



# AP<sup>®</sup> Computer Science A Picture Lab Student Guide

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Barbara Ericson of the Georgia Institute of Technology, who developed  
this lab and the accompanying documentation.*

# Picture Lab: Student Guide

## Introduction

In this lab you will be writing methods that modify digital pictures. In writing these methods you will learn how to traverse a two-dimensional array of integers or objects. You will also be introduced to nested loops, binary numbers, interfaces, and inheritance.

## Activities

You will be working through a set of activities. These activities will help you learn about how:

- digital pictures are represented on a computer;
- the binary number system is used to represent values;
- to create colors using light;
- Java handles two-dimensional arrays;
- data from a picture is stored; and
- to modify a digital picture.

## Set-up

You will need the `pixLab` folder and a Java Development Kit, also known as a JDK (see <http://www.oracle.com/technetwork/java/javase/downloads/index.html>). A development environment is also useful. DrJava is a free development environment for Java that allows students to try out code in an interactions pane. It also has a debugger, and can be downloaded from <http://drjava.org>. However, you can use any development environment with this lab. Just open the files in the `classes` folder and compile them. Please note that there are two small pictures in the `classes` folder that need to remain there: `leftArrow.gif` and `rightArrow.gif`. If you copy the Java source files to another folder you must copy these gif files as well.

Keep the `images` folder and the `classes` folder together in the `pixLab` folder. The `FileChooser` expects the images to be in a folder called `images`, at the same level as the `classes` folder. If it does not find the images there it also looks in the same folder as the class files that are executing. If you wish to modify this, change the `FileChooser.java` class to specify the folder where the pictures are stored. For example, if you want to store the images in “`r://student/images/`,” change the following line in the method `getMediaDirectory()` in `FileChooser.java`:

```
URL fileURL = new URL(classURL, "../images/");
```

And modify it to

```
URL fileURL = new URL("r://student/images/");
```

Then recompile.

## A1: Introduction to digital pictures and color

If you look at an advertisement for a digital camera, it will tell you how many *megapixels* the camera can record. What is a megapixel? A digital camera has sensors that record color at millions of points arranged in rows and columns (Figure 1). Each point is a *pixel* or *picture (abbreviated **pix**) element*. A *megapixel* is one million pixels. A 16.2 megapixel camera can store the color at over 16 million pixels. That's a lot of pixels! Do you really need all of them? If you are sending a small version of your picture to a friend's phone, then just a few megapixels will be plenty. But, if you are printing a huge poster from a picture or you want to zoom in on part of the picture, then more pixels will give you more detail.

How is the color of a pixel recorded? It can be represented using the RGB (Red, Green, Blue) color model, which stores values for red, green, and blue, each ranging from 0 to 255. You can make yellow by combining red and green. That probably sounds strange, but combining pixels isn't the same as mixing paint to make a color. The computer uses light to display color, not paint. Tilt the bottom of a CD in white light and you will see lots of colors. The CD acts as a prism and lets you see all the colors in white light. The RGB color model sometimes also stores an alpha value as well as the red, green, and blue values. The alpha value indicates how transparent or opaque the color is. A color that is transparent will let you see some of the color beneath it.

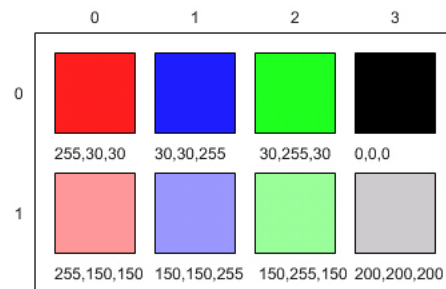


Figure 1: RGB values and the resulting colors displayed in rows and columns

How does the computer represent the values from 0 to 255? A decimal number uses the digits 0 to 9 and powers of 10 to represent values. The decimal number 325 means 5 ones ( $10^0$ ) plus 2 tens ( $10^1$ ) plus 3 hundreds ( $10^2$ ) for a total of three hundred and twenty-five. Computers use *binary numbers*, which use the digits 0 and 1 and powers of 2 to represent values using groups of bits. A *bit* is a **binary digit**, which can be either 0 or 1. A group of 8 bits is called a *byte*. The binary number 110 means 0 ones ( $2^0$ ) plus 1 two ( $2^1$ ) plus 1 four ( $2^2$ ), for a total of 6.

