Welcome to CS206

Based on notes from Steve Kautz

Bryn Mawr College
CS206 Intro to Data Structures
Please turn off your cell phone!

Example: Trapping rain water

Given *n* non-negative integers representing an elevation map where the width of each bar is 1, compute how much water it is able to trap after raining.
For example, given [0,1,0,2,1,0,1,3,2,1,2,1], return 6.

Example: Sudoku solver

- Write a program to solve a Sudoku puzzle by filling the empty cells

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

5	3	4	6	7	8	9	1	2
6	7	2	1	9	5	3	4	8
1	9	8	3	4	2	5	6	7
8	5	9	7	6	1	4	2	3
4	2	6	8	5	3	7	9	1
7	1	3	9	2	4	8	5	6
9	6	1	5	3	7	2	8	4
2	8	7	4	1	9	6	3	5
3	4	5	2	8	6	1	7	9

What are data structures & algorithms?

- A *data structure* is an arrangement of data in a computer's memory (or sometimes on a disk).
- Data structures include arrays, linked lists, stacks, binary trees, hash tables, and others.
- *Algorithms* manipulate the data in these structures in various ways, such as searching for a particular data item and sorting the data.

Data Structures & Algorithms in Java

1. Programming in Java
2. Objects
3. Data structures & algorithms

What is programming?

- Well, it isn't computer science
- Programming is like *craftsmanship* in building something
  - The end product is called *software*
    - *Applications and systems*
    - *Informally: "code"*
- In construction, architects *design* houses, craftsmen *build* them
  - Architects usually do not have the skills to build the things they design!
- In software, it never seems to work that way
  - There are software designers who don't actually write code
  - ...but they all start out *learning* to write code

The way it is

- Virtually every university program in CS or SE or CPRE starts out with a couple of semesters of programming
- So, here we are ☺

You didn't answer the question

- What is programming?
  - It just means writing out a sequence of instructions for a machine to carry out.
  - Instructions are usually very basic, e.g., "add these two numbers together"
- Any sequence of instructions can be called a "computer program"

Example: find the biggest number in a list

43 17 85 32 86 79 18

It's easy to spot, right?
But what if you had a bigger list?

196 61 429 105 522 398 144 274 23 354 145 47 511 516 278 507 526 404 27 16 486 320 284 56 395 318 178 4 217 354 160 279 510 98 345 568 257 98 435 234 493 124 171 96 542 397 349 393 540 379 37 513 159 329 213 58 404 526 170 33 422 399 535 323 150 432 422 116 231 140 434 188 305 542 449 504 108 99 410 189 259 83 573 310 332 51 120 244 325 530 417 84 180 407 391 93 264 484 570 530 17 102 324 76 248 564 265 247 170 262 370 509 108 398 176 370 21 527 61 544 517 495 49 29 185 198 395 112 77 37 417 350 83 444 149 469 299 346 281 512 351 95 474 443 488 517 83 494 18330 438 33 64 93 7132 402 2414 425 4964 433 382 0657 124 651 918 284 513 133 205 305 481 90 518 297 565 184 210 131 270 238 24 532 142 168 28 1 364 128 90 355 277 42 43 440 223 546 193 245 490 270 218 226 259 442 392 481 316 185 395 437 231 148 40 34 21 407 14 109 312 274 350 372 516 445 566 354 247 80 281 318 501 60 297 291 66 134 501 275 271 190 91 298 23 506 511 313 337 408 496 544 478 282 138 342 215 384 227 525 103 18 52 378 436 519 371 164 552 309 355 336 373 37 457 27 574 515 37 166 317 351 213 499 296 30 282 156 361 465 483 568 186 525 103 18 34 305 19 445 374 379 486 112 522 392 388 287

A strategy or "algorithm"

1. Look at the first number, and remember it
2. Read through the rows from left to right
3. If we've run out of numbers, then **we're done**.
4. Otherwise, look at the next number and compare it to the maximum we remembered
5. If the new number is bigger, then remember that one instead
6. Go back to step 3

Programming

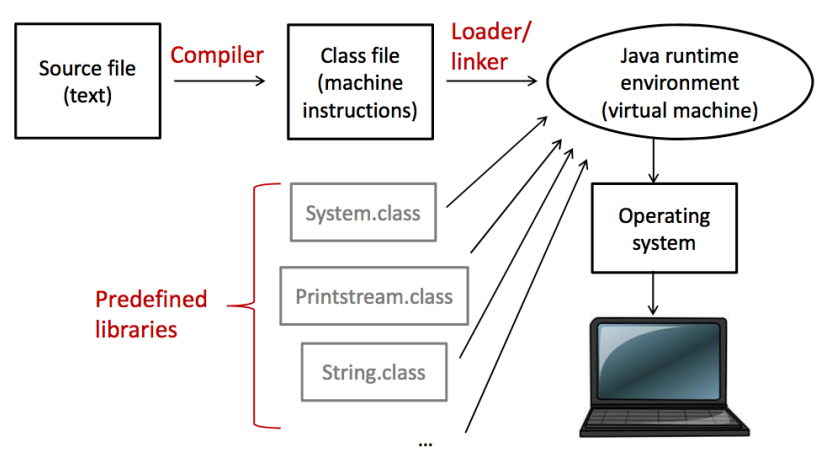
- We can turn these steps into a program by writing them down carefully in a *programming language*
- The statements in a programming language are translated, or *compiled*, into *machine instructions*
  - Numeric codes that control the millions of tiny electrical switches in the processor

Basic ingredients of computation

1. Store a value so we can remember it later
2. Do basic arithmetic
3. Check a condition and take some action, depending on whether the condition is true
4. Repeat some action, continuing as long as a condition is true
5. Get input or produce output

And that's all any computer can do!

