

CS1632, Static Analysis Part 1 Supplement: Type Checking

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What is a Type?

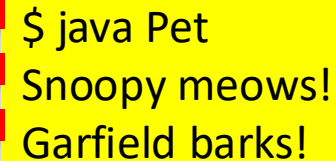
1. A set of values. E.g.:
 - Integers between MIN_INT and MAX_INT
 - Strings with UNICODE characters
 - Objects with one integer and one string as member variables
 2. A set of operations allowed on those values. E.g.:
 - Operators such as +, -, *, /, ==, !=, ...
 - Method calls
- Two types may have same set of values but different allowed operations

Example of a buggy class

```
public class Pet {
    String name;
    Boolean isCat;
    public Pet(String name, Boolean isCat) { this.name = name; this.isCat = isCat; }
    public void meow() { System.out.println(name + " meows!"); }
    public void bark() { System.out.println(name + " barks!"); }
    public static void converse(Pet cat, Pet dog) {
        cat.meow();
        dog.bark();
    }
    public static void main(String[] args) {
        Pet dog = new Pet("Snoopy", false);
        Pet cat = new Pet("Garfield", true);
        converse(dog, cat);
    }
}
```

Bug may go undetected as code still runs

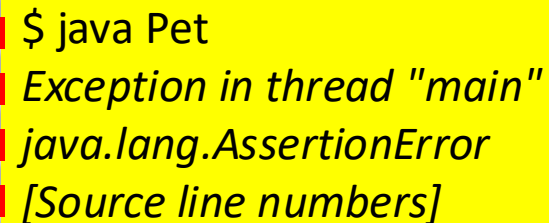
```
public class Pet {  
    String name;  
    Boolean isCat;  
    public Pet(String name, Boolean isCat) { this.name = name; this.isCat = isCat; }  
    public void meow() { System.out.println(name + " meows!"); }  
    public void bark() { System.out.println(name + " barks!"); }  
    public static void converse(Pet cat, Pet dog) {  
        cat.meow();  
        dog.bark();  
    }  
    public static void main(String[] args) {  
        Pet dog = new Pet("Snoopy", false);  
        Pet cat = new Pet("Garfield", true);  
        converse(dog, cat);  
    }  
}
```

A yellow rectangular box with a red dashed border containing the terminal output of the Java code.

\$ java Pet
Snoopy meows!
Garfield barks!

Better: Use runtime property checks

```
public class Pet {  
    String name;  
    Boolean isCat;  
    public Pet(String name, Boolean isCat) { this.name = name; this.isCat = isCat; }  
    public void meow() { assert isCat == true; System.out.println(name + " meows!"); }  
    public void bark() { assert isCat == false; System.out.println(name + " barks!"); }  
    public static void converse(Pet cat, Pet dog) {  
        cat.meow();  
        dog.bark();  
    }  
    public static void main(String[] args) {  
        Pet dog = new Pet("Snoopy", false);  
        Pet cat = new Pet("Garfield", true);  
        converse(dog, cat);  
    }  
}
```



```
$ java Pet  
Exception in thread "main"  
java.lang.AssertionError  
[Source line numbers]
```

Even Better: Use compile time type checks

```
public class Cat extends Pet {  
    public Cat(String name) { super(name); }  
    public void meow() { System.out.println(name + " meows!"); }  
}
```

```
public class Dog extends Pet {  
    public Dog(String name) { super(name); }  
    public void bark() { System.out.println(name + " barks!"); }  
}
```

- Created two types Cat and Dog that inherit from Pet
- Note that Cat and Dog have the same set of values, but different allowed operations
=> This is what we are going to leverage!

Even Better: Use compile time type checks

```
public class Pet {  
    String name;  
    public Pet(String name) { this.name = name; }  
    public static void converse(Cat cat, Dog dog) {  
        cat.meow();  
        dog.bark();  
    }  
    public static void main(String[] args) {  
        Dog dog = new Dog("Snoopy");  
        Cat cat = new Cat("Garfield");  
        converse(dog, cat);  
    }  
}
```

```
$ javac Pet.java Cat.java Dog.java  
Error: Type mismatch error  
[Source line numbers]
```

Type checks can check a wide range of properties

- Some type checks need extra language and compiler support
 - Example property: program does not have data races
 - Java: need to use an extension to Java called Deterministic Parallel Java (**DPJ**)
 - C: need to use a “safe” rendition of the C language called **Rust**
 - Both have language constructs to annotate variables as owned by one thread only
 - Languages explicitly designed for type checks: **TypeScript** (JavaScript), **Rust** (C/C++), etc.
- Many type checks can be done using the existing (Java) type system
 - Example property: only positive integers are passed to a method
 - By creating a “positive integer” type
 - Example property: plaintext is never stored to the database (for security)
 - By creating a “encrypted text” type

Property: plain text is never stored to the database

- This is correct code, but with no type checking for the property:

```
public class Text {
    String text;
    public Text(String s) { this.text = s; }
    public Text encrypt() { /* returns encrypted text */}
    public void storeDatabase() { /* stores text in database */ }
}

public class App {
    public static void main(String[] args) {
        Text text = new Text("Hello World");
        text = text.encrypt(); // Encrypt text before storing to DB
        text.storeDatabase();
    }
}
```

Property: plain text is never stored to the database

- With no type checking, incorrect code goes undetected:

```
public class Text {
    String text;
    public Text(String s) { this.text = s; }
    public Text encrypt() { /* returns encrypted text */}
    public void storeDatabase() { /* stores text in database */ }
}

public class App {
    public static void main(String[] args) {
        Text text = new Text("Hello World");
        // text = text.encrypt(); // Uh-oh. Commented out the encrypt.
        text.storeDatabase();      // App just stores the plain text. Fail!
    }
}
```

Property: plain text is never stored to the database

- This time, type checking is employed to check that property:

```
public class PlainText {
    String text;
    public PlainText(String s) { this.text = s; }
    public EncryptedText encrypt() { /* returns encrypted text */ }
}

public class EncryptedText {
    String text;
    public void storeDatabase() { /* stores text in database */ }
}

public class App {
    public static void main(String[] args) {
        PlainText text = new PlainText("Hello World");
        EncryptedText text2 = text.encrypt(); // Encrypt text before storing to DB
        text2.storeDatabase();
    }
}
```

Property: plain text is never stored to the database

- This time, type checking is employed to check that property:

```
public class PlainText {
    String text;
    public PlainText(String s) { this.text = s; }
    public EncryptedText encrypt() { /* returns encrypted text */}
}
public class EncryptedText {
    String text;
    public void storeDatabase() { /* stores text in database */ }
}
public class App {
    public static void main(String[] args) {
        PlainText text = new PlainText("Hello World");
        // EncryptedText text2 = text.encrypt();    // Uh-oh. Forgot to encrypt.
        text.storeDatabase();    // Type error! No storeDatabase method in PlainText
    }
}
```