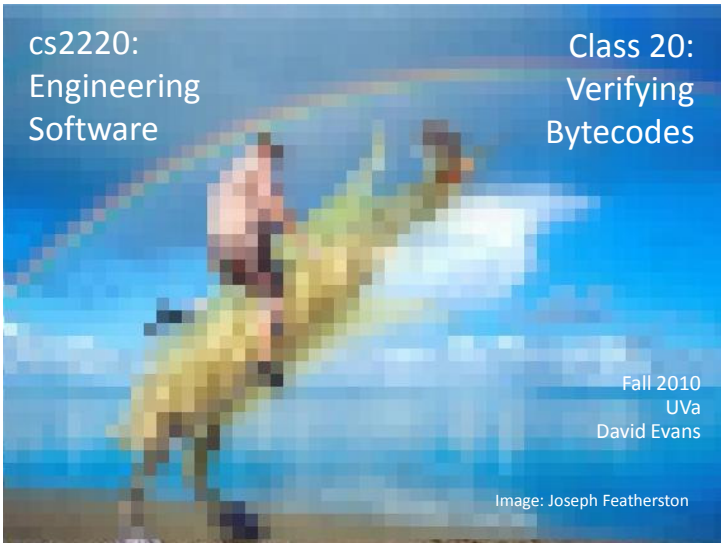

Plan for Today

- Project Ideas
- Low-level security: "Type Safety"
- Trusted Computing Base (Voting)
- High-level security: Policy

Project Teams
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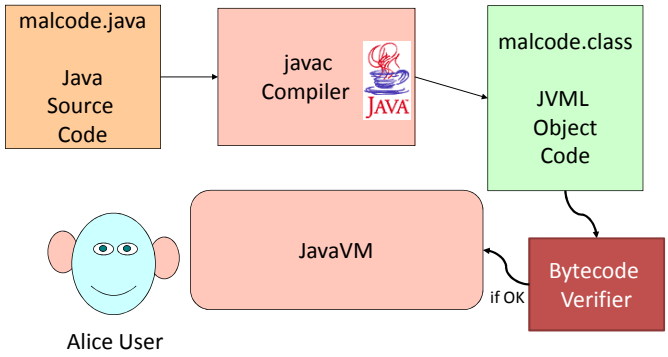
Recap: Java Platform



JVML Instruction Set

pushing constants	20	getstatic, putstatic	2
loads, stores	**66**	newarray, anewarray, multianewarray,arraylength	4
pop, dup, swap, etc.	9	invoke methods, throw	5
arithmetic	37	new	1
conversion (e.g., i2l)	15	getfield, putfield	2
comparisons (lcmp)	5	checkcast	1
goto, jsr, goto_w, jsr_w, ret	5	instanceof	1
tableswitch, lookupswitch	2	**monitorenter, monitorexit**	2
returns (e.g., ireturn)	6	wide	1
conditional jumps (ifeq, ifnull, ifnonnull)	16	nop, breakpoint, unused, implementation dependent	5

(205 out of 256 possible opcodes used)

Why so many loads and stores?

Instructions are **typed**

aload <index>	load **Object** from variable index
iload <index>	load **int** from variable index
fload <index>	load **float** from variable index
dload <index>	load **double** from variable index

Minimizing class file size
- aload_0, aload_1, aload_2, aload_3
- same for other types and stores

Array loads and stores
- Even more types (char, boolean, short)

Bytecode Verifier

- Checks class file is formatted correctly
- Checks JVML code satisfies safety properties
  - **Simulates** program execution to know types are correct, **but doesn't need to examine any instruction more than once**

This is what we win by having static typing!

