Data Representation and Applets

CSC 1051 – Data Structures and Algorithms I
Dr. Mary-Angela Papalaskari
Department of Computing Sciences
Villanova University

Course website:
http://www.csc.villanova.edu/~map/1051/
Overview

- **Binary representation**
  - Image representation
  - Java Applets
  - Data types revisited
  - Type conversions
Data Representation

- Computers store all information **digitally**, using **binary** codes:
  - numbers
  - text
  - images
  - audio
  - video
  - program instructions

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A byte is a group of eight bits

- a number?
- a letter?
- the red component of a pixel?
- a program instruction?

Computing devices store & use binary codes to represent data of all kinds
## Binary codes

<table>
<thead>
<tr>
<th>1 bit</th>
<th>2 bits</th>
<th>3 bits</th>
<th>4 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>00</td>
<td>000</td>
<td>0000</td>
</tr>
<tr>
<td>1</td>
<td>01</td>
<td>001</td>
<td>0001</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>010</td>
<td>0010</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>011</td>
<td>0011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>0100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>101</td>
<td>0110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>110</td>
<td>0111</td>
</tr>
<tr>
<td></td>
<td></td>
<td>111</td>
<td>1000</td>
</tr>
</tbody>
</table>

Each additional bit doubles the number of possible codes.
Binary Codes

• How many codes of N bits?

• How many bits are needed to represent 64 items?

• How many bits are needed to represent 80 items?

• How many bits are needed to represent each of the 50 states (so that each state corresponds to a unique code)?
Storage requirements examples

• If a code requires 5 bits, a document consisting of 4000 such codes will require a total of:
  
  \[ 5 \times 4000 = 20,000 \text{ bits} \]

  – how many \textit{bytes} is that? _______________

• If a code requires 8 bits (i.e., a byte), a document consisting of 2000 such codes will require 2000 bytes.

  – how many \textit{bits} is that? _______________

• If a code requires 32 bits, a program that needs to store 2000 such codes will require
  
  \[ \underline{\underline{\text{_______ bits}}} \quad \text{or} \quad \underline{\underline{\text{_______ bytes}}} \]
Storage Capacity

- Every memory device has a storage capacity, indicating the number of bytes it can hold.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Symbol</th>
<th>Number of Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilobyte</td>
<td>KB</td>
<td>$2^{10} = 1024$</td>
</tr>
<tr>
<td>megabyte</td>
<td>MB</td>
<td>$2^{20}$ (over one million)</td>
</tr>
<tr>
<td>gigabyte</td>
<td>GB</td>
<td>$2^{30}$ (over one billion)</td>
</tr>
<tr>
<td>terabyte</td>
<td>TB</td>
<td>$2^{40}$ (over one trillion)</td>
</tr>
<tr>
<td>petabyte</td>
<td>PB</td>
<td>$2^{50}$ (a whole bunch)</td>
</tr>
</tbody>
</table>
Overview

• Binary representation
• **Image representation**
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What’s a picture?

• programs represent pictures as grids of picture elements or pixels
Representing Images

- **Bitmap**: 1 bit
- **Grayscale**: 8 bits
- **RGB Color**: 3 colors: red, green, blue, 8 bits/color, 24 bits
Example: Representing Pixels

Color (01110100, 01010110, 10001110)

red=116  green=86  blue=142

x = 11  y = 8
Additive/Subtractive Color

We choose 3 primary colors that can be combined to produce almost all visible colors

Additive primaries
- combining light
  Red  Green  Blue

Subtractive primaries
- combining ink, thus subtracting light
  Cyan  Yellow  Magenta
A 2000 by 1000 bitmap image contains ___________ pixels.

Thus, we need ___________ bits to represent this image, or ___________ bytes.
A 2000 by 1000 grayscale image contains ___________ pixels.

Thus, we need ___________ bytes to represent this image, or ___________ bits.
A 2000 by 1000 RGB image contains _________ pixels.

Thus, we need _________ bytes to represent this image, or _________ bits.
Graphics and images in Java

• Images are represented as objects in Java.

• Color components and positions for pixels can be represented as integers (but also in other ways).

• Java libraries allow flexibility, providing many alternative ways of representing and processing images.

• We will be using the Graphics class of the awt package and Japplet from the swing
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Applets

• A Java *applet* is a program that is intended to be transported over the Web and executed using a web browser

