Interpreter Pattern

This lesson delves into the interpreter pattern, which allows us to simplify representation and implementation of a new programming language albeit with limited syntax.

What is it ?

The interpreter literally means a ***translator***, someone who can convert from one form of speech to a another. The interpreter pattern converts a language's sentences into its grammar and interprets them.

Understanding the interpreter pattern requires background knowledge in automata and theory of computation. We'll briefly go over some of the concepts required to understand the pattern.

Grammar

Every human language has an associated grammar that defines what constructs are legal or illegal. Similarly, computer languages are defined by *grammar* too. Given a snippet of code, the language defined by the grammar would determine if the code is syntactically correct or not. There are four types of grammar known as the Chomsky's hierarchy.

- Regular
- Context Free
- Context Sensitive
- Recursively Enumerable

Context Free Grammar

We'll be interested in ***context free grammar*** for the purposes of this lesson. Most programming languages use context free grammars to specify the syntax of a language. A syntactically correct program however may or may not compile.

A CFG consists of four components:

- start symbol
- a set of terminal symbols
- a set of non-terminal symbols
- a set of productions (rules)

Let's immediately see an example to understand what is meant by each of the above terms. Consider the below *productions* or rules for an arithematic expression

1. <*expression*> --> *number*
2. <*expression*> --> <*expression*> + <*expression*>
3. <*expression*> --> <*expression*> - <*expression*>
4. <*expression*> --> <*expression*> * <*expression*>
5. <*expression*> --> <*expression*> / <*expression*>

The above rules say that the left hand side expression, which is a non-terminal symbol, can be expanded into the values on the right hand side. A non-terminal symbol is nothing but a variable or a placeholder which can be expanded into the right hand side values. One can recursively keep expanding the non-terminal symbols till a terminal symbol is reached. This is similar to how a recursive algorithm stops recursion once it reaches the base case, otherwise the program would continue in an infinite loop.

The arithematic CFG will have <*expression*> as the start symbol and **+ - ***

/ number will form the set of terminals, where number is any valid number.

As an example, we can create the following expression using the CFG

- **<expression>** using the start symbol
- **<expression>** + **<expression>** using the second production rule
- 7 + **<expression>** * **<expression>** using the first and fourth production rules
- 7 + **4 * 3** using the first production rule

The string *7* + ***4 * 3*** is said to be ***in the language of the grammar*** that we defined.

Connecting back

With the above discussion, now we are in a better position to define the interpreter pattern. The Interpreter pattern uses a class to represent each grammar rule. Symbols on the right-hand side of the rule are instance variables of these classes.

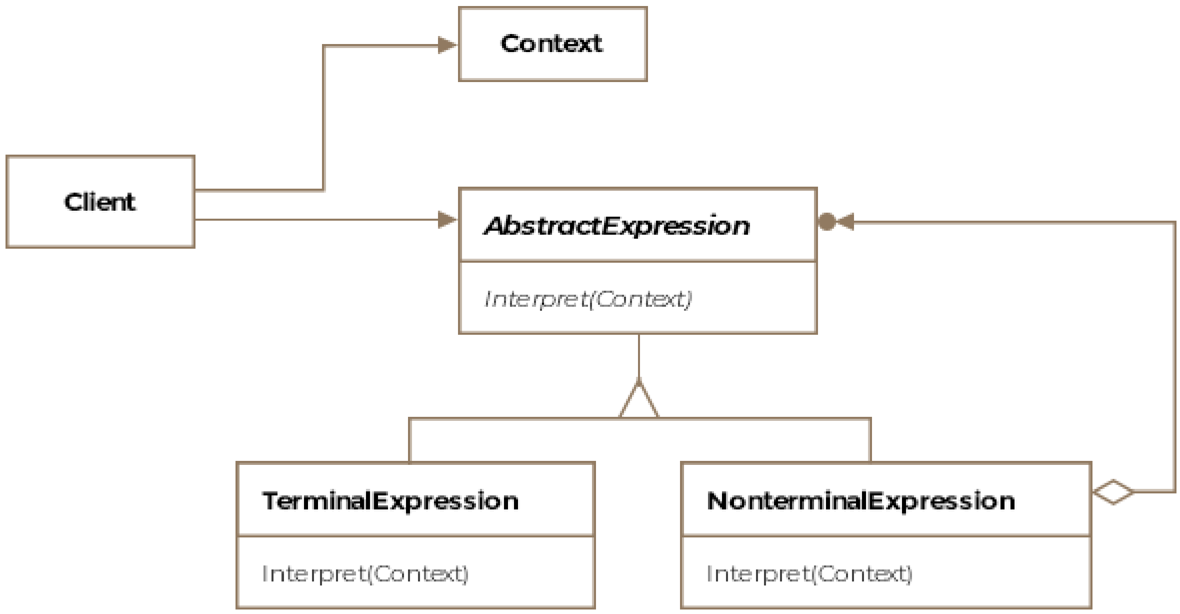
Formally, the pattern is defined as ***describe a way to represent the grammar of a language along with an interpreter that uses the representation to interpret sentences in the language***.

