designed a graphical user interface that allows the user to select a file, a design pattern, and the classes or methods to apply the pattern to. We also created a guide for how a user could add their own design pattern to our program. Future work includes more comprehensive error checking for design pattern generation and working to preserve all comments and whitespace.

This paper is organized in the following way. Section 2 discusses design patterns and syntax trees for the purpose of understanding the motivation of our project. Section 3 discusses our process for picking a language and set of design patterns to work with, and how we manipulated syntax trees to incorporate patterns into existing code. Section 4 discusses the general results of our project. Section 5 identifies areas of future work.

2. Background

Our program deals with the modification of existing code to implement design patterns. To fully understand the motivation for our project, it is important to recognize why design patterns are regarded as important tools for programmers. Additionally, our means of modifying existing code was to modify generated abstract syntax trees. An explanation as to how these structures work and can be modified is given.

2.1 Design Patterns

Design patterns are proven solution for a general problem [19]. In computer science, many problems occur frequently but in different forms or contexts. Once a solution for a problem is found, it can be modified to apply to other similar problems. Design patterns are the most effective and widely used of these solutions.

Design patterns are abstract in nature. On the concept of abstract patterns applied to building design, Christopher Alexander stated that "...each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" [3]. This same logic applies to design patterns in an object oriented coding context. One could use a single design pattern under many different contexts, but its basic structure and approach to solving the problem will remain the same.

The concept of reusable and flexible code is something that beginner programmers do not often grasp naturally. An experienced programmer can design code from the ground up with future changes in mind. “A designer who is familiar with such patterns can apply them immediately to design problems without having to rediscover them" [3]. Once a programmer has encountered a problem and solved it, he or she will recall that solution the next time a similar problem occurs. Eventually, an experienced programmer will have an idea as to what kinds of problems will lay ahead based on the requirements of their project. His or her code will be structured so that it can easily incorporate their pre-designed solution for the predicted obstacles. However, it is impossible to predict all challenges one will face whilst working on a project. For this reason, it is important to have your code remain flexible so that unforeseen future problems can be addressed.

Design patterns help the programmer communicate intent. Many patterns are easily recognizable; their relatively standardized structure can help future developers understand existing projects. "In the object oriented world, design patterns tell us how, in the context of a certain problem, we should structure the classes and objects. They do not translate directly into the solution; rather have to be adapted to suit the problem context." [2]. Design patterns provide abstract solutions to recurring problems, so if someone can identify a pattern in a project, they can also discern the problem it is trying to solve, which is a major step toward understanding the project as a whole.

2.2 Syntax Trees

A syntax tree is a tree representation of the structure of a program's source code. Syntax trees are generated by the parser during the compilation process before output code can be produced [24, 25]. In a syntax tree, each node represents a hierarchal piece of the code structure located in the source. For example, a function definition is a node which contains a series of child nodes for each of its expressions. These expressions may be arithmetic operations, variable declarations, function calls, or other code bodies. There are two types of syntax trees: parse trees, or concrete syntax trees (CSTs) and abstract syntax trees (ASTs). The parsers of certain compilers create ASTs directly, while others create a CST from which an AST is derived [1].

2.2.1 Concrete Syntax Trees

A CST represents every element of the syntax of the source code as its own node [1]. Figure 1 is an example of a CST for the C statement `return a + 2;`.

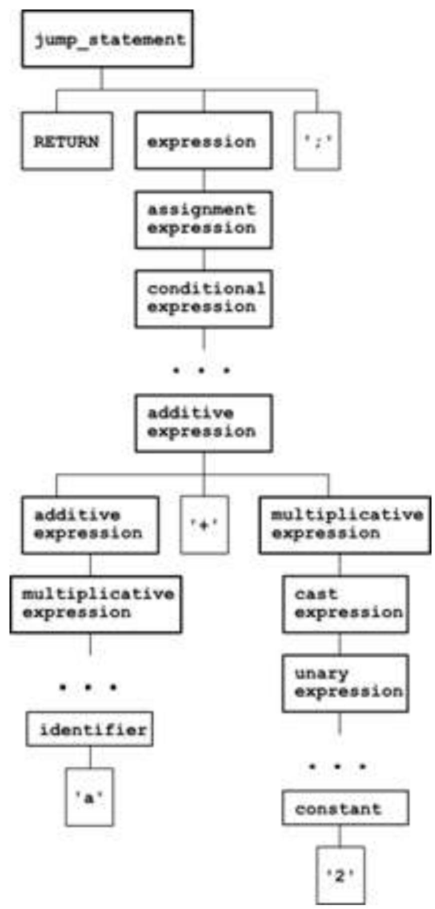


Figure 1- Concrete Syntax Tree Example

As shown by Figure 1, every element of the expression is allotted a node. There are sequences of compound nodes that list all specific types of expressions the statement is. This formal representation describes every detail of the syntax that the parser detected. However, such detail is often not needed, making CSTs more difficult to work with [1].

2.2.2 Abstract Syntax Trees

An AST "is a tree representation of the abstract syntactic structure of source code" [2]. The nodes provide a semantic representation of the code, but with abstract syntax. This means that certain syntactic nodes, such as terminating semicolons, are not present as singular nodes but instead are encompassed by the expression nodes. Figure 2 shows an AST representation of the same statement used for the CST in Figure 1.

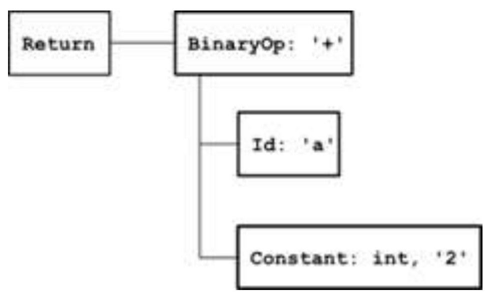


Figure 2 - Abstract Syntax Tree Example

ASTs are a more compact version of CSTs in that they eliminate nodes with no semantic meaning. For example, Figure 2 shows that sequence of expression nodes present in the CST in Figure 1 are now simply represented as a single `BinaryOp` node [1]. This leads to a smaller, more readable tree. However, the exact syntax derivation of the statement is lost in this process, thus making the tree an abstract representation.

2.2.2 Syntax Trees and Python

The Python interpreter creates an AST as part of its compilation process. The source code is first tokenized by the lexer and then sent to the parser, which creates a parse tree. An AST is then created from this parse tree, which is then sent to the bytecode generator and eventually the bytecode interpreter [24, 26]. The tools for generating the

ASTs, manipulating ASTs, and compiling ASTs into bytecode are included within the free Python `ast` and `compile` modules [25]. In the methodology section of this paper we discuss the process of modifying an AST and then converting it back into source code.

3. Methodology

This section of the paper discusses our process of picking a language in which to write our program, picking design patterns to implement, and modifying ASTs for the purpose of adding patterns to existing code.

3.1 Choosing a Language

The language we decided to write our program in was Python. This decision was made based on many factors: our target audience, ease of use, and our available tools.

3.1.1 Target Audience and Ease of Use

The goal of our project is to design a resource for new programmers that provides an easy way to implement design patterns into existing code. Therefore, it was important that we write our program to operate on a language that is often used by beginners. Python is one of the more popular introductory languages. It is listed as one of the top languages that is being used by computer science departments in university starter courses [33].

Python's popularity is attributed to its ease of use due to its readable syntax [22]. Newer programmers can easily grasp the language's grammar as it often uses English words opposed to symbols to represent logic and expressions.

```c
void foo(int x){
    if (x==0){
    bar();
    bar();
    }
    else{
    qux(x);
    foo(x-1);
    }
}
```

```python
def foo(x):
    if x == 0:
        bar()
        baz()
    else:
        qux(x)
        foo(x - 1)
```

Figure 3 - C and Python Code Comparison

Figure 3 compares the how the same program would be written in C, on the left, and in Python, on the right. The Python version of the code has a few important differences to note: the lack of braces, the lack of semicolons, and the lack of parameter typing. Python's scoping structure is defined predominantly by whitespace indentation. The indentation level of a line of code indicates what code block the line belongs to. This means that programmers do not need to keep track of parenthesis or brackets, but instead monitor their indentation levels. A consequence of having whitespace tied to syntax is that good indentation habits are enforced. Python also does not require any terminal character at the end of statements, nor does it require a parameter's type to be specified in a function's definition. Python functions are defined the same way regardless of their return value, or lack thereof. In general, Python is a straightforward language, syntactically speaking, with a short learning curve, making it ideal for beginners.

A key difference between Python and other programing languages lies in how classes are defined. Figure 4 gives an example of a Python class.

```python
class car(object):
    def __init__(self, make, model):
        self.make = make
        self.model = model

    def getInfo(self):
        return self.make, self.model
```

Figure 4 - Example Python Class

Import details to note for those unfamiliar with python are the `__init__` method and the `self` parameter. The `__init__` method is called by Python itself automatically when an instance of a class is created. This method sets the fields within the class. The `self` parameter is an instance object that is passed as the first parameter in Python methods. The `self` object is the actual instance of this individual class; multiple `car` classes will be distinguishable by their `self` variables. In this regard, the statement `self.make = make` sets the `make` field for a single instance of a car class. The `self` variable is how one accesses the data for a single instance of that class from within the class itself.

