

UNIVERSITY OF NEVADA, RENO



CS 302 — DATA STRUCTURES

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## Assignment #2

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## Contents

<b>1</b>	<b>Introduction</b>	<b>2</b>
<b>2</b>	<b>Use of Code</b>	<b>2</b>
<b>3</b>	<b>Functions</b>	<b>3</b>
3.1	Image.h	3
3.2	driver.cpp	15
3.3	cubicspline.h	35
3.4	imageIO.h	38
3.5	comp_curses.h	39
<b>4</b>	<b>Bugs and Errors</b>	<b>42</b>
<b>5</b>	<b>What was Learned</b>	<b>43</b>
<b>6</b>	<b>Division of Labor</b>	<b>44</b>
<b>7</b>	<b>Extras</b>	<b>44</b>

## List of Figures

1	subImage Example	9
2	Cubic Enlarge Example	9
3	Standard Enlarge Example	10
4	shrinkImage Example	10
5	reflectImage Example	12
6	translateImage Example	12
7	rotateImage Example	14
8	operator+ Example	14
9	operator- Example	16
10	negateImage Example	16
11	The Main Menu	18
12	difference image with noise	45
13	difference image without noise	45

## 1 Introduction

In this assignment, the students were asked to make an image class that manipulated a Portable Gray Map (PGM) and Portable Pixmap (PPM) images in various ways. The PPM format was to use a 2D array of a RGB class that the students were to implement, and the PGM format was stored using a 2D int array.

One of the first problems faced was how to use the supplied read and write image files. These functions were provided to simplify the build process as they allowed the students to concentrate on the manipulation of the images. These files were also changed slightly to accommodate the PPM and PGM file formats and were overloaded to accept either file.

After reading and writing images was mastered, the students undertook the bulk of the assignment which was to manipulate the images that had been read in with the supplied read function. This required the knowledge of manipulating dynamic 2D arrays of both the RGB and int classes.

The assignment also required the use of constructors, destructors, copy constructors, and operator overloading. These topics were reviewed from CS 202, but the use of them refreshed the students' minds on how they work and to their purposes. The students also had to implement these functions for the RGB class.

The students also extensively documented their program and made it as easy as possible to understand what was happening in the various algorithms that were implemented. The students realized that commenting and documenting the source code for projects is extremely important and is essential to the success of a powerful programmer.

## 2 Use of Code

The use of the program should be very intuitive. The user must use the arrow keys to scroll in the menu and press enter to select some option. The main program will first have the student decide to choose if the user wants to edit color or gray scale images. This is a limitation and was done to prevent the code from becoming too complex. The menu will then pop up windows and message boxes depending on the user's selection and the user's input. This provides for a very effective setup and takes the burden out of trying to look at the keyboard and the menu for key choices in a simple menu. Our menu uses ncurses to accomplish the scrolling menu. The students adapted a ncurses API written by Micheal Leverington from CS 135 to implement a simple curses menu at the beginning, but after all of the functions were completed, the students decided to make a more robust menu capable of scrolling. This was not required, but was done for aesthetic reasons and for the experience that it allowed the students.

The image class that was implemented has all of the requirements for the functions. Each function is defined exactly like Dr. Bebis wanted them to be defined and the coders adapted their coding style to match what Dr. Bebis expected. The code is built fairly modular and most of the time expects the class user to bounds and error check before information is sent to the class. The image class has also been templated. This allows the user to use any image type as long as there is a read and write function provided. The RGB class was also made to hold the data for the color images. As long as the read and write functions hold their info in a Red, Green, Blue setup, the image class should be able to handle the image. There is some rudimentary error checking in the class itself, but it only prevents the most foul and gross errors. The class is also setup to throw string objects in the case of an error. These thrown strings must be caught in the driver, so it is

up to the class user to implement the catches for these thrown strings. Strings were used as the errors because of their ease of use and ease of manipulation by the class user.

