

INFO1113 Object-Oriented Programming

Week 4A: Binary IO and Memory

Interpreting data and understanding the memory model

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- Binary Input/Output (s. 4)
- Stack (s. 24)
- Heap (s. 26)
- Garbage Collector (s. 34)

In the previous week we saw how we could read data from text files. We will start this lecture by reading a binary file and how we can store data in a non-readable format.

What info do we need?

Like text data we can employ patterns but they are not easily obvious to inspect.

When reading a binary file there is a specific layout to interpret it correctly. This is typically bundled with a **file format specification**.

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When reading a binary file there is a specific layout to interpret it correctly. This is typically bundled with a **file format specification**.

For example, a **poke.dex** file format.

pokedex_header: 40 bytes

seen_pokemon: seen*4 bytes

<pre>magic: 4 bytes : int owner: 32 bytes : char no_pkmn: 2 bytes : short seen: 2 bytes : short</pre>	<pre>pkmn_id: 2 bytes : short type_1 : 1 byte : byte type_2 : 1 byte : byte</pre>
---	---

What info do we need?

We also need to know about the **endianness** of the data as well.

Without this information we may not interpret the data correctly and therefore get strange values.

In the following examples we will assume **machine default**.

Let's read some files!

```
import java.io.FileInputStream;
import java.io.FileNotFoundException;
import java.io.IOException;

public class BinaryReader {

    public static void main(String[] args) {
        try {
            FileInputStream f = new FileInputStream("some_file.bin")
            byte[] buffer = new byte[4]; //We will read 1 integer
            f.read(buffer);
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```


Let's read some files!

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        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

Okay we have read the data but what can we do with it?

Let's read some files!

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            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

We need to **interpret** the data.

We need to convert the data

Let's read some files!

```
import java.io.FileInputStream;

public class BinaryReader {

    public static int convert(byte[] b) {
        return ((b[3] & 0xFF) |
                ((b[2] & 0xFF) << 8) |
                ((b[1] & 0xFF) << 16) |
                ((b[0] & 0xFF) << 24));
    }
}
```

Considering we have captured the data in a **byte[]** array

We need to transform this to an integer.

Shifting and bitwise operations

Let's read some files!

```
import java.io.FileInputStream;
import java.io.FileNotFoundException;
import java.io.IOException;

public class BinaryWriter {
    //<snip> Assume we have convert here
    public static void main(String[] args) {
        try {
            FileInputStream f = new FileInputStream("some_file.bin")
            byte[] buffer = new byte[4];
            f.read(buffer);
            int v = convert(buffer);
            System.out.println(v); //Output the integer
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

How about writing?

Let's write some files!

```
import java.io.FileOutputStream;
import java.io.FileNotFoundException;
import java.io.IOException;

public class BinaryWriter {
    //<snip> Assume we have convert here
    public static void main(String[] args) {
        try {
            FileOutputStream f = new FileOutputStream("some_file.bin")
            int v = 50;
            byte[] buffer = convert(v);
            f.write(buffer); //Write out the bytes
            f.close();
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```


Let's write some files!

```
import java.io.FileOutputStream;
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public class BinaryWriter {
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            f.close();
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }
}
```

We write the byte[] array to the file.

Let's write some files!

```
import java.io.FileOutputStream;

public class BinaryWriter {

    public static byte[] convert(int v) {
        byte[] b = new byte[4];
        b[0] = (byte) (v >> 24);
        b[1] = (byte) (v >> 16);
        b[2] = (byte) (v >> 8);
        b[3] = (byte) v;
        return b;
    }
}
```

From the integer we need to transform this to a byte array for writing.

Sidenote: How are classes encoded?

.class files are not human readable, just like image formats and executables but how does the **JVM** understand and interpret this file?

Simply, there is some method of interpreting binary files and being able to read them. By following the specification on the by Oracle[1] we can design a program to interpret and understand the class.

However, for demonstration purposes, let's start off with something that is a little more digestible.

Let's read and write some data

There must be a better way!

Of course!

We just showed the hard way of reading and writing. We can do away with these conversions entirely using **ByteBuffer** and **ByteOrder** classes to manipulate the data with its inbuilt methods.

We can even go a **step further** and use a **DataInputStream** and **DataOutputStream** and use methods such as **writeInt** and **readChar**.

Why would we want to do this?

There are going to be applications where the data itself will not be presented in a textual representation.

- Interacting with devices and peripherals (gamepads, midi devices)
- Modifying executables
- Encoding images
- Writing your own file format for your programs
- Writing software for automotive applications
- Video and audio streams
- Networking application

Let's simplify it

We're revisiting the **stack**.

Everytime we invoke a method it will be placed on the stack.

We need to understand the fixed limit of the stack within the **JVM**. By default the stack limit is **1MB**.

A **stack frame** can be thought of as an **instance** of a method. Each method has a size which is the combination of its **instructions, variables and argument data**.

Each stack frame has a **return address**.



Stack variables

The heap is separate memory space for which objects are **dynamically** allocated.

Whenever we use the **new** keyword, memory for the object is allocated and an address is returned.

Unlike the stack, heap allocated object lifetimes are a little more complicated.

Stack based objects exist in lexicographical scope. (**ie the {} braces**).

While heap objects can be aliased and their lifetimes are dictated when all references are no longer in scope.

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```
int[] array = new int[16];
```



