Introduction to Computers, Programs, and Java

CSE 114: Introduction to Object-Oriented Programming

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Contents

- How computers work (CPU/Processor, memory, hard disk, input and output)?
  - How Data is Stored and Processed? Number Systems.
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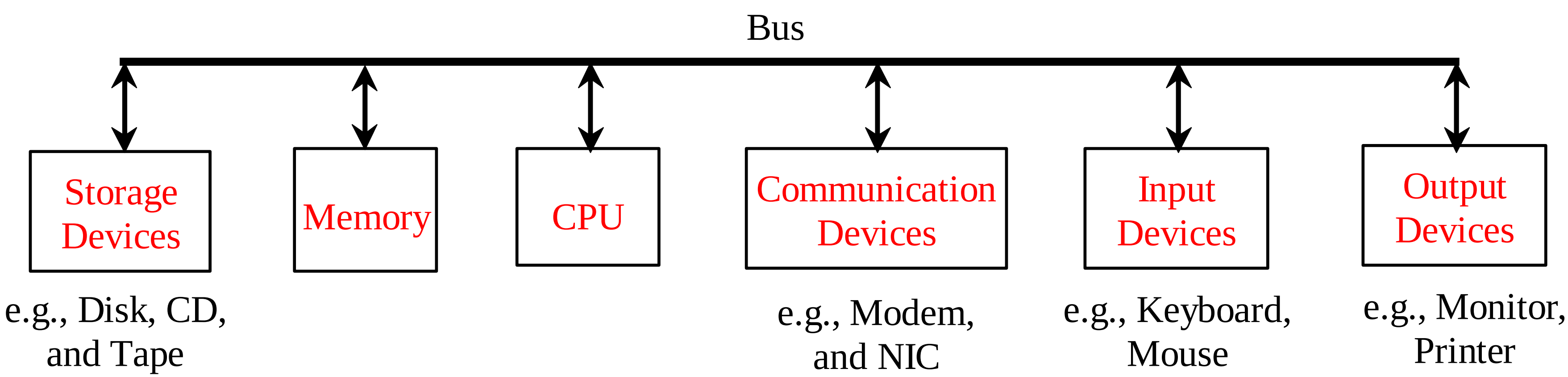
  - A Simple Java Program
  - Anatomy of Java Programs
- Programming Errors: syntax, runtime and logical errors/bugs

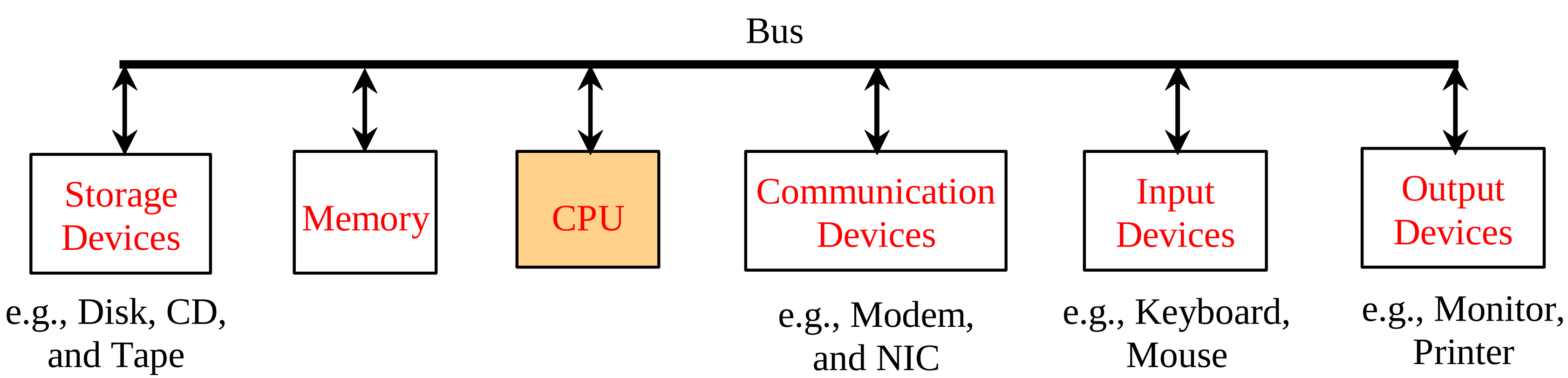
What is a Computer?

- A computer consists of a CPU, memory, hard disk, monitor, printer, input and output devices.



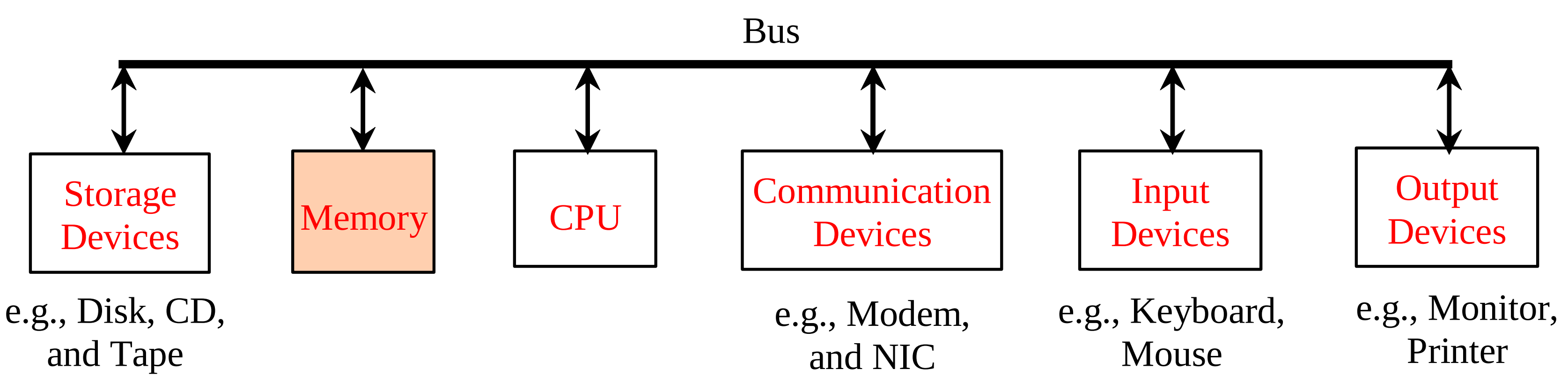
Central Processing Unit (CPU)

- Central Processing Unit (CPU, processor):
  - retrieves instructions from memory and executes them
  - the CPU speed is measured in cycles per second = hertz (Hz)
    - 1 MegaHertz (MHz) = 1 million pulses per second
    - 1 GigaHertz (GHz) = 1 billion pulses per second



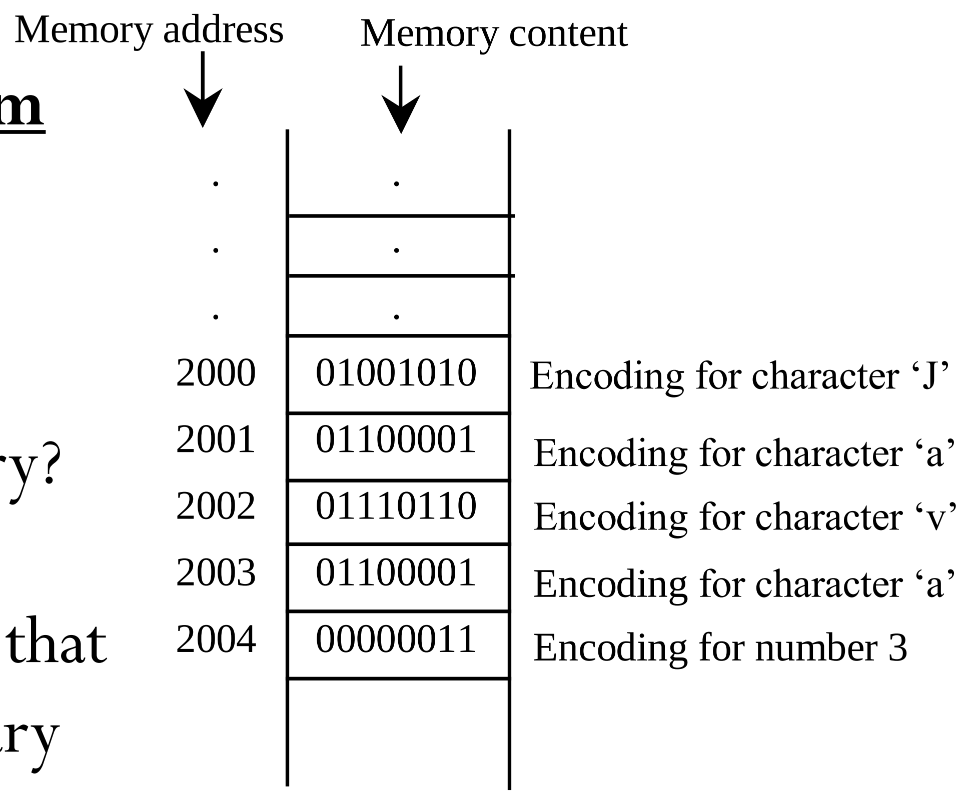
(Main) Memory

- Stores data and program instructions for CPU to execute
  - ordered sequence of bytes (i.e., 8 bits – a binary base unit)



How Data is Stored and Processed?

