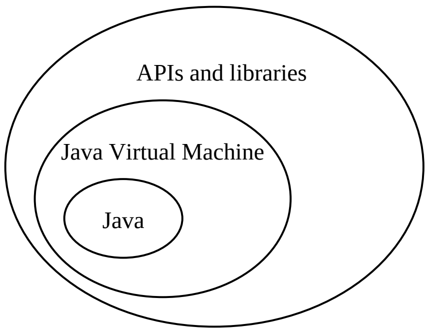
An Overview of Java

The Java Platform:



What is Java?

- An object oriented programming language with strong type-checking and automatic garbage collection.
- A "virtual machine" that performs run-time linking and run-time verification to guarantee the integrity of code.
- A set of libraries that abstract user interface issues to a platform neutral set of operations.
- A system that can support many levels of code: embedded applications; "applets" that run inside Web browsers; full-blown applications; or even an operating system.

History

- Began in 1990 with a project for consumer electronic device controllers.
- 1991: Programming language “Oak” for this project.
- 1992: Separate company (FirstPerson, Inc.) started for this project, but didn't thrive.
- 1994: Sun began adapting Oak for the Internet.
- April 1995: Initial release (including HotJava), and rename to Java.
- May 1995: Netscape agrees to incorporate Java with Navigator.
- April 1996: Microsoft announces incorporation of Java into Windows 95.
- Following months: Lots and lots of people announce Java projects and support.

What makes Java so popular?

- Platform independence
- Pure (although slightly incomplete) object oriented design
- Secure for running untrusted code

Is this new?

No!

- Platform independence has been seen many places: The UCSD P-System, the Zork-language virtual machine, etc.
- Object oriented languages are in abundance: Smalltalk, Eiffel, Dylan, etc.
- Secure for untrusted code: Some anti-virus techniques, restricted system access, etc. (Java's only big improvements come in this area)

So if it's all old technology, why all the fuss?

- Timing, timing, timing. Emergence as the web was "growing up" was perfect timing.
- Familiarity — large base of C++ programmers made learning curve very short.
- The right combination of technologies.
- Good, free tools: compiler, debugger, and libraries
- Very good and cheap commercial tools: visual development environments, etc.
- Good side effect of being safe for untrusted code: safer for untrusted programmers! Strong type-checking and verification catches many subtle programmer bugs, increasing programmer productivity.

Platform Independence

- Goal is "Write Once, Run Anywhere"^{TM} (yes, that phrase is a trademark of Sun)
- Don't have to have a PC version, a Mac version, a Solaris version, a Digital Unix version, an HP-UX version, ... One version works on *any* system that supports the JVM.
- Still not quite there — but the bugs are being worked out.
- Absolutely vital to maintain standards that allow Java code written for one system to work on other systems: Sun vs. Microsoft lawsuit.

Remainder of presentation: How to make programming more reliable.

Or: What causes program errors and unpredictable behavior?

Note: Some of the following problems are corrected with the language Java, and others are corrected in the Java Virtual Machine.

Problem 1: Unchecked pointer arithmetic treats memory as one big block.

Example:

```
int var1;
int *ptr = &var1;
int var2 = *(ptr + 100);  // This is legal but nonsensical!
```

Solution 1: No pointers in Java! *Reference* types in the Java VM, but cannot be mixed with integers (*no* pointer arithmetic), so at compile time can verify that they will always point to something reasonable.

Related problem/solution: All array bounds are checked before indexing is performed.

Problem 2: Stack problems/overwriting critical info.

Example: (Intel x86 assembly language)

```
mysubr  proc

        pop ax
        mov ax, 0
        push ax
        ret

mysubr  endp
```

Solution 2: Stack operations are restricted to be predictable and bounded to remain in the appropriate region. Somewhat restrictive, but loss is efficiency not capability.

Not allowed: (Intel x86 assembly language)

```
        mov bx, 10
        mov cx, 0
prloop: xor dx, dx
        div bx
        push dx
        inc cx
        cmp ax, 0
        jnz prloop
```

Problem 3: Uninitialized variables cause unpredictable results.

Example:

```
Object obj;   // Assume no constructor that initializes values
int var;
cout << obj.data;   // Unpredictable value!
cout << var;        // Unpredictable value!
```

Solution 3: All class fields get an initial, predictable *default value*. Local variable initializations verified at run-time.

Problem 4: Memory allocation problems (pointer/reference not pointing to a valid object but used anyway).

Example:

```
char *str;
strcpy(str, "Hello");    // What does str point to?!?
```

Solution 4: All dereference operators checked at run time.

Problem 5: Memory deallocation problems (memory not freed properly or used after freeing).

Example 1 (basic problem):

```
Object *obj = new Object;
// ... use *obj
delete obj;
// ... more stuff
obj->data = 1;
```

Example 2 (more subtle):

```
Node *curr = first;
while (curr != 0) {
    delete curr;
    curr = curr->next;   // *curr no longer there!
}
```

Example 3 (losing allocated memory):

```
Node *curr = new Node;
curr = first;     // What happened to new node?
```

Solution 5: No explicit deallocation available. All memory management is through automatic garbage collection, insuring consistency.

Problem 6: Types used inconsistently (at machine level or through unions in C/C++).

Example:

```
union {
    int ival;
    float fval;
} u;
u.ival = 10;
cout << u.fval;      // Not really a float value stored there!
```

Solution 6: Memory locations in Java VM have values with a *type*, so not just treated as strings of bits. Type consistency enforced at run-time (in Sun JDK this is done through load-time code validation).

Problem 7: Changing types/class signatures without proper recompilation of relevant modules causes "offset shift".

Example: Code compiled with this definition

```
class myclass {
public:
    int field1;
    float field2;
};
```

may use memory offset 0 within the object to refer to field 1. If later changed to

```
class myclass {
public:
    float field2;
    int field1;
};
```

now previously compiled code does not work correctly because fields have moved!

Solution 7: Java bytecode (i.e., object code) contains no offsets (which would require pointer arithmetic!), only *name based* references resolved at run-time.

Problem 8: Overloading integers and booleans allows incorrect test conditions to slip by.

Example:

```
if (x = 1)
    cout << "x is one!";
```

Solution 8: Addition of a separate boolean type, which is required for all test conditions. No casting between boolean and integer types.

Problem 9: At machine level, improperly coded transfers may not jump to the beginning of an instruction, causing totally unpredictable results.

Example: (Intel x86 machine code)

```
0FFF:0100 B80001        MOV     AX,0100
0FFF:0103 E83D01        CALL    0243
0FFF:0106 48            DEC     AX
0FFF:0107 75FB          JNZ     0104
0FFF:0109 C3            RET
```

Solution 9: All jump targets verified at loading time, before the code is executed.

Problem 10: For untrusted (downloaded) programs, machine code allows arbitrary OS calls (file modifications, deletions, etc.).

Solution 10: *Only* machine interface is through local, trusted libraries with access screened by a *security manager* class.

Final Note

These Java/JVM design decisions were made mostly to protect machine against *rogue code* or unpredictable behavior, but also excellent protection against *programmer error*!

- It's difficult to catch all the subtle machine-failure-type bugs in a C++ program.
- It's difficult for a subtle machine-failure-type bugs to get by testing in a Java program.

Of course, logic bugs are still the responsibility of the programmer!