3.1.2 Available AST Packages

Our choice of programming language depended on the amount of tools we had at our disposal to reach our goal. An AST can be generated from every syntactically correct Python program. However accessing an AST in order to print and manipulate it is not so easy. Rather than writing our own modules that manipulate ASTs, we searched for existing ones that we could adapt to our needs. Meta is a free package available for Python that can print a program's AST as well as generate Python source code from an AST [33]. Python itself comes with the `ast` module, which contains functions for editing, adding, and removing nodes from an AST [34. 35].

3.1.3 Printing ASTs

The Meta package allows for the printing of ASTs. The output shows the tree structure in the form of nodes. When working with an AST in Python, each node is set up as if it were an object, having fields and values which denote the structure of the statement or code block it represents. Meta prints out the tree of these objects exactly how they would be used by the Python `ast` module, but properly indented so that it is readable. Figure 5 shows an example of a simple python program and its AST printed out via the Meta package.

```
Module(body=[FunctionDef(args=arguments(args=[],
                                        defaults=[],
                                        kwarg=None,
                                        vararg=None),
                         body=[Print(dest=None,
                                     nl=True,
                                     values=[Str(s='hello world')])],
                         decorator_list=[],
                         name='helloworld')])
```

```
def helloworld():
    print "hello world"
```

Figure 5 - Example AST Printed With Meta

Due to the simple nature of this program, the AST is fairly straightforward. Every Python file has all of its classes and function definitions located within an all-encompassing `Module` node. In this example, you can see the function definition within the body of `Module`. The function definition has four key attributes; the arguments for the function, the body, a list of decorators, and its name. The arguments are a list of parameters that are passed into this function. The list is empty for this example because there are no input arguments. The body contains a node for a print expression with the value being a string that stores the message "hello world". This function is not decorated so the decorator list is empty. Finally, the `name` attribute holds the name of the function

```
def printAST(arg):
    filename = "%s" % (arg)
    with open(filename) as f:
        code = f.read()
    tree = ast.parse(code)
    printed_AST = meta.asttools.str_ast(tree)
    print printed_AST
```

Figure 6 - Printing an AST

Figure 6 shows the process to print an AST with Meta. First, a file is opened and saved as a code object. Then this code object is passed into a Python function called `ast.parse`, which generates an AST object. Finally, the AST object is passed into the Meta function `meta.asttools.str_ast` which generates a string representation of the tree which can be printed.

3.1.4 Editing the ASTS and Generating Code

To be able to understand node manipulation one must first grasp the structure of the tree. The initial node, `Module`, is the all-encompassing code body outside any function or object. Any functions, statements, or object definitions are all children of this foremost parent node, either directly or indirectly. The nodes of an AST can represent anything from a class definition to a single statement. For example, a node that represents a class will have several child nodes, each representing method definitions and fields. Certain changes to an AST propagate and other ones do not. For instance, removing an object node also removes all its constituent methods nodes, and so forth. However, modifying a node so that, for example, a field is renamed, will result in mismatched field names in function calls and syntactically incorrect code.

```python
class MyTransformer(ast.NodeTransformer):
    def visit_Name(self,node):
        node.id = node.id.upper()
        return node
if __name__ == '__main__':
    modify(sys.argv[1])
```

Figure 7 - AST Transformer Function

AST modification is best illustrated with an example. This section will show how one would modify an AST to change the names of variables. This requires the usage of the `ast.NodeTransformer` class, which is a part of the Python `ast` module. The `ast.NodeTransformer` class is an implementation of the visitor pattern the visits all nodes of the tree by type. The steps required for modifying a program's AST are as follows.

1. Generate an AST from the source code using the ast library.
2. Create a custom transformer class and overwrite the relevant visitor methods required for your task.
3. Traverse the tree, returning modified nodes.
4. Continue this process until all relevant nodes are visited and returned.
5. Generate source code from the modified AST using Meta.

In this example, we will be looking for `Name` nodes to change our variable names. Figure 7 represents step 2: a new transformer class is defined, containing a visitor method used to overwrite the pre-defined the `visit_Name` method. Our new `visit_Name` method will change all variables to upper case. Next, steps 3 and 4 are done at runtime using our custom transformer's visitor method. Figure 8 shows the results of step 5; an example function definition and the resulting code generated by the modified AST. You will notice that the output of our program shows that the comments are not preserved. This will be addressed in a later section.

```
def example():
    str = "this is a string called str"
    variable = str.capitalize() #Capitalizes the first letter of a string
    print str
    print variable
```

```
alfred@~/Desktop/MQP/Phase 1/mqp1/test> python ModifyAST.py ex.py
before

def example():
        str = "this is a string called str"
        variable = str.capitalize() #Capitalizes the first letter of a string
        print str
        print variable


after


def example():
    STR = 'this is a string called str'
    VARIABLE = STR.capitalize()
    print STR
    print VARIABLE
```

Figure 8 - Modified AST Example

3.2 Choosing Design Patterns

For a design pattern to be considered for our program, we had to take into consideration some key factors:

- Does the pattern work well with python as a language?
- Is the pattern an important concept for beginners?
- Does the pattern have a certain structure that is standard per its usage?

3.2.1 Patterns for Python

Python is an object oriented language typically used for rapid prototyping and application development [4]. To fill this role effectively, the language was designed to be flexible and dynamic [36]. As a result, Python "provides a good basis for a number of different and elegant solutions [to design problems]". The popular software engineering book *Design Patterns: Elements of Reusable Object-Oriented Software* describes 23 of the most widely used design patterns [3, 37, 38]. These patterns are called the Gang of Four (GoF) design patterns, referring to the four authors of the book. The Gang of Four patterns sometimes assume language traits that are absent from Python, however “it is not impossible to build pattern implementations that work like their GoF counterparts” [36]. While the resulting Python pattern implementations might have some non-typical features, they will still have the same functionality and recognizability.

Certain design patterns exist that lose their usefulness in Python. As a dynamic, high level language, Python eases the load on the programmer by managing memory, pointers, and determining types at runtime. A consequence of this is that Python programs have less need for bookkeeping patterns meant to manage those programming aspects [38]. Additionally, certain patterns such as the iterator and function decorator are not required to be constructed manually as they are built into Python, [37].

3.2.2 Patterns for Beginners

Beginner programmers need to understand the basics of good software design [23]. Using design patterns gives one exposure to proven techniques that utilize important software engineering concepts. Design patterns also give beginner and experienced programmers a common language in which to communicate [4]. The most well documented patterns are the most beneficial for a new programmer to learn. Doing so allows one to immediately be able to participate in a multitude of design discussions based around proposed patterns as solutions to a problem. The Gang of Four patterns are the most widely known and documented patterns, so they are the most ideal for beginners to learn about.

3.2.3 Pattern Structure

A key issue that a program such as ours faces is the lack of context as to what the input code is trying to accomplish. We have no way of knowing what the functionality of certain classes are, as there is no way to explicitly derive the real world purpose of the input bodies of code. Design patterns "do not translate directly into the solution; rather have to be adapted to suit the problem context" [4].

For our program to be useful, we need to be able to implement a design pattern without knowing what the bodies of our generated classes or functions will be. For this reason, the only design patterns that we can implement are ones that have constant structures not entirely dependent on their per-program application.

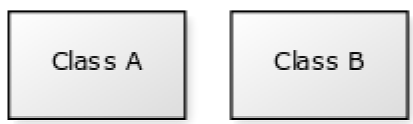


Figure 9 - Example Classes with Unknown Context

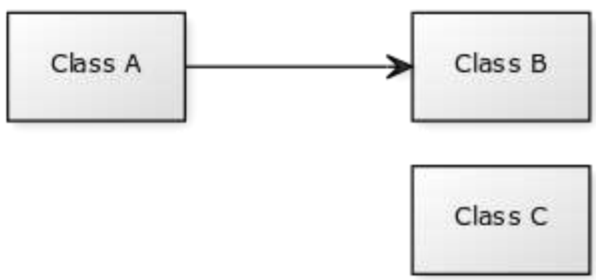


Figure 10 - Modified Classes

For example, a design pattern might always have a certain dependency between classes "A" and "B", shown in Figure 9. The pattern might also require a third class, "C", that has a relatively standard structure whenever that design pattern is implemented. Therefore, even though our program does not have any context as to what classes "A" and "B" have inside them or what purpose they serve, we can still implement the pattern by adding in the dependency between “A” and “B” as well as generating the structure of “C”. These changes are shown in Figure 10.

