SUPREME COURT OF THE UNITED STATES

Lecture 11
Interfaces

Syllabus

GOOGLE LLC *v.* ORACLE AMERICA, INC.

CERTIORARI TO THE UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

No. 18–956. Argued October 7, 2020—Decided April 5, 2021

Oracle America, Inc., owns a copyright in Java SE, a computer platform that uses the popular Java computer programming language. In 2005, Google acquired Android and sought to build a new software platform for mobile devices. To allow the millions of programmers familiar with the Java programming language to work with its new Android platform, Google copied roughly 11,500 lines of code from the Java SE program. The copied lines are part of a tool called an Application Programming Interface (API). An API allows programmers to call upon prewritten computing tasks for use in their own programs. Over the course of protracted litigation, the lower courts have considered (1) whether Java SE's owner could copyright the copied lines from the API, and (2) if so, whether Google's copying constituted a permissible "fair use" of that material freeing Google from copyright liability. In

Midterm rules and advice

- open book: notes, textbook, old exams, etc., all ok
- no Internet access; no collaboration (!)
- 90 minutes in a single sitting

- return exam to CS 311 as soon as possible after you finish it
  - drop in the box outside the door if I am not there
- by 5 PM Friday at the latest

- I'm trying to see if you understand; it's not meant to be tricky
- think straightforwardly; don't deconstruct; think about course topics
- if you're writing or computing a lot, you're on the wrong track
- know the powers of 2, powers of 10, hex digits, patterns thereof
- understand the Toy machine
- don't make careless arithmetic errors

Interfaces

- In computing, an interface is a shared boundary across which two or more separate components of a computer system exchange information. The exchange can be between software, computer hardware, peripheral devices, humans and combinations of these.
  - (Wikipedia, the source of all truth)

- there has to be agreement about what information is exchanged and how

- lots of technical issues
- surprisingly, some important legal issues

How applications use the operating system

- operating system provides services to be accessed by application programs
  - Unix "system calls", Windows Application Programming Interface ("API")
    "what is the exact time?"
    "allocate M more bytes of RAM to me"
    "read N bytes from file F into memory starting at location M"
    "write N bytes from memory locations starting at M into file F"
    "set up a network connection to www.princeton.edu"
    "write N bytes to the network connection"
    “I’m all done; get rid of me”
- operating system provides an interface for applications to use
  - programs access machine capabilities only through this interface
  - different physical hardware can provide the same interface
  - programs can be moved to any system that provides the same interface
  - different operating systems can provide the same interface
  - one operating system can simulate the interface provided by another
- operating system hides details of specific hardware

Example of system-call level coding

- C program to copy input to output ("copy" command)
- read, write, exit are system calls

```
main() {
  char buf[8192];
  int n;
  while ((n = read(0, buf, sizeof(buf))) > 0)
    write(1, buf, n);
  exit(0);
}
```

Software is organized into "layers"

- each layer presents an interface that higher layers can use
  - defines a "platform" for putting more on top
  - insulates the higher layer from how the lower layer is implemented
  - often called "Application Programming Interface" or API

