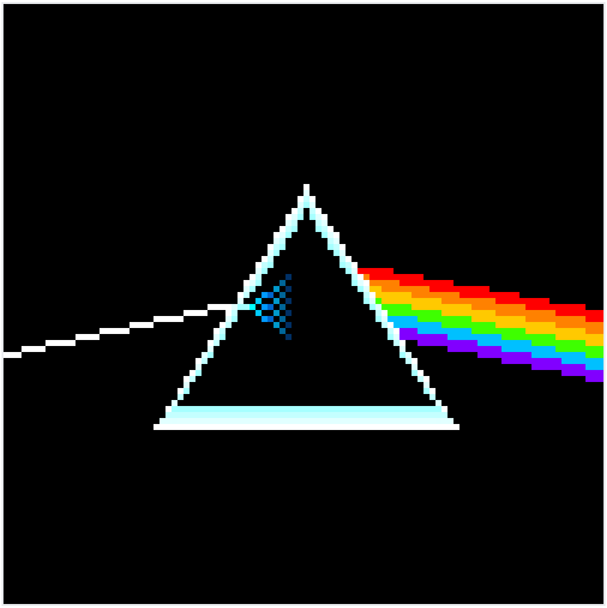
p4-coolpics

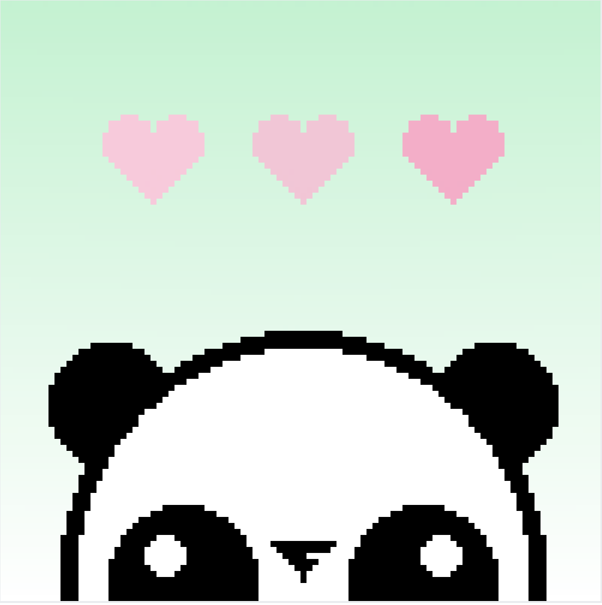
EECS 183 Project 4: CoolPics

Project Due Friday, November 4, 2022, 11:59 pm

Direct autograder link

In this project, you will create a program that reads in a description of shapes, draws those shapes, and saves the result to a file. You will represent the different shapes using classes. Here are some examples of images created by students in past semesters:





By completing this project, you will learn to:

- Develop an application using multiple classes
- Divide a C++ program into source and header files
- Read program input from a file with multiple line formats
- Write test cases for classes
- Write member function stubs given their declarations

You will apply the following skills you learned in lecture:

- Lecture 13
    - Use a stream's fail state to detect input format
    - Recover from a stream entering the fail state
    - Read and write to files using streams
- Lecture 14
    - Write code using classes
    - Write and use default and non-default constructors
- Lecture 15
    - Place class and member function declarations and definitions in the correct files
    - Access `public` and `private` portions of a class in the appropriate places
    - Write and use getter and setter functions
    - Define and use multiple non-default constructors
- Lecture 16
    - Create and use classes that contain member variables that are instances of other classes
- Lecture 17
    - Overload operator« and operator» to allow classes to be read from and written to streams
    - Write test cases for code structured with classes

Getting Started

Starter Files

Download the starter files using this link and create a project using them in your IDE.

You will be working with the following files:

File	Role	What you will do
`pics.cpp`	Driver for application	**Write code here and submit**

`test.cpp`	Test cases	**Write code here and submit**
`Circle.cpp, Color.cpp, Graphics.cpp, Line.cpp, Point.cpp, Rectangle.cpp, Triangle.cpp`	Member function definitions	**Write code here and submit**
`Circle.h, Color.h, Graphics.h, Line.h, Point.h, Rectangle.h, Triangle.h`	Class declarations	Do not modify!
`Shape.h, Shape.cpp`	Provided support code	Do not modify!
`bmp.h, utility.h`	Provided support code	Do not modify!
`.txt` files	Input to generate pictures	Use these as input for testing pics.cpp
`.bmp` files	Ouput from .txt files	Use these for testing the output of pics.cpp

We suggest writing the code in the following order:

1. `test.cpp` (ongoing as you develop each class)
2. `Point.cpp`
3. `Color.cpp`
4. `Graphics.cpp`
5. `Line.cpp`
6. `Triangle.cpp`
7. `Circle.cpp`
8. `Rectangle.cpp`
9. `pics.cpp`

Writing Function Stubs

The first time you try to run the starter code, you will see **many** compile errors. They will look something like the following.

```
Rectangle.obj : error LNK2001: unresolved external symbol "public: __thiscall P
```

These errors are due to missing function definitions for most of the class member functions. In previous projects in EECS 183, you were provided with all of the necessary functions for each project. The shell of the function definitons were given and you had to finish implementing them. For this project, you will be required to complete all of the shells of the function definitions. This must be completed for **all** classes before you will be able to compile your code. Each function declaration must have a corresponding function definition once any call to the function exists. This is called a function stub. You must write all of the stubs for each function definition immediately after creating your project in Visual Studio or Xcode.

A function stub for the Point class non-default constructor would look like the following, and appear in the file Point.cpp

```
Point::Point(int xVal, int yVal) {
    // to do - implement
}
```

While a function stub for the Point class checkRange function would look like the following:

```
int Point::checkRange(int val) {
    // to do - implement

    // to do - replace with correct return statement
    return val;
}
```

Submission and Grading

Submit your code to the autograder here. You receive 4 submits each day and your best overall submission counts as your score. *You will submit 11 files, which must be called `Circle.cpp`, `Color.cpp`, `Graphics.cpp`, `Line.cpp`, `pics.cpp`, `Point.cpp`, `Rectange.cpp`, `Triangle.cpp`, `test.cpp`, `data1.txt`, and `data2.txt`*

The `data1.txt` and `data2.txt` files can contain any content you wish. They are to help you write test cases for file I/O in `test.cpp`. You might use data1.txt with shapes you have added for reading in your test.cpp, and data2.txt to test writing.

- **Correctness (60 points).** To what extent does your code implement the features required by our specification? To what extent is your code consistent with our specifications and free of bugs?
- **Testing (10 points).** Write a test suite in `test.cpp` that exposes bugs on the autograder.
- **Style (10 points).** To what extent is your code written well? To what extent is your code readable? Consult the project style rubric and the EECS 183 Style Guide for some tips!

If you submit by 11:59 PM on Wednesday, November 2, you will earn 5% extra credit on the correctness portion of the project. If you submit by 11:59 PM on Thursday, November 3, you will earn 2.5% extra credit on the correctness portion of the project.