In other cases, new functions might be added. These functions might require access to fields that are supplied by a particular class. We can use the AST to get those fields from the class and make those the parameters of the generated function, as well as building the function definition and creating an empty code body. While any code bodies we create may be blank, we still have supplied the user with the skeletal structure of the requested design. They can now see how the pattern is structured, which can help them to understand how it works.

A new programmer can learn from a skeletal structure of a design pattern. Showing required functions, classes, and class dependencies helps one to visualize the pattern and potentially be able to recreate it in the future. This way, our program does not do all the work for the programmer; they still are tasked with adding the correct functionality to the code bodies. Our tool is not a way to get around having to think about patterns, but more of a shortcut to understanding them.

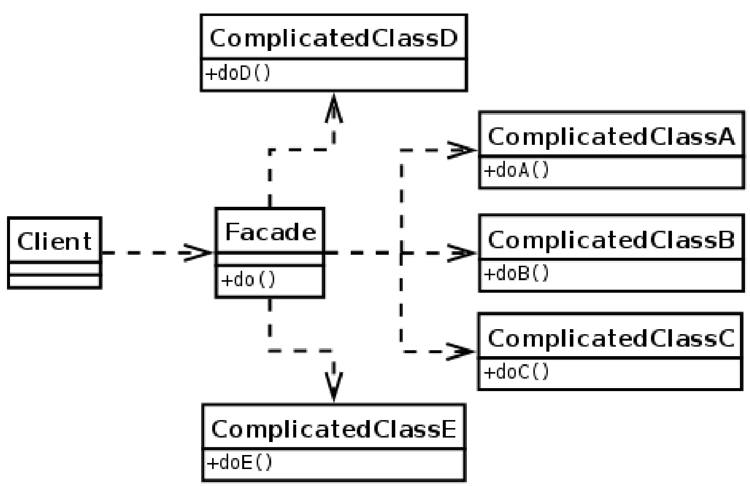


Figure 11- Façade Pattern Structure

Certain design patterns by their very nature are too program-dependent for our program to generate a meaningful amount of their structure. Take for example the façade pattern, whose purpose is to provide a version of an interface that is simplified for a chosen functionality [4]. The structure of a façade is simply a class that has methods defined for chosen purposes, which are often a series of method calls to existing and more complicated interfaces. A situation that would warrant the use of the façade pattern would be one where a user has many tests they would like to run at once. These tests involve several different method calls and initialization phases. The statements could be placed within one function definition that only needs to be called once; a façade. If our program attempted to create the facade pattern in this scenario, all it can do is simply generate an empty function definition, which is not clearly a façade at first glance. Our program does not have the same level of understanding of the program as the user, thus is cannot emulate the majority of the façade pattern's structure. Design patterns such as this have too much of their structure dependent on the program they are being applied to for them to be adequately generated by our program.

3.3 Class Adapter Pattern Implementation

The first pattern we implemented was the class adapter pattern. This pattern satisfies all of the requirements for it to work with our program; it works well with Python as a language, is a useful pattern for newer programmers to learn, and has a context-free structure that can be mostly recreated via AST manipulation. There are two types of adapter patterns: the object adapter pattern and the class adapter pattern. The object adapter pattern uses encapsulation to wrap a target interface, while a class adapter uses multiple inheritance to fuse the functionality of two classes into one. Our program generates object class adapters as they are considered more useful for Python [6].

The class adapter pattern is designed let the interface of an existing class to be used by another interface [5]. This is accomplished through the addition of an adapter class that implements the existing class's interface while correctly calling the corresponding methods from the secondary interface. The class adapter pattern works for Python in that the language is object oriented and can utilize interface-like classes. In Python, interfaces can be represented in the form of "abstract" classes, which have methods defined but without bodies [6]. The abstract nature of these classes is *faked* in that they are concrete classes that are intended to never be instantiated and instead dictate the structure of their subclasses. These "abstract" classes essentially function as interfaces and therefore fulfill their role in the pattern. True abstract classes exist in Python via the Abstract Base Class module but are not needed to implement the class adapter pattern [31].

3.3.1 Importance of the Class Adapter Pattern

Having the ability to add to a project without modifying existing code is necessary for a program's extensibility. When code needs to be changed, all other places in the program that rely on its previous structure also have to adapt to this change, often leading to bugs, client frustration, and wasted time. The class adapter pattern works to avoid these issues by encapsulating existing code for the purpose of adding additional functionality. A class adapter replicates the methods defined in a target interface but without modifying the interface itself. Beginner programmers armed with the knowledge of adapters can now start reusing old code for new purposes without having to modify it.

This power, coupled with the class adapter's relatively simple design and concept, makes it an excellent pattern for introductory programmers to know.

3.3.2 Class Adapter Pattern Structure

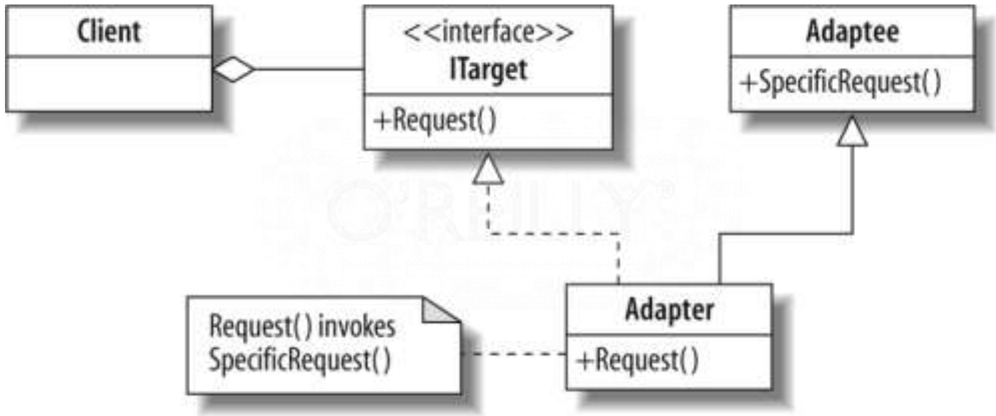


Figure 12 - Class Adapter Structure

The structure of the class adapter pattern makes it ideal for our program. Three classes are required for a class adapter; the target class (the interface to be adapted to), the adaptee (the interface that wishes to adapt to the target), and the class adapter itself. A client makes requests to the class adapter instance, which inherits all the methods from the target interface and calls the adaptee functions appropriately. In Python, a class adapter has a few standard traits: inheriting the target class, saving an instance of the input adapter class, overriding the target class methods, and calling the correct corresponding adaptee methods as appropriate. Provided only with names of the target and adaptee classes, an AST manipulation function can produce a class that contains all of the class adapter traits, excluding the adaptee method calls. These method calls are not possible to automate because an AST traversal function cannot know by code structure alone which adaptee methods correspond to each target method. However, the overall structure of the adapter can be generated, leaving TODO stubs where method calls are required.

3.3.3 Class Adapter Pattern Generation

For our program to generate a class adapter, three inputs are required: a Python file and the names of the target and adaptee classes defined within that file. Figure 13 illustrates an example file for input, where the `vehicle` class is the target and the `horse` class is the adaptee.

```
class vehicle(object):
    def drive(self):
        # Default method for driving a vehicle
        pass

class horse(object):
    def __init__(self, name):
        self.name = name # Set the name of the horse

    def ride(self):
        print "%s%s" % ( "You are now riding ", self.name)
```

Figure 13 - Example Target and Adaptee Classes

The input file is converted into a code object, which is then parsed for the purpose of generating an AST object that represents the structure of code in the file. A visitor method from the Python `ast` module is then utilized to traverse the tree. This visitor searches the tree until it locates the node corresponding to the target class's name. Once this node is located, a copy is saved for future use.

Once the target node has been isolated, the class adapter node is created from scratch. The body of the target node copy is then placed inside the body of the class adapter node. This places all of the existing method definitions of the target into the adapter. The bodies of each of these method nodes in the adapter are then wiped and replaced with TODO stubs. The adapter node is then modified so that it inherits the target class. An `__init__` method node is then added to the class adapter node. The body of this node contains an expression that saves an instance of an input class within the object. A `__getattr__` method node is also added to the class adapter node. The `__getattr__` method is a 'magic' method used by the Python interpreter when an object lookup on an unknown attribute is called [32]. This addition allows the adapter to pass any adaptee functions not defined within the adapter itself along to the adaptee. Finally, the name of the adapter node is set to "adapteeTargetAdapter". In this example, the name will be "horseVehicleAdapter".