Let's consider the following

```
public static void main(String[] args) {  
    int x = 5;  
    int[] array = new int[16];  
    int[] alias = array;  
    int y = x;  
}
```

Memory



Let's consider the following

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0x4000

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We can see that **array** has its own memory space which is of the size of 16 integers. What would occur in the following assignment with **alias**.

Memory



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```

Although, **x** and **y** we will compare the **copy-semantics** between a **primitive type** and a **reference type**.

Memory

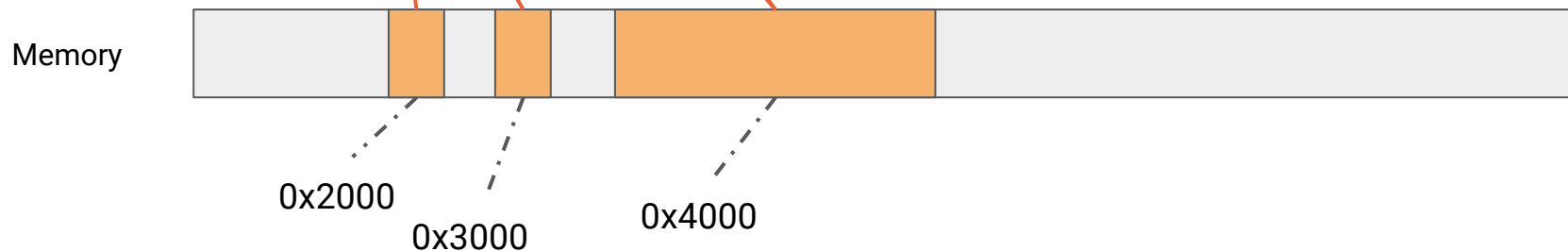


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Let's consider the following

```
public static void main(String[] args) {  
    int x = 5;  
    int[] array = new int[16];  
    int[] alias = array;  
    int y = x;  
}
```

Although, **x** and **y** are on the **stack** we will compare the **copy-semantics** between a **primitive type** and a **reference type**. Primitive types will copy the value between instead of the address.



Java employs the use of a **garbage collector** to free memory. Any memory that is allocated using the **new** keyword will be kept on the heap.

The garbage collector will subsequently free any allocation that no longer has a reference during execution.

The garbage collector will **stop-the-world** and act on allocations without a reference.

All I have known is garbage collecting? What was it like before?

What does manual look like?

Here's some C code!

```
person* create_object() {  
    person* p = malloc(sizeof( person ));  
    //things  
    return p;  
}
```

```
//<other bits of code>
```

```
void delete_person(person* p) {  
    free(p);  
}
```

**Okay! I know you don't know C so here's a
java-ized version**

What does manual look like?

Here's some C Java code!

```
Person createPerson() {  
    Person p = new Person();  
    //things  
    return p;  
}
```

```
//<other bits of code>
```

```
void deletePerson(Person p) {  
    delete p;  
}
```


What does manual look like?

Here's some C Java code!

```
Person createPerson() {  
    Person p = new Person(); ← We have allocated a new Person object  
    //things  
    return p;  
}  
  
//<other bits of code>  
  
void deletePerson(Person p) {  
    delete p;  
}
```

What does manual look like?