Working with a Partner

- For Projects 3 and 4, you may choose to work with one other student who is currently enrolled in EECS 183.
- Although you are welcome to work alone if you wish, we encourage you to consider partnering up for Project 4. If you would like a partner but don't know anyone in the class, we encourage you to use the Search for Teammates post on Piazza if you want to find someone! Please make sure to mark your search as *Done* once you've found a partner.
- As a further reminder, a partnership is defined as two people. You are encouraged to help each other and discuss the project in English (or in some other human language), but don't share project code with anyone but your partner.
- **To register a partnership on the autograder, go to the autograder link for the project and select "Send group invitation". Then, add your partner to the group by entering their email when prompted.** They will receive a confirmation after registration, and must accept the invitation before the partnership can submit. **You must choose whether or not to register for a group on the autograder before you can submit. If you select the option to work alone, you will not be able to work with a partner later in the project.** If a partnership needs to be changed after you register, you may submit an admin request.
- The partnership will be treated as one student for the purpose of the autograder, and you **will not** receive additional submits beyond the given ten submits per day.
- If you decide to work with a partner, be sure to review the guidelines for working with a partner.
- If you choose to use late days and you are working in a partnership, review this document for how late days will be charged against each partner.

Collaboration Policy

We want students to learn from and with each other, and we encourage you to collaborate. We also want to encourage you to reach out and get help when you need it. You are encouraged to:

- Give or receive help in understanding course concepts covered in lecture or lab.
- Practice and study with other students to prepare for assessments or exams.
- Consult with other students to better understand project specifications.
- Discuss general design principles or ideas as they relate to projects.
- Help others understand compiler errors or how to debug parts of their code.

To clarify the last item, you are permitted to look at another student's code to help them understand what is going on with their code. You are not allowed to tell them what to write for their code, and you are not allowed to copy their work to use in your own solution. If you are at all unsure whether your collaboration is allowed, please contact the course staff via the admin form before you do anything. We will help you determine if what you're thinking of doing is in the spirit of collaboration for EECS 183.

The following are considered Honor Code violations:

- Submitting others' work as your own.
- Copying or deriving portions of your code from others' solutions.
- Collaborating to write your code so that your solutions are identifiably similar.
- Sharing your code with others to use as a resource when writing their code.
- Receiving help from others to write your code.
- Sharing test cases with others if they are turned in as part of your solution.
- Sharing your code in any way, including making it publicly available in any form (e.g. a public GitHub repository or personal website).

The full collaboration policy can be found in the syllabus.

Suggested Timeline

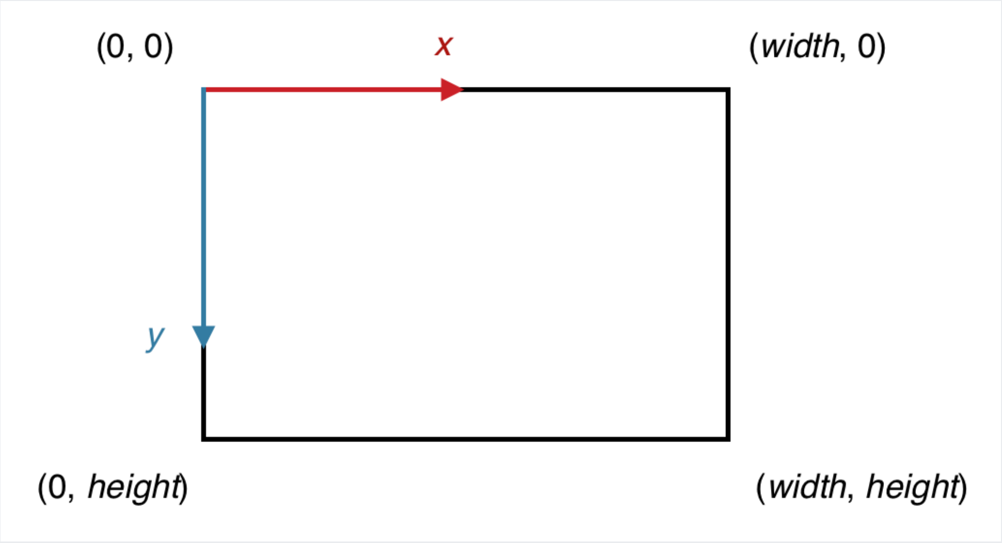
For this project, you will be implementing a variety of classes. You will be approximately on schedule if by each date you have written tests for, implemented, and submitted to the autograder each specified class.

- We, October 26: Written all function stubs and can compile your project locally.
- Fr, October 27: `Point.cpp`
- Sa, October 29: `Color.cpp` , `Graphics.cpp`
- Su, October 30: `Line.cpp` , `Triangle.cpp`
- Mo, October 31: `Circle.cpp` , `Rectangle.cpp` , and you have eaten plenty of candy :)
- We, November 2: `pics.cpp` and any final debugging. Make your final submission today for 5% extra credit!
- Fr, November 4: Project is due. Make your final submission to the autograder today before 11:59 PM.

Solution Overview

Your task in this project will be to write a program which can read in a .txt data file, process the data, and create and write a .bmp file for the corresponding image.

In computer 2D graphics, it is common to represent an image in a coordinate system where the *x* axis directed to the right, but the *y* axis is directed downward, so that the origin is in the top left corner. And so if the image is of size 100 pixels × 100 pixels, the pixel at coordinate (0,0) would be located in the top left corner, the pixel at coordinate (99,0) would be in the top right corner, the pixel at coordinate (0,99) would be in the bottom left corner and the pixel at coordinate (99,99) would be in the bottom right corner, as this graph demonstrates:



Color

Color is often represented with three numbers in computing. Red, green, and blue are the primary colors that are mixed to display the color of a pixel on a computer monitor. Nearly every color of emitted light that a human can see can be created by combining these three colors in varying levels. And so we can represent colors by specifying the amount of red, green and blue we want. If we use 8 bits to represent each of the three colors in a pixel, there are 2^8 = 256 possible values for a color. And so the intensity of red, green and blue ranges from 0 to 255, 0 meaning “no color” and 255 meaning “lots of that color”. Thus was developed the RGB representation of color: first the intensity of red is given, followed by the intensity of green and the intensity of blue. If you wanted to represent the color red, the value of red would be 255, the value of green would be 0 and the value of blue would be 0 and you’d have an RGB triple (255, 0, 0). The table below illustrates how red and some other colors are represented in the RGB model:

Color	Red value	Green value	Blue value
Red	255	0	0
Yellow	255	255	0

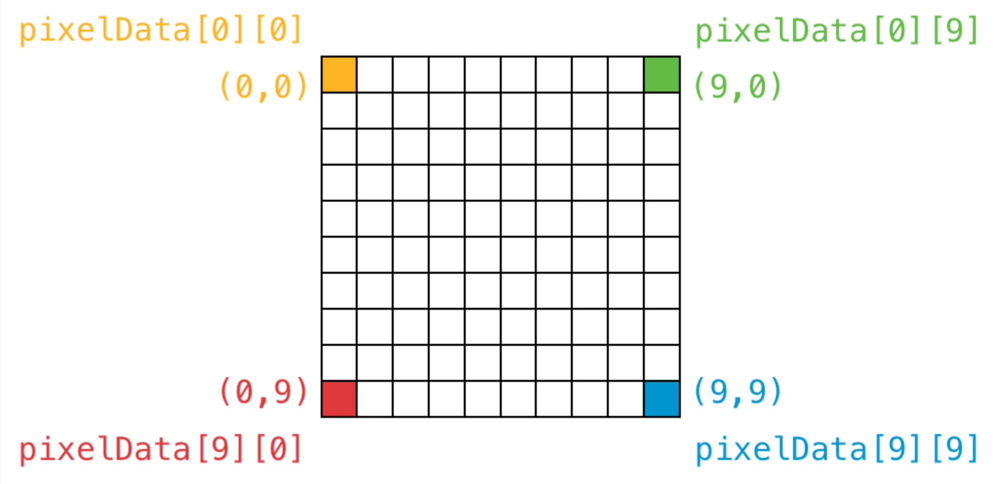
Color	Red value	Green value	Blue value
Green	0	255	0
Aqua	0	255	255
Blue	0	0	255
Magenta	255	0	255
White	255	255	255
Black	0	0	0

Incidentally, this same representation is used for the colors in HTML and CSS on the web. If interested, take a look at http://en.wikipedia.org/wiki/Web_colors for more details.

