EECS 10: Assignment 5

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August 25, 2016

Due Monday September 5, 2016 at 11:00pm. Note: this is a one-week assignment.

1 Digital Image Processing [80 points + 20 bonus points]

In this assignment you will learn some basic digital image processing (DIP) techniques by developing an image manipulation program called *PhotoLab*. Using the *PhotoLab*, the user can load an image from a file, apply a set of DIP operations to the image, and save the processed image in a file.

1.1 Introduction

A digital image is essentially a two-dimensional matrix, which can be represented in C by a two-dimensional array of pixels. A pixel is the smallest unit of an image. The color of each pixel is composed of three primary colors, i.e. red, green, and blue; each color is represented by an intensity value between 0 and 255. In this assignment, you will work on images with a fixed size, 530×384, and type, Portable Pixel Map (PPM).

The structure of a PPM file consists of two parts, a header and image data. In the header, the first line specifies the type of the image, P6; the next line shows the width and height of the image; the last line is the maximum intensity value. After the header follows the image data, arranged as RGBRGBRGB..., pixel by pixel in binary representation.

Here is an example of a PPM image file:

```
P6
530 384
255
RGBRGBRGB...
```

1.2 Initial Setup

Before you start working on the assignment, do the following:

```
mkdir hw5
cd hw5
cp ~eecs10/hw5/PhotoLab.c ./
cp ~eecs10/hw5/Sydney.ppm ./
cp ~eecs10/hw5/index.html ~/public_html/
```

NOTE: Please execute the above setup commands only **ONCE** before you start working on the assignment! Do not execute them after you start the implementation, otherwise your code will be overwritten!

The file *PhotoLab.c* is the template file where you get started. It provides the functions for image file reading and saving, test automation as well as the DIP function prototypes and some variables (do not change those function prototypes or variable definitions). You are free to add more variables and functions to the program.

The file *Sydney.ppm* is a PPM images that we will use to test the DIP operations. Once a DIP operation is done, you can save the modified image. You will be prompted for a name of the image. The saved image *name.ppm* will be automatically converted to a JPEG image and sent to the folder *public_html* in your home directory. You are then able to see the image in a web browser at: *http://newport.eecs.uci.edu/∼youruserid*, if a given name is provided(i.e. 'bw', 'negative', 'hflip', 'vflip', 'sharpen', 'noise', 'vmirror' or 'zoomin' for each corresponding function). If you save images by other names, use the link *http://newport.eecs.uci.edu/∼youruserid/imagename.jpg* to access the photo.

Note that whatever you put in the *public_html* directory will be publicly accessible; make sure you do not put files that you don't want to share, i.e. do not put your source code into that directory.

1.3 Program Specification

In this assignment, your program should be able to read and save image files. To let you concentrate on DIP operations, the functions for file reading and saving are provided. These functions are able to catch many file reading and saving errors, and show corresponding error messages.

Your program is a menu driven program. The user should be able to select DIP operations from a menu as the one shown below:

```
--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Note: options '9: Zoom in' and '10: Mirror an image vertically' are bonus questions (10 pts each). If you decide to skip these two options, you still need to implement the option '11: Test all functions'.

1.3.1 Load a PPM Image

This option prompts the user for the name of an image file. You don't have to implement a file reading function; just use the provided one, *ReadImage*. Once option 1 is selected, the following should be shown:

```
Please input the file name to load: Sydney
```

After a name, for example *Sydney*, is entered, the *PhotoLab* will load the file Sydney.ppm. Note that, in this assignment please always enter file names without the extension when you load or save a file (i.e. enter 'Sydney', instead of 'Sydney.ppm'). If it is read correctly, the following is shown:

```
please make your choice: 1
Please input the file name to load: Sydney
Sydney.ppm was read successfully!
```