The file IO functions that were provided by Dr. Bebis have been combined into a single file pair (.cpp and .h) called imageIO. This allows a much more unified and modular approach to the use of the image IO features. It also makes including the functions much easier to include into multiple source files. This file has been modified from the last lab to have the ability to read and write PPM and PGM files. The PPM functions depend on the RGB class to store the data.

Whenever a new image is needed by the user of the class, the user should always use the setImageInfo function that is included in the image class. This function takes the rows, columns, and levels and creates a blank image to manipulate. Another feature of this function is that it creates a checkered background of 25x25 squares that make it easy to see the dimensions of the image if it is saved without modification. It is also helpful for functions that take an image and move them somehow. For instance, if an image was translated by 55 pixels, the program user could see that there is 2.2 squares that are uncovered, showing that the images has been translated 55 pixels. This was a design choice that came about as a result of how other image manipulation programs work and the students attempt at creating a robust image manipulation resource.

One last area that needs some mention to properly use is the function of operator+. This function includes a coefficient that determines the weight that each image has when adding them together. The students mimicked Dr. Bebis name for this coefficient and called it 'a'. When 'a' is large, the first image has more weight in the addition; when 'a' is small, the second image has more weight, and when 'a' is .5, the images have equal weight in the addition. The coefficient can be between 0 and 1.

## 3 Functions

### 3.1 Image.h

#### CONSTRUCTOR

```
ImageType();
```

#### Purpose

default constructor allocates no memory and sets the size to zero

#### Input

None

#### Output

None

#### Assumptions

Sets everything to zero and sets the pixelValue array to NULL

#### CONSTRUCTOR WITH PARAMETERS

```
ImageType(int , int , int );
```

#### Purpose

change the dimensions of the image, delete, and re-allocate memory if required

---

**Input**

An N, M, and Q value to set the new image to

**Output**

None

**Assumptions**

Sets the image to a certain size and initializes the image as a grid

**DESTRUCTOR**

```
~ImageType ( );
```

**Purpose**

Deletes and memory that has been dynamically allocated

**Input**

None

**Output**

None

**Assumptions**

Checks to see if the pixelValue array has been set if so, deletes

**COPY\_CONSTRUCTOR**

```
ImageType( const ImageType<pType>& );
```

**Purpose**

Creates a new array based on the thing to be copied then sets the pixelValue of the new object the same as the old image

**Input**

ImageType rhs is the old image to be copied over into the new array

**Output**

None

**Assumptions**

The old image must be passed as reference to prevent an infinite loop

**OPERATOR=**

```
ImageType<pType>& operator= ( const ImageType<pType>& );
```

**Purpose**

equal operator overload, this is basically the same as the copy constructor except it will likely have to de-allocate memory before copying values, all this is decided in setImageInfo however

**Input**

imageType rhs which is the old image to be copied over to the new image

---

**Output**

Returns the `imageType` object so that equal chaining can be implemented

**Assumptions**

Assumes that the user is not trying to copy the same object into itself

**GETIMAGEINFO**

```
void getImageInfo(int&, int&, int&) const;
```

**Purpose**

returns the width height and color depth to reference variables

**Input**

- rows  
This parameter grabs the number of rows in the `imageType` object
- cols  
This parameter grabs the number of cols in the `imageType` object
- levels  
This parameter grabs the depth of the image in the `imageType` object

**Output**

None

**Assumptions**

Assumes nothing but it makes sense that the object being queried has been loaded with some image

**SETIMAGEINFO**

```
void setImageInfo(int, int, pType);
```

**Purpose**

Sets the image info, deleting and allocating memory as required, also creates a background grid

**Input**

- rows  
This parameter sets the number of rows in the `imageType` object
- cols  
This parameter sets the number of cols in the `imageType` object
- levels  
This parameter sets the depth of the image in the `imageType` object

