OOP with Java

4. Types, Variables, and Assignments

Thomas Weise · 汤卫思

tweise@hfuu.edu.cn · http://iao.hfuu.edu.cn

Hefei University, South Campus 2
Faculty of Computer Science and Technology
Institute of Applied Optimization
230601 Shushan District, Hefei, Anhui, China
Econ. & Tech. Devel. Zone, Jinxiu Dadao 99

合肥学院 南艳湖校区/南2区
计算机科学与技术系
应用优化研究所
中国 安徽省 合肥市 蜀山区 230601
经济技术开发区 锦绣大道99号

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5. Summary

website

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  - the type `char`, which uses its bits to represent a character

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`double`	signed 64 bit floating point number (1 sign bit, 11 bit signed exponent, 52 bit unsigned mantissa + hidden bit), subset of real numbers from $\pm[2^{-1074}, (2-2^{-52}) * 2^{1023}] \cup \{0, -\infty, \infty, \emptyset\}$

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`char`	a single 16 bit unicode character, can be any character from any of the major languages
`String`	a piece of text, at most 2147483647 characters (but literals are limited to 65536 characters), (not actually a primitive type)

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- When a program is executed, variables exist in the RAM assigned to the process. After the process has terminated, they disappear.

Examples for `boolean` Variables

Listing: A program allocating, initializing, and printing `boolean` variables.

```java
/** Examples for boolean variables */
public class BooleanVariables {

  /** The main routine
   * @param args
   *         we ignore this parameter for now */
  public static final void main(final String[] args) {
    boolean var; // allocate boolean variable "var"

    var = true; // set variable var to true
    System.out.println(var); // prints true

    var = false; // set variable var to false
    System.out.println(var);// prints false

    var = false; // set variable var to false
    var = true; // set variable var to true
    System.out.println(var); // prints true

    boolean a = false, b = true, c = false; // allocate and initialize three variables
    System.out.println(a); // print the value of a, which is false
    System.out.println(b); // print the value of b, which is true
    System.out.println(c); // print the value of c, which is false
  }
}
```

Examples for byte Variables

Listing: A program allocating, initializing, and printing byte variables.

```java
/** Examples for byte variables */
public class ByteVariables {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    byte var; // allocate byte variable "var"

    var = -1; // set variable var to -1
    System.out.println(var); // prints -1

    var = -128; // set variable var to -128
    System.out.println(var); // prints -128

    var = 1_2_7; // set variable var to 127
    System.out.println(var); // prints 127

    byte hex = 0x10; // set hex to hexadecimal 10, which is 1*16+0 = 16: starts with "0x"
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    byte bin = 0b0110_1111; // set bin to binary 01101111, which is 1+2+4+8+32+64=111: starts with
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    - `0b1234` is invalid, since only digits `0` and `1` can occur
    - `0b10100` means, in base 10, $0 * 2^0 + 0 * 2^1 + 1 * 2^2 + 0 * 2^3 + 1 * 2^4 = 1 * 4 + 1 * 16 = 20$

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  - `0x10100` means, in base 10, $0*16^0+0*16^1+1*16^2+0*16^3+1*16^4 = 1*256+1*65536 = 65792$

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  - `0x10100` means, in base 10, $0*16^0+0*16^1+1*16^2+0*16^3+1*16^4=1*256+1*65536=65792$
  - `0xef` means, in base 10, $15*16^0+14*16^1=15+14*16=239$

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  - `0xef` means, in base 10, $15*16^0+14*16^1 = 15+14*16 = 239$
- Hexadecimal numbers are heavily used when operations on bits (e.g., `|`, `^`, see Lesson 5: *Operators Expressions*) are performend

Examples for short Variables

Listing: A program allocating, initializing, and printing short variables.

```
/** Examples for short variables */
public class ShortVariables {

  /** The main routine
   * @param args
   *           we ignore this parameter for now */
  public static final void main(final String[] args) {
    short var; // allocate short variable "var"

    var = -1; // set variable var to -1
    System.out.println(var); // prints -1

    var = -32768; // set variable var to -32768
    System.out.println(var); // prints -32768

    var = 3_2767; // set variable var to 32767
    System.out.println(var); // prints 32767

    short hex = 0x10; // set hex to hexadecimal 10, which is 1*16+0 = 16: starts with "0x"
    System.out.println(hex); // prints 16

    short bin = 0b0110_1111; // set bin to binary 01101111, which is 1+2+4+8+32+64=111: starts with
        "0b"
    System.out.println(bin); // prints 111
  }
}
```

Examples for `int` Variables

Listing: A program allocating, initializing, and printing `int` variables.

