DM503
Programming B

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COURSE ORGANIZATION

Course Elements

- Lectures Monday 12-14 (every week)
- Lectures Wednesday 10-12 (every other week from next)

- 4 sections (???):
  - M1: Mathematics-Economy (2nd year)
  - S2: Mathematics / Applied Mathematics / Physics (2nd year)
  - S7 & S17: Computer Science (1st year)

- Discussion sections (marked "E" in your schedule)
- Labs (marked "L" in your schedule)

- Exam = practical project in 2 parts

Course Goals

- **Write non-trivial computer programs**

- To this end, you will learn
  - how to structure programs into classes
  - to use advanced object-oriented techniques
  - to encapsulate functionality in abstract data types

- Focus on general principles, NOT on the language Java

Practical Issues / Course Material

- Regularly check the course home page:
  - http://imada.sdu.dk/~petersk/DM503/
  - Slides, weekly notes, definite schedule, additional notes

- Reading material:
  - David J. Eck: *Introd. to Programming using Java*, Lulu, 2011.
  - Available as PDF and HTML from: http://math.hws.edu/javanotes/

  - Allen B. Downey: *Think Java*, Green Tea Press, 2011.
  - Available as PDF and HTML from: http://greenteapress.com/thinkapjava/

Course Contract 2.0

- I am offering you the following:
  1. I explain all needed concepts (as often as needed)
  2. I am available and always willing to help you
  3. I guide your learning by assigning exercises

- From you I expect the following:
  1. You ask questions, when something is unclear
  2. You contact me (or a TA), when you need help
  3. *You program early and you program often!*

- You and I have the right and duty to call upon the contract!

PROGRAMMING

Programming as Problem Solving

Customer → Problem

analysis

Specification

choices

Programming B — Design

coding

Programming A — Implementation

testing

Product = Program

Simple Instructions

- Administrative: `import java.util.Scanner;`
- Input:
```
s = new Scanner(System.in);
a = s.nextInt();
b = s.nextInt();
```
- Arithmetic operations: `c = Math.sqrt(a*a+b*b);`
- Output: `System.out.println("Result: "+c);`

- That is basically ALL a computer can do.

Simple Instructions

```
import java.util.Scanner;



s = new Scanner(System.in);
a = s.nextInt();
b = s.nextInt();
c = Math.sqrt(a*a+b*b);
System.out.println("Result: "+c);
```

Simple Instructions

```
import java.util.Scanner;
public class Pythagoras {
	public static void main(String[] as) {
		s = new Scanner(System.in);
		a = s.nextInt();
		b = s.nextInt();
		c = Math.sqrt(a*a+b*b);
		System.out.println("Result: "+c);
	} // main
} // Pythagoras
```

Simple Instructions

```
import java.util.Scanner;
public class Pythagoras {
        public static void main(String[] as) {
                Scanner s = new Scanner(System.in);
                int a = s.nextInt();
                int b = s.nextInt();
                double c = Math.sqrt(a*a+b*b);
                System.out.println("Result: "+c);
        } // main
} // Pythagoras
```

Combining Instructions

- Sequence: <instr$_1$>; <instr$_2$>; <instr$_3$>;
- Conditional Execution: if (<cond>) {

  <instr$_1$>; <instr$_2$>;

  } else {

  <instr$_3$>; <instr$_4$>; <instr$_5$>;

  }
- Subprograms / Functions: <type> <function>(<argument>) {

  <instr$_1$>; <instr$_2$>;