Once complete, the adapter node is added to the AST in the same code block as the target class's node. Using the Meta library, the AST object is then converted back into a code object which is then saved to a new file as Python code. The resulting file is syntactically identical to the input file, with the only change being the addition of the class adapter. Figure 14 shows a class adapter for the `horse` and `vehicle` classes that would be generated by our program. The `object` parameter for the `__init__` function is an instance of the adaptee, which in this example is the `horse` class. This instance is saved within the class adapter as `self.object`.

```
class horseVehicleAdapter(vehicle):
    def __init__(self, object):
        self.object = object
    def drive(self):
        #TODO
    def __getattr__(self, attr):
        return getattr(self.object, attr)
```

Figure 14 - Example Class Adapter

The final step of the class adapter process is done by the user. They have to decide which adaptee functions are to be called in the defined target methods within the adapter. Figure 15 shows the case where the user decided to call the `horse` class's `ride` method when the `drive` method is called.

```
class horseVehicleAdapter(vehicle):
    def __init__(self, object):
        self.object = object
    def drive(self):
        self.object.ride()
    def __getattr__(self, attr):
        return getattr(self.object, attr)
```

```
def main():
    Seabiscuit = horse("Seabiscuit")
    SeabiscuitAdapter = horseVehicleAdapter(Seabiscuit)
    SeabiscuitAdapter.drive()
```

Figure 15 - Example Class Adapter with Method Call

The `main` function in Figure 15 shows how this class adapter would be used. A `horse` instance is created and used to make a `horseVehicleAdapter` instance. This `horseVehicleAdapter` now has the functionality of a `horse` while implementing the `vehicle` interface.

3.4 Observer Pattern Implementation

The second pattern we implemented was the observer pattern. This pattern works well in Python, is useful for beginners, and has a mostly standard structure. Additionally, our program explores a new technique for adding this pattern to an existing program with minimal modification to the input files. This technique is discussed in detail later in this section.

The Observer Pattern is used to automatically notify dependent objects of any state changes that occur to the object they are dependent on. The subject is a class that maintains a list of observers which are dependent on the state of the subject. When the subject has a state change, it notifies all known dependent objects it has stored in its observers list via a notification function. Each dependent class has a notify function within itself that gets called whenever the subject notifies it of a state change [8]. Python projects are often object based, so the observer pattern’s ability to automatically inform multiple objects of a subject's change in state is relevant to the language.

3.4.1 Importance of the Observer Pattern

Properly maintaining the states of objects is an important concept in object oriented programming. When an event occurs in a program and a state of a class instance changes, all objects dependent on that instance must be notified. The challenge in doing this involves maintaining these dependences without tightly coupling the related objects. In software engineering, coupling is how closely two classes rely on each other [10]. Decoupling two objects means to limit their interaction, and is often considered the most pragmatic way to approach object oriented design. Tight coupling between two objects inhibits change; if one object is modified, all those tightly coupled to it may need to be modified as well [11]. The observer pattern is useful to know because it maintains consistency between dependent objects while avoiding tight coupling [10]. The subject does not need to know any information about its observers; all it does is add them to its list observers and notify them of a state change via a uniform notification function. New programmers can gain useful insight as to how a program can update all dependent classes while keeping them loosely coupled through the use of the observer pattern.

3.4.2 Observer Pattern Structure

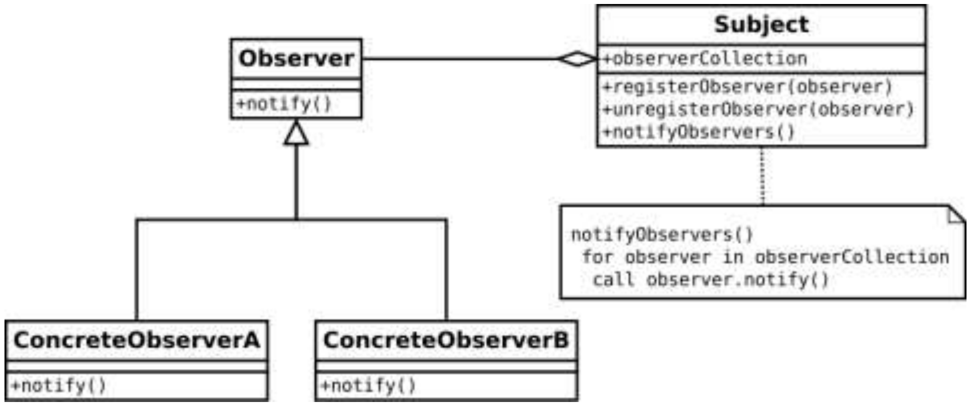


Figure 16 - Observer Pattern Structure

The relatively simple structure of the observer pattern makes it a good candidate for our program. Two classes are required for this pattern; an observable class (the subject to be observed by others) and the observer class (dependent on the subject). The observable class maintains a collection of observers. Observers are added to this collection via a register method and removed from the collection via an unregister method. The observable also contains a notification method that calls the notify method for all observers in its collection. This notification method is how the observable class updates all of its dependent classes. A class that has many dependencies and wishes to act as a subject would inherit the observable class to gain its functionality. The observer class contains a notify method that acts accordingly in response to the information provided by the observable class. These notify methods can behave differently among observers but are called the same way by the observable class. A class that depends on the state changes of the subject would inherit the observer class.

The functionality of the observer pattern is captured in the definitions of the observable and observer classes. These classes often do not change when used in completely different programs. For this reason, we decided to have our program generate these class definitions in a separate, standard file. When a user submits a file to have the observer pattern applied to, two files are generated: a completely new file that contains the observer pattern class definitions, and a slightly modified version of their input file that imports the newly generated file and uses it appropriately. With this method of approach, the input file is modified as little as possible while still employing the observer pattern.

3.4.3 Observer Pattern Generation

For our program to generate an observer, three inputs are required: a python file and the names of the subject and observer classes defined within that file. Figure 17 illustrates an example file for input, where the `master` class is the subject and the `dog` class is the observer. In this example, the `master` class initially inherits a `person` class. A super call is placed inside the master class's `__init__` method that initializes the information required by the inherited `person` class.

```
class person(object):
    def __init__(self,name):
        self.name = name

class master(person):
    def __init__(self,name):
        super(master, self).__init__(name)

    def sayName(self):
        print ('%s%s' % ('My name is ', self.name))

class dog():
    def __init__(self, name, age):
        self.name = name
        self.age = age

    def doTrick(self, command):
        if command == 'sit':
            print self.name + " has sat"
            return;
        else:
            print self.name + " did not understand the command"
```

Figure 17- Example Subject and Observer Classes

The first step of the observer pattern generation process is to create a file that has the class definitions for the observable and observer classes. Our program has an AST representation of these class definitions saved within it. Source code is generated from this AST and written to a file called “generatedObserver.py”. If that file already exists, the previous version is overwritten. Figure 18 shows the contents of the generated file.

```python
class metaClass(type):
    @property
    def List(cls):
        if getattr(cls, '_observers', None) is None:
            cls._observers = []

class Observable(object):
    __metaclass__ = metaClass

    def __init__(self):
        pass

    def register_observer(self, observer):
        Observable._observers.append(observer)

    def unregister_observer(self, observer):
        Observable._observers.remove(observer)

    def notify_observers(self, *args, **kwargs):
        for observer in Observable._observers:
            observer(self, *args, **kwargs)

class Observer(object):
    def __init__(self, observable):
        pass

    def notify(self, observable, *args, **kwargs):
        print ('Got', args, kwargs, 'From', observable)
```

Figure 18 - Generated Observer File: generatedObserver.py

There are three classes defined within this file; the `Observable` class, the `Observer` class, and the `metaClass` class. The `Observable` class acts as the subject. It has methods defined that add, remove, and notify observers in its observer list. The `Observer` class has a `notify` function that by default prints out the input arguments received when the observable notifies its observers. This functionality can be changed or overwritten. The third and most mysterious class is the `metaClass`. To grasp the logic and purpose of this class, one must first understand multiple inheritance initializations in Python.

Figure 17 shows, the `master` class inherits the `person` class. Our program intends to have master also inherit the `Observable` class. In Python, multiple inheritance is acceptable, but at a price [14]. If any of the inherited classes required initialization (a call to their `__init__` method), then Python's `super` method is required. In our example, both of the classes `master` inherits would require their own initialization; `person` wishes to set the `name` field and `Observable` wishes to create an observers list. The expression `super(master, self).__init__(name)` inside the `master` class effectively is calling the `__init__` method defined within the `person` class. Without this `super` call, `master` instances would not have their `name` property set, and calls to the `sayName` method would yield an error. Complications start to arise when multiple inherited classes require initialization. The expression `super(master, self).__init__(name)` only initializes one of the inherited classes. To initialize both classes, a chain of super calls each initializing the next class is required. This process can get cumbersome and is best avoided [16].

To avoid having to generate excessive and confusing code in the form of multiple super calls, we decided to utilize a method of pseudo-lazy initialization via a custom metaclass. This is all done in the name of initialing the `Observable` class with a field for a list of observers. In Python, all classes are instances of metaclasses, which define how classes are created. Most classes are created with the default `type` metaclass, however, custom metaclasses that allow for the dictation of how a class is instantiated are allowed [12, 13]. Our procedure for creating a custom metaclass that creates the `Observable` class with an observers list is as follows.