Class Diagram

The class diagram consists of the following entities

- **Abstract Expression**
- **Terminal Expression**
- **Nonterminal Expression**
- **Context**

- **Context**
- **Client**



Class Diagram

Example

Let's say you are writing an educational programming language for kids who aspire to be pilots someday. Your language would be very simple and will allow kids to control a plane object on-screen using the following keywords, which make up your programming language:

- *Glide*
- *SplitS*
- *BarrelRoll*

The plane object on the screen will perform one of the three actions when reading the program script. However the restriction is that a plane must start and end with a glide operation and can't perform stunts consecutively, i.e. the splitS and barrelRoll must be separated by a glide operation.

The above language can be defined by the grammar below:

The above language can be defined by the grammar below:

- ***Flight*** is the start symbol and represents the program a child wrties.
- Terminal symbols includes: **glide, splitS, barrelRoll**
- Non-terminal symbols include: **<Flight>** and **<ShowOff>**
- The production rules are:

  1. **<Flight> --> <Flight> <ShowOff> <Flight>**
  2. **<Flight> --> glide**
  3. **<ShowOff> --> splitS**
  4. **<ShowOff> --> barrelRoll**

  Or we can express the same as below when using BNF form:

  1. **<Flight> ::= glide | <Flight> <ShowOff> <Flight>**
  2. **<ShowOff> ::= splitS | barrelRoll**

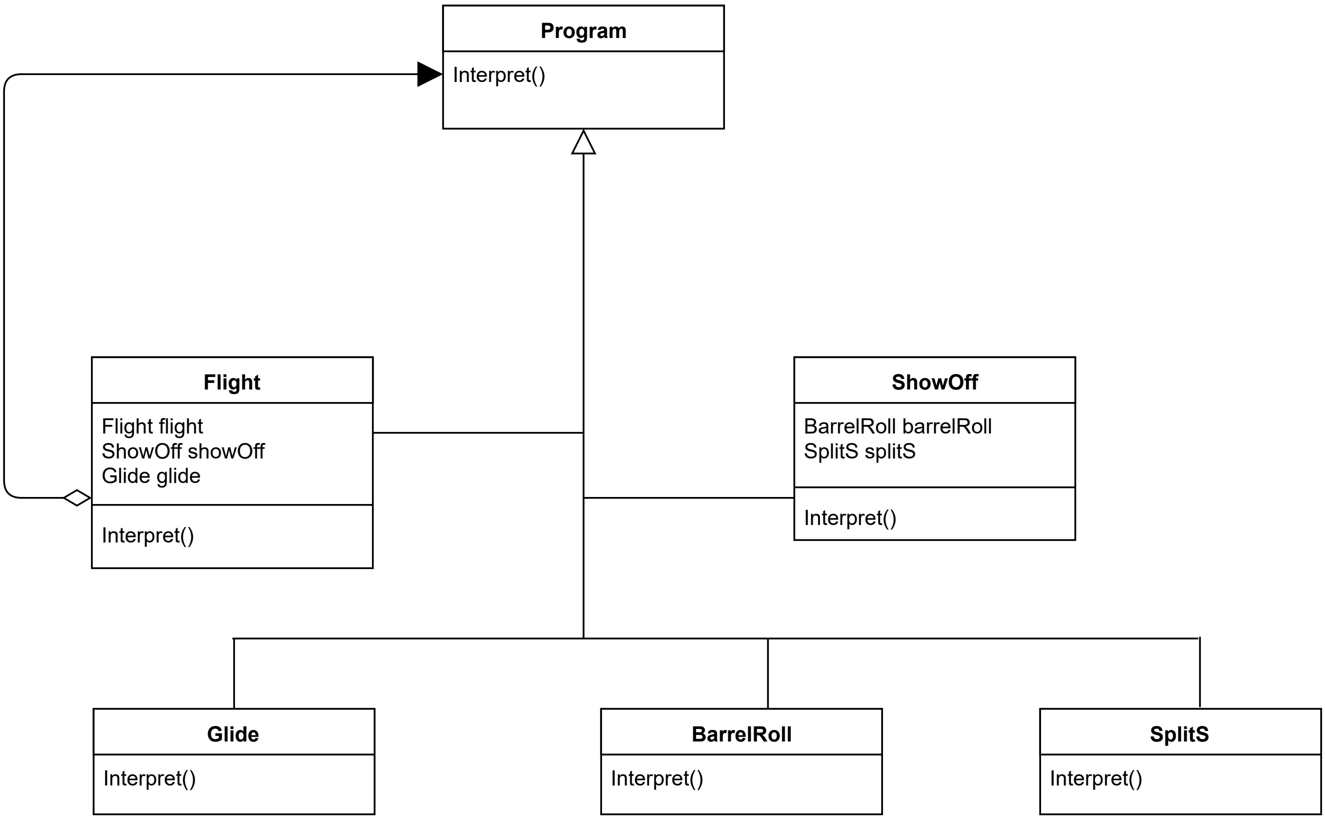
As an example we can generate a string from the following sequence of operations using the grammar rules:

1. <Flight>
2. <Flight> <ShowOff> <Flight>
3. glide splitS <Flight> <ShowOff> <Flight>
4. **glide splitS glide barelRoll glide** This sequence of commands would be considered syntactically correct for our educational programming language.

The recursion ends with the terminal symbols. Applying the interpreter pattern, we model each of the grammar rules as a class. Symbols on the right-hand side of the rule are instance variables of these classes.

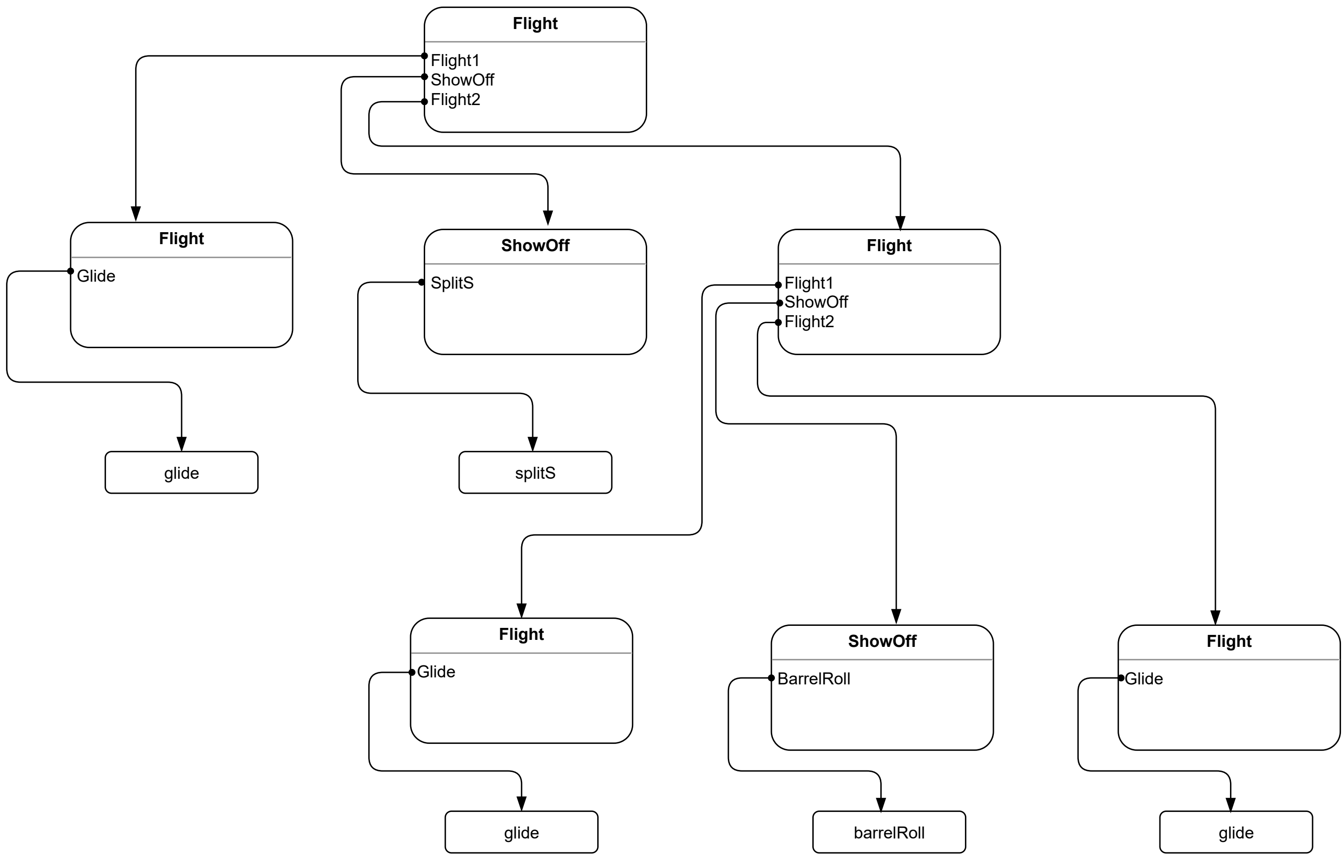
Since we use *Flight* as both the start symbol as well as a non-terminal symbol, we can introduce an abstract `Program` class from which all the other classes derive. The `Program` class has an abstract method `interpret()` that all derived classes implement and is required by the pattern.