Graphics class

The Graphics class holds a representation of pixels in an image and provides some functions that can be used to do things such as setting an individual pixel or writing an entire image to a file. One of your tasks is to finish implementing these functions.

Notice that the pixel information is stored in `pixelData`, a two-dimensional array (100 × 100) of objects of class `Color`. This array thus defines "intensity values" of red, green and blue for each of the pixels in the image of size 100 pixels × 100 pixels. Recall that valid *x* and *y* coordinates range from 0 to 99 and allow the image below be an illustration of how you could access pixels in each of the four corners of the image.



Shape classes

There are multiple classes that represent shapes. Each of these classes contains a `draw` member function that is used to draw that shape in a `Graphics` instance.

Your application will create instances of these classes based on instructions in the input .txt file.

Point

A **point** is a representation of a single coordinate on the image. In the input .txt file, it starts with a left parenthesis and is followed by an *x* coordinate, a *y* coordinate and then by a right parenthesis, for example, `(1,2)`.

Points in CoolPics are not used to define a single pixel of color, instead they are used to define the coordinates of other shapes that can be seen, including Line, Triangle, Rectangle, and Circle.

Line

The input .txt file asks for a **line** using the following format: the input line will start with an `L` and be followed by the start point, the end point, and the color.

```
L (10,10) (90,20)  255 150 0
L (x1,y1) (x2,y2)   r   g  b
```

The line will go between the start point to the end point and will be of 'color'

Triangle

A **triangle** starts with a `T` which is followed by the three points of the triangle. Following the points, there is a color for the Triangle.

```
T (15,50) (15,90) (40,80)  0 140 20
T (x1,y1) (x2,y2) (x3,y3)  r  g  b
```

Triangle also has a second form where a color is defined for each vertex. In this form, triangle starts with a `T` and is followed by a point, color, point, color, point, color.

```
T (90,60)   0 0 255  (90,90)   0 255 0  (40, 80)  255 0 0
T (x1,y1)  r1 g1 b1  (x2,y2)  r2 g2 b2  (x3, y3)  r3 g3 b3
```

The three points determine the vertices of the triangle. The fill is a gradation of the three colors of the points (meaning that it will blend between the three colors based on the distance from each). To achieve two different forms of triangle input, we recommend creating two different constructors for the Triangle class.

Circle

A circle starts with a `C` , followed by a center point, radius, color.

```
C (50,50)  25   235 230 0
C center radius  r   g  b
```

Rectangle

A rectangle starts with an `R` and is followed by a start point (top-left), end point (bottom-right) and color.

```
R (20,20) (40,40)  80 30 200
R  start    end     r  g  b
```

The two points will be opposite top-left and bottom-right vertices of the rectangle and will fill between them with the specified color.

As with the Triangle class above, the Rectangle class must also be able to interpret a second form of input where four colors are specified (one in each corner), and the color is blended. In this specification, the first color corresponds to the top left corner of the Rectangle, and the other three colors are specified in clockwise order. Note that this is different from the way that blended Triangles are defined.

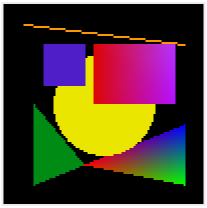
```
R (45,20) (85,49)  220 5 5   180 51 255   180 15 255     220 5 5
R  start    end   top-lt rgb top-rt rgb bottom-rt rgb bottom-lt rgb
```

Sample Input

Here’s an example of what an input file might look like:

```
L (10,10)  (90,20)  255 150 0
T (15,50)  (15,90)  (40,80)  0 140 20
T (90,60)  0 0 255  (90,90)  0 255 0  (40,80)  255 0 0
C (50,50)  25  235 230 0
R (20,20)  (40,40)  80 30 200
R (45,20)  (85,49)  220 5 5     180 51 255     180 15 255     220 5 5
```

It would ultimately produce this image:



operator» and operator«

In the distribution header files (`Line.h` , `Color.h` , `Circle.h` , etc.) you will notice a couple of lines of code very similar to the ones shown below, which are taken from `Line.cpp` .

```
istream& operator>> (istream& ins, Line& line);
ostream& operator<< (ostream& outs, Line line);
```

These are special function declarations that are used to “overload” the functionality of the `<<` and `>>` operators so that you can read and write class instances to and from streams.

Here are a few notes on how to interpret the first declaration:

1. The function returns a object of type `istream` (the `&` means that you are actually returning a reference to an `istream`).
2. `operator>>` is the name of the function. However, this function name is special because it tells C++ that you want this function to be called whenever a developer uses the `>>` operator like `cin >> x;` .
3. Notice that, when you use the `>>` operator, there are two operands involved (e. g., `cin` and `x` in the previous sample statement). The two declared function parameters (the first of type `istream` and the second of type `Line`) let C++ know that these are the left and right operands to be used, respectively, when calling `>>` .
4. The implementation of these functions looks like the following. More details will be covered in lecture:

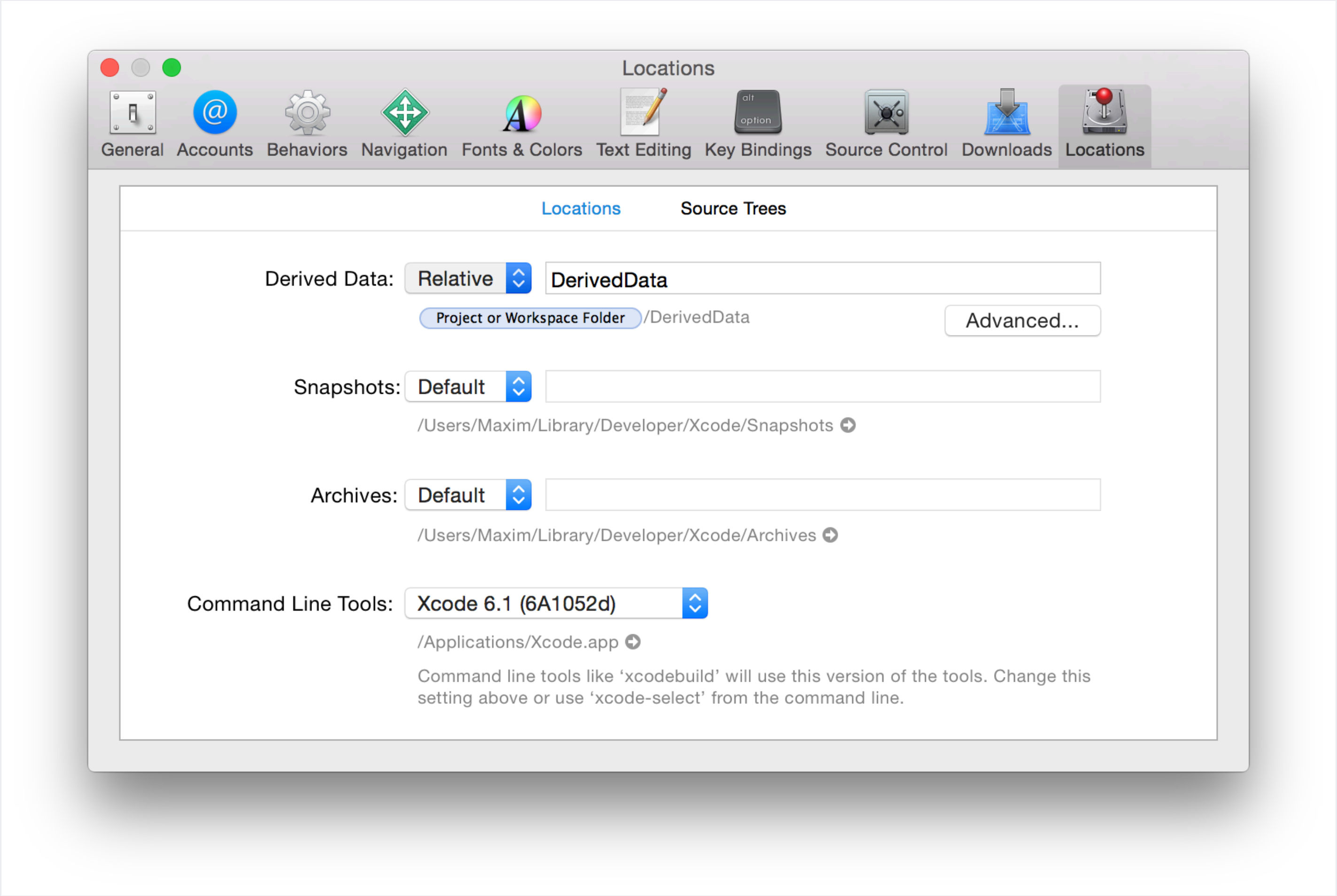
```
istream& operator>> (istream& ins, Line& line) {
    line.read(ins);
    return ins;
}
```

