Memory Management in Rust, Java, and C++

Submitted by

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Advanced Programming Language

Rust Program

```
fn square_in_place(x: &mut i32) {
    *x = *x * *x;
}

fn main() {
    let mut num = 5;
    // Pass mutable reference ⟶ borrow, no copy
    square_in_place(&mut num);

    println!("Squared = {}", num); // 25
} // memory automatically freed here
```

Execution

Rust compiler enforces that only one mutable borrow exists at a time. No dangling pointers allowed.

Java Program

```
class Box {
   int value;
   Box(int v) { value = v; }
}

public class MemoryTest {
   static void square(Box b) {
      b.value = b.value * b.value; // object modified via reference
   }

   public static void main(String[] args) {
      Box num = new Box(5);
      square(num);
      System.out.println("Squared = " + num.value); // 25
   }
}
```

Execution

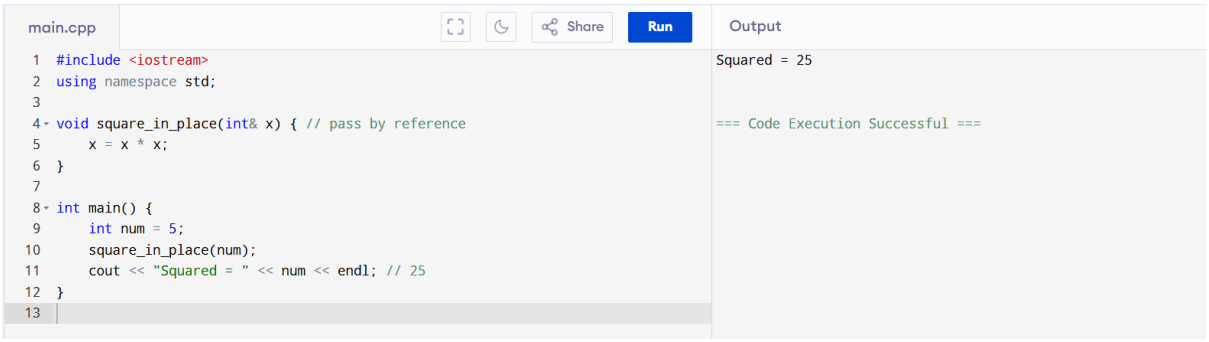
In Java, all objects are references. When you pass num into square, the method gets a reference (pointer) to the same object. GC frees memory when Box is no longer reachable.

C++ Program

```cpp
#include <iostream>
using namespace std;

void square_in_place(int& x) { // pass by reference
    x = x * x;
}

int main() {
    int num = 5;
    square_in_place(num);
    cout << "Squared = " << num << endl; // 25
}
```



Int & is an alias to the original variable. No copying. Unlike Rust, dangling references are possible if you return refs to locals. Unlike Java, no GC—you must manage heap objects explicitly.

Analysis of references & memory

Rust:

References (&T, &mut T) are *borrows* with strict rules.

Compiler prevents dangling refs or data races.

Memory automatically freed (RAII) when the owner goes out of scope.

Java:

References are opaque handles to heap objects.

No explicit free—GC reclaims unreachable objects.

Errors come from *logical leaks* (holding references too long), not dangling pointers.

C++:

References (&) are just aliases; powerful but dangerous.

Can dangle if you return a reference to a local variable.

Memory must be freed manually (unless using smart pointers/RAII).

GITHUB LINK

https://github.com/gowthamvidi/MSCS632_Assignment.git