**Output**

None

**Assumptions**

Assumes nothing

## GETPIXELVAL

```
int getPixelVal(int , int) const;
```

## Purpose

Returns the value of a pixel

## Input

- *i*  
The row of the pixel
- *j*  
The column of the pixel

## Output

The integer value of the pixel at pixelValue[i][j]

## Assumptions

It is assumed that the image has been initialized

## SETPIXELVAL

```
pType setPixelVal(int , int , int);
```

## Purpose

Sets the value of a pixel

## Input

- *i*  
The row of the pixel to be changed
- *j*  
The column of the pixel to be changed

## Output

None

## Assumptions

Assumes the image has been initialized

## GETSUBIMAGE

```
void getSubImage( int , int , int , int , const ImageType<pType>& );
```

## Purpose

Obtain a sub-image from old. Uses the coordinates of the upper left corner and lower right corner to obtain image.

## Input

- *ULr*  
The upper left row of the pixel to be x in (0,0) in the new image.
- *ULc*  
The upper left column of the pixel to be y in (0,0) in the new image

- LRr  
The lower right row of the pixel to be x in (max\_x, max\_y) in the new image
- LRC  
The lower right row of the pixel to be y in (max\_x, max\_y) in the new image

**Output**

None

**Assumptions**

Assumes that the UL{r,c} and LR{r,c} have been properly bounds and error checked before the function call

**Example**

See figure 1 on page 9

**MEANGRAY**

```
double meanGray() const;
```

**Purpose**

this calculates the average gray value in the picture, this is done by adding all of the pixels and dividing by the total number of pixels

**Input**

None

**Output**

A double value that is the mean value of all the pixels in pixelValue

**Assumptions**

Assumes nothing and returns 0 if the image has not been initialized

**ENLARGEIMAGE**

```
void enlargeImage( double , const ImageType<pType>& );
void enlargeImage( int , const ImageType<pType>& );
```

**Purpose**

This function enlarges an image by a magnitude of s, so for example if the original function was 100x100 and s is 10, then the new image is 1000x1000

**Input**

- S  
This is the magnitude of the enlargement  
The function is also overloaded to accept ints as well as doubles
- ImageType old  
This is the image to be enlarged
- cubic  
A bool value that decides which type of interpolation to use. If true, use cubic interpolation If false, use linear interpolation



**Output**

None

**Assumptions**

The method chosen to use was bi-cubic/linear interpolation which creates splines for each column(cubic or linear), then using those splines create an image which is a stretched version of the original image. The way this was achieved was to stretch the entire image only vertically, and then stretch that image horizontally. Then the same thing was done except reversed (stretched image horizontally first) and then the two image summed together. This gives an average value between both methods. Although it can handle S values less than 1, the shrinkImage function works better for this.

**Example**

See figure 2 on page 9

See figure 3 on page 10

**SHRINKIMAGE**

```
void shrinkImage( int , const ImageType<pType>& );
```

**Purpose**

Shrink image, average all the values in the block to make the new pixel, this makes the shrink much less jagged looking in the end

**Input**

- s  
The integer value of the shrink factor
- ImageType old  
The image to be shrunk

**Output**

None

**Assumptions**

Assumes the image has been initialized and that error checking has been done.

**Example**

See figure 4 on page 10

**REFLECTIMAGE**

```
void reflectImage( bool , const ImageType<pType>& );
```

**Purpose**

reflects image by moving the pixel to N or M minus the current row or column depending on the value of the flag (true being a horizontal reflection and false being a vertical reflection)