Here's some C Java code!

```
Person createPerson() {  
    Person p = new Person();  
    //things  
    return p;  We have returned p to the calling method  
}
```

```
//<other bits of code>
```

```
void deletePerson(Person p) {  
    delete p;  
}
```


What does manual look like?

Here's some C Java code!

```
Person createPerson() {  
    Person p = new Person();  
    //things  
    return p;  
}
```

Once the allocation has been used and the programmer wants it deleted it is sent to the **deletePerson** method

```
//<other bits of code>
```


```
void deletePerson(Person p) {  
    delete p;  
}
```

What does manual look like?

Here's some C Java code!

```
Person createPerson() {  
    Person p = new Person();  
    //things  
    return p;  
}
```

```
//<other bits of code>
```

```
void deletePerson(Person p) {  
    delete p;  At this point allocation is deleted  
}
```

Scenario 1: Forgot to free

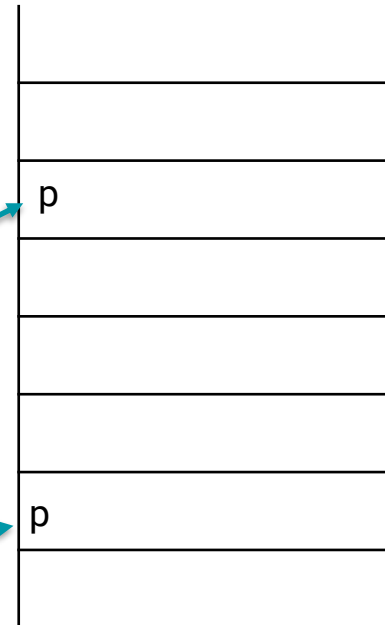
When we forget to deallocate:

```
Person createPerson() {  
    Person p = new Person();  
    return p;  
}
```

```
//<other bits of code>
```

```
void main(String[] args) {  
    Person p = createPerson();  
    someWork(p);  
    p = createPerson();
```

```
}
```



← Uhoh! We didn't deallocate the previous one!

**How does the garbage collector
handle this?**

Scenario 1: Forgot to free

When we forget to deallocate:

```
Person createPerson() {  
    Person p = new Person();  
    return p;  
}
```

```
//<other bits of code>
```

```
void main(String[] args) {  
    Person p = createPerson();  
    someWork(p);  
    p = createPerson();  
}
```

← Since the original allocation has no references to it, when the GC passes it, it will be marked for deletion.

Scenario 2: Oops! I thought it was still allocated

```
Person createPerson() {  
    Person p = new Person();  
    return p;  
}
```

```
//<other bits of code>
```

```
void main(String[] args) {  
    Person p = createPerson();  
    Person c = p;  
    delete p;  
    someWork(c);
```

← Uhoh! If the memory has been freed then potentially we could be using memory that we don't own anymore

```
}
```

Scenario 2: Oops! I thought it was still allocated

```
Person createPerson() {  
    Person p = new Person();  
    return p;  
}
```

```
//<other bits of code>
```

```
void main(String[] args) {  
    Person p = createPerson();  
    Person c = p;
```

```
delete p;
```

```
someWork(c);
```

```
}
```

We don't do
this anymore

← Simply: There is no manual deallocation

Why?

Shouldn't you just be more careful?

It's about simplifying writing software for everyone. It allows you as a programmer to be able to write software without needing to worry about memory management.

We can minimise errors and make programming **safer** through this method.

How does the garbage collector clean up?

