Java Bytecode

What's inside class files.

MIT AITI

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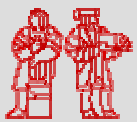
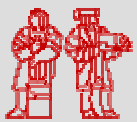
What are these .class files?

- You've created .java source code files.
- You've compiled .java source code into .class files.
- You've run your .class files.
- But what's *are* those .class files?



Typical Software Production

- Source code is ported to different platform-specific sources.
- Each port is compiled with a platform-specific compiler.
- Each compiler produces platform-specific machine code (or binaries).
- Binaries execute on a single platform.



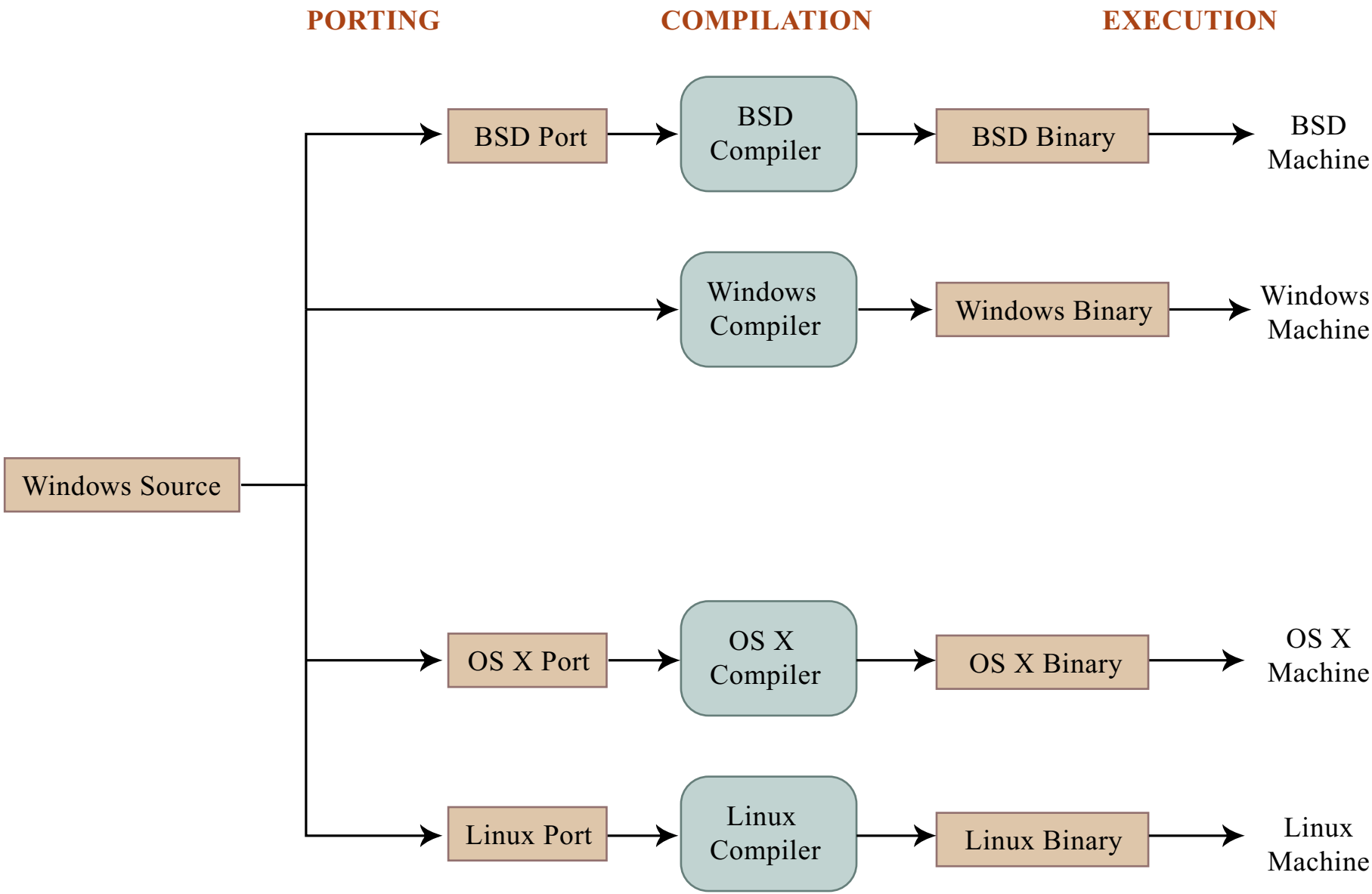
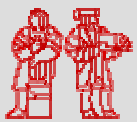


Figure by MIT OCW.