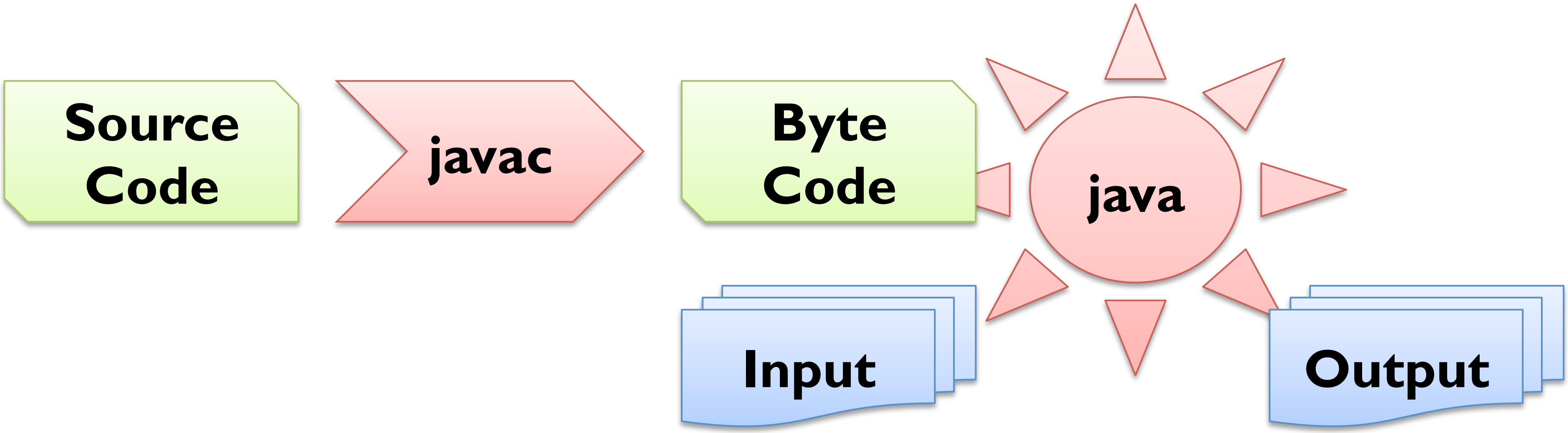
  }
- Repetition: while (<cond>) {

  <instr$_1$>; <instr$_2$>; <instr$_3$>;

  }

Executing Programs

- Program stored in a file (*source code* file)
- Program is *compiled* to machine-readable code (*byte code*)
- Java *Virtual Machine* (JVM) executes byte code



Debugging

- Any reasonably complex program contains errors
- Three types of errors (in Java)
  - Compiler Errors
    - Syntactic Errors `public ssalc HelloWorld {}`
    - Type Errors `int a = new Scanner();`
  - Runtime Errors `int c = 42 / 0;`
  - Semantic Errors `int c = a*a+b*b;`
- Debugging is finding out why an error occurred

VARIABLES, EXPRESSIONS & STATEMENTS

Values and Types

- Values = basic data objects 42 23.0 "Hello!"
- Types = classes of values int double String

- Types need to be declared
  - <type> <var>; int answer;

- Values can be printed:
  - System.out.println(<value>); System.out.println(23.0);

- Values can be compared:
  - <value> == <value> -3 == -3.0

Variables

- variable = name that refers to value of certain type
- program state = mapping from variables to values

- values are *assigned* to variables using "=":
  - <var> = <value>; answer = 42;

- the value referred to by a variable can be printed:
  - System.out.println(<var>); System.out.println(answer);

- the type of a variable is given by its declaration

Primitive Types

Type	Bits	Range
boolean	1	{true, false}
byte	8	$\{-2^7 = -128, \ldots, 127 = 2^7-1\}$
short	16	$\{-2^{15} = -32768, \ldots, 32767 = 2^{15}-1\}$
char	16	{'a', …,'z', '%', …}
int	32	$\{-2^{31}, \ldots, 2^{31}-1\}$
float	32	1 sign, 23(+1) mantissa, 8 exponent bits
long	64	$\{-2^{63}, \ldots, 2^{63}-1\}$
double	64	1 sign, 52(+1) mantissa, 11 exponent bits

Reference Types

- references types = non-primitive types
- references types typically implemented by classes and objects

- Example 1: String

- Example 2: arrays (mutable, fixed-length lists)

Variable Names

- start with a letter (convention: a-z) or underscore "_"
- contain letters a-z and A-Z, digits 0-9, and underscore "_"
- can be any such name except for 50 reserved names:

abstract	continue	for	new	switch
assert	default	goto	package	synchronized
boolean	do	if	private	this
break	double	implements	protected	throw
byte	else	import	public	throws
case	enum	instanceof	return	transient
catch	extends	int	short	try
char	final	interface	static	void
class	finally	long	strictfp	volatile
const	float	native	super	while