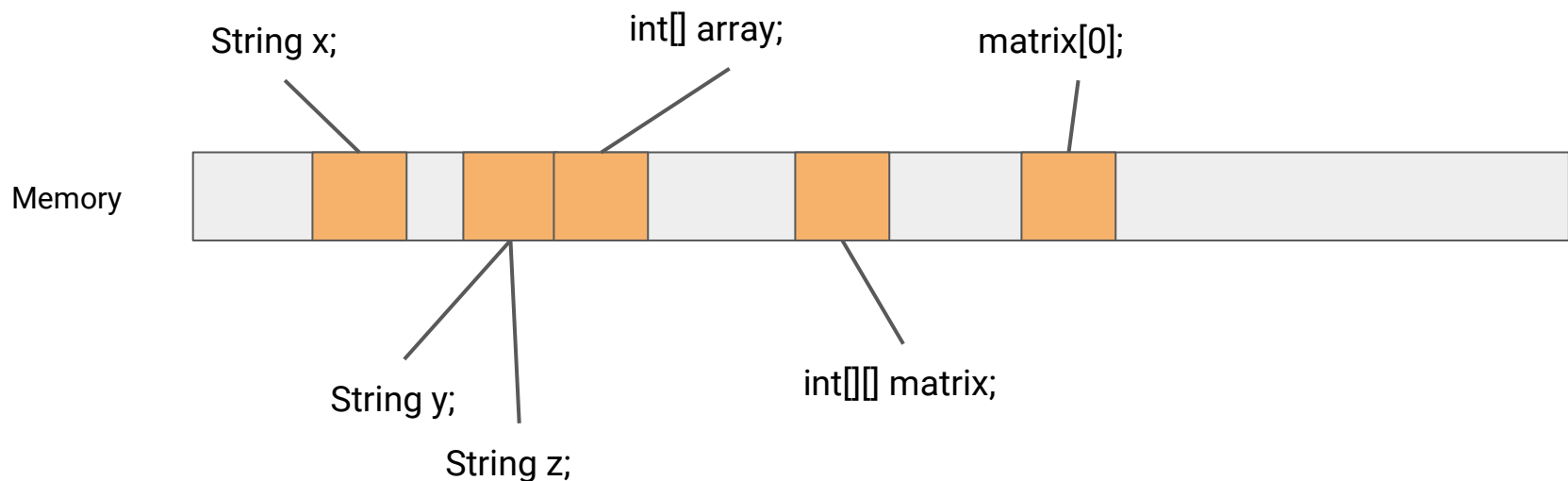
When an **allocation** no longer has a reference it, the garbage collector will **mark** it for deletion.

Garbage Collector

How does the garbage collector clean up?

When an **allocation** no longer has a reference it, the garbage collector will **mark** it for deletion. This is when all references have gone out of scope.

Let's see how the following works:

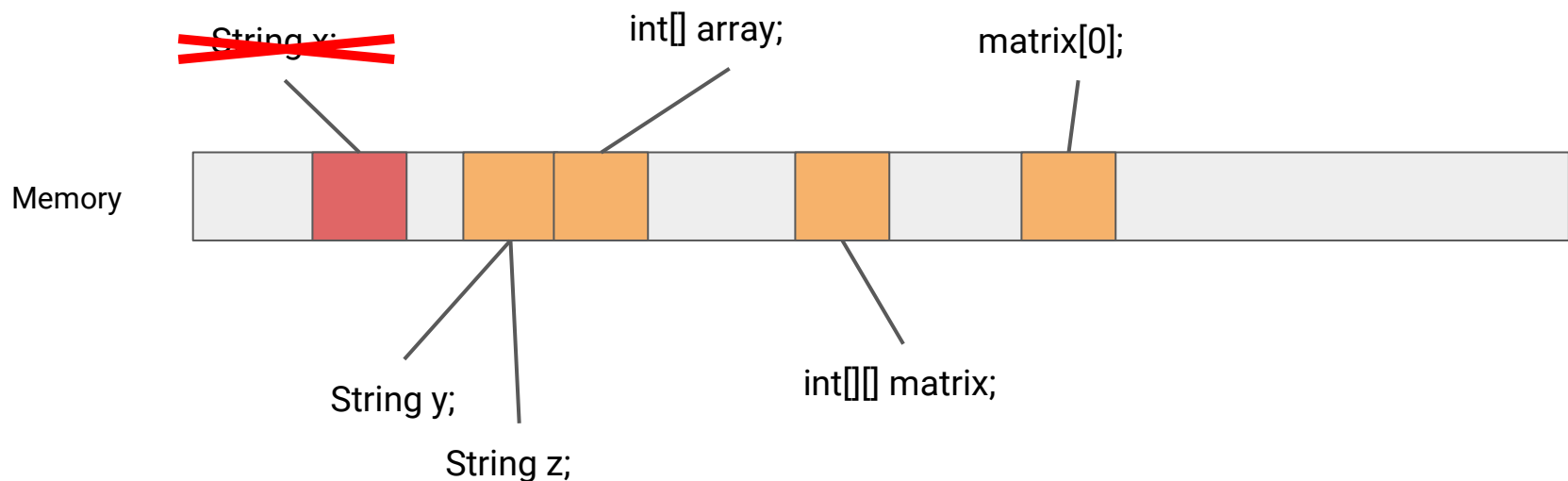


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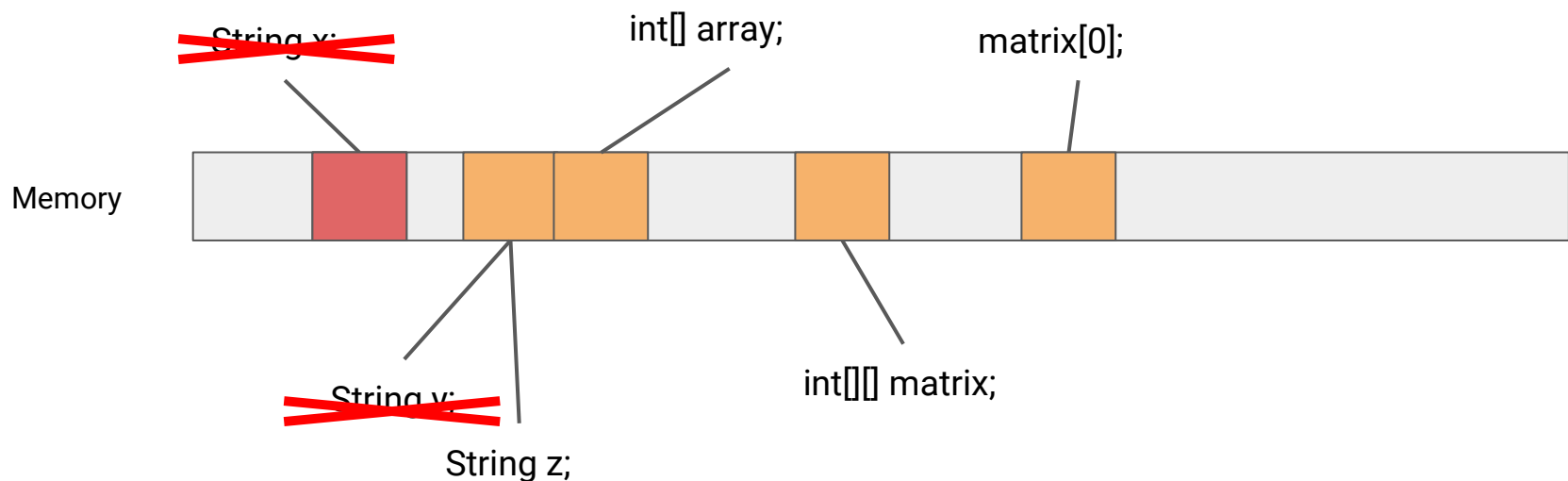


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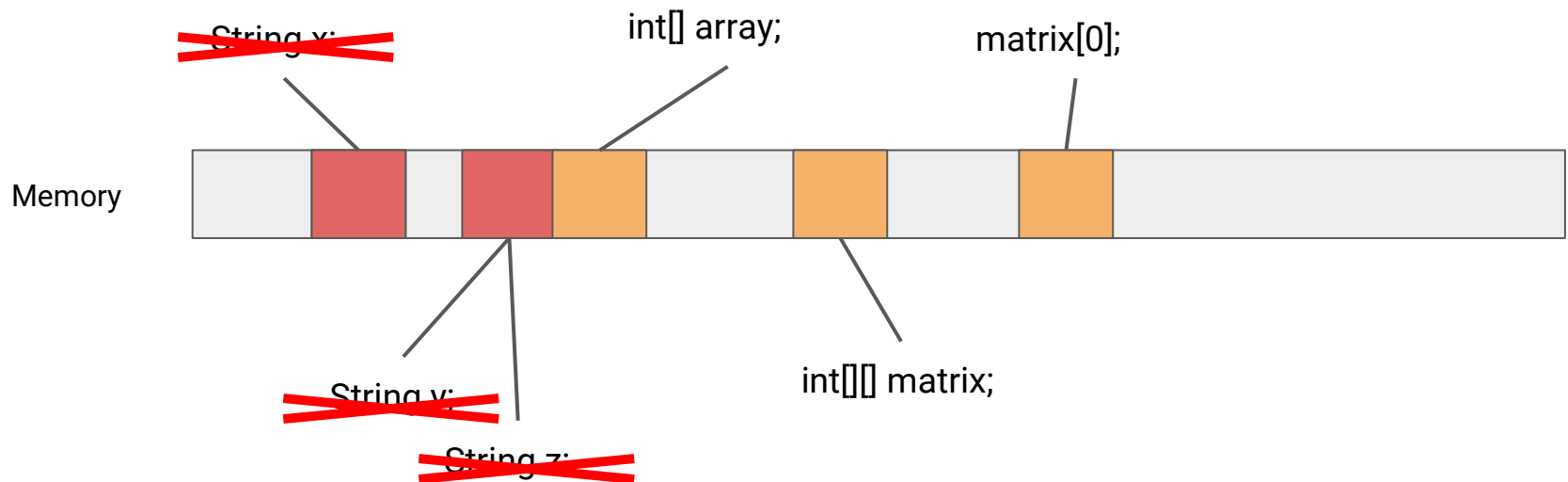