• An applet doesn't have a *main* method
  
  – The type of program we have seen so far is a Java *application* - a stand-alone program with a *main* method
Example: `Einstein.java`

```java
//****************************************************************************
//  Einstein.java       Author: Lewis/Loftus
//
//  Demonstrates a basic applet.
//****************************************************************************

import javax.swing.JApplet;
import java.awt.*;

public class Einstein extends JApplet
{
    //----------------------------------------------------------------------------
    //  Draws a quotation by Albert Einstein among some shapes.
    //----------------------------------------------------------------------------
    public void paint (Graphics page)
    {
        page.drawRect (50, 50, 40, 40);   // square
        page.drawRect (60, 80, 225, 30);   // rectangle
        page.drawOval (75, 65, 20, 20);    // circle
        page.drawLine (35, 60, 100, 120);  // line

        page.drawString ("Out of clutter, find simplicity.", 110, 70);
        page.drawString ("-- Albert Einstein", 130, 100);
    }
}
```
import javax.swing.JApplet;
import java.awt.*;

public class Einstein extends JApplet {

    //-----------------------------------------------------------------
    // Draws a quotation by Albert Einstein among some shapes.
    //-----------------------------------------------------------------
    public void paint (Graphics page) {
        page.drawRect (50, 50, 40, 40); // square
        page.drawRect (60, 80, 225, 30); // rectangle
        page.drawOval (75, 65, 20, 20); // circle
        page.drawLine (35, 60, 100, 120); // line
        page.drawString ("Out of clutter, find simplicity.", 110, 70);
        page.drawString ("-- Albert Einstein", 130, 100);
    }

}
Drawing a Line

```
page.drawLine (10, 20, 150, 45);
page.drawLine (150, 45, 10, 20);
```

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Drawing a Rectangle

```java
page.drawRect (50, 20, 100, 40);
```

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Drawing an Oval

```
page.drawOval (175, 20, 50, 80);
```

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Drawing an Arc

- An arc is defined by an oval, a start angle, and an arc angle:
Filled vs unfilled shapes

• Instead of using `drawRect()`, `drawOval()` etc, we can use `fillRect()`, `fillOval()` etc

• We can set the color using `setColor()`

• See `Snowman.java`

• See also `Snowman applet on a webpage`
import javax.swing.JApplet;
import java.awt.*;

public class Snowman extends JApplet
{
    //-------------------------------------------------------------
    // Draws a snowman.
    //-------------------------------------------------------------
    public void paint (Graphics page)
    {
        final int MID = 150;
        final int TOP = 50;

        setBackground (Color.cyan);

        page.setColor (Color.blue);
        page.fillRect (0, 175, 300, 50);  // ground

        page.setColor (Color.yellow);
        page.fillOval (-40, -40, 80, 80);  // sun

        continued
continued

```java
page.setColor(Color.white);
page.fillOval(MID-20, TOP, 40, 40); // head
page.fillOval(MID-35, TOP+35, 70, 50); // upper torso
page.fillOval(MID-50, TOP+80, 100, 60); // lower torso

page.setColor(Color.black);
page.fillOval(MID-10, TOP+10, 5, 5); // left eye
page.fillOval(MID+5, TOP+10, 5, 5); // right eye

page.drawArc(MID-10, TOP+20, 20, 10, 190, 160); // smile

page.drawLine(MID-25, TOP+60, MID-50, TOP+40); // left arm
page.drawLine(MID+25, TOP+60, MID+55, TOP+60); // right arm

page.drawLine(MID-20, TOP+5, MID+20, TOP+5); // brim of hat
page.fillRect(MID-15, TOP-20, 30, 25); // top of hat
```

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The Java Color Class

- A color in a Java program is represented as an object created from the `Color` class

- The `Color` class also contains several predefined colors, eg:

<table>
<thead>
<tr>
<th>Object</th>
<th>RGB Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color.black</td>
<td>0, 0, 0</td>
</tr>
<tr>
<td>Color.blue</td>
<td>0, 0, 255</td>
</tr>
<tr>
<td>Color.cyan</td>
<td>0, 255, 255</td>
</tr>
<tr>
<td>Color.orange</td>
<td>255, 200, 0</td>
</tr>
<tr>
<td>Color.white</td>
<td>255, 255, 255</td>
</tr>
<tr>
<td>Color.yellow</td>
<td>255, 255, 0</td>
</tr>
</tbody>
</table>

- Using a color: `page.setColor(Color.blue);`
- Creating a new color:

```
Color salmon = new Color(255, 140, 128);
page.setColor(salmon);
```
Translation of programs into machine code

Java code:

```java
public class Einstein extends JApplet {
    // Draws a quotation by Albert Einstein
    public void paint (Graphics page) {
        page.drawRect (50, 50, 100, 100);
        page.drawRect (150, 50, 200, 100);
        page.drawOval (50, 50, 100, 100);
        page.drawLine (50, 50, 200, 200);
        page.drawString ("Out of clutter, I
                page.drawString ("-- Albert Einstein
```
Java Translation is different

High-level language

Java source code

Java compiler

Bytecode interpreter

Bytecode compiler

machine-independent intermediate language

machine-dependent low-level language

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The HTML applet Tag

• An applet is embedded into an HTML file using a tag that references the bytecode file of the applet

• The bytecode version of the program is transported across the web and executed by a Java interpreter that is part of the browser.

```html
<html>
  <head>
    <title>The Einstein Applet</title>
  </head>
  <body>
    <applet code="Einstein.class" width=350 height=175>
    
    </applet>
  </body>
</html>
```
Overview

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• **Data types revisited**
• Type conversions
Variables