```
--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Then, you can select other options. If there is a reading error, for example the file name is entered incorrectly or the file does not exist, the following message is shown:

```
please make your choice: 1
Please input the file name to load: Sydney.ppm
Cannot open file "Sydney.ppm" for reading!

--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

In this case, try option 1 again with the correct filename.

1.3.2 Save a PPM Image

This option prompts the user for the name of the target image file. You don't have to implement a file saving function; just use the provided one, *SaveImage*. Once option 2 is selected, the following is shown:

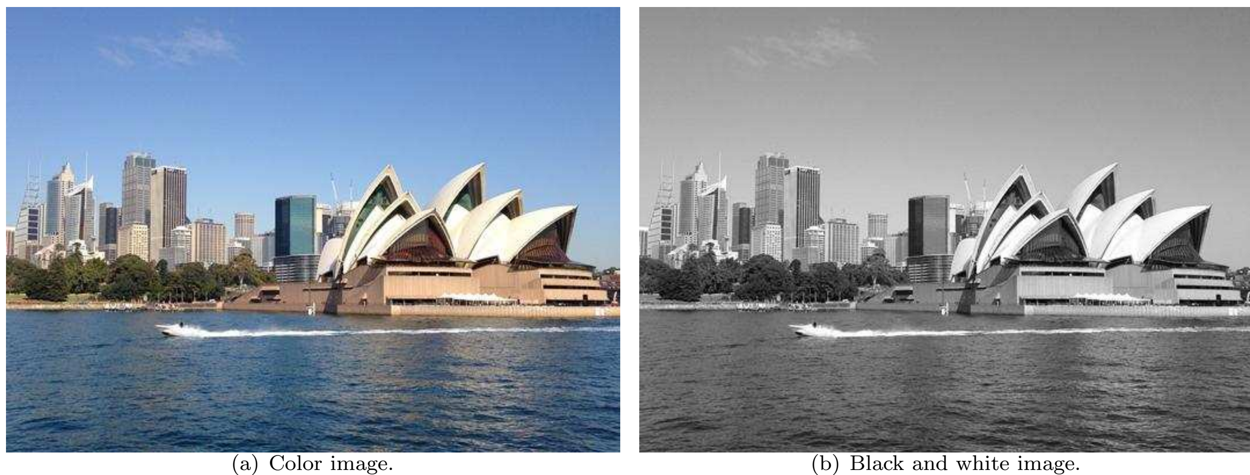
```
please make your choice: 2
Please input the file name to save: bw
bw.ppm was saved successfully.
bw.jpg was stored for viewing.

--------------------------------
 1: Load a PPM image
```

```
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

The saved image will be automatically converted to a JPEG image and sent to the folder *public_html*. You then are able to see the image at: *http://newport.eecs.uci.edu/∼youruserid* (For off campus, the link is: *http://newport.eecs.uci.edu/∼youruserid/imagename.jpg*)

1.3.3 Change a Color Image to Black and White



(a) Color image. (b) Black and white image.

Figure 1: A color image and its black and white counterpart.

A black and white image is the one that the intensity values are the same for all color channels, red, green, and blue, at each pixel. To change a color image to grey, assign a new intensity, which is given by $(R+G+B)/3$, to all the color channels at a pixel. The R, G, B are the old intensity values for the red, the green, and the blue channels at the pixel. You need to define and implement the following function to do the job.

```
/* Change a color image to black and white */
void  BlackNWhite(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

Figure 1 shows an example of this operation. Your program's output for this option should be like:

```
Please make your choice: 3
"Black & White" operation is done!
```

```
--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Save the image with name 'bw' after this step.

1.3.4 Make a Negative of an Image

A negative image is an image in which all the intensity values have been inverted. To achieve this, each intensity value at a pixel is subtracted from the maximum value, 255, and the result is assigned to the pixel as a new intensity. You need to define and implement a function to do the job.