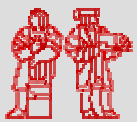
Write Once, Run Anywhere

- Java source code is is compiled into machine-independent bytecode class files.
- `javac` command compiles .java source code into .class bytecode.
- Bytecode is interpreted by machine-specific Java Virtual Machines (JVMs).
- Bytecode consists of simple, step-by-step instructions for the JVM.



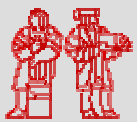
Java Virtual Machines

- JVM is a computer simulated in a computer.
- JVMs are built into most web browsers.
- java command gives .class file to JVM.
- JVM interprets the bytecode into instructions that a specific platform can understand.
- Different JVMs for different platforms: Windows, Mac OS X, Linux, cell phones.



Using javap

- `javap` is a program that can give you information on .class files.
- If you get a class file without documentation, `javap` can tell you what methods you can call.
- `javap` can show you how `javac` compiles your program into simple instructions.
- Good for high-performance optimizations or if you don't have access to an Application Programming Interface (API).



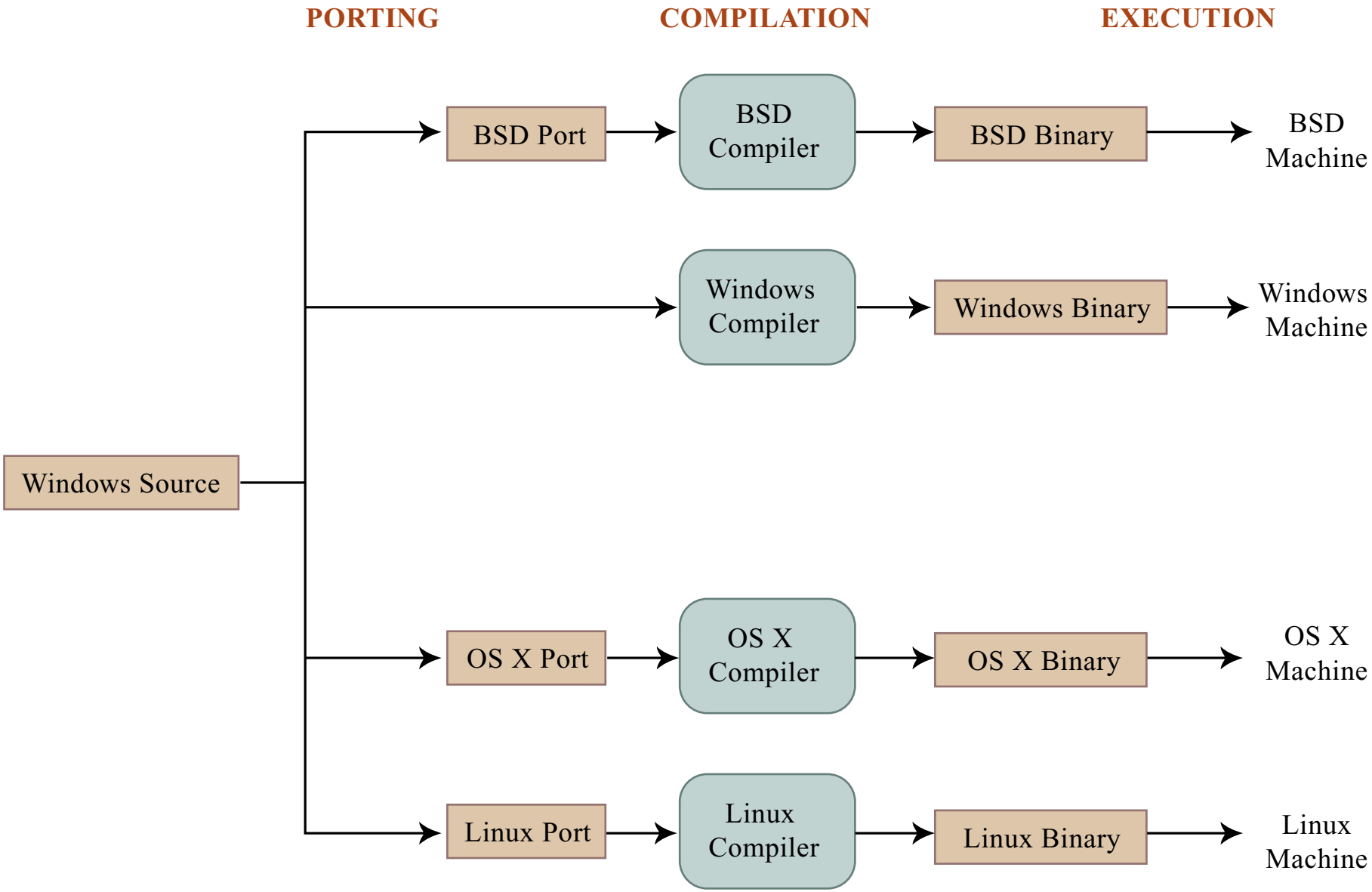


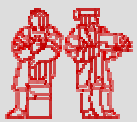
Figure by MIT OCW.

javap Output

- Given “Mystery.class”:

```
> javap Mystery
Compiled from "Mystery.java"
class Mystery extends java.lang.Object{
    Mystery();
    public static int unknown(int,int);
}
```

- One static method called “unknown” that takes two integers and returns an integer.



javap -c Output

- Using the “-c” flag will disassemble the bytecode:

```
public static int unknown(int,int);
  Code:
     0:   iload_0
     1:   iload_1
     2:   iadd
     3:   ireturn
}
```

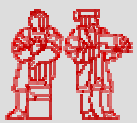
Loads the first integer argument.

Loads the second integer argument.

Adds the two loaded integer values.

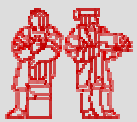
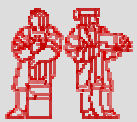
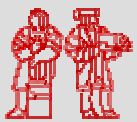
Returns the integer sum.

This method just adds two numbers together and returns the sum.