**Input**

- flag  
The flag that sets either vertical or horizontal reflection

Figure 1: subImage Example



Figure 2: Cubic Enlarge Example

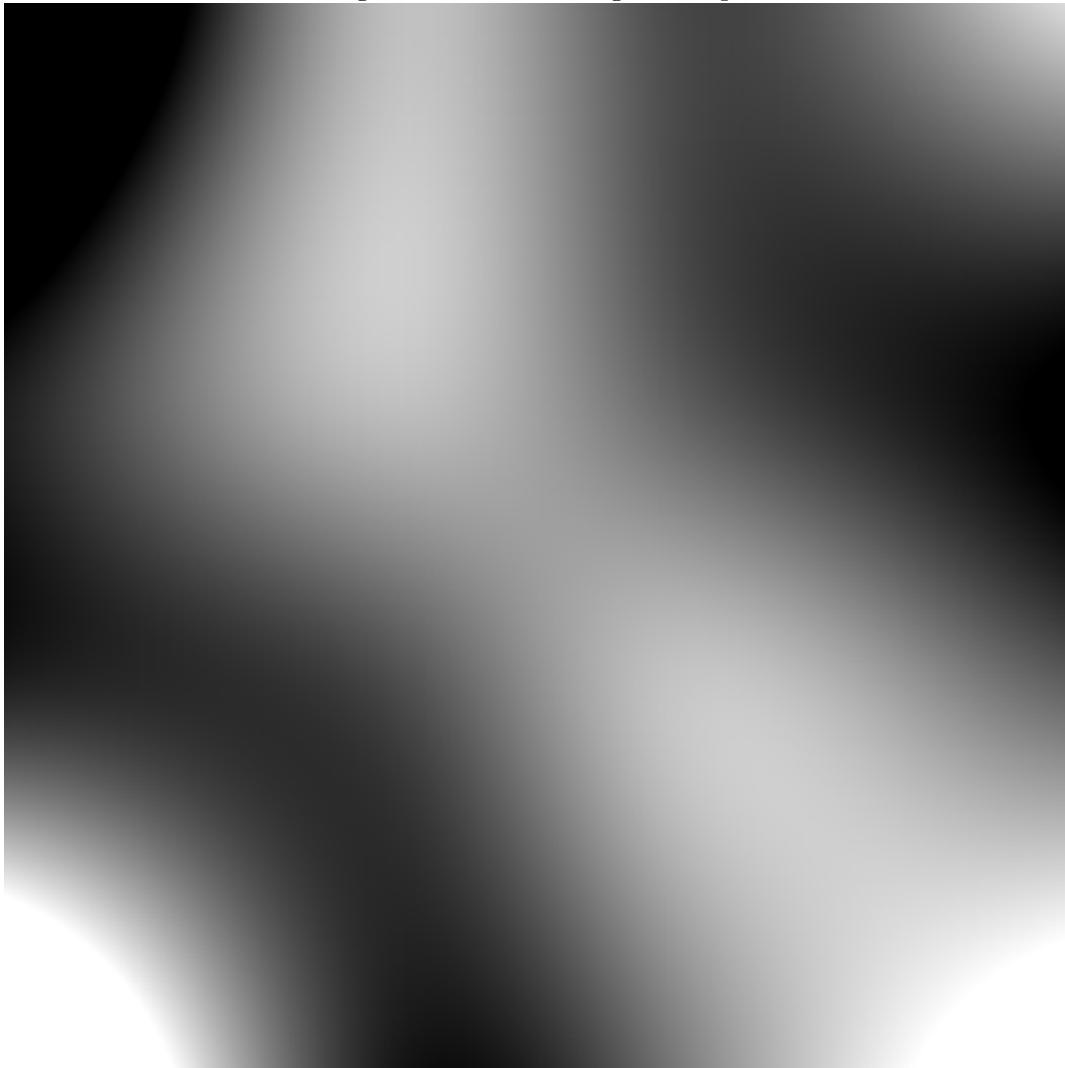


Figure 3: Standard Enlarge Example

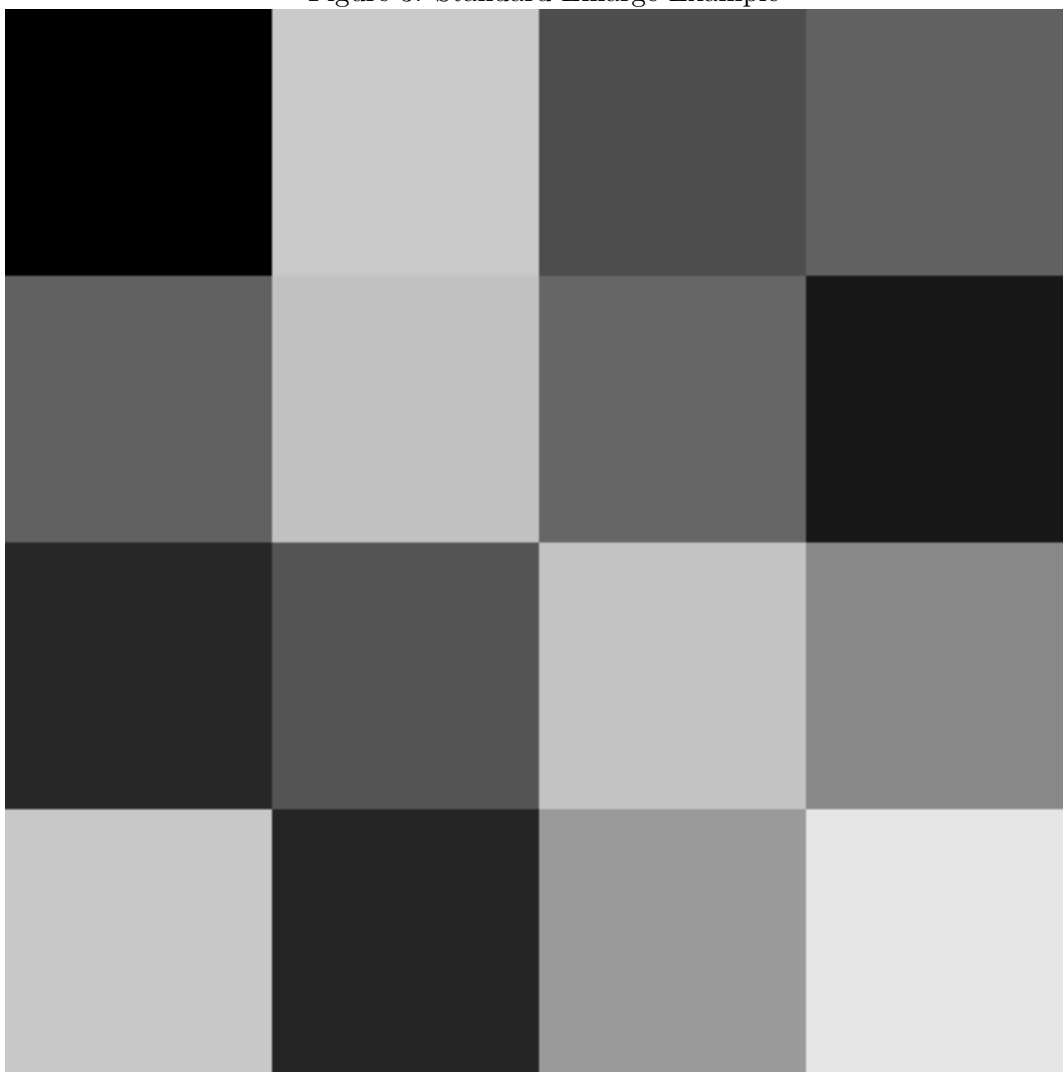
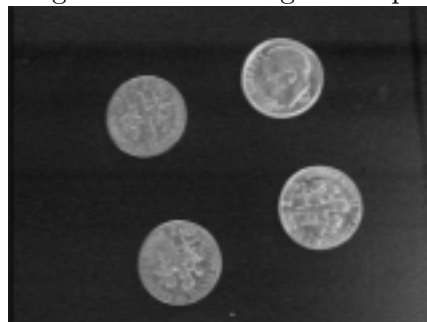


Figure 4: shrinkImage Example



- ImageType old  
The image to be reflected

#### Output

None

#### Assumptions

Assumes nothing, but it makes sense to have an initialized image to reflect

#### Example

See figure 5 on page 12

### TRANSLATEIMAGE

```
void translateImage( int , const ImageType<pType>& );
```

#### Purpose

Translate the image down to the right, any part that goes out of the screen is not calculated. Checkered background from setImageInfo is retained.