You need to define and implement the following function to do this DIP.

```
/* Reverse the image color */
void  Negative(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

(a) Original image.

(b) Negative image.

Figure 2: An image and its negative counterpart.

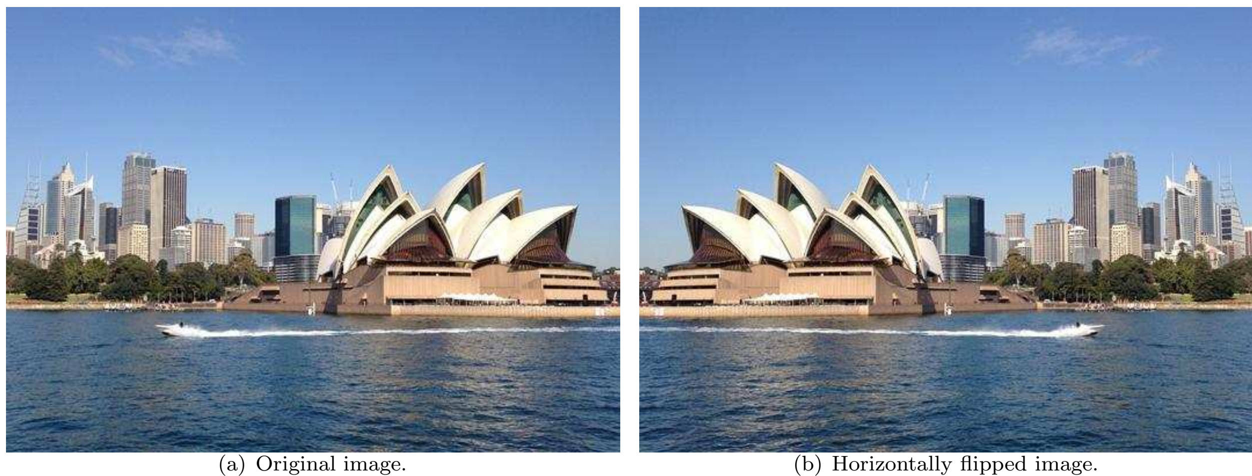
Figure 2 shows an example of this operation. Your program's output for this option should be like:

```
Please make your choice: 4
"Negative" operation is done!
```

```
--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Save the image with name 'negative' after this step.

1.3.5 Flip an Image Horizontally



(a) Original image. (b) Horizontally flipped image.

Figure 3: An image and its horizontally flipped counterpart.

To flip an image horizontally, the intensity values in horizontal direction should be reversed. The following shows an example.

```
                          1 2 3 4 5                              5 4 3 2 1
  Before horizontal flip: 0 1 2 3 4      After horizontal flip:  4 3 2 1 0
                          3 4 5 6 7                              7 6 5 4 3
```

You need to define and implement the following function to do this DIP.

```
/* Flip an image horizontally */
void  HFlip(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

Figure 3 shows an example of this operation. Your program's output for this option should be like:

```
Please make your choice: 5
"HFlip" operation is done!

--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Save the image with name 'hflip' after this step.

1.3.6 Flip an Image Vertically

(a) Original image.

(b) Vertically flipped image.

Figure 4: An image and its vertically flipped counterpart.

To flip an image vertically, the intensity values in vertical direction should be reversed. The following shows an example.

```
                        1 2 3 4 5                               3 4 5 6 7
  Before vertical flip: 0 1 2 3 4       After vertical flip:    0 1 2 3 4
                        3 4 5 6 7                               1 2 3 4 5
```

You need to define and implement the following function to do this DIP.

```
/* Flip an image vertically */
void  VFlip(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

Figure 4 shows an example of this operation. Your program's output for this option should be like:

```
Please make your choice: 6
"VFlip" operation is done!

--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Save the image with name 'vflip' after this step.

1.3.7 Sharpen

The sharpening works this way: the intensity value at each pixel is mapped to a new value, which is the sum of itself and its 8 neighbours with different parameters. To sharpen the image is very similar to finding edges. Adding the original image to its edge will result in a new image where the edges are enhanced, and make it look sharper. Note the sum of all parameters is 1, which will result in an image with the same brightness as the original, but sharper. The following shows an example of the filter and the applied pixel:

```
    Filter :            Original Pixels
    X  X  X  X  X        X  X  X  X  X
    X -1 -1 -1  X        X  A  B  C  X
    X -1  9 -1  X        X  D  E  F  X
    X -1 -1 -1  X        X  G  H  I  X
    X  X  X  X  X        X  X  X  X  X
```

To sharpen an edge of the image, the intensity of the center pixel (E) with the value is changed to $(-A - B - C - D + 9 * E - F - G - H - I)$. Repeat this for every pixel, and for every color channel (red, green, and blue) of the image. You need to define and implement a function to do this DIP. Note that you have to set the boundary for the newly generated pixel value, i.e., the value should be within the range of [0,255]
Note that special care has to be taken for pixels located at the image boundaries. For ease of implementation, you may choose to ignore the pixels at the border of the image where no neighbor pixels exist.
You need to define and implement the following function to do this DIP.

```
/* Sharpen an image */
void Sharpen(unsigned char R[WIDTH][HEIGHT],
             unsigned char G[WIDTH][HEIGHT],
             unsigned char B[WIDTH][HEIGHT]);
```

The sharpen image should look like the figure shown in Figure 5(b):