Multiple Assignment

- variables can be assigned to different values of the same type:
  - Example:
    ```
    int x = 23;
    x = 42;
    ```
  - Instructions are executed top-to bottom => x refers to 42

- variables cannot be assigned to values of different type:
  - Example:
    ```
    int x = 23;
    x = 42.0;        // !ERROR!
    ```
- only exception is if types are "compatible":
  - Example:
    ```
    double x = 23.0;
    x = 42;          // :-)
    ```

Operators & Operands

- Operators represent computations: + * - / ++ --
  - Example: 23+19 day+month*30 2*2*2*2*2*2-22

- Addition "+", Multiplication "*", Subtraction "-" as usual
- there is no exponentiation operator to compute x^y
- need to use Math.pow(x, y) write your own function power

```
static int power(a, b) {
  if (b == 0) return 1; else return a*power(a,b-1);
}
```

- Division "/" rounds down integers (differently from Python)
  - Example Java: 3/-2 has value -1
  - Example Python: 3/-2 has value -2

Boolean Expressions

- expressions of type boolean with value either true or false
- logic operators for computing with Boolean values:
  - x && y true if, and only if, x is true and y is true
  - x || y true if (x is true or y is true)
  - !x true if, and only if, x is false
- Java does NOT treat numbers as Boolean expressions ☺

Expressions

- Expressions can be:
  - Values: 42 23.0 "Hej med dig!"
  - Variables: x y name1234
  - built from operators: 19+23.0 x*x+y*y
- grammar rule:
  - <expr> => <value> |
    <var> |
    <expr> <operator> <expr> |
    (<expr>)
- every expression has a value:
  - replace variables by their values
  - perform operations

Increment and Decrement

- abbreviation for incrementing / decrementing (like in Python)
- Example:

```
counter = counter + 1;
counter += 1;
```

- in special case of "+1", we can use "++" operator
- Example:

```
counter++;
```

- two variants: post- and pre-increment
- Example:

```
int x = 42;
int y = x++;        // x == 43 && y == 42
int z = ++y;        // y == 43 && z == 43
```

- same for decrementing with "--" operator

Relational Operators

- relational operators are operators, whose value is boolean

- important relational operators are:

	Example True	Example False
x < y	23 < 42	'W' < 'H'
x <= y	42 <= 42.0	Math.PI <= 2
x == y	42 == 42.0	2 == 2.00001
x != y	42 != 42.00001	2 != 2.0
x >= y	42 >= 42	'H' >= 'h'
x > y	'W' > 'H'	42 > 42

- remember to use "==" instead of "=" (assignment)!

Conditional Operator

- select one out of two expressions depending on condition

- as a grammar rule:

  <cond-op> => <cond> ? <expr$_1$> : <expr$_2$>

- Example:

```
int answer = (1 > 0) ? 42 : 23;
```

- useful as abbreviation for many small if-then-else constructs

Operator Precedence

- expressions are evaluated left-to-right
  - Example: 64 - 24 + 2 == 42
- BUT: like in mathematics, "*" binds more strongly than "+"
  - Example: 2 + 8 * 5 == 42
- parentheses have highest precedence: 64 - (24 + 2) == 38
  - Parentheses "(<expr>)"
  - Increment "++" and Decrement "--"
  - Multiplication "*" and Division "/"
  - Addition "+" and Subtraction "-"
  - Relational Operators, Boolean Operators, Conditonal, …

String Operations

- Addition “+” works on strings; “-”, “*”, and “/” do NOT
- other operations implemented as methods of class String:

```
String s1 = "Hello "; String s2 = "hello ";
boolean b1 = s1.equals(s2);                // b1 == false
boolean b2 = s1.equalsIgnoreCase(s2);      // b2 == true
int i1 = s1.length();                      // i1 == 5
char c = s1.charAt(1);                     // c == 'e'
String s3 = s1.substring(1,3);             // s3.equals("el")
int i2 = s1.indexOf(s3);                   // i2 == 1
int i3 = s1.compareTo(s2);                 // i3 == -1
String s4 = s1.toLowerCase();              // s4.equals(s2)
String s5 = s1.trim();                     // s5.equals("Hello")
```