- In binary
- What's binary?
  - the base-2 **number system**
- What do humans use?
  - base-10
  - Why? 10 fingers.
- Why do computers like binary?
  - electronics
    - easier to make hardware that stores and processes binary numbers than decimal numbers
    - more efficient: space & cost



Number Systems

Decimal: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

Binary: 0, 1

Hexadecimal: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

Octal: 0, 1, 2, 3, 4, 5, 6, 7

Number Systems: Decimal

- The digits in the decimal number system are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.
  - A decimal number is represented using a sequence of one or more of these digits.
    - The value that each digit in the sequence represents depends on its position.
    - A position in a sequence has a value that is an integral power of 10.
      - e.g., the digits 7, 4, 2, and 3 in decimal number 7423 represent 7000, 400, 20, and 3, respectively:

7	4	2	3
10^3	10^2	10^1	10^0

$$= 7 \times 10^3 + 4 \times 10^2 + 2 \times 10^1 + 3 \times 10^0$$

$$= 7000 + 400 + 20 + 3 \ = 7423$$

- We say that 10 is the *base* or *radix* of the decimal number system.
  - The base of the binary number system is 2 since the binary number system has two digits: 0 and 1.
  - The base of the hex number system is 16 since the hex number system has sixteen digits: 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F.
  - The base of the octal number system is 8 with digits: 0,1,2,3,4,5,6,7.

Binary

- Computers use binary numbers internally because storage devices like memory and disk are made to store **0s and 1s**.
- Each 0 and 1 is called a **bit** (short for **bi**nary digi**t)**
- Binary numbers are not intuitive to us, since we use decimal numbers in our daily life.
  - When you write a number like 20 in a program, it is assumed to be a decimal number.
  - Internally, computer software is used to **convert decimal numbers into binary numbers**, and vice versa.
    - A number or a text (see character encodings later) inside a computer is stored as a sequence of 0s and 1s.

Binary Numbers => Decimals

Given a binary number $(b_n b_{n-1} b_{n-2} \ldots b_2 b_1 b_0)_2$
the equivalent decimal value is

$$b_n \times 2^n + b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + \ldots + b_2 \times 2^2 + b_1 \times 2^1 + b_0 \times 2^0$$

Examples:

$(10)_2$ in binary is $1 \times 2^1 + 0 = 2$ in decimal

$(1010)_2$ in binary is $1 \times 2^3 + 0 \times 2^2 + 1 \times 2 + 0 = 10$ in decimal

$(10101011)_2$ in binary $1 \times 2^7 + 0 \times 2^6 + 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2 + 1 = 171$ in decimal

Common Binary Powers

$2^0 = 1$

$2^1 = 2$

$2^2 = 4$

$2^3 = 8$

$2^4 = 16$

$2^5 = 32$

$2^6 = 64$

$2^7 = 128$

$2^8 = 256$

$2^9 = 512$

$2^{10} = 1024$

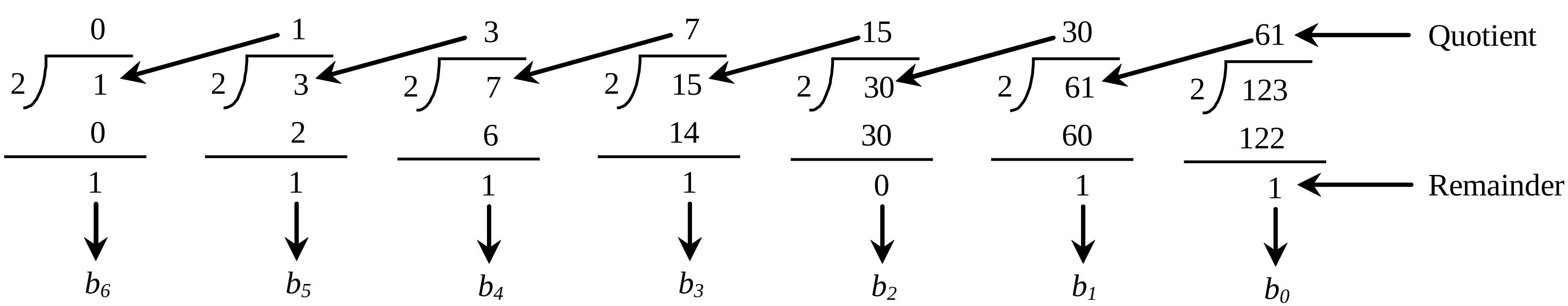
Decimal => Binary

- To convert a decimal number d to a binary number is to find the binary digits $(b_n, b_{n-1}, b_{n-2}, \ldots, b_2, b_1, b_0)_2$ such that

$$d = b_n \times 2^n + b_{n-1} \times 2^{n-1} + b_{n-2} \times 2^{n-2} + \ldots + b_2 \times 2^2 + b_1 \times 2^1 + b_0 \times 2^0$$

- These numbers can be found by successively dividing d by 2 until the quotient is 0. The remainders are $b_0, b_1, b_2, \ldots, b_{n-2}, b_{n-1}, b_n$

For example, the decimal number 123 is $(1111011)_2$ in binary. The conversion is conducted as follows:



Hexadecimal and Octal

- Binary numbers tend to be very long and cumbersome:
  - For example: $(11\ 1010\ 1011\ 1110)_2$
- Hexadecimal and octal numbers are often used to abbreviate binary numbers:
  - For example: $(11\_1010\_1011\_1110)_2 = (3ABE)_H$
    and $(11\_101\_010\_111\_110)_2 = (35276)_8$
- The hexadecimal number system has 16 digits:
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F.
  - The letters A, B, C, D, E, and F correspond to the decimal numbers 10,11,12,13,14, and 15.
  - Each hex digit corresponds to 4 bits (grouped from the end)
- The octal number system has 8 digits:
  - 0, 1, 2, 3, 4, 5, 6, and 7
  - Each octal digit corresponds to 3 bits (grouped from the end)

Hexadecimals <=> Binary

Binary	Decimal	Hex
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

To convert a hexadecimal number to a binary number, simply convert each digit in the hexadecimal number into a four-digit binary number. For example,

$$(38D)_H = (11\_1000\_1101)_2$$

To convert a binary number to a hexadecimal, convert every four binary digits <u>from right to left</u> in the binary number into a hexadecimal number. For example, $(1\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 0\ 1)_2$

$$(3 \quad 8 \quad D)_H$$

Octal <=> Binary

Binary	Decimal	Octal
000	0	0
001	1	1
010	2	2
011	3	3
100	4	4
101	5	5
110	6	6
111	7	7

To convert an octal number to a binary number, simply convert each digit in the octal number into a three-digit binary number. For example,

$(1615)_8 = (1\_110\_001\_101)_2$

To convert a binary number to an octal number, convert every three binary digits <u>from right to left</u> in the binary number into an octal digit. For example,

$(\quad 1\ 1\ 1\ 0\ 0\ 0\ 1\ 1\ 0\ 1)_2$

$(\quad 1 \quad 6 \quad 1 \quad 5\ )_8$

Hexadecimals => Decimals

- Given a hexadecimal number $(h_n h_{n-1} h_{n-2} \ldots h_2 h_1 h_0)_H$

The equivalent decimal value is

$$h_n \times 16^n + h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + \ldots + h_2 \times 16^2 + h_1 \times 16^1 + h_0 \times 16^0$$

$(7F)_H$ in hex is $7 \times 16^1 + 15 = 127$ in decimal

$(FFFF)_H$ in hex $15 \times 16^3 + 15 \times 16^2 + 15 \times 16 + 15 = 65535$ in decimal

- Octal number system is similar, but *base* is 8.