1. Define a new class that inherits the class `type`

2. Place the `__metaclass = metaClass` expression within the class to be created via our custom metaclass. The `metaClass` component is the name of our custom metaclass.
3. Add a `List` method is to `metaClass` which will enable an observers list to be added to the `Observable` class. `List` is a class method, which means it takes in a class structure as an argument in the form of `cls`, opposed to an instance of a class in the form of `self` [18]. `List` takes in the `Observable` class and calls the `getattr` method to determine if the input class has the `_observers` attribute. If it does not, the attribute is added to the input class as an empty list.
4. Decorate `List` with a property descriptor. A descriptor is "an object attribute with 'binding behavior', one whose attribute access has been overridden by methods in the descriptor protocol" [15]. Placing the `@property` tag above the `List` method definition essentially means that the List method is now an accessible property of the custom metaclass.
5. Place the expression `Observable.List` within the class that will be inheriting `Observable`. This calls the `List` method added to the `Observable` class by our custom metaclass, creating an observers list.

Once the file containing the `Observable`, `Observer`, and `metaClass` classes has been generated, the next step it to edit the input code to accept this new file. This process is as follows.

1. Parse the input source code into a code object, which is then used to generate an AST object.

2. Traverse the tree via a node visitor, searching for the nodes that define the input classes denoted as the subject and the observer.
3. Modify the subject node so that it now inherits the `Observable` class and has the expression `Observable.List` within its `__init__` method. Now when this initialization method is call, the `Observable` class has an observer list created without requiring a call to its `__init__` method, thus avoiding the `super` chain issue.
4. Modify the observer node so that it now inherits the `Observer` class
5. Add an expression that imports the `Observable` and `Observer` classes defined in the generated file

Figure 19 is an example of the modified input file shown earlier.

```
from generatedObserver import Observable, Observer

class person(object):
    def __init__(self,name):
        self.name = name

class master(person, Observable):
    def __init__(self,name):
        Observable.List
        super(master, self).__init__(name)

    def sayName(self):
        print ('%s%s' % ('My name is ', self.name))

class dog(Observer):
    def __init__(self, name, age):
        self.name = name
        self.age = age

    def doTrick(self, command):
        if command == 'sit':
            print self.name + " has sat"
            return;
        else:
            print self.name + " did not understand the command"
```

Figure 19 - Modified File for Observer Pattern

The top image of Figure 20 shows the observer pattern in action. Janet is an instance of a `dog` while Bob is an instance of a `master`. The expression `Bob.register_observer(Janet.notify)` registers Janet as an observer of Bob. When Bob calls his `notify_observers` method, Janet will now be notified. Additionally, the notify methods of the observers can be overwritten. The bottom image of Figure 20 shows the `dog` class overwriting `notify` to be a method call to `doTrick`.

```
def main():
    Janet = dog('Janet',1)
    Bob = master("Bob")

    Bob.register_observer(Janet.notify)
    Bob.notify_observers("sit")
```

```
class dog():
    def __init__(self, name, age):
        self.name = name
        self.age = age

    def doTrick(self, command):
        if command == 'sit':
            print self.name + " has sat"
            return;
        else:
            print self.name + " did not understand the command"

    def notify(self, observable, *args, **kwargs):
        self.doTrick(args[0])
```

Figure 20 - Using the Observer Pattern

3.5 Factory Pattern Implementation

The third pattern we implemented was the factory pattern, which is a creational pattern that handles object creation without specifying the class of the created object [40]. Factories produce objects based on the given arguments which describe what kind of object is being requested. This allows for a level of abstraction in the object creation. Python, being an object oriented language, naturally can support the factory pattern.

3.5.1 Importance of the Factory Pattern

Factories allow for the type of desired object instance to be decided at runtime [41]. This functionality is useful in the situation where a "system needs to be independent from the way the products it works with are created." Independent creation methods allow for a program to group and compare the different options for creating objects more effectively. Depending on the input arguments, an object instantiation request can interpreted and passed to its appropriate creation method. This system is also receptive to new creation methods. Relying too heavily on built in creation methods that return a single version of an object every time can make your code less flexibly. Factories help newer programmers to understand how a level of abstraction can be beneficial for object creation in programs.

3.5.2 Factory Pattern Structure

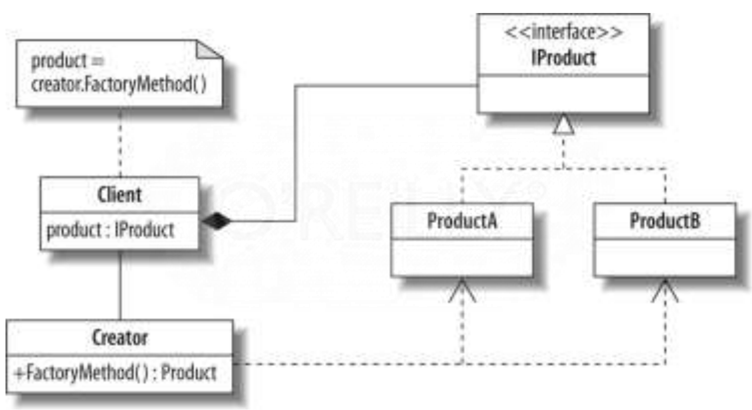


Figure 21 - Factory Pattern Structure

The structure of the factory is one that works well with our program. Figure 21 shows the components of this pattern: a creator class which contains factory, and a set of related products. A client makes requests to the creator by calling a factory with a given set of arguments that describe the desired product to be returned. The products are all related, and may inherit a common interface. The client does not know or care which type of product is returned, they simply want a correct instance of an object that matches their input specifications. In Python, factories have a general structure that consists of a class that serves as the creator which contains internal factory methods design to return related objects. An AST manipulation function can detect all classes that inherit from a specified interface, generate simple factory methods for these classes, and then place those factories into a creator class. The logic that determines which factories are called under different conditions is up to the user to determine.

3.5.3 Factory generation

In order to generate the factory pattern, our program requires two inputs: a python file and the name of the interface for which an creator class defining factory methods will be built. Figure 22 shows an example file for input, where the `car` class is the interface that will have a creator class generated. The `bmw` and `mazda` classes inherit the `car` class, and thus will require their own factory method within the creator class that will be generated.

```
class car(object):
    def __init__(self):
        pass

class bmw(car):
    def __init__(self,year):
        self.year = year

class mazda(car):
    def __init__(self,year,make):
        self.year = year
        self.make = make
```

Figure 22 - Example Interface

The steps for generating the creator class are as follows:

1. The input file is converted into a code object, which is then converted into an AST object.
2. A visitor method traverses the AST searching for all class nodes that inherit the given interface.
3. Once a match is found, the arguments for that class node's `__init__` method are converted into an array and stored in a dictionary structure, with the key being the name of the class. This is done so that each of the classes and their required initialization arguments can be accessed later.
4. A new class node is created and placed on the AST.
5. Factory methods for each of the class nodes located in step 3 are then created as methods within the creator.
6. The arguments for each of the factories are retrieved from the dictionary by using the name of their respective class node as the key.

By default, the factory methods simply return an instance of the corresponding class. Each of these factory methods is labeled as a `@classmethod`, and list `cls` as their first argument. This means that an instance of creator class is will not be required for the individual factory methods to be called. The `cls` argument is different than the typical `self` argument in that `cls` passes the structure of the class to the method, not an instance of it.

The creator node is now complete. The modified AST is converted back to source code which is then saved to a new file. Figure 23 shows the class from Figure 22, now modified to incorporate the factory pattern.

```python
class car(object):
    def __init__(self):
        pass
class carFactory():
    @classmethod
    def fabricate_bmw(cls, year):
        #Your code here...
        return bmw(year)
    @classmethod
    def fabricate_mazda(cls, year, make):
        #Your code here...
        return mazda(year, make)
class bmw(car):
    def __init__(self, year):
        self.year = year
class mazda(car):
    def __init__(self, year, make):
        self.year = year
        self.make = make
```

Figure 23 - Modified Class with Abstract Factory

When building a factory pattern, one has many options to pursue depending on the needs of the program. Several layers of logic can applied to decide which type of object will be returned. Our creator class is very general in that is simply creates a single factory method for each type of product. The users' job is to decide how they want to expand our creator. This can be done by introducing more specific factory methods and introducing logic statements that decide which of these methods to be called depending on certain inputs. Our factory pattern provides a convenient starting point for a plethora of factory structures.

3.6 Class Decorator Pattern Implementation

The final pattern we implemented in our program was the class decorator pattern. Class decorators can be implemented in Python, are useful for beginners, and have a standard structure. Decorators are structures that allow behavior to be added to an individual object without affected the behavior of other objects from the same class [42]. Decorators can change the decorated class's functionality by wrapping and intercepting actions the decorated class's methods. This can be done statically or at runtime. Decorated instances of the same class are all independent. Function decorators are built into Python; their usage and purpose in the class decorator pattern is discussed later in this section.