Running Mistyped Code

```
> java Simple
Exception in thread "main" java.lang.VerifyError:
(class: Simple, method: main signature:
([Ljava/lang/String;)V)
Register 0 contains wrong type
```

Verifying Safety Properties

iadd

Type safe

Stack and variable slots must store and load as same type

Memory safe

Must not attempt to pop more values from stack than are on it

Doesn't access private fields and methods outside class implementation

Control flow safe

Jumps must be to valid addresses within function, or call/return

from Class 6:

Wait a sec…

Hopelessness of Analysis

It is impossible to correctly determine if any interesting property is true for an arbitrary program!

The Halting Problem: it is impossible to write a program that determines if an arbitrary program halts.

Making Verification Easier

Class files include lots of extra information to make verification easier

```
public class Simple {
   static public int add (int a, int b) {
      return a + b;
   }
}
```

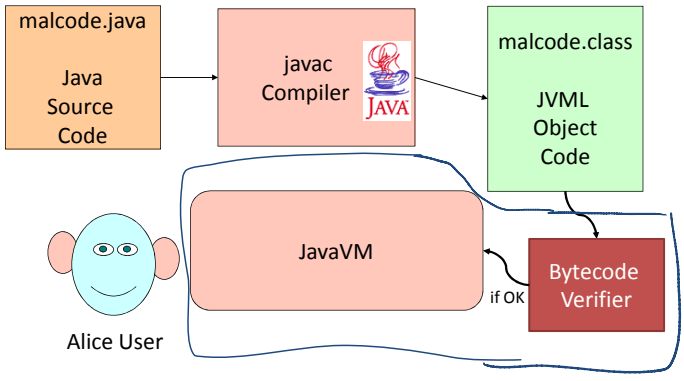
Even with this help there are many "correct" JVML programs that would not pass the verifier! (but every program produced by Java compiler should pass)

```
> javac Simple.java
> javap -verbose -c Simple
public class Simple extends java.lang.Object {
   public Simple();
      /* Stack=1, Locals=1, Args_size=1 */
   public static int add(int, int);
      /* Stack=2, Locals=2, Args_size=2 */
}

Method Simple()
  0 aload_0
  1 invokespecial #1 <Method java.lang.Object()>
  4 return

Method int add(int, int)
  0 iload_0
  1 iload_1
  2 iadd
  3 ireturn
```

Trusted Computing Base



Project Ideas

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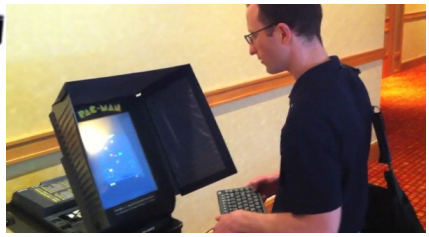
Voting



What is the Trusted Computing Base for an election?

"We do have people complain and say they don't get it, I completely understand what they're saying, but it's not something I can control."
Sheri Iachetta,
Charlottesville general registrar (on 2006 problems with voting machines displaying "James H. 'Jim'")

How do I know my voting equipment is accurate?
Under the Code of Virginia, the State Board of Elections must approve any mechanical or electronic voting system or equipment before it can be used by any locality.

Each system must successfully complete three distinct levels of testing:

1. **Qualification testing** (testing of hardware and software that may be conducted by Independent Testing Authority);
2. **Certification testing** (to ensure it meets all applicable requirements of the Code of Virginia); and,
3. **Acceptance testing** (conducted by the locality to assure it meets their needs and is identical to the certified system).

www.sbe.virginia.gov/cms/Election_Information/Election_Procedures/Index.html

"Independent" Testing

- Done by ITAs paid by vendors
- No vulnerability analysis
- No source code analysis

"Program testing can be used to show the presence of bugs, but never to show their absence!"
Edsger W. Dijkstra

How could we design elections with smaller Trusted Computing Base?