### Questions

1. How many bits does it take to represent the values from 0 to 255?
2. How many bytes does it take to represent a color in the RGB color model?
3. How many pixels are in a picture that is 640 pixels wide and 480 pixels high?

## A2: Picking a color

Run the `main` method in `ColorChooser.java`. This will pop up a window (Figure 2) asking you to pick a color. Click on the RGB tab and move the sliders to make different colors.

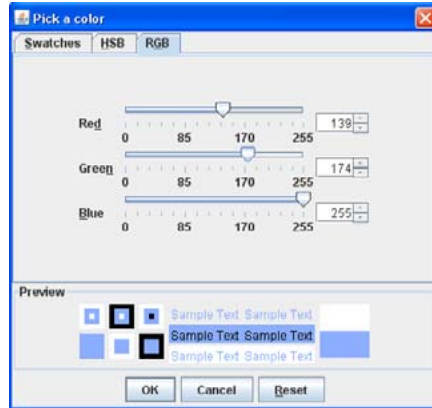


Figure 2: The Color Chooser (This is the version from Java 6.)

When you click the OK button, the red, green, and blue values for the color you picked will be displayed as shown below. The `Color` class has a `toString` method that displays the class name followed by the red, green, and blue values. The `toString` method is automatically called when you print an object.

```
java.awt.Color[r=139,g=174,b=255]
```

Java represents color using the `java.awt.Color` class. This is the *full name* for the `Color` class, which includes the *package* name of `java.awt` followed by a period and then the class name `Color`. Java groups related classes into *packages*. The *awt* stands for Abstract Windowing Toolkit, which is the package that contains the original Graphical User Interface (GUI) classes developed for Java. You can use just the short name for a class, like `Color`, as long as you include an import statement at the beginning of a class source file, as shown below. The `Picture` class contains the following import statement.

```
import java.awt.Color;
```

Use the `ColorChooser` class (run the `main` method) to answer the following questions.

### Questions

1. How can you make pink?
2. How can you make yellow?
3. How can you make purple?
4. How can you make white?

5. How can you make dark gray?

## How image processing is related to new scientific breakthroughs

Many of today's important scientific breakthroughs are being made by large, interdisciplinary collaborations of scientists working in geographically widely distributed locations, producing, collecting, and analyzing vast and complex datasets.

One of the computer scientists who works on a large interdisciplinary scientific team is Dr. Cecilia Aragon. She is an associate professor in the Department of Human Centered Design & Engineering and the eScience Institute at the University of Washington, where she directs the Scientific Collaboration and Creativity Lab. Previously, she was a computer scientist in the Computational Research Division at Lawrence Berkeley National Laboratory for six years, after earning her Ph.D. in Computer Science from UC Berkeley in 2004. She earned her B.S. in mathematics from the California Institute of Technology.



Her current research focuses on human-computer interaction (HCI) and computer-supported cooperative work (CSCW) in scientific collaborations, distributed creativity, information visualization, and the visual understanding of very large data sets. She is interested in how social media and new methods of computer-mediated communication are changing scientific practice. She has developed novel visual interfaces for collaborative exploration of very large scientific data sets, and has authored or co-authored many papers in the areas of computer-supported cooperative work, human-computer interaction, visualization, visual analytics, image processing, machine learning, cyberinfrastructure, and astrophysics.

In 2008, she received the Presidential Early Career Award for Scientists and Engineers (PECASE) for her work in collaborative data-intensive science. Her research has been recognized with four Best Paper awards since 2004, and she was named one of the Top 25 Women of 2009 by Hispanic Business Magazine. She was the architect of the Sunfall data visualization and workflow management system for the Nearby Supernova Factory, which helped advance the study of supernovae in order to reduce the statistical uncertainties on key cosmological parameters that categorize dark energy, one of the grand challenges in physics today.



Cecilia Aragon is also one of the most skilled aerobatic pilots flying today. A two-time member of the U.S. Aerobatic Team, she was a medalist at the 1993 U.S. National Championships and the 1994 World Aerobatic Championships, and was the California State Aerobatic Champion.