$(12)_8$ in octal is $1 \times 8^1 + 2 = 10$ in decimal

Decimals => Hexadecimals

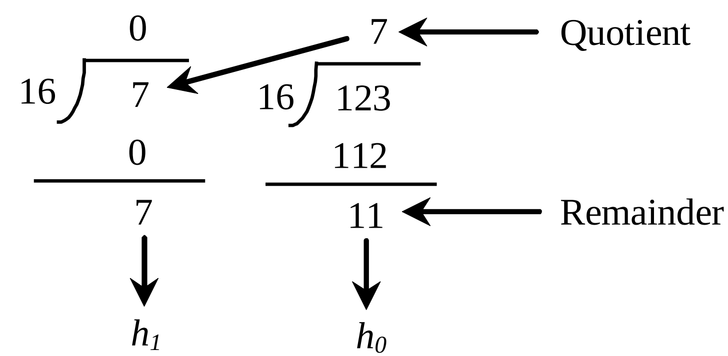
To convert a decimal number d to a hexadecimal number is to find the hexadecimal digits $(h_n, h_{n-1}, h_{n-2}, \ldots, h_2, h_1, h_0)_H$ such that

$$d = h_n \times 16^n + h_{n-1} \times 16^{n-1} + h_{n-2} \times 16^{n-2} + \ldots + h_2 \times 16^2 + h_1 \times 16^1 + h_0 \times 16^0$$

These numbers can be found by successively dividing d by 16 until the quotient is 0. The remainders are

$$h_0, h_1, h_2, \ldots, h_{n-2}, h_{n-1}, h_n$$

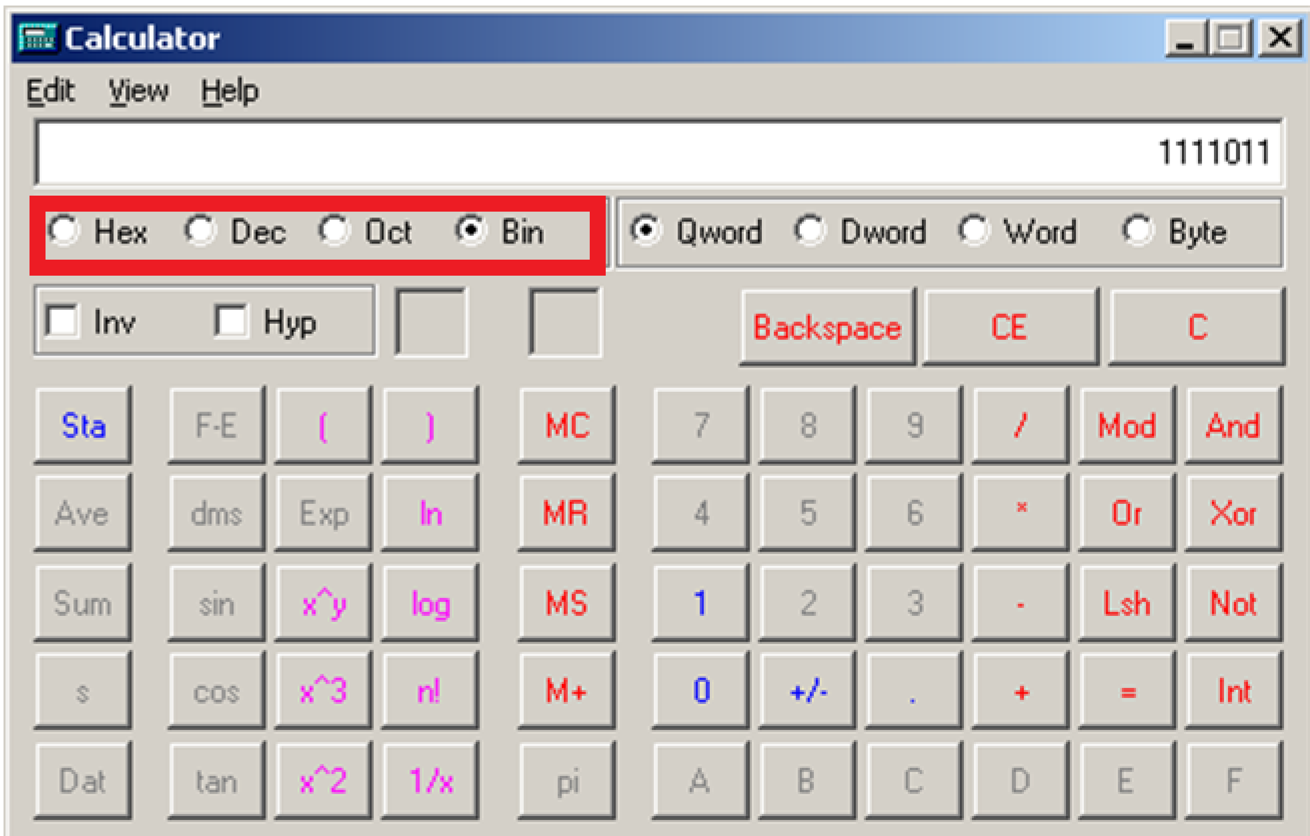
For example, the decimal number 123 is $(7B)_H$ in hexadecimal. The conversion is conducted as follows:



- Preferred alternative: decimal->binary->hex
- Octal number system is similar, but *base* is 8, so we divide by 8 instead of 16.

Windows Calculator

The Windows Calculator is a useful tool for performing number conversions. To run it, choose *Programs*, *Accessories*, and *Calculator* from the Start button, and switch to Programmer View:



So Hardware stores 0s & 1s

- **How do we store text?**
  - Numerically (i.e., using numeric codes)
    - Each character is stored in memory as a number
  - Standard character encoding sets: ASCII, Unicode
    - ASCII uses 1 byte per character (128 chars)
      - For example: 'A' is 65
    - Unicode: ~65K different characters
      - Multiple encodings (UTF-8, UTF-16, UTF-32,…)
        - short encodings use the first bit for continuation (variable length encodings) and may be more efficient for communication (shorter encoding)

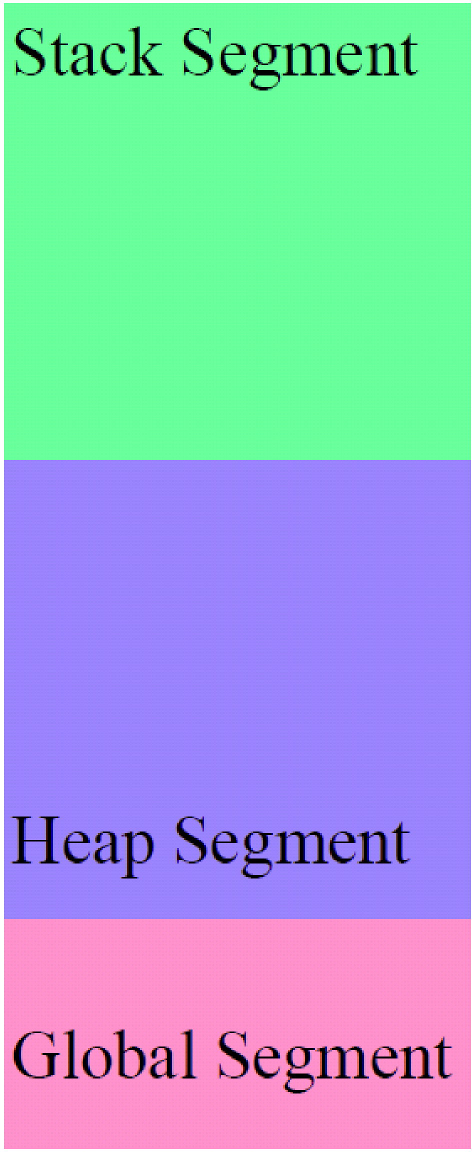
ASCII Table

http://enteos2.area.trieste.it/russo/IntroInfo2001-2002/CorsoRetiGomezel/ASCII-EBIC_files/ascii_table.jpg

Dec	Hx	Oct	Char		Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL	(null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH	(start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX	(start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX	(end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT	(end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ	(enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK	(acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL	(bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS	(backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB	(horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF	(NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT	(vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF	(NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR	(carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO	(shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI	(shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE	(data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1	(device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2	(device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3	(device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4	(device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK	(negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN	(synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB	(end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN	(cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM	(end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB	(substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC	(escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS	(file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS	(group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS	(record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US	(unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Memory: What goes in each memory segment?