Setting up File I/O

File Locations

Xcode

There are a few things that must be done for Xcode. First, ensure that Derived Data is stored relative to your project folder. Select **Xcode > Preferences** in the menu bar, click on **Locations** icon at the top on the window and choose Relative next to Derived Data. This will ensure that executables are saved in your Project folder.



Derived Data: Relative DerivedData
Project or Workspace Folder /DerivedData

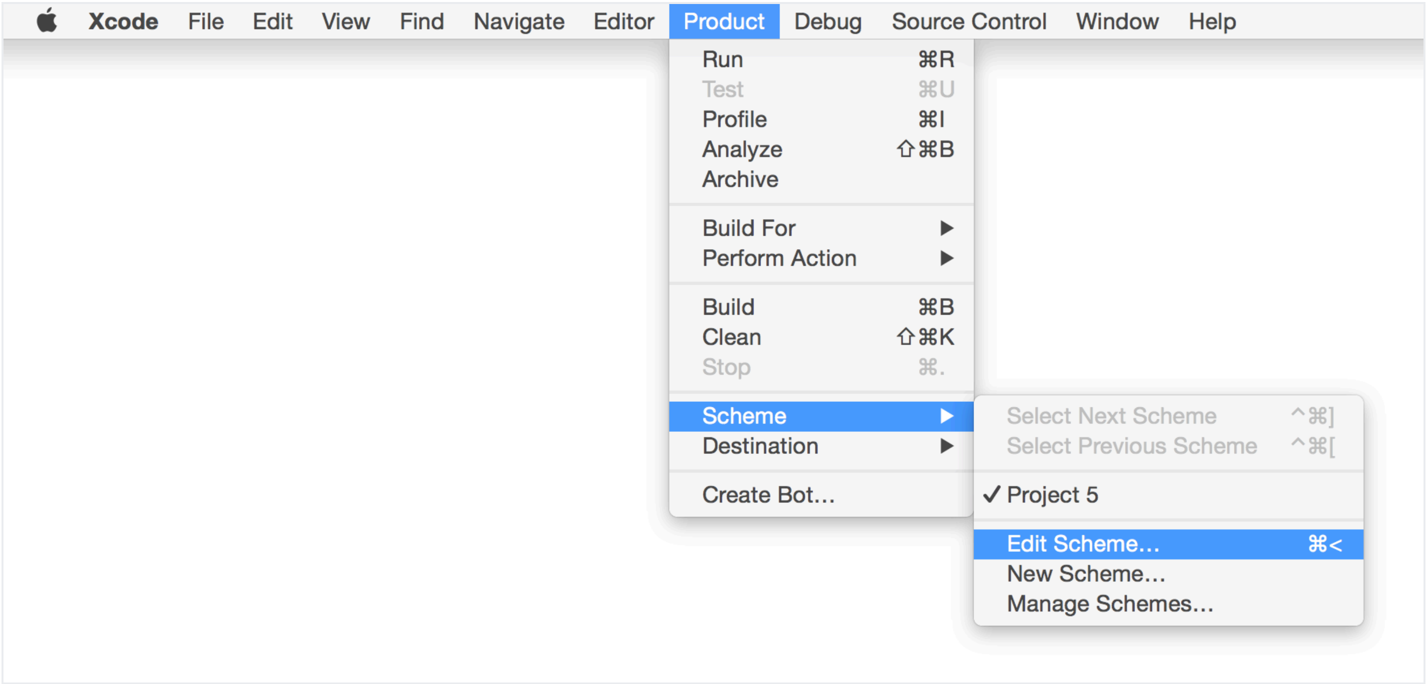
Snapshots: Default
/Users/Maxim/Library/Developer/Xcode/Snapshots

Archives: Default
/Users/Maxim/Library/Developer/Xcode/Archives

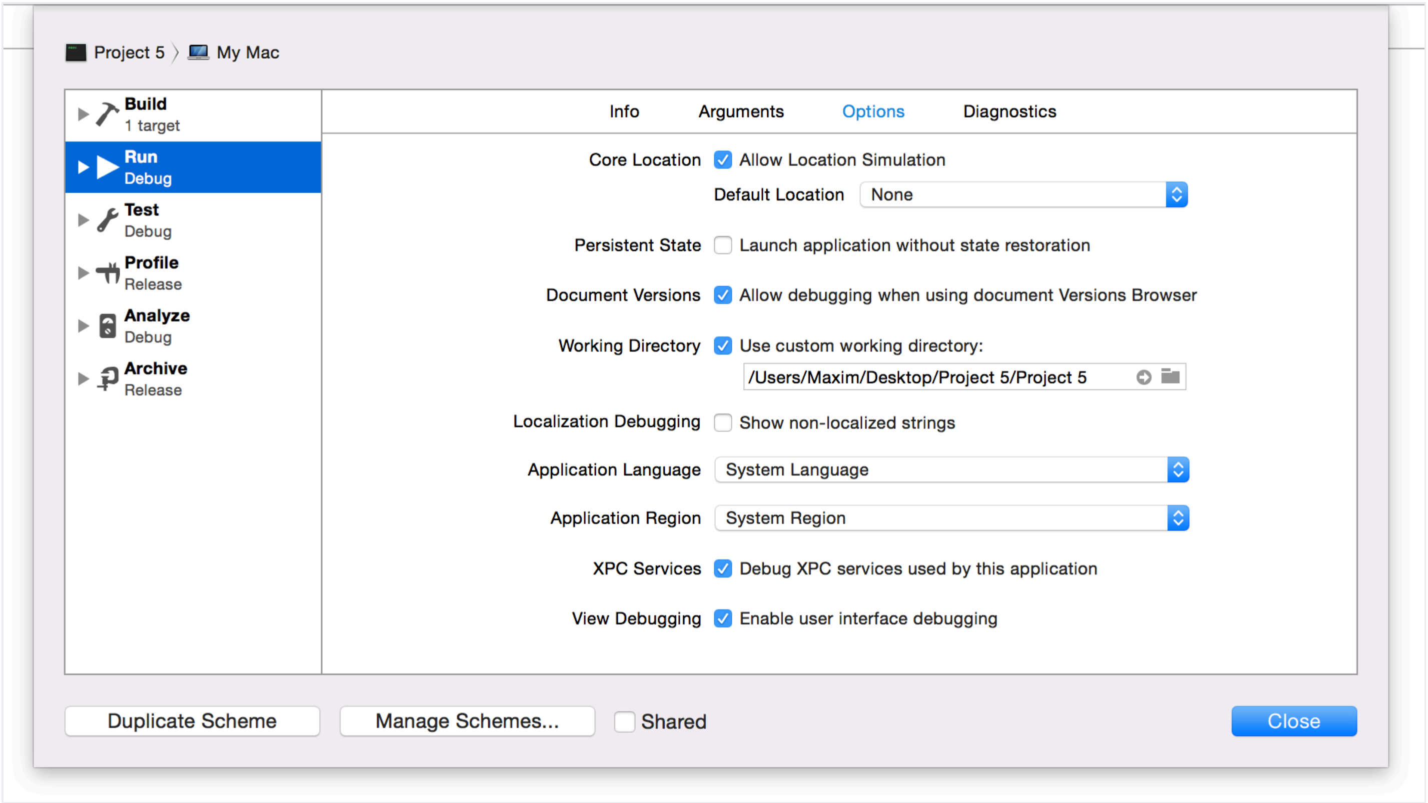
Command Line Tools: Xcode 6.1 (6A1052d)
/Applications/Xcode.app