```java
/** Examples for integer variables */
public class IntVariables {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    int var; // allocate integer variable "var"

    var = -1; // set variable var to -1
    System.out.println(var); // prints -1

    var = -2147483648; // set variable var to -2147483648
    System.out.println(var); // prints -2147483648

    var = 2_147_483_647; // set variable var to 2147483647
    System.out.println(var); // prints 2147483647

    int hex = 0x10; // set hex to hexadecimal 10, which is 1*16+0 = 16: starts with "0x"
    System.out.println(hex); // prints 16

    int bin = 0b0110_1111; // set bin to binary 01101111, which is 1+2+4+8+32+64=111: starts with "0b"
    System.out.println(bin); // prints 111
  }
}
```

Examples for `long` Variables

Listing: A program allocating, initializing, and printing `long` variables.

```java
/** Examples for long variables */
public class LongVariables {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    long var; // allocate long variable "var"

    var = -1L; // set variable var to -1; notice the "L" which marks "long" literals for the compiler
    System.out.println(var); // prints -1

    var = -9223372036854775808L; // set variable var to -9223372036854775808
    System.out.println(var); // prints -9223372036854775808

    var = 9_223_372_036_854_775_807L; // set variable var to 9223372036854775807
    System.out.println(var); // prints 9223372036854775807

    long hex = 0x10L; // set hex to hexadecimal 10, which is 1*16+0 = 16: starts with "0x"
    System.out.println(hex); // prints 16

    long bin = 0b0110_1111L; // set bin to binary 01101111, which is 1+2+4+8+32+64=111: starts with "0b"
    System.out.println(bin); // prints 111
  }
}
```

Examples for `float` Variables

Listing: A program allocating, initializing, and printing float variables.

```java
/** Examples for float variables */
public class FloatVariables {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    float var; // allocate float variable "var"

    var = -1f; // set variable var to -1; notice the "f" marking the "float" literal for the compiler
    System.out.println(var); // prints -1.0

    float fraction = 0.8f; // allocate and set variable faction to 0.8
    System.out.println(fraction); // prints 0.8

    var = 1.4e-45f; // set variable var to 1.4*10^{-45}, the "aaaExxx" means "aaa*10^{xxx}"
    System.out.println(var); // prints 1.4E-45

    var = 3.4028235e38f; // set variable var to 3.4028235*10^{38}
    System.out.println(var); // prints 4028235E38

    float pi = 3.141592653589793238462643383279502884197169399375105820974944592307816406286f; // set
        pi to, well, π
    System.out.println(pi); // prints 3.1415927 <- precision of float is about 7 decimals
  }
}
```

Examples for `double` Variables

Listing: A program allocating, initializing, and printing double variables.

```java
/** Examples for double variables */
public class DoubleVariables {

  /** The main routine
   * @param args
   *           we ignore this parameter for now */
  public static final void main(final String[] args) {
    double var; // allocate double variable "var"

    var = -1d; // set variable var to -1; notice the "d" marking the "double" literal for the compiler
    System.out.println(var); // prints -1.0

    double fraction = 0.8d; // allocate and set variable faction to 0.8
    System.out.println(fraction); // prints 0.8

    var = 4.9e-324d; // set variable var to $4.9*10^{-324}$, the "aaaExxx" means "$aaa*10^{xxx}$"
    System.out.println(var); // prints 4.9E-324

    var = 1.7976931348623157e308d; // set variable var to $1.7976931348623157*10^{308}$
    System.out.println(var); // prints 1.7976931348623157E308d

    double pi = 3.14159265358979323846264338327950288419716939937510582097494459230781640628 6d; // set pi to, well, $\pi$
    System.out.println(pi); // prints 3.141592653589793 <- precision of double is about 15 decimals
  }
}
```

Examples for `char` Variables

Listing: A program allocating, initializing, and printing `char` variables.