- **Stack Segment**
  - variables declared inside methods (called local)
    - removed from memory when the method returns
- **Heap Segment**
  - for dynamic data (whenever you use the operator **`new`**)
    - i.e., the data for constructed objects
      - persistent as long as an existing a variable references this region of memory (because garbage collection)
- **Global Segment**
  - data that can be reserved at compile time
    - the program
    - global data (like **`static`** data)
    - constants (e.g., interned **`String`**)



Programming Languages

Machine Language   Assembly Language   High-Level Language

- A *machine language* is a set of instructions executed directly by a computer's central processing unit (CPU).
  - At the beginning there was only machine language: a sequence of bits that directly controls a processor, causing it to add, compare, move data from one place to another
    - Example: GCD program in x86 machine language (represented in hexadecimal here):

```
55 89 e5 53  83 ec 04 83  e4 f0 e8 31  00 00 00 89  c3 e8 2a 00
00 00 39 c3  74 10 8d b6  00 00 00 00  39 c3 7e 13  29 c3 39 c3
75 f6 89 1c  24 e8 6e 00  00 00 8b 5d  fc c9 c3 29  d8 eb eb 90
```

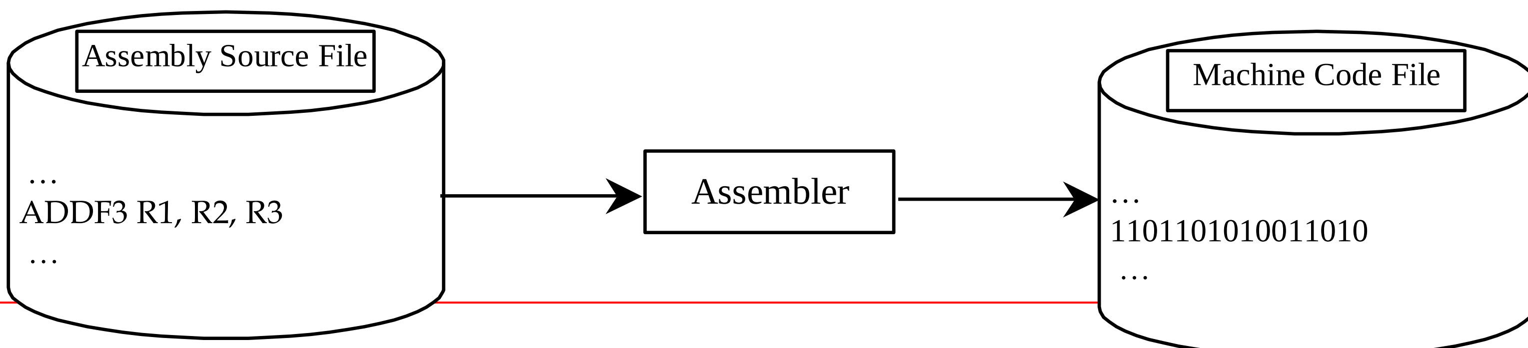
Programming Languages

Machine Language   Assembly Language   High-Level Language

- *Assembly languages* were invented to allow operations to be expressed with **mnemonic** abbreviations
  - For example, to add two numbers, you might write an instruction in assembly code like this:

```
ADDF3 R1, R2, R3
```

- A program called **assembler** is used to convert assembly language programs into machine language



Programming Languages

Machine Language Assembly Language High-Level Language

- Example: the GCD program in x86 assembly:

```
    pushl   %ebp
    movl    %esp, %ebp
    pushl   %ebx
    subl    $4, %esp
    andl    $-16, %esp
    call    getint
    movl    %eax, %ebx
    call    getint
    cmpl    %eax, %ebx
    je      C
A:  cmpl    %eax, %ebx
    jle     D
    subl    %eax, %ebx
B:  cmpl    %eax, %ebx
    jne     A
C:  movl    %ebx, (%esp)
    call    putint
    movl    -4(%ebp), %ebx
    leave
    ret
D:  subl    %ebx, %eax
    jmp     B
```

Programming Languages

Machine Language   Assembly Language   High-Level Language

Assembly was easier to use than binary machine language, **BUT:** not very user friendly, very low-level operations, machine language dependent, programming is very time consuming.

<u>High Level programming Languages</u>: languages with strong abstraction from the details of the computer: methods, classes, etc.

– platform independent

– can use previously-developed libraries

– more user friendly, easy to use

Popular High-Level Languages

- FORTRAN (FORmula TRANslation)
- LISP
- COBOL (COmmon Business Oriented Language)
- BASIC (Beginner All-purpose Symbolic Instructional Code)
- Pascal (named for Blaise Pascal)
- Ada (named for Ada Lovelace)
- C (whose developer designed B first)
- Visual Basic (Basic-like visual language developed by Microsoft)
- C++ (an object-oriented language, based on C)
- Java
- C# (a Java-like language developed by Microsoft)
- python
- …

Source Code

- You write programs in text, they are called *source code*
  - *Source code*, or simply *code* or *source*, is a program, with or without comments, written by a human in plain text (i.e., human readable alphanumeric characters).
  - Brief history (of source code):
    - The earliest programs for stored-program computers were entered in binary through the front panel switches of the computer.
    - Punched cards replaced binary switches.
    - IBM started distributing high-level programming languages source code printed or stored in persistent memory.
  - Legal aspects:
    - In 1974, the US Commission on New Technological Uses of Copyrighted Works (CONTU) decided that "computer programs, to the extent that they embody an author's original creation, are proper subject matter of copyright".

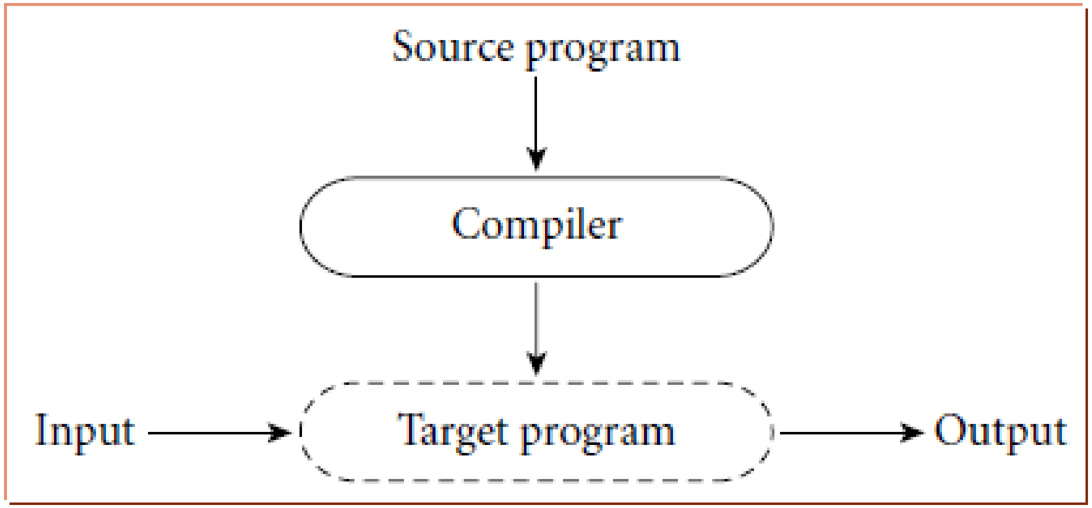
Source Code

How does a program run?