3.6.1 Importance of the Class Decorator Pattern

Maintaining the structure of a pre-existing project while still being able to expand its functionality is an important concept. In many cases, the classes being used in a project are imported from other inaccessible files or are tightly coupled with other design components. Knowing how to make seemingly rigid code flexible in order to incorporate new changes is very important. Decorators provide a means to add functionality to existing functions or classes without requiring their modification. By using a decorator, pre-existing structures can be wrapped and interpreted differently. Decorators also allow for runtime changes; based on how an object is instantiated or a method is called, different results can be returned. The ability to maintain prior code structure while implementing new changes is an important concept for programmers to grasp, making decorators a useful pattern for beginners.

3.6.2 Class Decorator Structure

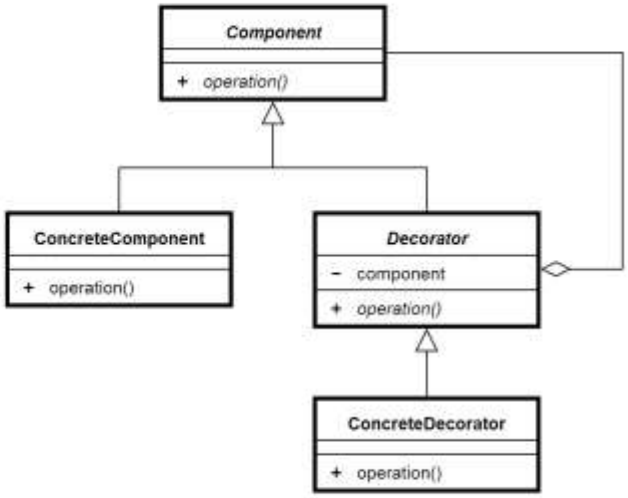


Figure 24 - Decorator Structure

The decorator pattern has a standard structure that works well for our program. There are four key classes in this pattern; a component, a decorator, and instances of both. The component is a class that will be decorated. The decorator wraps the component within itself and redirects all component methods calls to it. The concrete instance of the decorator overrides the component methods that require modification [42]. In Python, function decorators are built in and easy to implement. Figure 25 shows an example of Python function decorator [43].

```
class myDecorator(object):

    def __init__(self, f):
        print "inside myDecorator.__init__()"
        f() # Prove that function definition has completed

    def __call__(self):
        print "inside myDecorator.__call__()"

@myDecorator
def aFunction():
    print "inside aFunction()"

print "Finished decorating aFunction()"

aFunction()
```

Figure 25 - Function Decorator Example

The built in decorators in Python are declared by placing the name of the decorator preceded by the '@' symbol above the component it is decorating. In the above example, the `aFunction` function is being decorated by the `myDecorator` class. When the `aFunction()` expression is run, the resulting print outs occur:

```
inside myDecorator.__init__()
inside aFunction()
Finished decorating aFunction()
inside myDecorator.__call__()
```

Figure 26 - Function Declaration Printout

The decorator is first initialized. During its initialization, there is a call to the original `aFunction` component, which was stored internally. Now the decorator has been fully initialized, denoted by the "Finished decorating aFunction()" print statement. Finally, the call to `aFunction` is processed and intercepted by `myDecorator`, and "inside myDecorator.__call__()" is printed. In this example, `myDecorator` could also have been a function instead of a class. The syntax on how the decorated function are caught and returned would be slightly different, but the functionality remains the same.

The built in function decorators in Python can be used to build a similarly functioning and structured class decorator. A class rebuilder can be used to return a modified component class that has decorated methods. The code blocks that determine the logic that determines when decorators are called as well as the functionality of those decorators are isolated, meaning the class decorator structure can be generated by our program.

3.6.3 Class Decorator Generation

```
class example(object):
    integer = 1
    def __init__(self):
        self.integer = 2
    def function1(self, arg1):
        print ('I am in example function1 with arg: ', arg1)
        if (arg1 == 'ex1'):
            print 'ex1'

    def function2(self, arg1, arg2):
        print ('I am in example function2 with args: ', arg1, arg2)
        self.integer = (self.integer + arg2)
        print self.integer
    def function3(self):
        print 'I am in example function3 with no args'
```

Figure 27 - Example Class

The inputs required by our program to generate a class adapter are: a python file, the name of the class to decorate, and the names of all methods that are to be decorated. Figure 27 shows an example file to input, where the `example` class and all three of its methods will be decorated.

The input file is converted into a code object, which is then converted into an AST object. A visitor method traverse the tree until it locates the class node that is to be decorated. The names of the methods defined within this class are saved.

The next step is to generate a function, called `class_decorator`, which will serve as our class decorator. The `class_decorator` function is then added to the list of decorators for the component class. The decorator is specified to have arguments that represent the methods to be decorated in the component class, which in this case is `example`. By default, all methods are decorated except `__init__`. The `class_decorator` function will be returning a new class rebuilder that will replace the default builder for the `example` class. This new rebuilder class, called `decorated_componentName`, creates a new class that inherits `cls`. The `cls` object holds the structure of the input component class. The `class_rebuilder` function will be called immediately after the component class is built, returning a rebuilt class that contains a decorator for each of the specified class methods. Figure 28 shows a code representation of the `class_decorator` function for `example` at this point in the process.

```
def class_decorator(*method_names):
    def class_rebuilder(cls):
        class decorated_example(cls):
            #FYI - any objects of the original class can be reached using self, ie self.fieldname

            def function1_decorator(self, example_function1):
                def decorator(*args ,**kwargs):
                    print ('Inside the decorator for function1 with args: ', args)
                    return example_function1(*args , **kwargs)
                return decorator

            def function2_decorator(self, example_function2):
                def decorator(*args ,**kwargs):
                    print ('Inside the decorator for function2 with args: ', args)
                    return example_function2(*args , **kwargs)
                return decorator

            def function3_decorator(self, example_function3):
                def decorator(*args ,**kwargs):
                    print ('Inside the decorator for function3 with args: ', args)
                    return example_function3(*args , **kwargs)
                return decorator
```

Figure 28 - Partially Constructed Class Decorator

The `__getattribute__` Python magic method is also added to this returned class. `__getattribute__` is automatically called by Python whenever a class's methods or fields are accessed. Our class rebuilder modifies the default `__getattribute__` functionality so that this method can be used to gain access to attributes of the component class from within the class decorator. When calls to the component class's methods are detected by `__getattribute__`, our decorated class returns our decorated methods in their place. It is important to note the different between the `__getattribute__` method used here and the `__getattr__` method used previously for other design pattern implementations. `__getattribute__` is called by Python every single time a class has a call to its methods or fields. `__getattr__` is only called when a class receives a method call for a method that it does not have defined. Figure 29 shows what the body of the `__getattribute__` method will be for the `example` class.

```
def __getattribute__(self, attr_name):
    obj = super(decorated_example, self).__getattribute__(attr_name)
    if (hasattr(obj, '__call__') and (attr_name in method_names)):
        if (attr_name == 'function1'):
            return self.function1_decorator(obj)

        if (attr_name == 'function2'):
            return self.function2_decorator(obj)

        if (attr_name == 'function3'):
            return self.function3_decorator(obj)

        #TODO - implement any of your own if statments and/or modify the above
```

Figure 29 - Generated __getattribute__ Method

When `__getattribute__` is called, a super call to the `__getattribute__` function of the component class occurs. This saves the requested class attribute into the `obj` variable. `obj` is checked to see if it has a `__call__` attribute. If it does, then that attribute is a method. If the requested method stored in `obj` is in the list of method names that are requested to be decorated, the corresponding decorator is returned. Figure 30 and Figure 31 show the route a method call takes within the class decorator.