(a) Original Image

(b) Sharpened Image

Figure 5: An image and its sharpened counterpart.

```
Ple1ase enter your choice: 7
"Sharpen" operation is done!
--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Save the image with name 'sharpen' after this step.

1.3.8 Add Noise to an Image

In this operation, you add noise to an image. The noise added is a special kind, called salt-and-pepper noise, which means the noise is either black or white. You need to define and implement a function to do the job. If the percentage of noise is n, then the number of noise added to the image is given by $n * WIDTH * HEIGHT/100$, where $WIDTH$ and $HEIGHT$ are the image size. You need the knowledge of random number generation from the previous assignments. Figure 6 shows an example of this operation with n set to 20%.

You need to define and implement the following function to do this DIP.

```
/* Add noise to an image */
void  AddNoise(unsigned int percentage, unsigned char R[WIDTH][HEIGHT],
        unsigned char G[WIDTH][HEIGHT] ,unsigned char B[WIDTH][HEIGHT]);
```

(a) Original image.

(b) Noise setting: n=20.

Figure 6: An image and its noise (salt-and-pepper) corrupted counterpart.

Once user chooses this option, yout program's output should be like:

```
please make your choice: 8
"Add noise" operation is done!

--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

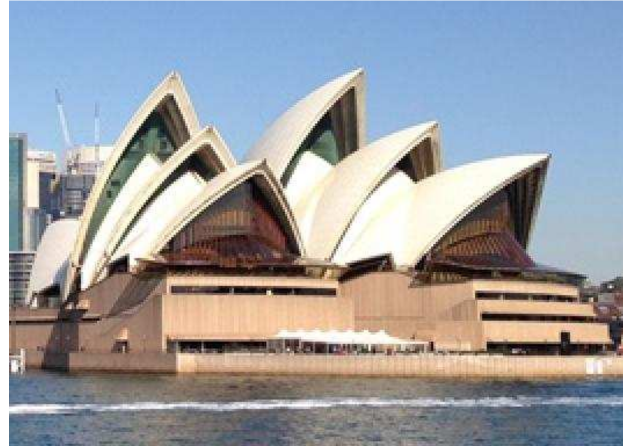
Save the image with name 'noise' after this step.

Implementation hint: calculate first the number of noise pixels depending on the noise percentage; then, use the random number generator to determine the position (x and y coordinates) of each noise pixel. Create a white or black pixel by setting the intensity value at each color channel to its maximum (255) or minimum (0) respectively. Noted that the number of white pixels should be approximately equal to the number of black pixels.

1.3.9 Zoom In [Bonus: 10 pts]

In this section, you need to implement a simple zoom-in 2x function, which enlarge the right-top part of the image by a factor of two.

(a) Original image.



(b) 2x zoom-in image.

Figure 7: An image and its 2x zoom-in counterpart.

To zoom in, the intensity values in the center of the picture are distributed to the whole picture. The following shows an example:

```
                  1 |5  4| 10                            5  5  4  4
                  4 |2  6| 11                            5  5  4  4
  Before zoom-in: 3  8  7  14       After zoom-in: 2  2  6  6
                  2  9  2  12                            2  2  6  6
```

You need to define and implement a function to do this DIP. The part of the image you want to zoom in is within the area of (220, 0), (220, 245), (384, 245) and (384, 0).

```
/* Zoom in an image */
void  Zoomin(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

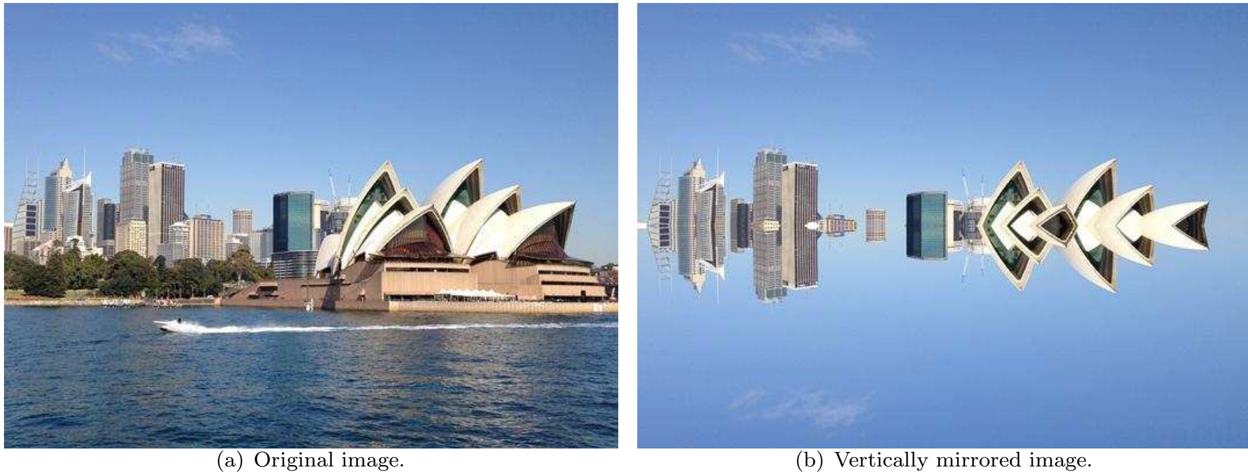
Figure 7 shows an example of this operation.