Command line tools like 'xcodebuild' will use this version of the tools. Change this setting above or use 'xcode-select' from the command line.

Then, tell Xcode to look for files in the folder where all other project files are stored. From the menu bar, choose **Product > Scheme > Edit Scheme**.



Select **Run** on the left, **Options** on top and then select the checkbox **Use custom working directory** and navigate to your Project folder where you will store input files.



Core Location ☑ Allow Location Simulation

Default Location: None

Persistent State ☐ Launch application without state restoration

Document Versions ☑ Allow debugging when using document Versions Browser

Working Directory ☑ Use custom working directory:

/Users/Maxim/Desktop/Project 5/Project 5

Localization Debugging ☐ Show non-localized strings

Application Language: System Language

Application Region: System Region

XPC Services ☑ Debug XPC services used by this application

View Debugging ☑ Enable user interface debugging

☐ Shared

Now you can place input `txt` files right with your `.h` and `.cpp` files. You'll find `bmp` files created by your program in the same place.

If you move your project folder, you'll have to reset the project's working directory.

Visual Studio

Fortuately, Visual Studio's working directory is the project folder itselt. So head to the project folder that is named the same as the project. There should be another folder with that same name. Place the input files in that second folder.

User Commands

The user will interact with CoolPics program using the following commands:

- `load filename`

  The program will append `.txt` to the filename, open the file, and load the representation of the image into drawer.

- `write filename`

The program will append `.bmp` to the filename, open the file and write the image stored in drawer out to this file.

- `quit`

  This command will quit program after printing an ending message.

Commands from the menu should not be case sensitive (e.g., `Load` , `load` , `lOAd` , or `LoaD` should all work the same way).

Sample Run

Here is an example of the way your program output should look, wherein red text represents a user's input.

```
-------------------------------
EECS 183 Project 4 Menu Options
-------------------------------
1) Execute testing functions in test.cpp
2) Execute coolPics() function to make pics
Choice --> 2
=================================================
            Welcome to CoolPics
=================================================

Command:            Description:
--------            ------------
load filename       Loads data from a txt file
write filename      Creates a bmp image from data
quit                Quits the program

load snowman

[Loaded snowman.txt]
Command:            Description:
-------             ------------
load filename       Loads data from a txt file
write filename      Creates a bmp image from data
quit                Quits the program

write snowman

[Wrote snowman.bmp]
```

```
Command:            Description:
--------            ------------
load filename       Loads data from a txt file
write filename      Creates a bmp image from data
quit                Quits the program

quit

=================================================
            Thanks for using CoolPics!
=================================================
```

Testing

Classes

When it comes to a class, getting it to compile is only the beginning. There are many errors that do not show up at all until you call the different member functions. Therefore, in your testing, make sure you call every constructor and every member function. The code we provide in `test.cpp` gives an example of this for the Point class.

Similarity of Images

One way to test your program is to view the results by opening the BMP image and visually analyzing it. But because files are essentially sequences of bits, diff programs will work too (though not the online ones).

Visually

One of the easiest way to check the similarity or difference of two images is visually, by double-clicking. This can be done in most image manipulation tools (e.g., Preview, Photoshop, GIMP). For a demo of how to compare two images visually in GIMP, take a peak at http://www.youtube.com/watch?v=KLjdCJ9t4VU.

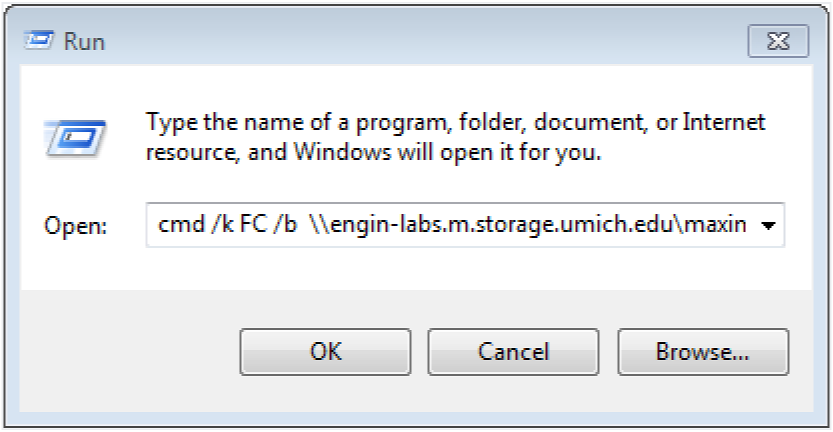
Mac

When you installed Xcode on your computer, it came with a program called FileMerge. You can open it by right-clicking on **Xcode** icon in the Dock and selecting **Open Developer Tool > FileMerge** from the top menu bar. Drag and drop two files into **Left** and **Right** fields and click

Compare. You’ll most likely see a message saying “Files are not ascii.” Click **Proceed anyway**. If files are identical, you’ll see **status: 0 differences** at the bottom of FileMerge window.