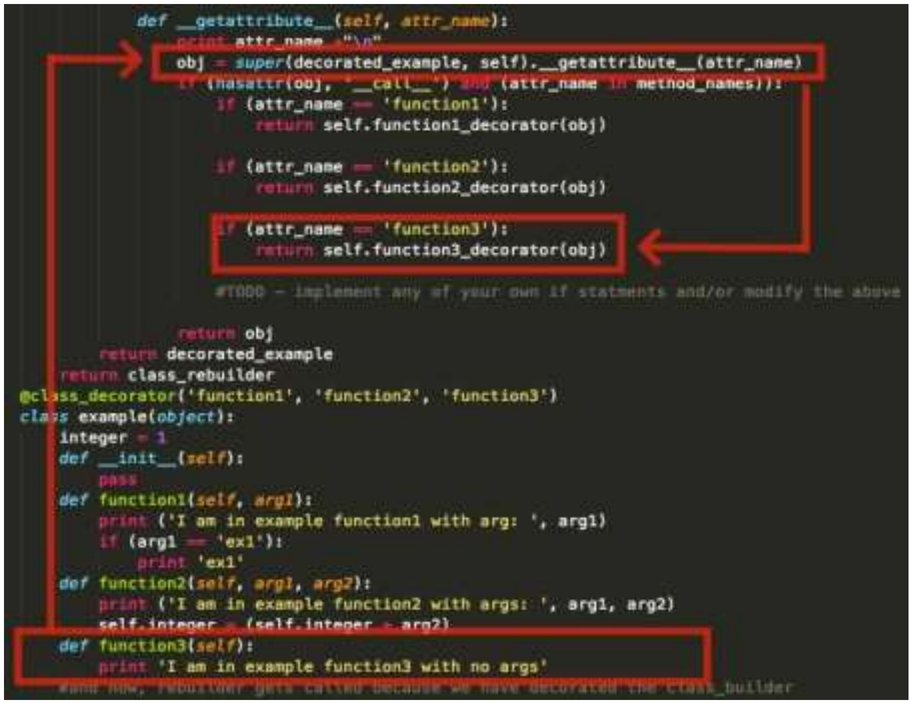


Figure 30 - Decorator Pathway Part A

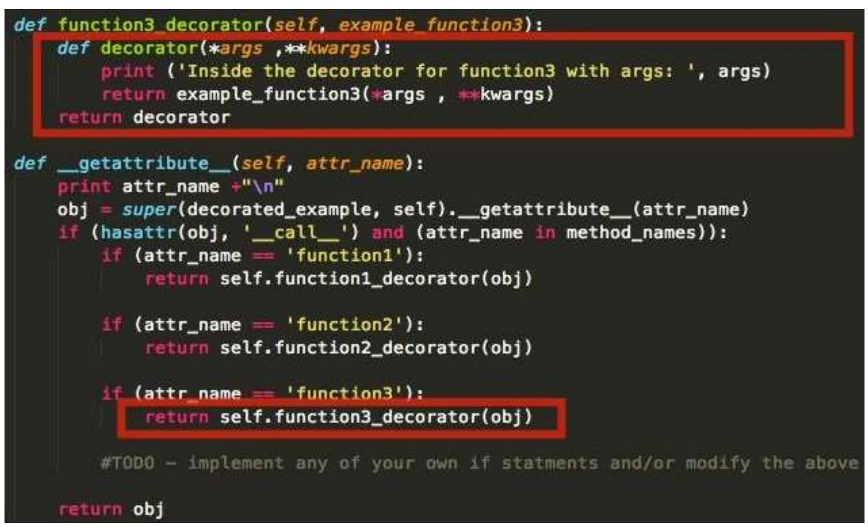


Figure 31 - Decorator Pathway Part B

When a component method is called, `__getattribute__` detects this and returns the correct corresponding decorated method from the class decorator. For example, when function3 in the example class is called, `__getattribute__` detects that a method lookup has occurred for a decorated method, and a call to `function3_decorator` is returned.

```
def class_decorator(*method_names):
    def class_rebuilder(cls):
        class decorated_example(cls):
            #FYI - any objects of the original class can be reached using self, ie self.fieldname

            def function1_decorator(self, example_function1):
                def decorator(*args ,**kwargs):
                    print ('Inside the decorator for function1 with args: ', args)
                    return example_function1(*args , **kwargs)
                return decorator

            def function2_decorator(self, example_function2):
                def decorator(*args ,**kwargs):
                    print ('Inside the decorator for function2 with args: ', args)
                    return example_function2(*args , **kwargs)
                return decorator

            def function3_decorator(self, example_function3):
                def decorator(*args ,**kwargs):
                    print ('Inside the decorator for function3 with args: ', args)
                    return example_function3(*args , **kwargs)
                return decorator

            def __getattribute__(self, attr_name):
                obj = super(decorated_example, self).__getattribute__(attr_name)
                if (hasattr(obj, '__call__') and (attr_name in method_names)):
                    if (attr_name == 'function1'):
                        return self.function1_decorator(obj)

                    if (attr_name == 'function2'):
                        return self.function2_decorator(obj)

                    if (attr_name == 'function3'):
                        return self.function3_decorator(obj)

                    #TODO - implement any of your own if statments and/or modify the above
                return obj
        return decorated_example
    return class_rebuilder
```

Figure 32 - Complete Class Decorator

Figure 32 shows our generated class decorator in its entirety. By default, all class methods are decorated and called under all circumstances. These methods simply print that they are a decorator and then return the normal component method. The user can decide under what situations these decorators are called by modifying the logic in `__getattribute__`. Each of the method decorators can be given functionality within their respective code blocks.

3.7 Comment Preservation

Comments are annotations added to code that are intended to be read by the programmer [44]. Descriptive comments serve the invaluable purpose of explaining the logic of a potentially confusing program for future contributors. Whitespace can also be used to separate larger code blocks into more readable sections.

In Python, comments are preceded by the ‘#’ character and are considered to be whitespace by the compiler. When the `ast` module is used to generate an abstract syntax tree of a Python file, all unneeded whitespace is unfortunately ignored. This means that if you convert a program into an AST and then back into Python code using this module, the generated code has no comments or non-syntactic whitespace. The result is as compact code that is syntactically possible. Thankfully, due to Python’s inherently clean syntax, this code is still well formatted. The problem is, as mentioned before, comments are very important. A program that modifies code but removes all of your comments is most likely going to be an avoided program. We want our program to encourage a good coding practice, but not at the expense of another.

To combat this problem, we utilized the fact that Python allows for strings to sit anywhere within a program. These strings are detected by the AST and given their own node, thus persevered during the AST manipulation process. To preserve the comments, we simply convert them to strings. Before the code is to be converted to an AST, we first parse the file for any comments. This is done searching for the last “#” that appears on any line; all following characters are a comment. Once a comment is located, we copy all the characters following the “#” and place them within a string. This string is given a tag at the beginning so that our program will know in the future which strings are actually comments. This tag varies depending on whether or not the comment was in-line. Once all comments are converted to strings, the AST manipulation can take place. When the new Python code has been generated, we parse the file as a string and search for any of our comment tags. Once a tag is found, the text including and following the "#" character is plucked from the string and placed back as a comment. If the tag denotes it as an in-line comment, it is placed at the end of the following line. Once the parsing is complete, all comments are back in their rightful place. This process works but has some drawbacks which will be discussed in a later section.

3.8 Graphical User Interface

We designed a simple graphical user interface (GUI) prototype for our program. This GUI first takes in a file that the user would like to add a design pattern to. The user then selects which pattern they want. An AST is then generated from their input file and is searched for any classes or methods that could be used as arguments for our pattern insertion function. These options are piped into a series of drop downs. The user selects which options they would like for their pattern. A file is then generated that has their modified code in the same directory as their input file. Screenshots of our GUI are located in Appendix A.

4. Results and Analysis

At the start of this project we set out to prove that generating design patterns through manipulation of ASTs was possible. Our intent was to generate three or more design patterns and place them into existing python code. We accomplished this goal by designing a program that can generate four design patterns: the class adapter, observer, factory, and class decorator. The patterns we generate are the proof that creating a tool for generating patterns with AST manipulation is possible. The file "generate.py" which contains all the logic for our code generation consisted of 1149 lines, including all documentation and whitespace. 783 of those lines are actual functional code. The file consists of 17 standalone function definitions, and 14 node visitors and transformers.

Our project has a few issues. First, the secondary file that our observer pattern generates gets placed in the same directory as "generate.py", not the input file. If the input file is not located in the same directory as "generate.py", our observer pattern will yield errors. Second, the Meta module and comment preservation techniques we used have some bugs; these are discussed in more detail in the future work section.

5. Future Work and Conclusion

Our project has many avenues in which it can be expanded. Our comment preservation method was mostly successful but imperfect. If a comment exists on the same line as a multiline string, our comment tokenizer gets tripped up and fails to preserve the comment correctly during AST manipulation. Additionally, our solution only attempts to preserve comments and does not address the problem of unneeded whitespace being ignored by the AST. Two solutions exist to fix these problems:

- Write a more complete comment and whitespace tokenizer
- Purchase proprietary software

Proprietary software exists that claims to successfully preserve all comments and whitespace. If a product version of our program were to be released, utilizing third party software for comment preservation would be worthwhile solution.

An additional problem we encountered was that the Meta package we used for deconstruction of syntax trees to create syntactically correct code was not bug free. For example, we found Meta could not generate correct code for the following kinds of expressions: print statements containing multiple comma separated arguments, multiline strings, and usage of the `format` function. Other invalid expressions that did we did not come upon may also be present. Three solutions exist to address these problems:

- Modify the Meta package to handle the problem expressions
- Write a new syntax tree code generator package
- Purchase proprietary software

Another area where our project could be expanded is in the amount of options our design patterns have. For instance, it would be possible to ask the user which method calls they would like placed in their adapters. Our observer could ask the user if they would like to override the default notify function. A larger variety of factory methods could be generated inside our factory pattern. Our class decorator could provide more logic options for when decorator methods get called.