- **Compilers and interpreters.**

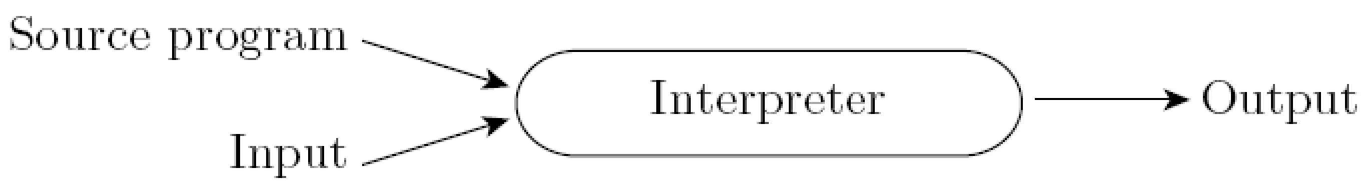
What's a compiler?

- A software program that translates the high-level source program into an equivalent target program (typically in machine language), and then goes away. E.g., C, C++.



Interpretation

- Pure Interpretation
  - Interpreter stays around for the execution of the program
    - Interpreter is the locus of control during execution



- Example: python.

Why Java?

Java is somewhat different from previous languages

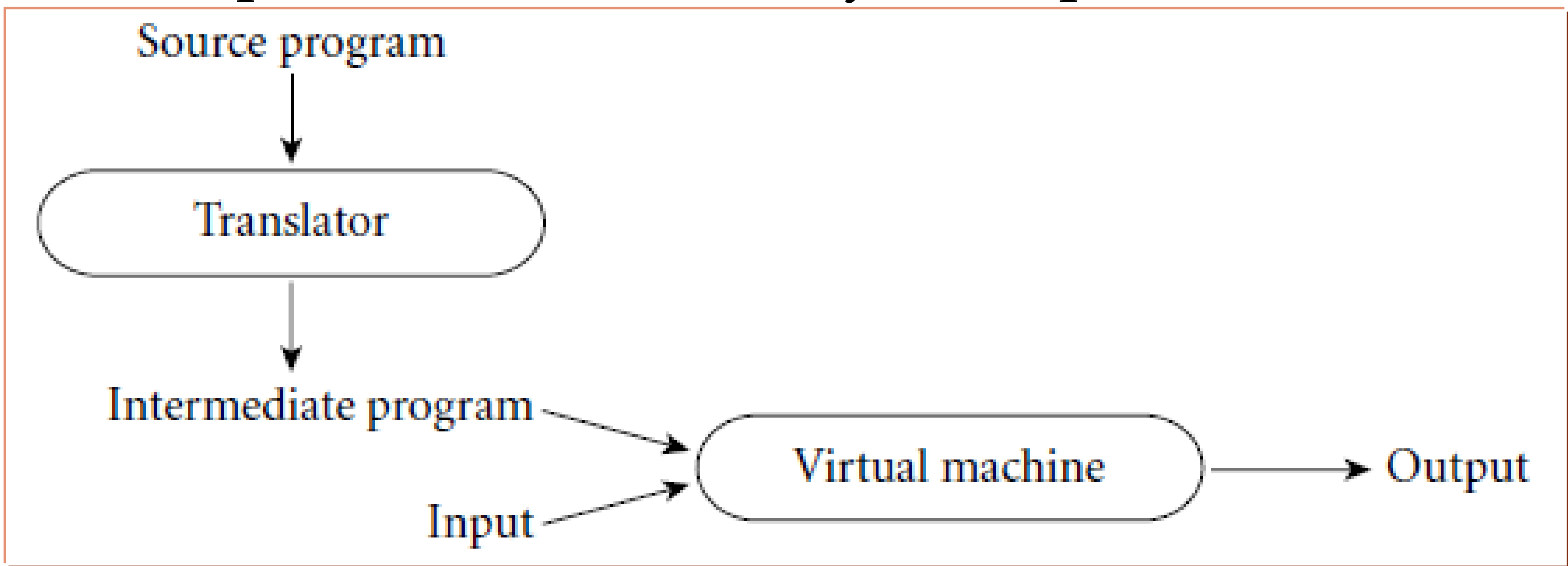
- Java started a principle, "***write once, run anywhere***"
- What does that mean?
  - Platform (and operator system) independence for compiled Java code

How?

- The Java Virtual Machine (JVM)
  - Java programs are compiled into Java bytecode
  - Bytecode is then executed by the JVM on any OS and any platform

Compilation and Interpretation

- Most modern language implementations (starting with Java) include a mixture of both compilation and interpretation
  - Compilation followed by interpretation:



Java, JVM, Web, and Beyond

- **Java Virtual Machine**
  - A program that runs Java programs and manages memory for Java programs.
    - **Why?**
      - Each platform is different (Mac, PC, Linux, Android,etc.)
- The Java Development Kit (JDK) is a distribution of Java Technology, i.e., the Java Application Programming Interface (API), the Java compiler and the Java Virtual Machine, to compile and execute Java programs.

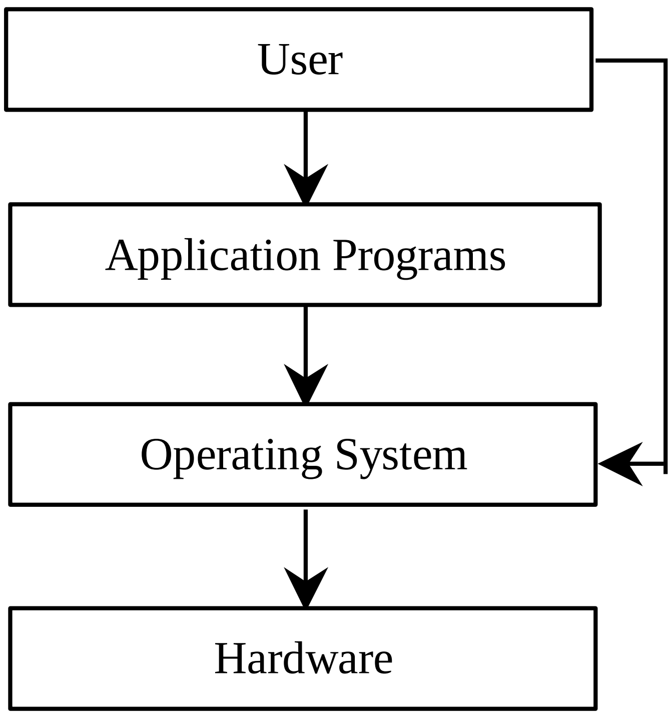
Java Development Kit (JDK)

- JDK 1.02 (1995)
- JDK 1.1 (1996), J2SE 1.2 (1998), J2SE 1.3 (2000), J2SE 1.4 (2002)
- J2SE 5.0 (2004) (Major Refactoring: Generics)
- Java SE 6 (2006), Java SE 7 (2011)
- Java SE 8 (2014) (Major Refactoring: Language-level support for lambda expressions)
  - Long Term Support (LTS)
- Java SE 9 (2017), Java SE 10, 11 (LTS) (2018)
- Java SE 12, 13 (2019), Java SE 14, 15 (2020)

  …
- Java SE 21 (LTS, 2023)
- Java SE 22, 23 (2024)

Operating Systems

The ***operating system*** (OS) is a program that manages and controls a computer's activities