Windows

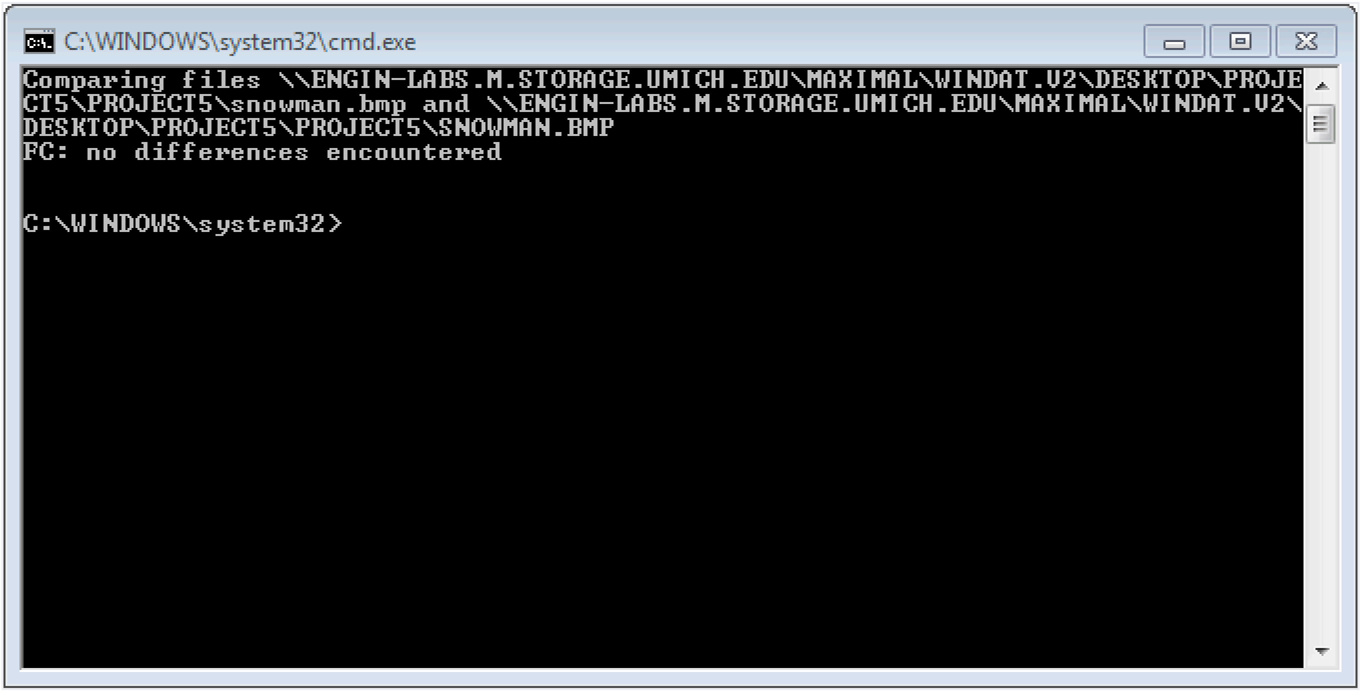
If you are using Windows, open the **Run** command, either by selecting it from the Start menu or by pressing **Windows + R**. Start typing `cmd /k FC /b` . Now you need to provide it with two paths for the two files you want to compare. You can either type the file paths by hand, or just drag the two files and drop them in the text box.



Type the name of a program, folder, document, or Internet resource, and Windows will open it for you.

Open: cmd /k FC /b \\engin-labs.m.storage.umich.edu\maxin

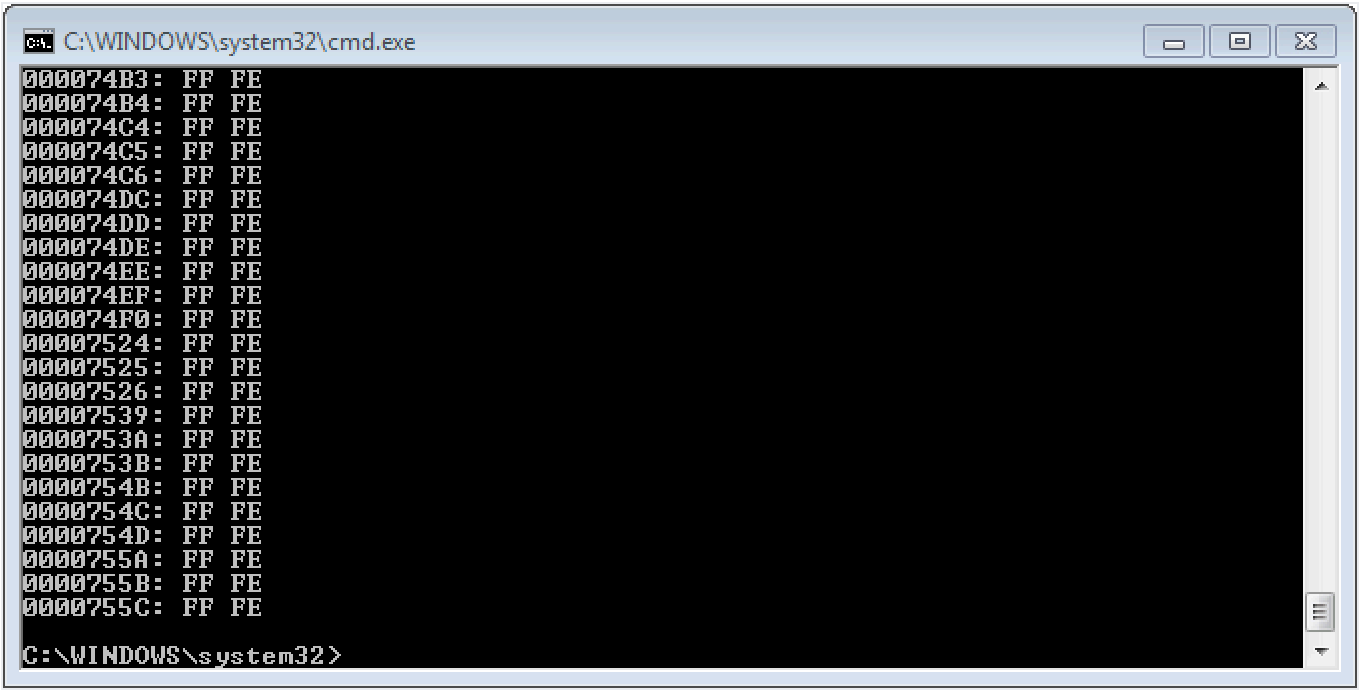
Press **OK** to start comparing two files. If the files are identical, you’ll see a windows similar to this one.



```
Comparing files \\ENGIN-LABS.M.STORAGE.UMICH.EDU\MAXIMAL\WINDAT.V2\DESKTOP\PROJE
CT5\PROJECT5\snowman.bmp and \\ENGIN-LABS.M.STORAGE.UMICH.EDU\MAXIMAL\WINDAT.V2\
DESKTOP\PROJECT5\PROJECT5\SNOWMAN.BMP
FC: no differences encountered


C:\WINDOWS\system32>
```

If instead the files are different, you’ll see something like this:



```
000074B3: FF FE
000074B4: FF FE
000074C4: FF FE
000074C5: FF FE
000074C6: FF FE
000074DC: FF FE
000074DD: FF FE
000074DE: FF FE
000074EE: FF FE
000074EF: FF FE
000074F0: FF FE
00007524: FF FE
00007525: FF FE
00007526: FF FE
00007539: FF FE
0000753A: FF FE
0000753B: FF FE
0000754B: FF FE
0000754C: FF FE
0000754D: FF FE
0000755A: FF FE
0000755B: FF FE
0000755C: FF FE

C:\WINDOWS\system32>
```

Bugs To Expose

For your `test.cpp`, there are a total of 26 unique bugs to find in our implementations. Your tests do not need to expose all of the bugs to receive full points for the lab. The autograder will tell you the names of the bugs that you have exposed, from the following set:

- POINT_NON_DEFAULT_CONSTRUCTOR
- POINT_SETTERS_1
- POINT_SETTERS_2
- POINT_GET_X
- LINE_CONSTRUCTOR
- LINE_SET_END
- LINE_GET_START
- LINE_WRITE
- COLOR_CONSTRUCTOR
- COLOR_SET_BLUE
- COLOR_GET_BLUE
- COLOR_GET_GREEN
- COLOR_CHECK_RANGE
- TRIANGLE_CONSTRUCTORS
- TRIANGLE_SET_VERTEX
- TRIANGLE_GET_VERTEX

- TRIANGLE_GET_VERTEX_COLOR
- TRIANGLE_WRITE
- CIRCLE_CONSTRUCTORS
- CIRCLE_SET_RADIUS
- CIRCLE_SET_CENTER
- RECTANGLE_CONSTRUCTORS_1
- RECTANGLE_CONSTRUCTORS_2
- RECTANGLE_SET_COLOR
- RECTANGLE_GET_END
- RECTANGLE_SET_START

Extra Credit

Maximum of 5 points!