The class diagram for the language defined by the grammar would look like below:



Abstract Syntax Tree

Abstract syntax trees (AST) are widely used in compilers to represent the structure of a program. Don't confuse the *abstract* to mean an abstract class or interface. Without getting into too much detail, the takeaway is that all the language strings produced by a grammar can be represented as an abstract syntax tree. The tree nodes would be the classes we created from the grammar rules. The internal nodes will be non-terminal symbols and the leaves must necessarily be terminal symbols. Lets take the string we generated earlier ***glide splitS glide barelRoll glide*** and see how its AST would look like.



Tying it All Together

Each of our subclass implements the `interpret( Context )` method. Interpret takes as an argument the context in which to interpret the expression. Each interpret operation of the terminal symbols defines the base case for recursion. The context contains the input string and information on how much of it has been matched so far. Each subclass of `Program` implements Interpret to match the next part of the input string based on the current context. For instance:

- The classes `Glide`, `BarrelRoll` and `SplitS` will check to see if the input matches any of those words.
- The class `ShowOff` will check if the input matches either of the two values it can take on.
- The class `Flight` class will check if the input matches the terminal symbol or expands into another concatenation of non-terminal symbols.

We'll skip the implementation that'll contain the logic for matching the input stream as its not necessary to understand the pattern.

The listing for the classes appears below

```
public abstract class Program {
    public void interpret(Context context) {}
}

public abstract class Flight extends Program {

    Flight flight;
    ShowOff showOff;
    Glide glide;

    @Override
    public void interpret(Context context) {}
}

public class ShowOff extends Program {

    BarrelRoll barrelRoll;
    SplitS splitS;

    @Override
    public void interpret(Context context) {

    }
}

public class BarrelRoll extends Flight {

    @Override
    public void interpret(Context context) {

    }
}

public class Glide extends Program {
```

```
    @Override
    public void interpret(Context context) {


    }
}

public class SplitS extends Program {

    @Override
    public void interpret(Context context) {

    }
}
```

The client will use pattern like below:

```
public class Client {

    public void main(AbstractSyntaxTree ast) {

        Context context = new Context("glide splitS glide barelRoll g
lide");

        while (ast.hasNext()) {
            Program node = ast.getNextNode();
            node.interpret(context);
        }
    }
}
```

Other Examples

- `java.util.Pattern` is a compiled representation of a regular expression.
- `java.text.Normalizer` provides functionality to transform Unicode text.

Caveats

- The `interpret()` method can also be put in a visitor object instead of putting it in the expression classes.
- The terminal symbols can also implemented as flyweight objects.
- Its easy to implement, extend and change grammars with limited rules that are implemented using the interpreter pattern. However grammars will lots of rules become hard to manage since there's one class per rule in the interpreter pattern.