• A variable is a name for a location in memory

• A variable must be declared by specifying the variable's name and the type of information that it will hold

```
int sum;
double milesPerGallon;
String name, petName;
```
Numeric Primitive Data

- The difference between the numeric primitive types is their size and the values they can store:

<table>
<thead>
<tr>
<th>Type</th>
<th>Storage</th>
<th>Min Value</th>
<th>Max Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>8 bits</td>
<td>-128</td>
<td>127</td>
</tr>
<tr>
<td>short</td>
<td>16 bits</td>
<td>-32,768</td>
<td>32,767</td>
</tr>
<tr>
<td>int</td>
<td>32 bits</td>
<td>-2,147,483,648</td>
<td>2,147,483,647</td>
</tr>
<tr>
<td>long</td>
<td>64 bits</td>
<td>&lt; -9 x 10^{18}</td>
<td>&gt; 9 x 10^{18}</td>
</tr>
<tr>
<td>float</td>
<td>32 bits</td>
<td>+/- 3.4 x 10^{38} with 7 significant digits</td>
<td></td>
</tr>
<tr>
<td>double</td>
<td>64 bits</td>
<td>+/- 1.7 x 10^{308} with 15 significant digits</td>
<td></td>
</tr>
</tbody>
</table>
Example: Representing Text

- Characters, including spaces, digits, and punctuation are represented by numeric codes

  Hi, Heather.

  72 105 44 32 72 101 97 116 104 101 114 46

  01110100  ASCII
  00000000 01110100  UNICODE

The ASCII (American Standard Code for Information Interchange) character set uses eight bits per character, allowing for 256 unique characters.

The Unicode character set extends ASCII to sixteen bits per character, allowing for 65,536 unique characters.

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Characters in Java

- A `char` variable stores a single character.
- Character literals are delimited by single quotes:
  
  'a'   'X'    '7'    '$'    ','    '\n'

```java
char topGrade = 'A';

char terminator = ';',' separator = ' ';

char nextToTopGrade = (char)(topGrade + 1);
```

Note the difference between a primitive character variable, which holds only one character, and a `String` object, which can hold multiple characters.
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Automatic type conversion

Values of different types can be combined in an assignment or an expression

• **Example:**

```java
int dollars = 5;

double money = dollars + 2.50;

System.out.println(dollars + " dollars");
```

• These are all examples of **widening conversions**, i.e., “smaller” data type \(\rightarrow\) “larger” data type
Converting from one type to another

- **Widening conversions**
  - “small” data type $\rightarrow$ “larger” one
  - eg: `int` $\rightarrow$ `double`
    - 32 bits $\rightarrow$ 64 bits

- **Narrowing conversions**
  - “large” data type $\rightarrow$ “smaller” one
  - eg: `double` $\rightarrow$ `int`
    - 64 bits $\rightarrow$ 32 bits
  - **narrowing conversions can lose information!**
  - **narrowing conversions cannot happen automatically (for example, through assignment)**
Casting

- *Casting* forces a change of type, even if information is lost
- Can be used for both widening and narrowing conversion
- To cast, put the type in parentheses in front of the value to be converted:

```java
int total = 5;
double result = (double) total / 2;
int answer = (int) result + 4;
double angle = 0;  // 0 radians
int x = (int)(Math.cos(angle) * 300);
```

(cast has higher precedence than arithmetic operators)
## Data Conversion

### Widening Conversions

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>short, int, long, float, or double</td>
</tr>
<tr>
<td>short</td>
<td>int, long, float, or double</td>
</tr>
<tr>
<td>char</td>
<td>int, long, float, or double</td>
</tr>
<tr>
<td>int</td>
<td>long, float, or double</td>
</tr>
<tr>
<td>long</td>
<td>float or double</td>
</tr>
<tr>
<td>float</td>
<td>double</td>
</tr>
</tbody>
</table>

### Narrowing Conversions

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>byte</td>
<td>char</td>
</tr>
<tr>
<td>short</td>
<td>byte or char</td>
</tr>
<tr>
<td>char</td>
<td>byte or short</td>
</tr>
<tr>
<td>int</td>
<td>byte, short, or char</td>
</tr>
<tr>
<td>long</td>
<td>byte, short, char, or int</td>
</tr>
<tr>
<td>float</td>
<td>byte, short, char, int, or long</td>
</tr>
<tr>
<td>double</td>
<td>byte, short, char, int, long, or float</td>
</tr>
</tbody>
</table>
How to use cast?

Forcing floating point division between int expressions

```c
int qp = 35;
int credits = 10;
double gpa = (double) qp / credits;
```

Gpa should be 3.5

```c
int qp = 35;
int credits = 10;
double gpa = (double) (qp / credits);
```
How to use cast?

**Scaling a double and converting to int**

```java
double gpa = 3.2;
int gpaPercent = (int) (gpa / 4) * 100;
```

`gpaPercent` should be 80

```java
double gpa = 3.2;
int gpaPercent = (int) ((gpa / 4) * 100);
```