This is an opportunity to earn extra credit for interesting, artistic, or fun inmages . Submit a file called `ec.txt` to generate a BMP image. You **must** use at least 3 different shapes and adhere to the spirit of the extra credit.

The teaching staff will do the judging. The file must be submitted to **https://autograder.io1789** by Friday November 4, 2022, 11:59 pm Eastern.

- This `txt` file **must** be named `ec.txt` . Note that the name is all lowercase ("ec" is short for "extra credit").
- When you create your own input `txt` files, remember that **the origin (0,0) is in the upper left-hand corner** and that the image will ultimately be 100 by 100 pixels.
- *Extra credit must be done individually;* ***you may not work with a partner on your extra credit file****.*
- For the 5 points extra credit, the image that is generated must be outstanding. Less outstanding will receive less points. If the generated image is one of the distribution images, it will receive 0 points.

Style

Your code must follow the EECS 183 style guide.

Style Rubric

Top Comment

Must have name, uniqname, program name, and project description at the top of each file.

If all or part of the top comment is missing, take 1 point off.

Readability violations

-1 for each of the following:

Indentations

- Not using a consistent number of spaces for each level of code indentation
  - This includes using tabs on some lines and spaces on others
- Not indenting lines at all
- Failing to indent the blocks of code inside curly braces

Spacing

- Not putting a space around operators (e.g., `5*7` instead of `5 * 7` or `count=0;` instead of `count = 0;`)
  - Includes stream insertion (<<) and extraction (>>) operators
- Not putting a space between if, while, or for and the condition to be evaluated
- Putting a space between a function name and the opening parenthesis

Bracing

- Using a mix of Egyptian-style and hanging braces
  - Egyptian-style: '{' at the end of a statement
  - Hanging: '{' on its own line
- Braces should always be used for conditionals, loops, and functions
  - Examples:

```
// good
```

```
if (x == 1) {
    return false;
}
if (x == 2)
{
    return true;
}

// bad
if (x == 1) return false;
if (x == 2)
    return true;
```

Variables

- Variable names not meaningful
- Inconsistent variable naming style (`camelCase` vs. `snake_case`)
    - Excluding const variables, which are always `SNAKE_CASE`
- Not declaring const variables as `const`
- Not using all uppercase `SNAKE_CASE` for `const` variable names
- Using variable types that do not make sense in context

Line limit

- Going over 80 characters on a line
    - Includes lines of comments and lines of code

Statements

- More than one statement on a single line
    - A statement ends in a semicolon
    - Do not count off for multiple statements as part of a for loop declaration

Comments

- Commenting on the end of a line of code

```
// A comment should be placed before a line of code
```

```
int count = 0; // not on the same line as the code
```

- Insufficient comments or excessive comments
    - Code should be thoroughly commented such that lines’ functionality is apparent from comments alone or from quickly glancing at code
    - Example of appropriate comment:

      ```
      // convert cups of flour to bags of flour
      int bagFlour = ceil((CUPS_FLOUR * numBatches) / CUPS_IN_LB_FLOUR);
      ```

    - Example of excessive comments:

      ```
      // declare variable
      int bagFlour;
      ```

    - Unneeded comments left in the code:

      ```
      // your code goes here
      // TODO: implement
      // this function doesn't work
      // FIXED
      ```

    - Commented out code:

      ```
      // int numBatches = people / 12;
      int numBatches = ceil(people / NUM_IN_BATCH);
      ```

RMEs

- Missing RMEs for any of the defined functions, except for main. This includes functions from the distribution code and any functions created by the student
- Having RMEs outside of header files

Coding quality

-2 for each of the following:

Global variables

- Global variables not declared as const

Magic numbers

- Using 100 instead of DIMENSION
- 0, 1, and 255 are OK

Egregious code

- Having redundant statements for RED and BLUE instead of using `opposite_color()`
- Logic that is clearly too involved or incorrect
  - e.g. instead of basing numbers on conversions, writing:

    ```
    if (year >= 1700 && year < 1800) {
       century = 17;
    } else if (year >= 1800 && year < 1900) {
       century = 18;
    }
    ```

    and so on

Function misuse

- Not calling helper functions where appropriate
  - Reimplementing reads and writes, instead of calling read and write method functions or using overloaded insertion and extraction operators
  - Reimplementing initArray instead of calling it where appropriate

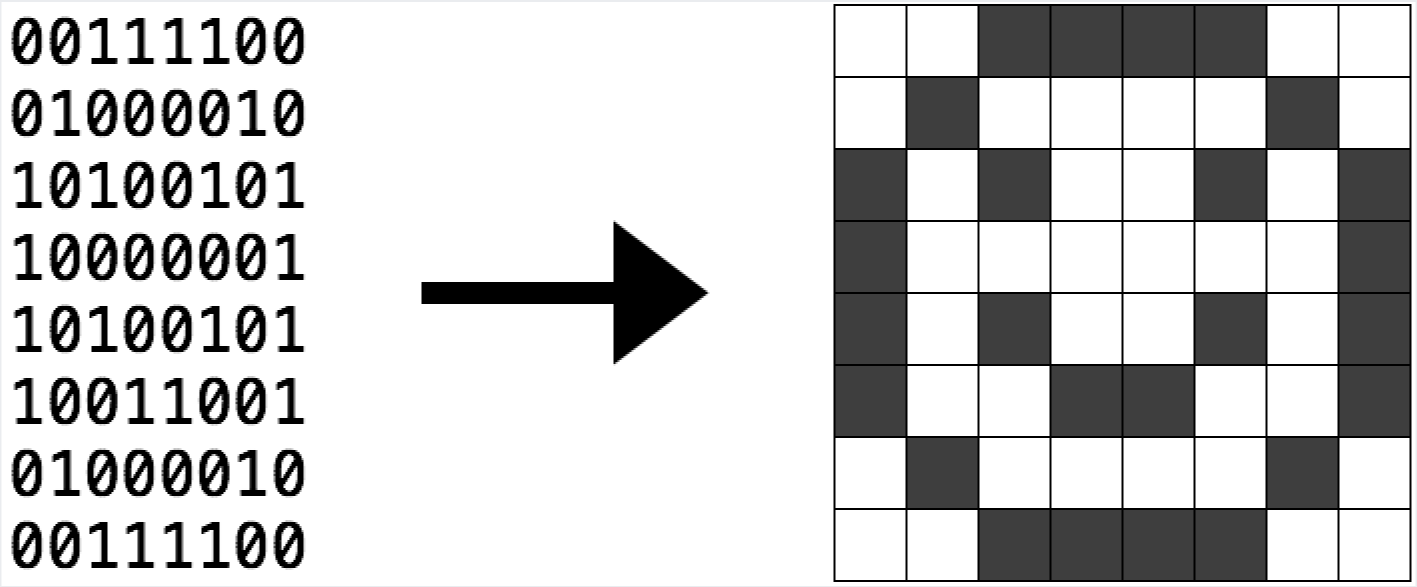
bools

- **Only deduct 1 point for this category**
- Writing `<bool> == true` , `<bool> != true` , `<bool> == false` , or `<bool> != false`
  - Same for comparing bools to `0` and `1`
- Returning `0` and `1` instead of `true` and `false` for a bool functions

Optional Appendix: BMP Image Format

If you’ve ever taken a digital photograph, then you’ve seen a JPEG image. If you’ve ever taken a screenshot on your Mac, then you’ve seen a PNG file. If you’ve ever seen a moving image on a webpage, then you’ve seen a GIF. If you’ve ever looked at Windows XP’s default wallpaper, then you’ve seen a BMP. JPEG, PNG, GIF and BMP are all different file formats that store graphical images. In this project, you will write a program that produces BMP images. Though the code to write BMP files is already written for you, it's still useful to know something about how BMP files are formatted.