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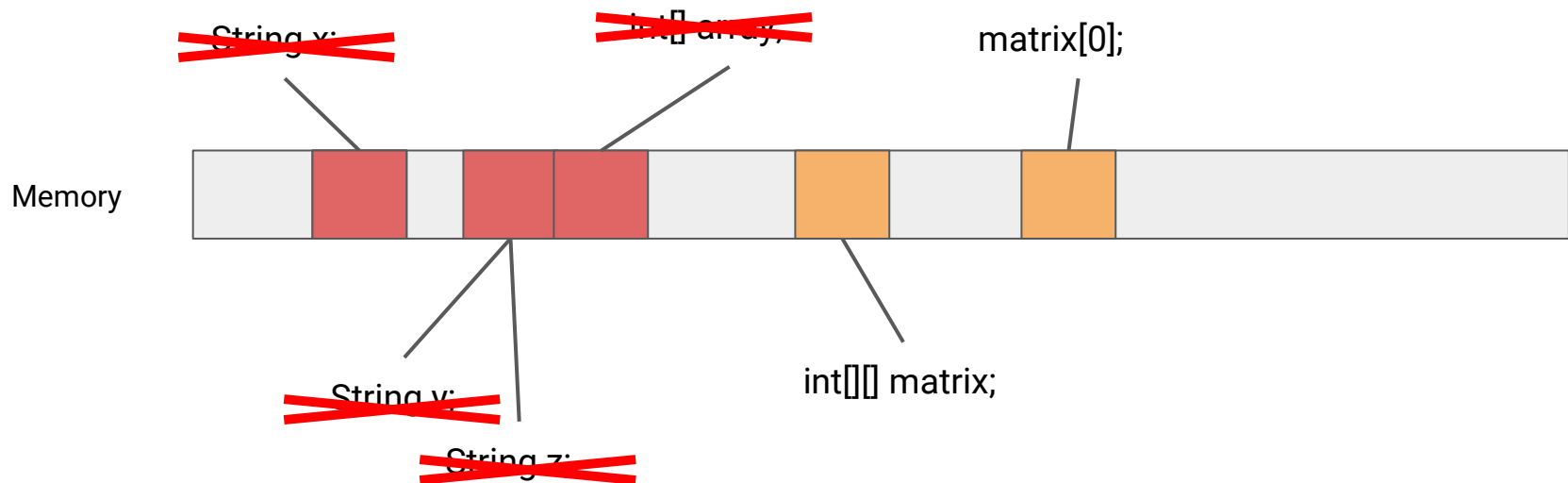