```java
/** Examples for character variables */
public class CharVariables {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    char var; // allocate character variable "var"

    var = 'T'; // set variable var to 'T'
    System.out.println(var); // prints 'T' (without the primes "'")

    var = '\u597d'; // set variable var to unicode char 0x597d
    System.out.println(var); // prints the Chinese character for "good"

    var = '\n'; // set variable var to literal \n, which stands for newline
    System.out.println(var); // prints a newline, i.e., an empty line

    char space = '␣'; // set space to a space character
    System.out.println(space); // prints ' ' (without the primes "'")

    var = '\''; // setting var to ', using escaped single quote
    System.out.println(var); // prints '
  }
}
```

Examples for `String` Variables

Listing: A program allocating, initializing, and printing `String` variables.

```java
/** Examples for String variables */
public class StringVariables {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    String var; // allocate String variable "var"

    var = "Hello␣World!"; // set variable var to "Hello World!" //$NON-NLS-1$
    System.out.println(var); // prints "Hello World!" (without the quotation marks)

    var = "Hello\nWorld!"; // set variable var to "Hello\nWorld!" //$NON-NLS-1$
    System.out.println(var); // prints Hello, newline, World!

    String niHao="\u4f60\u597d"; // set variable var to Hello in Chinese //$NON-NLS-1$
    System.out.println(niHao); // prints a "Ni Hao" in Chinese for Hello

    var = "\"Hello\""; // set variable var to "Hello" (using escaped double quotes)
        //$NON-NLS-1$
    System.out.println(var); // prints a "Hello" (without the quotation marks)
  }
}
```

Remark: These //NON-NLS-1 things can safely be ignored, they are just there to tell Eclipse that a `String` literal is not internationalized/stored in a resource but to be used as it. Ignore them.

The limits of the type byte

Listing: The limits of the type byte.

```java
/** Examples for the limits of byte variables */
public class ByteLimits {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    byte var; // allocate byte variable "var"

    var = Byte.MIN_VALUE; // set variable var to the minimum byte value
    System.out.println(var); // prints -128

    var = Byte.MAX_VALUE; // set variable var to the maximum byte value
    System.out.println(var); // prints 127

    var = Byte.SIZE; // set variable var to the size in bits of 1 byte
    System.out.println(var); // prints 8
  }
}
```

The limits of the type short

Listing: The limits of the type short.

```java
/** Examples for the limits of short variables */
public class ShortLimits {

  /** The main routine
   * @param args
   *           we ignore this parameter for now */
  public static final void main(final String[] args) {
    short var; // allocate short variable "var"

    var = Short.MIN_VALUE; // set variable var to the minimum short value
    System.out.println(var); // prints -32768

    var = Short.MAX_VALUE; // set variable var to the maximum byte value
    System.out.println(var); // prints 32767

    var = Short.SIZE; // set variable var to the size in bits of 1 short
    System.out.println(var); // prints 16
  }
}
```

The limits of the type `int`

Listing: The limits of the type `int`.

```java
/** Examples for the limits of integer variables */
public class IntLimits {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    int var; // allocate int variable "var"

    var = Integer.MIN_VALUE; // set variable var to the minimum int value
    System.out.println(var); // prints -2147483648

    var = Integer.MAX_VALUE; // set variable var to the maximum int value
    System.out.println(var); // prints 2147483647

    var = Integer.SIZE; // set variable var to the size in bits of 1 int
    System.out.println(var); // prints 32
  }
}
```

The limits of the type `long`

Listing: The limits of the type `long`.

```java
/** Examples for the limits of long variables */
public class LongLimits {

  /** The main routine
   * @param args
   *           we ignore this parameter for now */
  public static final void main(final String[] args) {
    long var; // allocate long variable "var"

    var = Long.MIN_VALUE; // set variable var to the minimum long value
    System.out.println(var); // prints -9223372036854775808

    var = Long.MAX_VALUE; // set variable var to the maximum long value
    System.out.println(var); // prints 9223372036854775807

    var = Long.SIZE; // set variable var to the size in bits of 1 long
    System.out.println(var); // prints 64
  }
}
```

The limits of the type `float`

Listing: The limits of the type `float`.