Compiling and running



A simple Java program

- Write the program in a text editor
- Invoke the Java compiler to create the class file (machine instructions)
- Invoke the Java runtime to execute the compiled code

We usually use an integrated development environment to perform these steps.

A simple Java program

```
public class HelloPrinter
{
   /**
    * The 'main' method is always the entry point
    * for a Java application.
    */
    public static void main(String[] args)
    {
       // Display a greeting on a text console
       System.out.println("Hello, world!");
     }
}
```

But, what does it mean to "design" software?

Designing software

- Suppose you have a few hundred lines of instruction
  - Tic-tac-toe game, print loan table, sort list of names...
  - Well, this is probably just a "program"
- Applications like Word or Firefox may involve a *million* lines of code
  - Too complex for one person to understand...
  - ...unless very carefully designed!

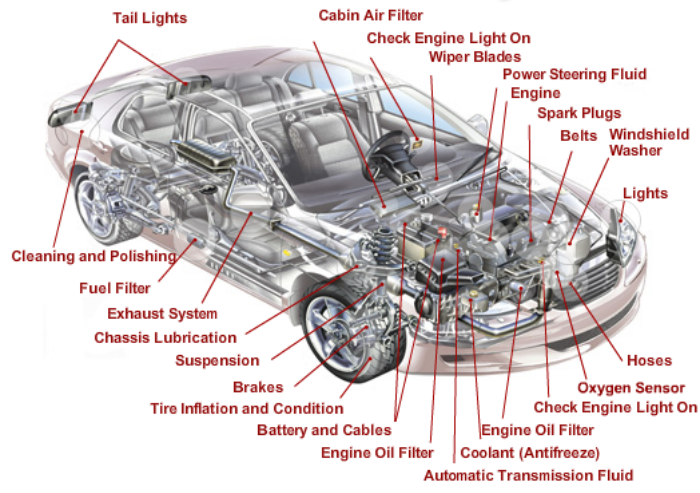
Object-oriented design

- This is where the "OO" comes in
- Modern applications are too complex to be written as a simple sequence of instructions
- OO is a natural way of breaking down a complex system into components
  - Each component is simpler than the whole
  - You specify
    - What does each component do?
    - How do the components interact?

Analogy

Analogy

But it makes a lot more sense as a system of interacting components.



Objects

- In OO design and programming, the components are called "objects"
  - Within each component there is a sequence of instructions to execute...
  - But we understand an application as a *system of interacting objects*

Invoking a method

- The System.out object has a method called **println()**. We invoke the method using the "dot" operator
  - The expression we want to print goes in the parentheses, and is called the *argument* to the method
  - The semicolon at the end is just a required piece of syntax, forming a *statement:*

    System.out.println("Hello, world!");

Classes

- The definition for a type of object is called a *class*

```
public class HelloPrinter
{
    ... attributes and methods go here ...
}
```

- "HelloPrinter" is an *identifier* (a name we chose for the class)
- **public** and **class** are *keywords* in Java
  – I.e., part of the syntax (grammar) for the language

A simple Java program

- Our class has one method, called main()
  - main() contains one *statement*
- The entry point for executing a program must always be a method called main with this form

```
public class HelloPrinter
{
   public static void main(String[] args)
   {
      System.out.println("Hello, world!");
   }
}
```

Language ingredients

- Keywords (reserved words such as public, class, void, ~50 others...)
- Identifiers (names such as HelloPrinter or System)
- Literal values (42, 3.14, "Hello, world!")
- Operators (+, -, *, /, etc.)
- Syntax rules ("every statement ends with a semicolon")

Compile errors

- If a syntax rule is violated, the compiler can't translate the code into machine instructions
  - Compile errors are flagged in Eclipse with red squiggles
- Comments are ignored by the compiler
  - Comments are used to document code
  - See code example for two forms of comments
    - // - style for "internal" comments
    - /** - */ style for "Javadoc" comments

Every value has a type

- 8 primitive types
  – int for whole numbers
  – double for "floating-point" numbers
  – boolean for true/false values
  – (There are 5 others, byte, short, long, float, char, not used too much)
- *Everything else is a kind of object*
  – System.out has type PrintStream
  – "Hello" is a literal value of type String

Expression

- An *expression* is something that represents a value
  - As opposed to a *statement*, which means "do this"
- Every literal is an expression
- We can create new expressions by combining them with *operators*
  - (2 + 3) * 5
  - 3.14 / 2.0

Examples

- The println() method can be used to print many types of expressions, e.g.
  - System.out.println((2 + 3) * 5);
- (See sample code...)

Variables

- A variable can be used to store a value
- Must be *declared* first with a type
- Value is assigned using the symbol "="
  – Called the assignment operator, does not mean "equals"!!
  – Works right-to-left only
- Examples (see sample code)

Restrictions on identifiers

- May contain only letters, numbers, and underscores
  - Compiler-generated identifiers may contain '$'
- Must start with letter or underscore

Conventions for identifiers

- Variable names start with lowercase letter
- Multiple words use camelCase
- Variable names should be meaningful
- Method names start with lowercase letter
- Class names start with upper case letter