```
please make your choice: 9
"Zoom in 2x" operation is done!

--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Save the image with name 'zoomin' after this step.

1.3.10 Mirror an Image Vertically [Bonus: 10 pts]



(a) Original image. (b) Vertically mirrored image.

Figure 8: An image and its vertically mirrored counterpart.

To mirror an image vertically, the intensity values in horizontal direction at the top should be reversed and copied to the bottom. The following shows an example.

```
                            1 2 3 4 5                                1 2 3 4 5
  Before horizontal mirror: 4 3 2 1 0      After horizontal mirror: 4 3 2 1 0
                            3 4 5 6 7                                1 2 3 4 5
```

You need to define and implement the following function to do this DIP.

```
/* Mirror an image vertically */
void  VMirror(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

Figure 8 shows an example of this operation. Your program's output for this option should be like:

```
please make your choice: 10
"VMirror" operation is done!

--------------------------------
 1: Load a PPM image
 2: Save an image in PPM and JPEG format
 3: Change a color image to black and white
 4: Make a negative of an image
 5: Flip an image horizontally
 6: Flip an image vertically
 7: Sharpen an image
 8: Add noise to an image
 9: Zoom in (Bonus)
 10: Mirror an image vertically (Bonus)
 11: Test all functions
 12: Exit
please make your choice:
```

Save the image with name 'vmirror' after this step.

1.3.11 Test all Functions

Finally, you are going to write a function to test all previous functions. In this function, you are going to call DIP functions one by one and to observe the results. The function is for the designer to quickly test the program, so you should supply all necessary parameters when testing. The function should look like:

```
void  AutoTest(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT])
{
    char fname[SLEN] = "Sydney";
    char sname[SLEN];

    ReadImage(fname, R, G, B);
    BlackNWhite(R, G, B);
    strcpy(sname, "bw");
    SaveImage(sname, R, G, B);
    printf("Black & White tested!\n\n");

    ReadImage(fname, R, G, B);
    Negative(R, G, B);
    strcpy(sname, "negative");
    SaveImage(sname, R, G, B);
    printf("Negative tested!\n\n");

...

    ReadImage(fname, R, G, B);
    Sharpen(R, G, B);
    strcpy(sname, "sharpen");
    SaveImage(sname, R, G, B);
    printf("Sharpen tested!\n\n");

...

...

    ReadImage(fname, R, G, B);
    VMirror(R, G, B);
    strcpy(sname, "vmirror");
    SaveImage(sname, R, G, B);
    printf("VMirror tested!\n\n");

...

}
```

Once user chooses this option, your program's output should be like:

```
please make your choice: 11
Sydney.ppm was read successfully!
bw.ppm was saved successfully.
bw.jpg was stored for viewing.
Black & White tested!
```

```
Sydney.ppm was read successfully!
negative.ppm was saved successfully.
negative.jpg was stored for viewing.
Negative tested!