Optical Scan ballots
Can be recounted by humans

Project Ideas

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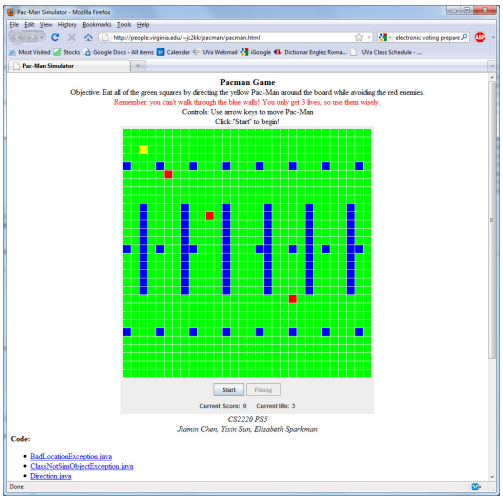
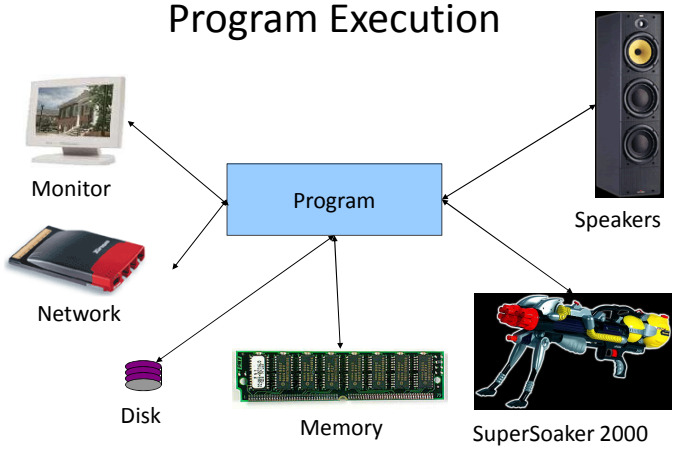
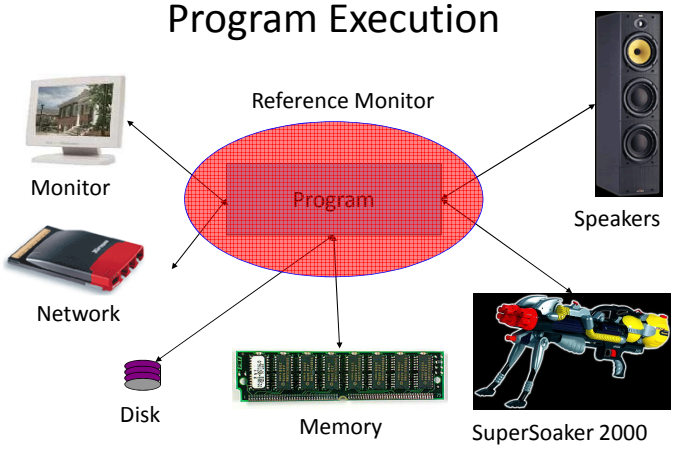


Java Applet Security

Program Execution



Program Execution



Ideal Reference Monitor

1. Sees *everything* a program is about to do before it does it
2. Can *instantly* and *completely* stop program execution (or prevent action)
3. Has *no other effect* on the program or system

Can we build this?

Probably not unless we can build a time machine...

Ideal Reference Monitor

1. Sees *everything* a program is about to do before it does it
2. Can *instantly* and *completely* stop program execution (or prevent action)
3. Has *no other effect* on the program or system

Operating Systems

- Provide reference monitors for most security-critical resources
  - When a program opens a file in Unix or Windows, the OS checks that the principal running the program can open that file
- Doesn't allow different policies for different programs
- No flexibility over what is monitored
  - OS decides for everyone
  - Hence, can't monitor inexpensive operations

Java Security Manager

- (Non-Ideal) Reference monitor
  - Limits how Java executions can manipulate system resources
- User/host application creates a subclass of SecurityManager to define a policy

JavaVM Policy Enforcment

[JDK 1.0 – JDK 1.1]

synchronized

From java.io.File:

```
public boolean delete() {
  SecurityManager security =
    System.getSecurityManager();
  if (security != null) {
    security.checkDelete(path);
  }
  if (isDirectory()) return rmdir0();
  else return delete0();
}
```

checkDelete throws a **SecurityExecption** if the delete would violate the policy (re-thrown by delete)

What could go seriously wrong with this?!