Perhaps the simplest way to represent an image is with a grid of pixels. A pixel is just a dot, a single picture element. For instance, a black and white image can be represented with a two-color grid of bits: a 0 would mean that the pixel is off (white) and a 1 would meant that the pixel is on (black).



```
00111100
01000010
10100101
10000001
10100101
10011001
01000010
00111100
```

(Image adapted from http://www.brackeen.com/vga/bitmaps.html)

In this sense, an image is just a map of bits. For a larger image, you would simply need a larger grid, and for a more colorful image, you'd need more bits per pixel, in order to store more information. Many file formats support "24-bit color," which means they represent a pixel with 24 bits (24 zeroes and ones).

A 24-bit BMP uses 8 of those bits to signify the amount of red in a pixel's color, 8 bits to signify the amount of green in a pixel's color and 8 bits to signify the amount of blue in a pixel's color. Thus was developed the RGB representation of color. Incidentally, this same representation is used for the colors in HTML and CSS on the web. If interested, take a look at http://en.wikipedia.org/wiki/Web_colors for more details.

Since each color (red, green, blue) in a pixel is represented by 8 bits, there are 2^8 = 256 possible values for that color, ranging from 0 to 255. A value of 0 for a color would imply "no color", while the value of 255 would imply "a lot of that color."" So if you wanted to represent a pixel that is purely blue, it would have a value of 0 for red, a value of 0 for green and a value of 255 for blue. On the web—and in the rest of this discussion—instead of representing this with the decimal numbers 0-255, we use the equivalent hexadecimal numbers 00-FF, and colors can be defined with a 24-bit triplet of these hexadecimal values (e.g., `ff0000` is red `ffffff` is white and

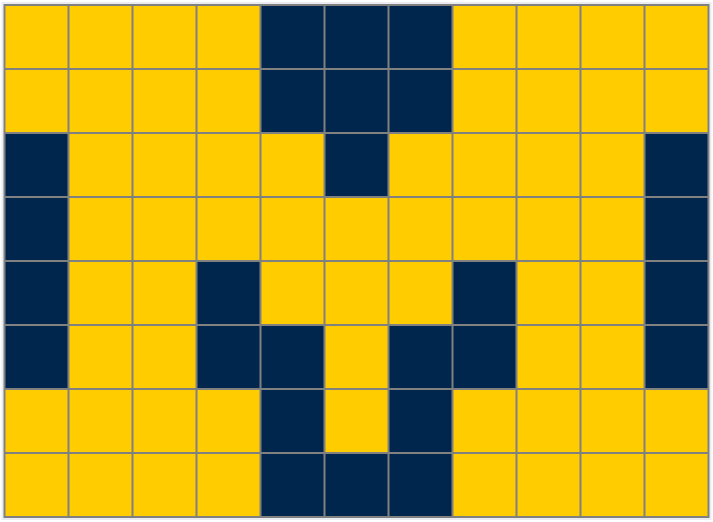
`0000ff` is blue). The above link, http://en.wikipedia.org/wiki/Web_colors, has an extensive explanation of using hex (i.e., hexadecimal) for color description.

Since a file is just a sequence of bits, we can create an image file by sequentially placing each 24 bits that represent colors in a pixel. This is (almost) how a BMP (bitmap) file is structured. First, it contains some “metadata”, general information about the file, such as the format, width, and height of the image. This metadata is stored in the beginning of the file in the form of two data structures known as “headers” (not to be confused with C++ header files). Don’t worry about what exactly should go in the headers (besides the image’s width and height); the staff has taken care of writing them to a file.

Immediately following the headers comes the representation of the image in a bitmap (i.e., a collection of pixels). Each pixel is stored as a triple (1 byte for each of red, green and blue values). However, BMP stores these triples backwards (i.e., as BGR), with 8 bits for blue, followed by 8 bits for green, followed by 8 bits for red. And so if we converted the above black and white smiley to red, each white pixel would be represented by the triple (255,255,255), or `ffffff` in hexadecimal, and each red pixel would be represented by (0,0,255), or similarly `0000ff` in hexadecimal. And we get

```
ffffff ffffff 0000ff 0000ff 0000ff 0000ff ffffff ffffff
ffffff 0000ff ffffff ffffff ffffff ffffff 0000ff ffffff
0000ff ffffff 0000ff ffffff ffffff 0000ff ffffff 0000ff
0000ff ffffff ffffff ffffff ffffff ffffff ffffff 0000ff
0000ff ffffff 0000ff ffffff ffffff 0000ff ffffff 0000ff
0000ff ffffff ffffff 0000ff 0000ff ffffff ffffff 0000ff
ffffff 0000ff ffffff ffffff ffffff ffffff 0000ff ffffff
ffffff ffffff 0000ff 0000ff 0000ff 0000ff ffffff ffffff
```

Now, a word on padding. It turns out that 24-bit BMPs are stored a bit differently if the number of pixels in each row is not a multiple of 4. `m.bmp`, for instance, is 11 pixels wide by 8 pixels tall.



The colors of the University of Michigan are Maize (`ffcb05`) and Blue (`00274c`). Each row in the image is composed of 11 pixels. And so the row is “padded” with zeroes to make up for the difference. In this case, 3 bytes (24-bits) of zeros are needed ((*12 pixels needed – 11 pixels*) ✕ *3 bytes per pixel*). And so each row requires 3 bytes of zero values (or one hexadecimal `000000` value) appended to its end, and we could represent the image as follows (remember that BMP switches red and blue):

```
05cbff 05cbff 05cbff 05cbff 4c2700 4c2700 4c2700 05cbff 05cbff 05cbff 05cbff 00
05cbff 05cbff 05cbff 05cbff 4c2700 4c2700 4c2700 05cbff 05cbff 05cbff 05cbff 00
4c2700 05cbff 05cbff 05cbff 05cbff 4c2700 05cbff 05cbff 05cbff 05cbff 4c2700 00
4c2700 05cbff 05cbff 05cbff 05cbff 05cbff 05cbff 05cbff 05cbff 05cbff 4c2700 00
4c2700 05cbff 05cbff 4c2700 05cbff 05cbff 05cbff 4c2700 05cbff 05cbff 4c2700 00
4c2700 05cbff 05cbff 4c2700 4c2700 05cbff 4c2700 4c2700 05cbff 05cbff 4c2700 00
05cbff 05cbff 05cbff 05cbff 4c2700 05cbff 4c2700 05cbff 05cbff 05cbff 05cbff 00
05cbff 05cbff 05cbff 05cbff 4c2700 4c2700 4c2700 05cbff 05cbff 05cbff 05cbff 00
```

In the image above, the padding zeros are shown in gray.