Windows

Unix

Linux

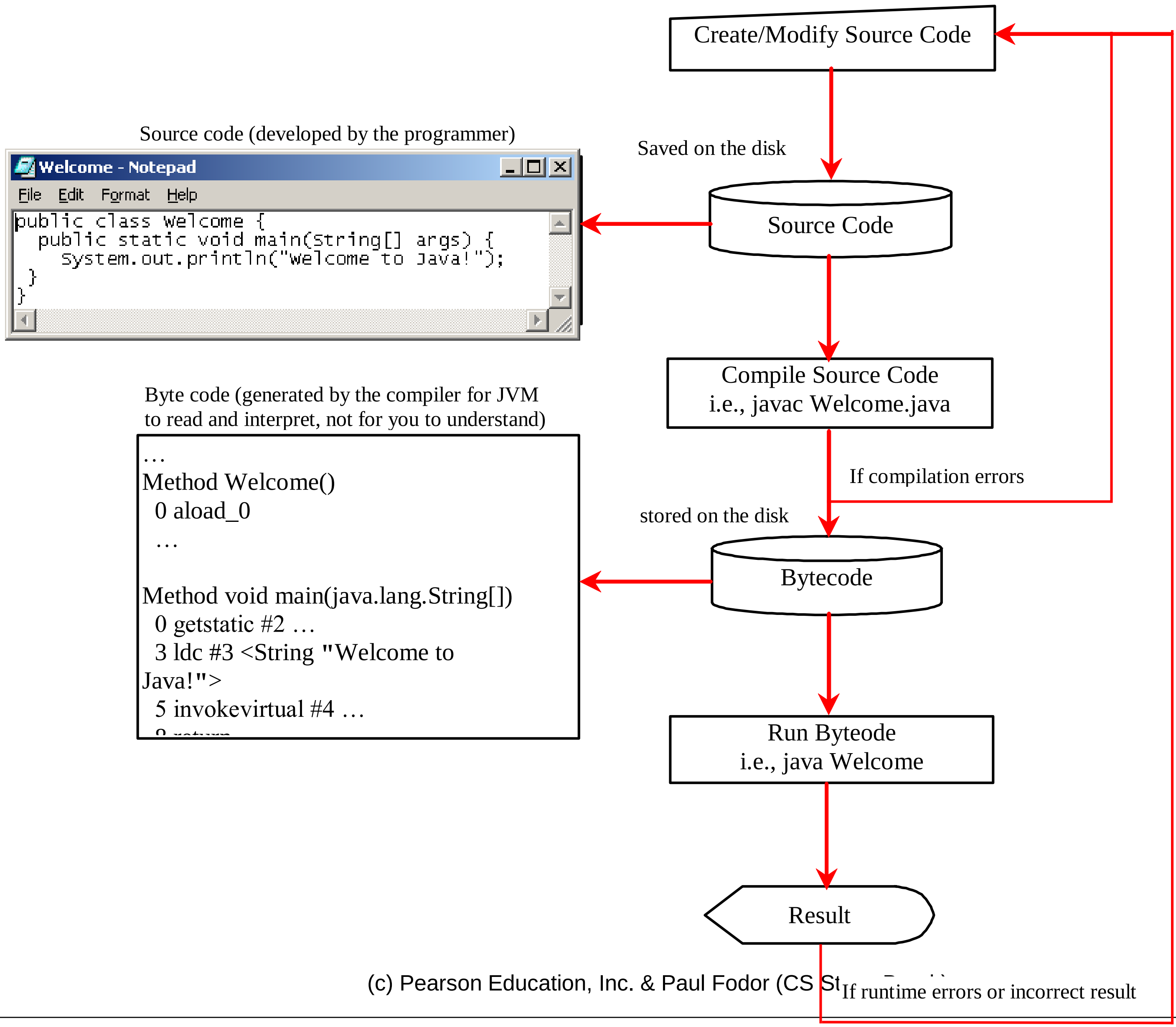
Mac OsX

Android

A Simple Java Program

```
// Welcome.java
//  This program prints Welcome to Java!
public class Welcome {
   public static void main(String[] args) {
      System.out.println("Welcome to Java!");
   }
}
```

Creating, Compiling, and Running Programs



Running Programs from command line

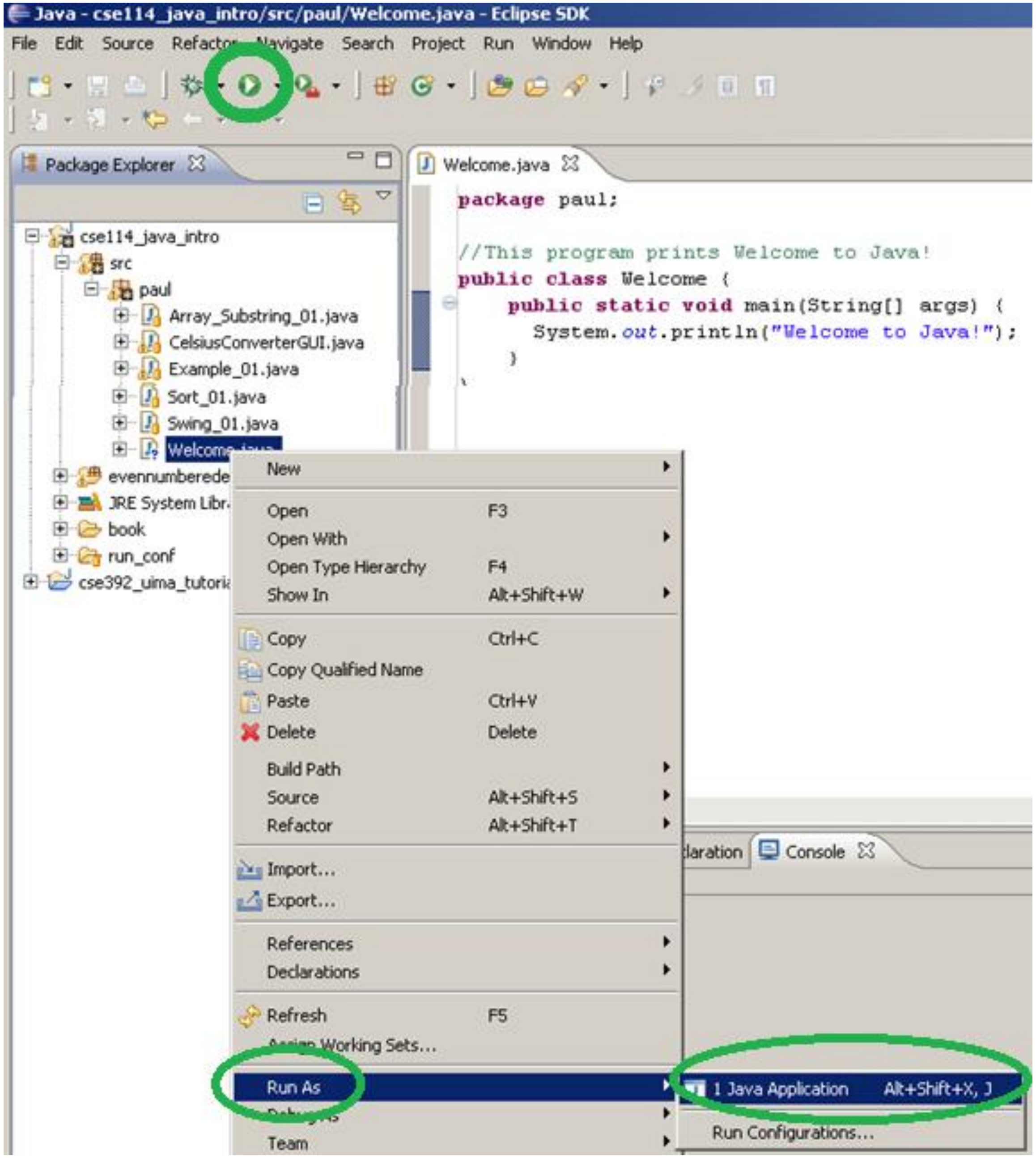
```
pfodor@sparky ~$ emacs Welcome.java

 public class Welcome {
   public static void main(String[] args) {
     System.out.println("Welcome to Java!");
   }
 }

pfodor@sparky ~$ javac Welcome.java

pfodor@sparky ~$ java Welcome
Welcome to Java!
```

Running Programs in Eclipse



Settings: Compiling and Running Java from the Command Window

- Set the path to JDK bin directory, so that the console knows where **`javac`** and **`java`** are:

```
set PATH=$PATH;c:\Java\jdk1.8.0\bin
```

- Set Classpath to include the current directory, so that javac and java know where used libraries are:

```
set CLASSPATH=...
```

Trace a Program Execution

Enter main method

```
//This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

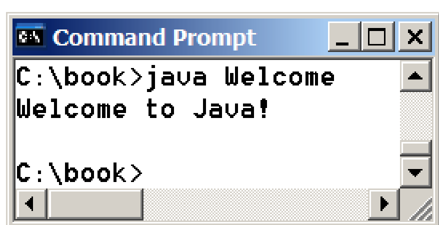
Trace a Program Execution

Execute statement

```
//This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

Trace a Program Execution

```
//This program prints Welcome to Java!
public class Welcome {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```



print a message to the console

Anatomy of Java Programs

- Comments
- Reserved words
- Modifiers
- Statements
- Blocks
- Classes
- Methods
- The main method

Comments

- Three types of comments in Java:
  - *Line comment*: A line comment is preceded by two slashes (//) in a line.
  - *Paragraph comment*: A paragraph comment is enclosed between /* and */ in one or multiple lines.
  - *javadoc comment*: javadoc comments begin with /** and end with */.
    - They are used for documenting classes, data, and methods.
    - They can be extracted into an HTML file using JDK's javadoc command.

Comments

- The code that explains itself let it be (no need to comment).

- Good programmers can always figure out what something is done from the code. But it is much more difficult to figure out why or how it was done.

- Just use good meaningful names for your identifiers (variables, methods).