```java
/** Examples for the limits of float variables */
public class FloatLimits {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    float var; // allocate long variable "var"

    var = Float.MIN_VALUE; // set variable var to the minimum positive! float value
    System.out.println(var); // prints 1.4E-45

    var = Float.MIN_NORMAL; // set variable var to the minimum normal float value
    System.out.println(var); // prints 1.17549435E-38

    var = Float.MAX_VALUE; // set variable var to the maximum float value
    System.out.println(var); // prints 3.4028235E38

    int size = Float.SIZE; // set variable size to the size in bits of 1 float
    System.out.println(size); // prints 32

    var = Float.NEGATIVE_INFINITY; // set variable var to negative infinity
    System.out.println(var); // prints -Infinity

    var = Float.POSITIVE_INFINITY; // set variable var to positive infinity
    System.out.println(var); // prints Infinity

    var = Float.NaN; // set variable var to "not a number"
    System.out.println(var); // prints NaN
  }
}
```

The limits of the type `double`

Listing: The limits of the type double.

```java
/** Examples for the limits of double variables */
public class DoubleLimits {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    double var; // allocate long variable "var"

    var = Double.MIN_VALUE; // set variable var to the minimum positive! double value
    System.out.println(var); // prints 4.9E-324

    var = Double.MIN_NORMAL; // set variable var to the minimum normal double value
    System.out.println(var); // prints 2.2250738585072014E-308

    var = Double.MAX_VALUE; // set variable var to the maximum double value
    System.out.println(var); // prints 1.7976931348623157E308

    int size = Double.SIZE; // set variable size to the size in bits of 1 double
    System.out.println(size); // prints 64

    var = Double.NEGATIVE_INFINITY; // set variable var to negative infinity
    System.out.println(var); // prints -Infinity

    var = Double.POSITIVE_INFINITY; // set variable var to positive infinity
    System.out.println(var); // prints Infinity

    var = Double.NaN; // set variable var to "not a number"
    System.out.println(var); // prints NaN
  }
}
```

Losslessly Compatible Types

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Losslessly Compatible Types

- It is possible to store values of a smaller type into a variable of a larger type of the same sort without any loss, i.e.

  1. a `byte` value in a `short` variable
  2. a `short` value in an `int` variable
  3. an `int` value in a `long` variable
  4. a `float` value in a `double` variable

Losslessly Compatible Types Example

Listing: Example for lossless compatible types.

```java
/** Examples for lesslessly compatible variables */
public class CompatibleTypes1 {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    byte myByte = -128; // allocate byte variable "myByte"
    short myShort = myByte; // store value of myByte into variable myShort
    System.out.println(myShort); // prints -128

    myShort = 32767; // now store the maximum short value in the variable
    int myInt = myShort; // and copy the value over to the new myInt variable
    System.out.println(myInt); // prints 32767

    myInt = 2147483647; // set myInt to the maximum integer value
    long myLong = myInt; // and copy it to the new long variable myLong
    System.out.println(myLong); // prints 2147483647

    float myFloat = 1.4E-45f; // new float variable with the smallest positive float value
    double myDouble = myFloat; // copy its value into a double variable
    System.out.println(myDouble); // prints 1.401298464324817E-45, which is equivalent to 1.4E-45f
  }
}
```

Integer-to-Floating Point: Potential Loss of Information

- It is possible to store values of an integer type into a floating point variable, but maybe with loss of information

Integer-to-Floating Point: Potential Loss of Information

- It is possible to store values of an integer type into a floating point variable, but maybe with loss of information, i.e.
  1. a `byte` value in a `float` variable (no loss of infos)
  2. a `short` value in an `float` variable (no loss of infos)
  3. an `int` value in a `float` variable (possible loss of infos)
  4. a `long` value in a `float` variable (possible loss of infos)
  5. a `byte` value in a `double` variable (no loss of infos)
  6. a `short` value in an `double` variable (no loss of infos)
  7. an `int` value in a `double` variable (no loss of infos)
  8. a `long` value in a `double` variable (possible loss of infos)

Conversation of Integer Types to `float`

Listing: Examples for the conversation of Integer Types to `float`.