HotJava's Policy (JDK 1.1.7)

```
public class AppletSecurity
    extends SecurityManager {
    ...
    public synchronized void checkDelete(String file)
        throws Security Exception {
      checkWrite(file);
  }
}
```

AppletSecurity.checkWrite

(some exception handling code removed)

```
public synchronized void checkWrite(String file) {
  if (inApplet()) {
    if (!initACL) initializeACLs();
    String realPath = (new File(file)).getCanonicalPath();

    for (int i = writeACL.length ; i-- > 0 ;) {
      if (realPath.startsWith(writeACL[i])) return;
    }
    throw new AppletSecurityException
                    ("checkwrite", file, realPath);
  }
}
```

Note: no checking if not inApplet!
Very important this does the right thing.

inApplet

```
boolean inApplet() {
  return inClassLoader();
}
```

Inherited from **java.lang.SecurityManager**:

```
protected boolean inClassLoader() {
  return currentClassLoader() != null;
}
```

currentClassLoader

```
/**
  Returns an object describing the most recent class
  loader executing on the stack.

  Returns  the class loader of the most recent occurrence
  on the stack of a method from a class defined using a
  class loader; returns null if there is no occurrence on
  the stack of a method from a class defined using a class
  loader.
*/
protected native ClassLoader currentClassLoader();
```

Recap

- **java.io.File.delete** calls **SecurityManager.checkDelete** before deleting
- **HotJava** overrides **SecurityManager** with **AppletSecurity** to set policy
- **AppletSecurity.checkDelete** calls **AppletSecurity.checkWrite**
- **AppletSecurity.checkWrite** checks if any method on stack has a **ClassLoader**
- If not, no checks; if it does, checks ACL list

JDK 1.0 Trust Model

- When JavaVM loads a class from the CLASSPATH, it has no associated ClassLoader (can do anything)
- When JavaVM loads a class from elsewhere (e.g., the web), it has an associated ClassLoader

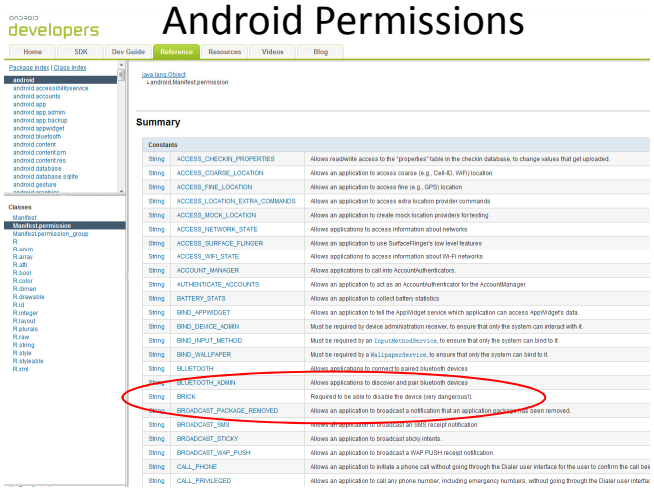
JDK Evolution

- JDK 1.1: Signed classes from elsewhere and have no associated ClassLoader
- JDK 1.2:
  - Different classes can have different policies based on ClassLoader
  - Explict enable/disable/check privileges
  - SecurityManager is now AccessController

Policy and Mechanism

- AccessController provides a mechanisms for enforcing a security policy
  - Can insert checking code before certain operations are allowed
- A *security policy* determines what the checking code allows

Android Permissions



Charge

Only ask for the Brick permission if you really need it!

Only grant the Brick permission to code that you really trust!

"It's better to beg forgiveness than ask permission."
Grace Hopper
(Applies to most things, but not Java applets.)