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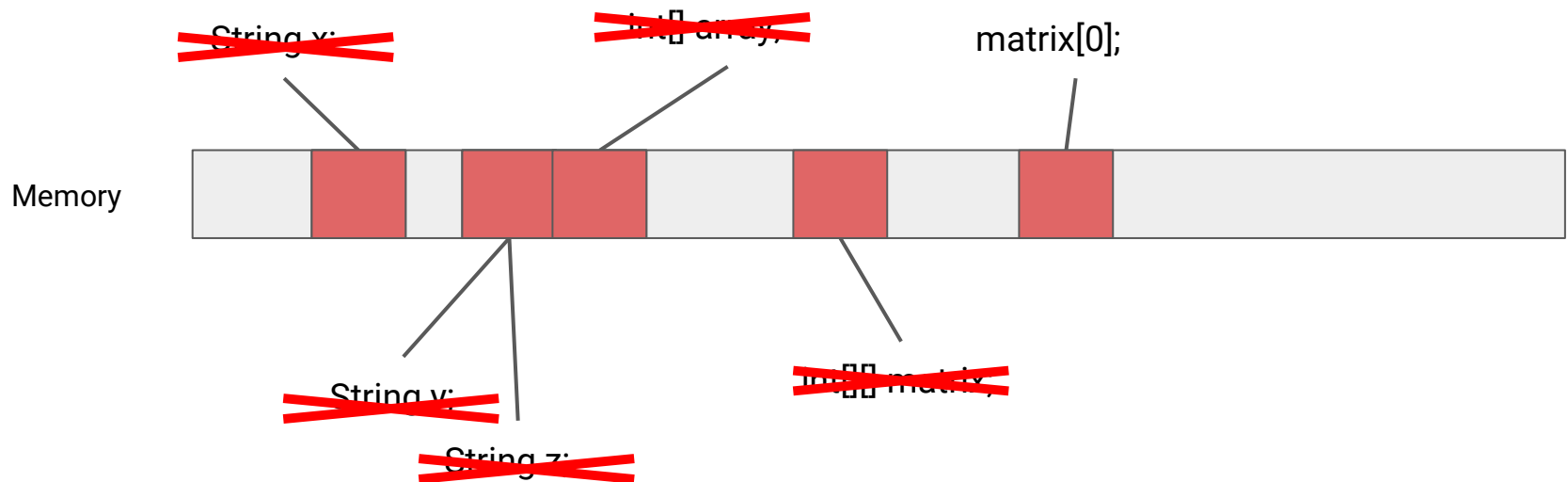


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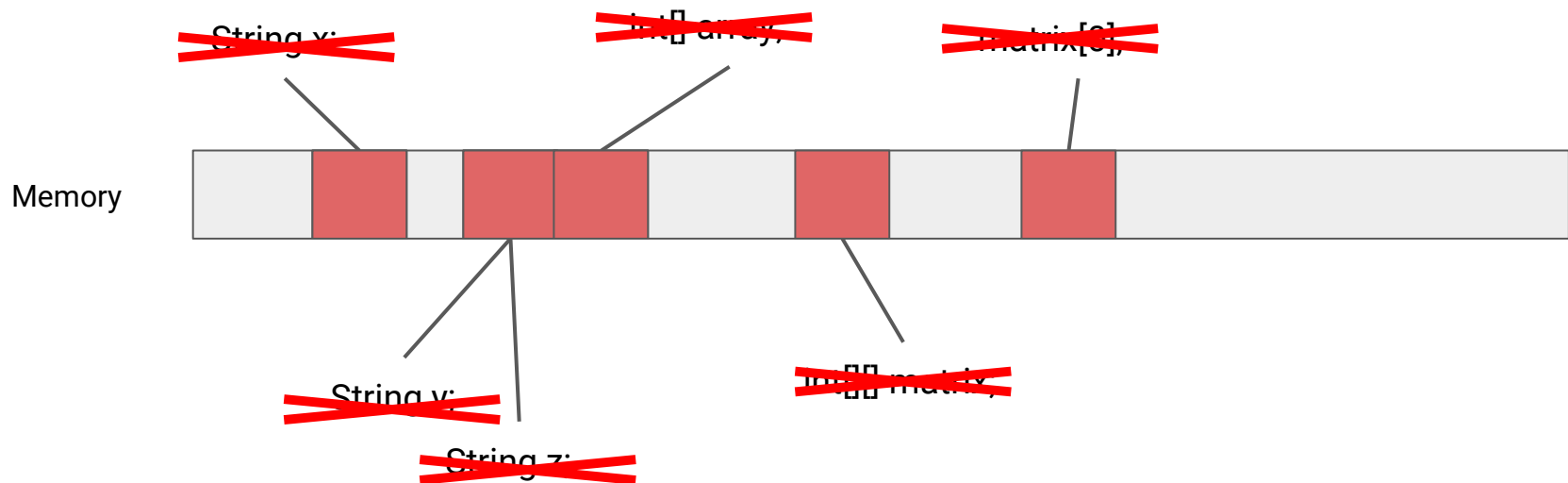


Garbage Collector

How does the garbage collector clean up?

When an **allocation** no longer has a reference it, the garbage collector will **mark** it for deletion. This is when all references have gone out of scope.

Let's see how the following works:



Simple references

See you next time!