```java
/** Examples for int-to-float compatibility */
public class CompatibleTypes2Float {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    byte myByte = -128; // allocate byte variable "myByte"
    float myFloat = myByte; // store value of myByte into variable myFloat
    System.out.println(myFloat); // prints -128.0: no loss of infos, 8 bit fit into float mantissa

    short myShort = 32767; // now store the maximum short value in the variable
    myFloat= myShort; // and copy the value over to the new myFloat variable
    System.out.println(myFloat); // prints 32767.0: no loss of infos, 16 bit fit into float mantissa

    int myInt = 2147483646; // set myInt to the maximum integer value -1
    myFloat= myInt; // and copy it to the new long variable myLong
    System.out.println(myFloat); // prints 2.14748365E9, .e., rounding up to 2147483650

    long myLong = 9223372036854775806L; // set myLong to the maximum long value - 1
    myFloat= myLong; // and copy it to the new long variable myLong
    System.out.println(myFloat); // prints 9.223372E18, i.e., rounding down to 9223372000000000000L
  }
}
```

Conversation of Integer Types to `double`

Listing: Examples for the conversation of Integer Types to double.

```java
/** Examples for int-to-double compatibility */
public class CompatibleTypes2Double {

  /** The main routine
   * @param args
   *          we ignore this parameter for now */
  public static final void main(final String[] args) {
    byte myByte = -128; // allocate byte variable "myByte"
    double myDouble = myByte; // store value of myByte into variable myDouble
    System.out.println(myDouble); // prints -128.0: no loss of infos, 8 bit fit into double mantissa

    short myShort = 32767; // now store the maximum short value in the variable
    myDouble= myShort; // and copy the value over to the new myDouble variable
    System.out.println(myDouble); // prints 32767.0: no loss of infos, 16 bit fit into double mantissa

    int myInt = 2147483646; // set myInt to the maximum integer value -1
    myDouble= myInt; // and copy it to the new long variable myLong
    System.out.println(myDouble); // prints 2.147483646E9: no loss of infos, 32 bit fit into double mantissa

    long myLong = 9223372036854775806L; // set myLong to the maximum long value - 1
    myDouble= myLong; // and copy it to the new long variable myLong
    System.out.println(myDouble); // prints 9.223372036854776E18, i.e., rounding up to 9223372036854776000
  }
}
```

Other Compatibilities

- When doing I/O (seel Lesson 28: *I/O and Streams*, a `char` is sometimes represented as `int` value, which allows us to express that no more character can be read from a file as `-1` . . . but this is subject to another lesson (Lesson 28: *I/O and Streams*)

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Other Compatibilities

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- Type casting allows us to transform floating point numbers back to integers via truncation, likely resulting in loss of information ... and this is also subject of a later lesson (Lesson 20: *Type Casts*)
- Types can be automatically transformed to `String` when appearing in a `String` expression ... and this is subject to a later lesson as well (Lesson 5: *Operators Expressions*).

Summary

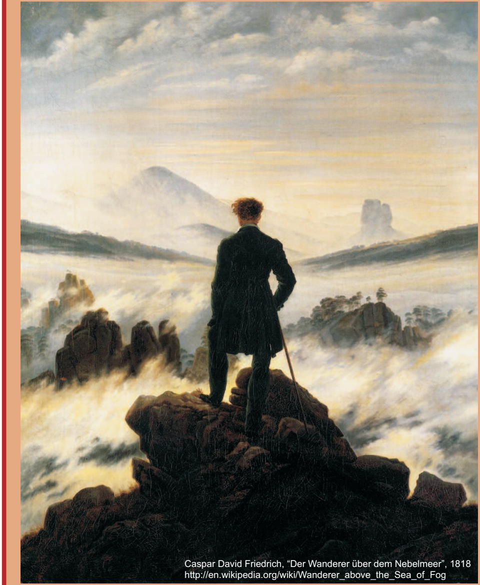
1. We have learned the basic primitive types of Java (plus the non-primitive type `String`).
2. We have learned how to declare variables.
3. We have learned how to store values in variables.
4. We have learned how to print out variables to the console (via `System.out.println(...)`.
5. We have learned that some types are losslessly compatible.
6. We have learned that some conversations are lossy.

谢谢

Thank you

Thomas Weise [汤卫思]
tweise@hfuu.edu.cn
http://iao.hfuu.edu.cn

Hefei University, South Campus 2
Institute of Applied Optimization
Shushan District, Hefei, Anhui,
China



Caspar David Friedrich, “Der Wanderer über dem Nebelmeer”, 1818
http://en.wikipedia.org/wiki/Wanderer_above_the_Sea_of_Fog