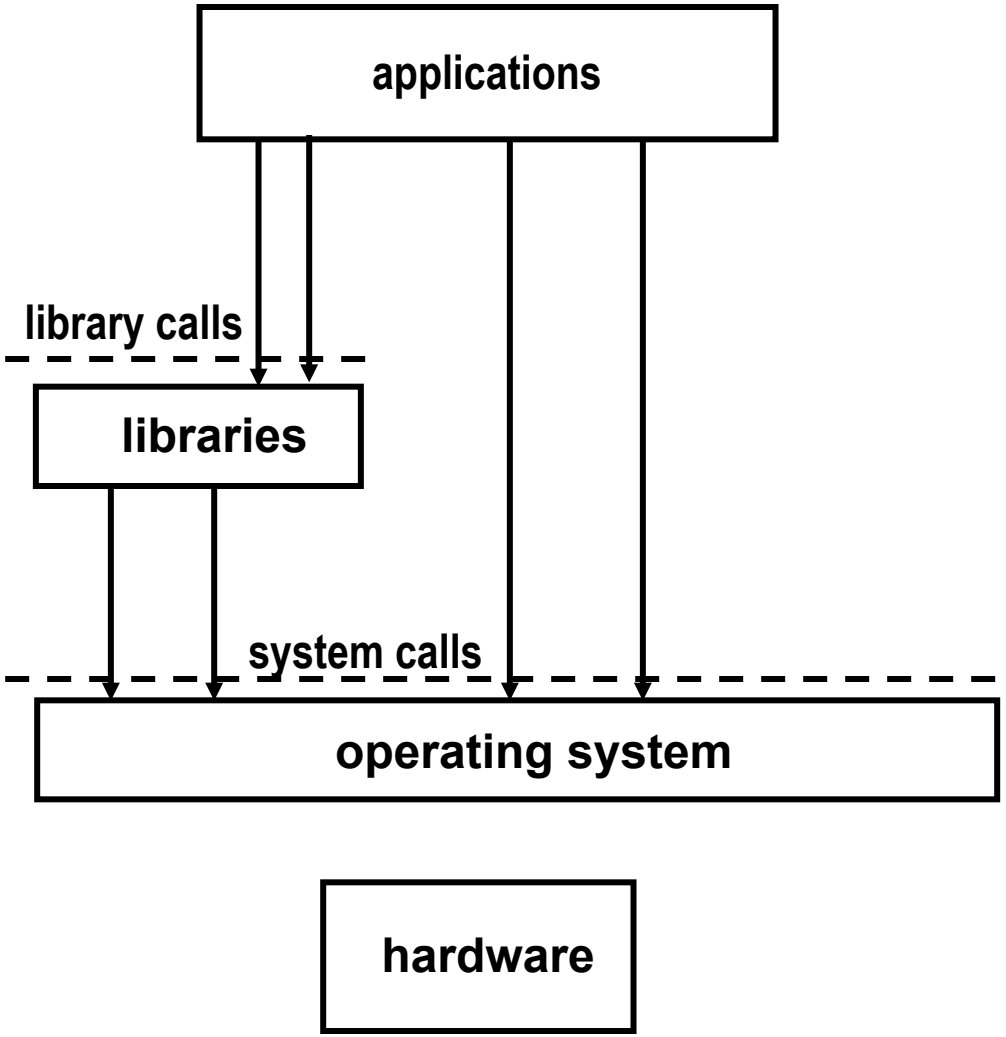
- operating system ("kernel")
  - lowest software layer, on top of hardware
    (usually: virtual machine is on top of another program, e.g., an operating system)
  - presents its capabilities as system calls

- libraries
  - code to be used as building blocks in programs
  - present their capabilities as APIs

- applications
  - e.g., browser, word processor, mailer, compiler, directory lister, ...
  - use libraries and system calls through APIs

Layering

- an application generally calls multiple libraries
  - might not make direct system calls
- a library generally calls other libraries
- library and system call levels define interfaces (APIs)
- programmers may not know what is "library" and what is "system call"



What's an API?

Operating systems perform many functions, including allocating computer memory and controlling peripherals such as printers and keyboards. Operating systems also function as platforms for software applications. They do this by "exposing" — i.e., making available to software developers — routines or protocols that perform certain widely-used functions. These are known as Application Programming Interfaces, or "APIs."

Excerpted from Final Judgment

State of New York, et al v. Microsoft Corporation

US District Court, District of Columbia, Nov 1, 2002

Sample Python API

input([*prompt*])

If the *prompt* argument is present, it is written to standard output without a trailing newline. The function then reads a line from input, converts it to a string (stripping a trailing newline), and returns that. When EOF is read, `EOFError` is raised. Example:

```
>>> s = input('--> ')
--> Monty Python's Flying Circus
>>> s
"Monty Python's Flying Circus"
```

If the `readline` module was loaded, then `input()` will use it to provide elaborate line editing and history features.

Raises an auditing event `builtins.input` with argument `prompt` before reading input

Raises an auditing event `builtins.input/result` with the result after successfully reading input.

Independent implementations of an interface

- can interfaces be owned?