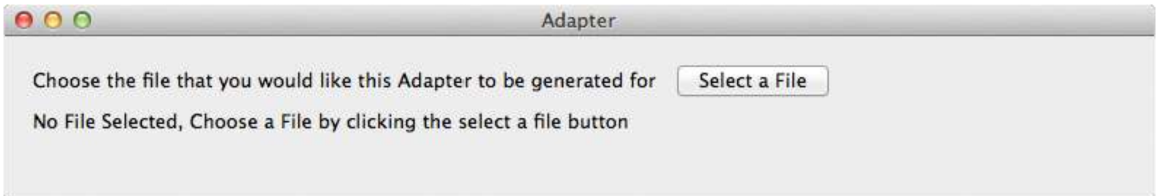
The final issue to be address with our project is its graphical user interface. Currently, our GUI is very basic. This could be expanded to include more options for the user, such as specifying method calls to be placed inside of certain code blocks. Help sections could also be included to give a detailed explanation as to what each pattern is, what it requires, and problem it aims to solve.

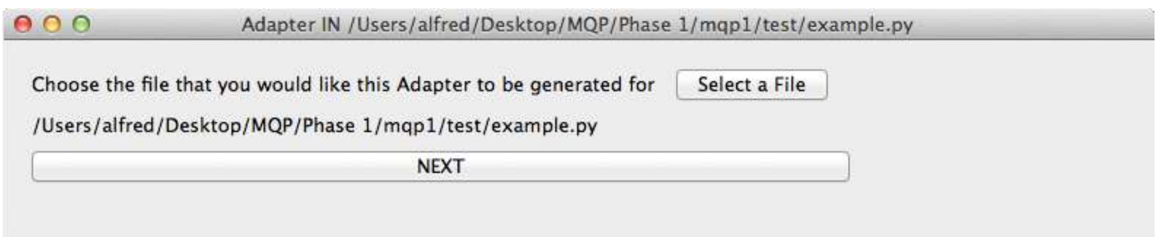
5.1 Conclusion

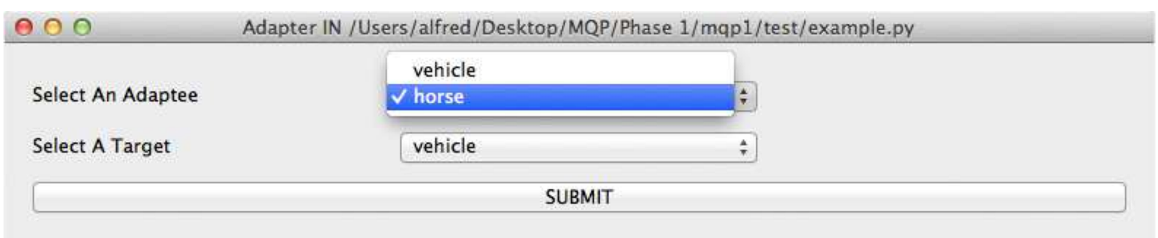
This project was a successful proof of concept in that generation of design patterns in existing code is possible through manipulation of its abstract syntax tree. Research was performed on the usefulness of design patterns and the structure of syntax trees. Python was decided to be the most appropriate programing language for design pattern generation for the purpose of reaching newer programmers. A set of criteria were constructed for selecting the most appropriate design patterns to generate. We were able to design a program that can generate the structure of the class adapter, observer, factory, and class decorator design patterns. A graphical user interface prototype was developed. A user guide on how to generate patterns as well as expand our program with more design patterns was developed.

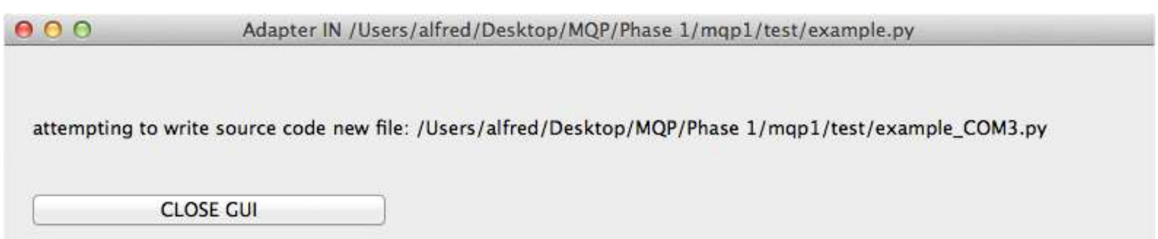
Appendices

Appendix A – User Guide: Generating a Pattern









Appendix B – User Guide: Expanding Our Program

This section discusses the steps required to expand our program through the addition of more design patterns. The steps are as following:

1. Select an appropriate pattern
2. Produce code for an abstract version of your pattern structure
3. Determine what is required for your pattern to be fully functional
4. Write node transformer and visitor functions that modify an AST to incorporate your pattern
5. Utilize our helper functions to correctly generate and modify a program's AST by using your custom node transformer

Step one of the process involves selecting an appropriate pattern for our program. As outlined in our methodology, for a pattern to work in our program it should make sense for Python as a language, be useful for beginners, and have a standard structure where program specific expressions are isolated.

Step two is to produce an abstract version of the structure of your pattern. This is best done by replicating a UML diagram of your pattern in as simple of terms as possible. This will allow you to proceed to step three by helping you visualize what parts of your pattern can be generated based on information available from a program's AST, and which parts cannot.

Step three is to analyze your patterns structure. Make note of the structural properties that are always present, as these will be the key parts of the pattern that can be recreated via AST manipulation. Attempt to rework the structure of your pattern so that it isolates code blocks where program specific expressions will be located. Do so in a manner that still preserves the overall structure of the pattern so as not to impede its recognizability. Use the resulting structure to determine what input arguments would be required to fill in the blanks of your structure. These arguments can be anything from class to function names.

Step four is to write node transformer and visitor functions that will modify an AST to incorporate the refined pattern structure you created during the previous steps. Your node visitor will walk the AST, and any node it returns will be replaced by the node transformer. After the AST has been modified, it is important to call the function `ast.fix_missing_locations(node)`, where "node" is the most recently added or modified node. This allows your node to sit correctly within the AST. For an in-depth explanation about the structure of ASTs in Python as well as a rundown on node transformers and visitors, visit http://greentreesnakes.readthedocs.org/en/latest/.

Step five is to set up the process for generating an AST, modifying it with your custom node transformer and visitor, and finally generating code. To add your new pattern, create a new function that receives a filename and any other necessary inputs for your pattern as arguments. Inside this new function, call the `openAndParse(filename)` method, which will create an AST of the code located at the filename that is ready to be modified and that has all comments replaced as strings. Next, call your note transformer and visitor functions accordingly. Once you are done modifying the AST, call the function `writeToSource(AST, filename)` which will write out the AST as source code to a file with the same name as the *filename* input argument.

Sample code is show below that shows an implementation of this process.

```python
def generatePattern(filename):
    tree = openAndParse(filename)           #Create AST from file

    treeVisitor().visit(tree)               #Visit the tree
    treeTransformer().visit(tree)           #modify the tree

    result = writeToSource(tree, filename) #write AST (arg1) as code to a file(arg2) called filename_COM3.py
    return result                           #returns a string saying where the new file is

class treeVisitor(ast.NodeVisitor):         #visitor for ASTs
    def visit_ClassDef(self,node):
        #TODO do anything but modify the tree here
        print node

class treeTransformer(ast.NodeTransformer):#transformer for ASTs
    def visit_ClassDef(self,node):
        #Modify the tree by visiting nodes of a certain type, editing them and returning new modified node
        #this visits all the class definition nodes
        newNode = node

        modifyNode(newNode)

        ast.copy_location(newNode, node)
        ast.fix_missing_locations(newNode)
        return newNode
    def visit_FunctionDef(self,node):
        #Modify the tree by visiting nodes of a certain type, editing them and returning new modified node
        #this visits all the function definition nodes
        return node
```

```python
def generatePattern(filename):
    tree = openAndParse(filename)           #Create AST from file

    treeVisitor().visit(tree)               #Visit the tree
    treeTransformer().visit(tree)           #modify the tree

    result = writeToSource(tree, filename) #write AST (arg1) as code to a file(arg2) called filename_COM3.py
    return result                           #returns a string saying where the new file is

class treeVisitor(ast.NodeVisitor):         #visitor for ASTs
    def visit_ClassDef(self,node):
        #TODO do anything but modify the tree here
        print node

class treeTransformer(ast.NodeTransformer):#transformer for ASTs
    def visit_ClassDef(self,node):
        #Modify the tree by visiting nodes of a certain type, editing them and returning new modified node
        #this visits all the class definition nodes
        return node
    def visit_FunctionDef(self,node):
        #Modify the tree by visiting nodes of a certain type, editing them and returning new modified node
        #this visits all the function definition nodes
        return node
```

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