...
...
```

1.4 Implementation

1.4.1 Function Prototypes

For this assignment, you need the following functions (those function prototypes/declarations are already provided in *PhotoLab.c*. Please do not change them):

```
/* Print a menu */
void  PrintMenu();

/* Read an image from a file */
int   ReadImage(char fname[SLEN], unsigned char R[WIDTH][HEIGHT],
        unsigned char G[WIDTH][HEIGHT], unsigned char B[WIDTH][HEIGHT]);

/* Save a processed image */
int   SaveImage(char fname[SLEN], unsigned char R[WIDTH][HEIGHT],
        unsigned char G[WIDTH][HEIGHT], unsigned char B[WIDTH][HEIGHT]);

/* Change a color image to black & white */
void  BlackNWhite(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);

/* Reverse the image color */
void  Negative(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);

/* Flip an image horizontally */
void  HFlip(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);

/* Flip an image vertically */
void  VFlip(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);

/* Sharpen an image */
void  Sharpen(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);

/* Add noise to an image */
void  AddNoise(unsigned int percentage, unsigned char R[WIDTH][HEIGHT],
        unsigned char G[WIDTH][HEIGHT], unsigned char B[WIDTH][HEIGHT]);

/* Zoom in an image */
void  Zoomin(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

```
/* Mirror an image vertically */
void  VMirror(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);

/* Test all functions */
void  AutoTest(unsigned char R[WIDTH][HEIGHT], unsigned char G[WIDTH][HEIGHT],
        unsigned char B[WIDTH][HEIGHT]);
```

You may define other functions as needed.

NOTE: The *ReadImage()*, *SaveImage()* and *Border()* functions are already defined in *PhotoLab.c*. The *AutoTest()* function is partially defined (You need to complete the definition of *AutoTest()*). The *AutoTest()* function is called in the *main()* function without the menu. This is just an example to show how to call the *AutoTest()* function. You need to add the code for the menu of this program and use proper function calls for different DIP operations.

1.4.2 Global Constants

You also need the following global constants (they are also declared in *PhotoLab.c*, please do not change their names):

```
  #define WIDTH  530 /* Image width */
  #define HEIGHT 384 /* Image height */
  #define SLEN    80 /* Maximum length of file names */
```

1.4.3 Pass in arrays by reference

In the main function, three two-dimensional arrays are defined. They are used to save the RGB information for the current image:

```
int main()
{
    unsigned char R[WIDTH][HEIGHT];  /* for image data */
    unsigned char G[WIDTH][HEIGHT];
    unsigned char B[WIDTH][HEIGHT];
}
```

When any of the DIP operations is called in the main function, those three arrays, R[WIDTH][HEIGHT], G[WIDTH][HEIGHT], B[WIDTH][HEIGHT] are the parameters passed into the DIP functions. Since arrays are passed by reference, any changes to R[ ][ ], G[ ][ ], B[ ][ ] in the DIP functions will be applied to those variables in the main function. In this way, the current image can be updated by DIP functions without defining global variables.

In your DIP function implementation, there are two ways to save the target image information in R[ ][ ], G[ ][ ], B[ ][ ]. Both options work and you should decide which option is better based on the specific DIP manipulation function at hand.

Option 1: using local variables You can define local variables to save the target image information. For example:

```
void DIP_function_name()
{
    unsigned char RT[WIDTH][HEIGHT];  /* for target image data */
```

```
    unsigned char GT[WIDTH][HEIGHT];
    unsigned char BT[WIDTH][HEIGHT];
}
```

Then, at the end of each DIP function implementation, you should copy the data in RT[ ][ ], GT[ ][ ], BT[ ][ ] over to R[ ][ ], G[ ][ ], B[ ][ ].

Option 2: in place manipulation Sometimes you do not have to create new local array variables to save the target image information. Instead, you can just manipulate on R[ ][ ], G[ ][ ], B[ ][ ] directly. For example, in the implementation of Negative() function, you can assign the result of 255 minus each pixel value directly back to this pixel entry.

2 Script File

To demonstrate that your program works correctly, perform the following steps and submit the log as your script file:

1. Start the script by typing the command: *script*.
2. Compile and run your program.
3. Choose 'Test all functions' (The file names must be 'bw', 'negative', 'hflip', 'vflip', 'sharpen', 'noise', 'vmirror', and 'zoomin' for the corresponding functions).
4. Exit the program.
5. Stop the script by typing the command: *exit*.
6. Rename the script file to *PhotoLab.script*.

NOTE: make sure you use exactly the same names as shown in the above steps when saving modified images! The script file is important, and will be checked in grading; you must follow the above steps to create the script file.

3 Submission

Use the standard submission procedure to submit the following files:

- *PhotoLab.c* (with your code filled in!)
- *PhotoLab.script*
- *PhotoLab.txt*

Please leave the images generated by your program in your *public_html* directory. Don't delete them as we may consider them when grading! You don't have to submit any images.