Example: String Appends

- Disassemble the following method using `javap -c`:
- ```
  public String
  append(String a, String b) {
     return a+b;
  }
  ```
- The output is surprisingly complicated…

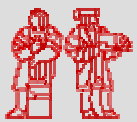

  ```

```
public static java.lang.String
  stringAdd(java.lang.String,java.lang.String,int);
Code:
0:   new     #2; //class StringBuffer
3:   dup
4:   invokespecial   #3; //Method
  java/lang/StringBuffer."<init>":()V
7:   aload_0
8:   invokevirtual   #4; //Method
  java/lang/StringBuffer.append:(Ljava/lang/String;)Ljava/
  lang/StringBuffer;
11:  aload_1
12:  invokevirtual   #4; //Method
  java/lang/StringBuffer.append:(Ljava/lang/String;)Ljava/
  lang/StringBuffer;
15:  invokevirtual   #5; //Method
  java/lang/StringBuffer.toString:()Ljava/lang/String;
18:  areturn
}
```

Example: String Appends

- All that bytecode is equivalent to:

```
StringBuffer temp;
temp = new StringBuffer();
temp.append(a);
temp.append(b);
return temp.toString();
```

- One line of code initializes an object and makes three method calls.



String Append Optimization

- What if we had:
- ```
  String a =“”; String b = “hello”;
   for (int i=0; i<n; i++)
     a += b;
  ```
- This code performs n initializations and 3n method calls.
- Using javap showed us there’s a class called StringBuffer that has an append() function.


  ```

String Append Optimization

- A more efficient way:

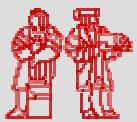
```
StringBuffer aBuff =
   new StringBuffer();
String b = “hello”;
for (int i=0; i<n; i++)
   a.append(b);
String a = aBuff.toString();
```

- Only performs two initializations and n+1 method calls -- three times faster.



Questions

- What advantages are there in running programs on simulated computers, like JVMs?
- What disadvantages might there be?
- Could you compile Java directly into native machine code like C or C++, instead of using a JVM?
- Is it possible to generate Java source code from class files, i.e. decompile?



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