```
public static int baseX2decimal(int base, String s){
    int dec = 0;
    for(int i=0;i<s.length();i++) {
     char c = s.charAt(i);
     // extract the decimal digit from the character 0..9 or A..Z for 10,11,...
     int e = ('0'<=c && c<='9')
       ? c-'0'
       : ('a'<=c && c<='z')
       ? c-'a'+10
       : c-'A'+10;
        dec = dec*base + e;
    }
    return dec;
}
```

No other comments are needed.

Just comment parts that are hard to understand.

Reserved Words (Keywords)

- ***Reserved words*** or ***keywords*** are words that have a **<u>specific meaning to the compiler</u>**
  - **Cannot be used for other purposes in the program**
  - Example: **`class`**
    - the word after **`class`** is the name for the class

Java Keywords

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

http://docs.oracle.com/javase/tutorial/java/nutsandbolts/_keywords.html

Modifiers

- Java uses certain reserved words called ***modifiers*** that specify the **properties** of the data, methods, and classes and how they can be used
  - Examples: **`public, static, private, final, abstract, protected`**
    - A **`public`** datum, method, or class can be accessed by other programs
    - A **`private`** datum or method cannot be accessed by other programs

Statements

- A statement represents an action or a sequence of actions
  - Every statement in Java ends with a semicolon (;)
  - Examples:

```
System.out.print("Welcome to Java!");
```

is a statement to display the greeting "Welcome to Java!" without moving to the new line.

```
System.out.println("Welcome to Java!");
```

is a statement to display the greeting "Welcome to Java!" followed by a new line.

Statements

- Printing is overloaded for all types in Java:

```
System.out.println(1);
System.out.println(1.2);
System.out.println(true);
```

- Java is weakly typed:

```
System.out.print("result is " + 123);
```

is a statement to displays "result is 123"

Blocks

A pair of braces in a program forms a block that groups components of a program.

```
public class Test {
  public static void main(String[] args) {
    System.out.println("Welcome to Java!");
  }
}
```

Class block

Method block

Block Styles

- We use end-of-line style for braces:

End-of-line style

```
public class Test {
  public static void main(String[] args) {
    System.out.println("Block Styles");
  }
}
```

Next-line style

```
public class Test
{
  public static void main(String[] args)
  {
    System.out.println("Block Styles");
  }
}
```

Programming Errors

- Syntax Errors
  - Detected by the compiler
- Runtime Errors
  - Causes the program to abort
- Logic Errors
  - Produces incorrect result (may or may not run into a runtime error)

Syntax Errors

```
public class ShowSyntaxError {
  public static void main(String[] args) {
    i = 30; // Detected by the compiler
    System.out.println(i + 4);
  }
}
```

The program does not compile.

Runtime Error

```
public class ShowRuntimeError {
  public static void main(String[] args) {
    int i = 1 / 0;
    // Runtime error: Division with 0
  }
}
```

The program compiles (because it is syntactically correct), but it crashes at runtime.

Logic Errors