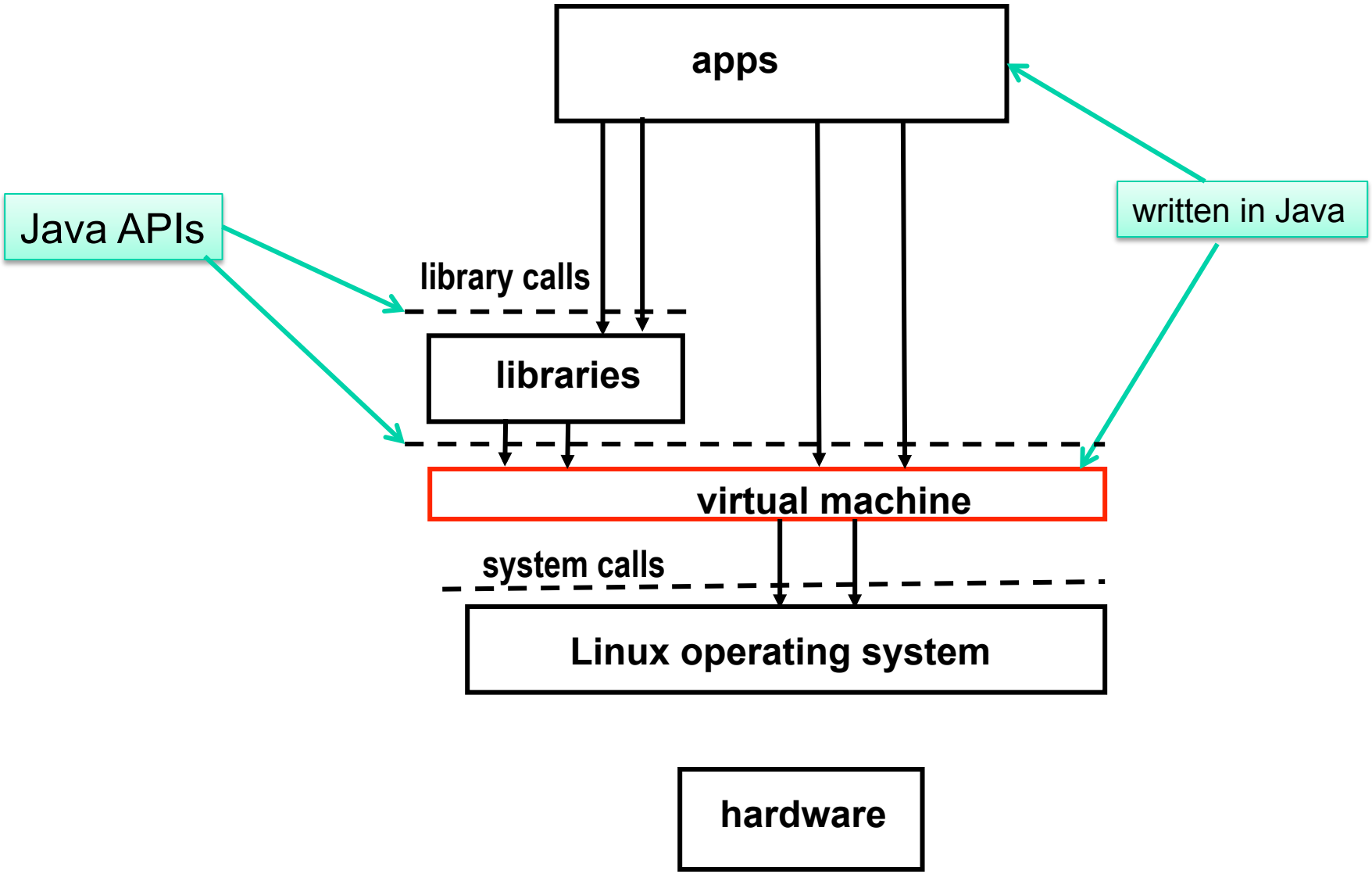
- company A sells something (hardware or software)
- company A publishes (widely) the API for programming it
  - with the intent that third parties will develop applications for the thing
  - and thus make it more attractive so company A will sell more

- company B uses A's interface definition to make a cheaper version of the thing that works the same
  - so all the third-party applications will run on B's cheaper version
  - thus cutting into A's market

- company A sues company B for copying A's interface

- who should win?

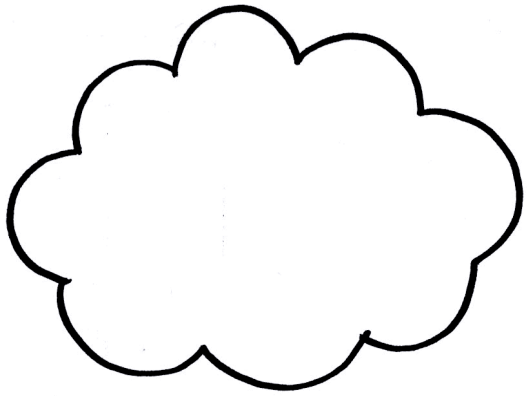
Android phone organization



Cloud computing APIs

- 'Cloud' has been a go-to metaphor for almost as long as the Internet has existed, conveying a sense that the Internet was intangible and bigger than the sum of its parts."

  (Wall Street Journal, 9/23/08)



- software services delivered via the Internet
  - Gmail, ...
  - Facebook, Twitter, Instagram, …
  - Google Docs, calendar,
  - Windows Live, Office 360
  - Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform

- most cloud services have an API for access by programs