## Glossary

1. Abstract class — You cannot create an object of an abstract class type. But, you can create an object of a subclass of an abstract class (as long as the subclass is not also an abstract class).
2. Abstract method — An abstract method cannot have a method body in the class where the method is declared to be abstract.
3. Algorithm — A step-by-step description of how to solve a problem.
4. AWT — The Abstract Windowing Toolkit. It is the package that contains the original Graphical User Interface (GUI) classes developed for Java.
5. Binary number — A binary number contains only the digits 0 and 1. Each place is a power of 2 starting with  $2^0$  on the right. The decimal number 6 would be 110 in binary. That would be  $0 * 2^0 + 1 * 2^1 + 1 * 2^2 = 6$ .
6. Bit — A **binary digit**, which means that it has a value of either 0 or 1.
7. Byte — A consecutive group of 8 bits.
8. Column-major order — An order for storing two-dimensional array data in a one-dimensional array, so that all the data for the first column is stored before all the data for the second column and so on. In a two-dimensional array represented using an array of arrays (like in Java) this means that the outer array represents the columns and the inner arrays represent the rows.
9. Digital camera — A camera that can take digital pictures.
10. Digital picture — A picture that can be stored on a computer.
11. Inheritance — In Java, a class can specify the parent class from which it inherits instance variables (object fields) and object methods. Even though instance variables may be inherited, if they are declared to be private they cannot be directly accessed using dot notation in the inheriting class. Private methods that are inherited can also not be directly called in an inheriting class.
12. Inner loop — In a nested loop (a loop inside of another loop) the loop that is inside of another loop is considered the inner loop.
13. Interface — A special type of class that can only have public abstract methods in it and/or static constants.
14. Lossy compression — Lossy compression means that the amount of data that is stored is much smaller than the available data, but the part that is not stored is data that humans would not miss.
15. Media computation — A method of teaching programming by having students write programs that manipulate media: pictures, sounds, text, movies. This approach was developed by Dr. Mark Guzdial at Georgia Tech.
16. Megapixel — One million pixels.
17. Nested loop — One loop inside of another loop.
18. Outer loop — In a nested loop (a loop inside of another loop) the loop that is outside of another loop is considered the outer loop.
19. Package — A package in Java is a group of related classes.
20. Pixel — A picture (abbreviated **pix**) element.
21. RGB model — Represents color as amounts of red, green, and blue light. It sometimes also includes alpha, which is the amount of transparency.

- 22. Row-major order — An order for storing two-dimensional array data in a one-dimensional array, so that all the data for the first row is stored before all the data for the second row, and so on. In a two-dimensional array represented using an array of arrays (like in Java) this means that the outer array represents the rows and the inner arrays represent the columns.
- 23. Subclass — A class that has inherited from another class.
- 24. Superclass — A class that another class has inherited from.
- 25. UML —Unified Modeling Language. It is a general purpose modeling language used in object-oriented software development.



## References

Dann, W., Cooper, S., & Ericson, B. (2009) *Exploring Wonderland: Java Programming Using Alice and Media Computation*. Englewood, NJ: Prentice-Hall.

Guzdial, M., & Ericson B. (2006) *Introduction to Computing and Programming in Java: A Multimedia Approach*. Englewood, NJ: Prentice-Hall.

Guzdial, M., & Ericson, B. (2009) *Introduction to Computing and Programming in Python: A Multimedia Approach*. (2<sup>nd</sup> ed.). Englewood, NJ: Prentice-Hall.

Guzdial, M., & Ericson, B. (2010) *Problem Solving with Data Structures using Java: A Multimedia Approach*. Englewood, NJ: Prentice-Hall.

## Quick Reference

### DigitalPicture Interface

```
Pixel[][] getPixels2D()           // implemented in SimplePicture
void explore()                   // implemented in SimplePicture
boolean write(String fileName)   // implemented in SimplePicture
```

### SimplePicture Class (implements Digital Picture)

```
public SimplePicture()
public SimplePicture(int width, int height)
public SimplePicture(SimplePicture copyPicture)
public SimplePicture(String fileName)
public Pixel[][] getPixels2D()
public void explore()
public boolean write(String fileName)
```

### Picture Class (extends SimplePicture)

```
public Picture()
public Picture(int height, int width)
public Picture(Picture copyPicture)
public Picture(String fileName)
public Pixel[][] getPixels2D()           // from SimplePicture
public void explore()                   // from SimplePicture
public boolean write(String fileName)   // from SimplePicture
```

### Pixel Class

```
public double colorDistance(Color testColor)
public double getAverage()
public int getRed()
public int getGreen()
public int getBlue()
public Color getColor()
public int getRow()
public int getCol()
public void setRed(int value)
public void setGreen(int value)
public void setBlue(int value)
public void setColor(Color newColor)
```

### java.awt.Color Class

```
public Color(int r, int g, int b)
public int getRed()
public int getGreen()
public int getBlue()
```