```
public class ShowLogicError {
  // Determine if a number is between 1 and 100 inclusively
  public static void main(String[] args) {
    Scanner input = new Scanner(System.in);
    int number = input.nextInt();
    // Display the result
    System.out.println(
      "The number is between 1 and 100, inclusively: " +
            ((1 < number) && (number < 100)) );
          // Wrong result if the entered number is 1 or 100
    System.exit(0);
  }
}
```

The program compiles and may run without a crash, but <u>the results are incorrect!</u>

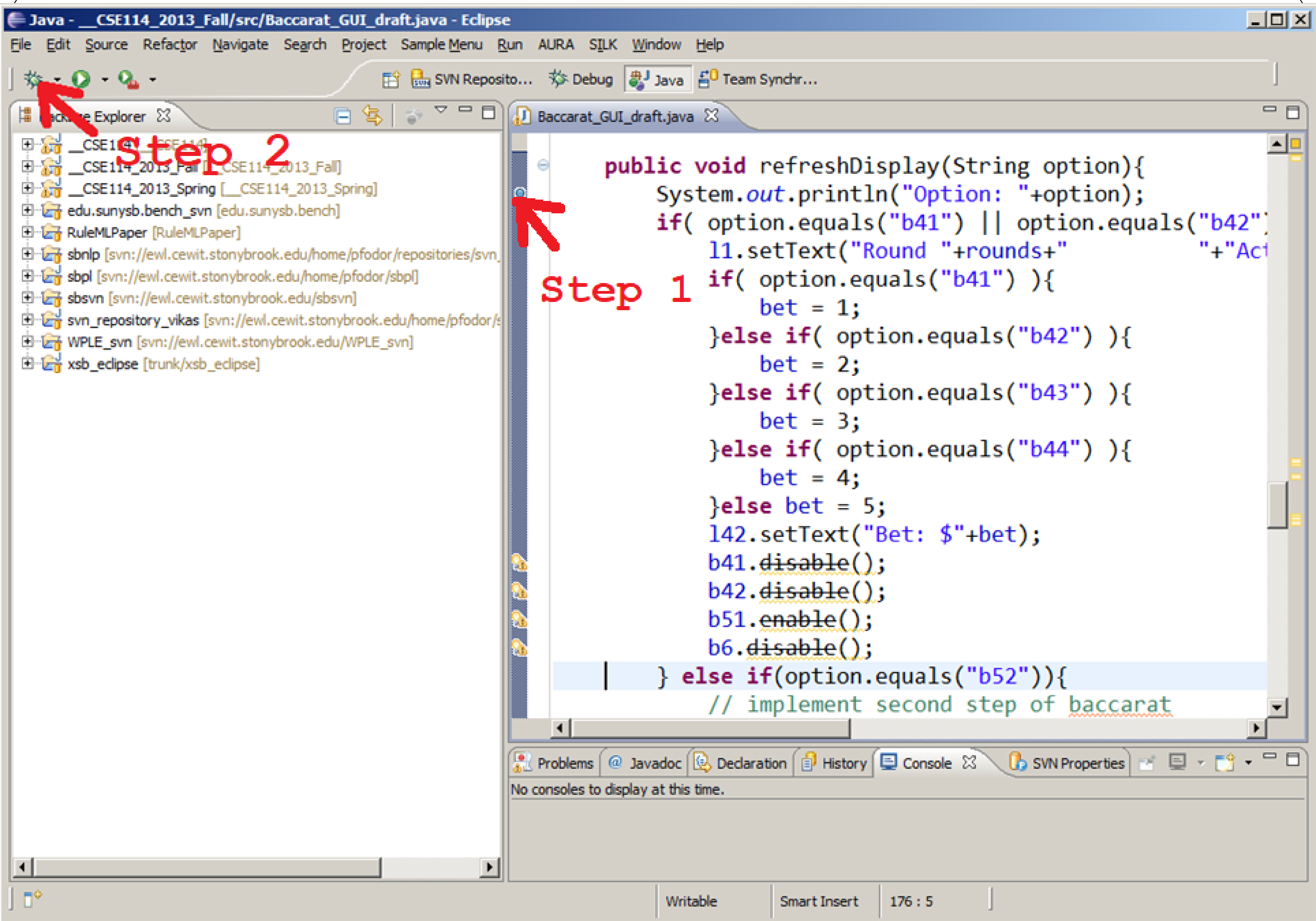
Logic Errors Debugging

- Logic errors are also called ***bugs***
  - The process of finding and correcting errors is called ***debugging***
- Methods of debugging:
  - hand-trace the program (i.e., catch errors by reading the program),
  - insert print statements in order to show the values of the variables
  - for a large, complex program, the most effective approach for debugging is to use a debugger utility

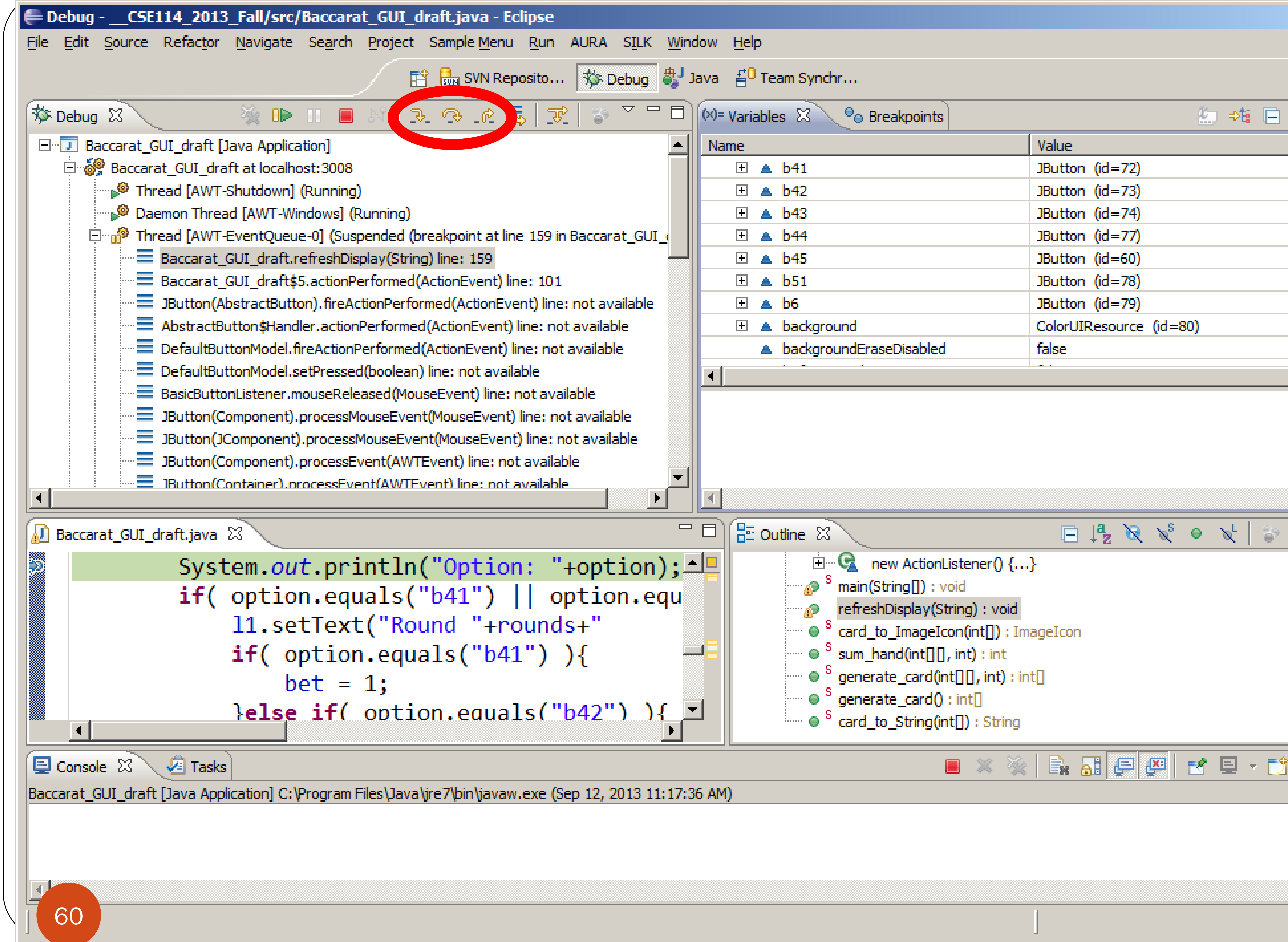
Debugger

Debugger is a program that facilitates debugging. You can use a debugger to:

- Step1: Set breakpoints where the execution pauses when we are debugging.
- Step 2: Start the debugger and Execute a single statement at a time from the first encountered breakpoint.
  - Trace into or stepping over a method.
  - Display variables.



Java - __CSE114_2013_Fall/src/Baccarat_GUI_draft.java - Eclipse
File Edit Source Refactor Navigate Search Project Sample Menu Run AURA SILK Window Help
SVN Reposito... Debug Java Team Synchr...
Package Explorer
Step 2
__CSE114_2013_Fall [__CSE114_2013_Fall]
__CSE114_2013_Spring [__CSE114_2013_Spring]
edu.sunysb.bench_svn [edu.sunysb.bench]
RuleMLPaper [RuleMLPaper]
sbnlp [svn://ewl.cewit.stonybrook.edu/home/pfodor/repositories/svn_
sbpl [svn://ewl.cewit.stonybrook.edu/home/pfodor/sbpl]
sbsvn [svn://ewl.cewit.stonybrook.edu/sbsvn]
svn_repository_vikas [svn://ewl.cewit.stonybrook.edu/home/pfodor/s
WPLE_svn [svn://ewl.cewit.stonybrook.edu/WPLE_svn]
xsb_eclipse [trunk/xsb_eclipse]
Baccarat_GUI_draft.java
Step 1
public void refreshDisplay(String option){
System.out.println("Option: "+option);
if(option.equals("b41") || option.equals("b42")
l1.setText("Round "+rounds+" "+"Act
if(option.equals("b41")){
bet = 1;
}else if(option.equals("b42")){
bet = 2;
}else if(option.equals("b43")){
bet = 3;
}else if(option.equals("b44")){
bet = 4;
}else bet = 5;
l42.setText("Bet: $"+bet);
b41.disable();
b42.disable();
b51.enable();
b6.disable();
} else if(option.equals("b52")){
// implement second step of baccarat
Problems Javadoc Declaration History Console SVN Properties
No consoles to display at this time.
Writable Smart Insert 176 : 5


Debug - __CSE114_2013_Fall/src/Baccarat_GUI_draft.java - Eclipse
File Edit Source Refactor Navigate Search Project Sample Menu Run AURA SILK Window Help
SVN Reposito... Debug Java Team Synchr...
Debug
Baccarat_GUI_draft [Java Application]
Baccarat_GUI_draft at localhost:3008
Thread [AWT-Shutdown] (Running)
Daemon Thread [AWT-Windows] (Running)
Thread [AWT-EventQueue-0] (Suspended (breakpoint at line 159 in Baccarat_GUI_
Baccarat_GUI_draft.refreshDisplay(String) line: 159
Baccarat_GUI_draft$5.actionPerformed(ActionEvent) line: 101
JButton(AbstractButton).fireActionPerformed(ActionEvent) line: not available
AbstractButton$Handler.actionPerformed(ActionEvent) line: not available
DefaultButtonModel.fireActionPerformed(ActionEvent) line: not available
DefaultButtonModel.setPressed(boolean) line: not available
BasicButtonListener.mouseReleased(MouseEvent) line: not available
JButton(Component).processMouseEvent(MouseEvent) line: not available
JButton(JComponent).processMouseEvent(MouseEvent) line: not available
JButton(Component).processEvent(AWTEvent) line: not available
Variables
Breakpoints
Name
Value
b41
JButton (id=72)
b42
JButton (id=73)
b43
JButton (id=74)
b44
JButton (id=77)
b45
JButton (id=60)
b51
JButton (id=78)
b6
JButton (id=79)
background
ColorUIResource (id=80)
backgroundEraseDisabled
false
Baccarat_GUI_draft.java
System.out.println("Option: "+option);
if(option.equals("b41") || option.equ
l1.setText("Round "+rounds+"
if(option.equals("b41")){
bet = 1;
}else if(option.equals("b42")){
Outline
new ActionListener() {...}
main(String[]) : void
refreshDisplay(String) : void
card_to_ImageIcon(int[]) : ImageIcon
sum_hand(int[][], int) : int
generate_card(int[][], int) : int[]
generate_card() : int[]
card_to_String(int[]) : String
Console
Tasks
Baccarat_GUI_draft [Java Application] C:\Program Files\Java\jre7\bin\javaw.exe (Sep 12, 2013 11:17:36 AM)