#### Input

- t  
The integer value of the translation. The translation will occur down and to the right 't' pixels
- ImageType old  
The image to be translated

#### Output

None

#### Assumptions

No assumptions are made, but it makes sense to have an initialized image

#### Example

See figure 6 on page 12

### ROTATEIMAGE

```
void rotateImage( int , const ImageType<pType>& );
```

#### Purpose

Rotate the image clockwise using bi-linear interpolation, basically traversing the entire image going from the destination to the source by using the in reverse (which is why its clockwise). Once a location is determined the surrounding pixels are used to calculate intermediate values between the pixels, this gives a pretty smooth rotate.

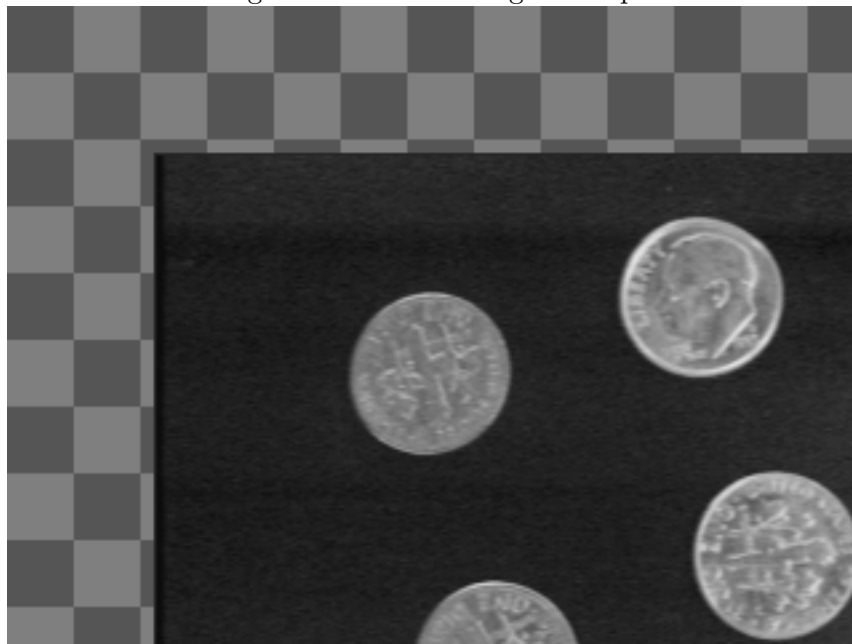
#### Input

- theta  
The degrees to rotate. This is converted to radians inside the function
- ImageType old  
The image to be rotated

Figure 5: reflectImage Example



Figure 6: translateImage Example



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Output

None

## Assumptions

Assumes that theta is in degrees because theta is converted to radians from degrees inside the function for the use of the trig functions. It is also assumed that the image has been initialized before the function call. It is also assumed that theta is between 0 and 360.

## Example

See figure 7 on page 14

## OPERATOR+

```
ImageType& operator+ ( const ImageType<pType>& );
```

## Purpose

Sum two images together, basically just finding the average pixel value of every pixel between two images. Throws an exception if dimensions of both images don't match

## Input

- ImageType rhs  
This is the image to be added to 'this' image

## Output

ImageType object to chain additions

## Assumptions

It is assumed that each image have the same dimensions. However, if the images do not have the same dimensions, then a string is thrown stating that the images do not have the same dimensions. It is not necessary to have each image initialized, but it makes senses that they would each be initialized.

## Example

See figure 8 on page 14

## OPERATOR-

```
ImageType& operator- ( const ImageType<pType>& );
```

## Purpose

subtract two images from each other to see the differences, if the magnitude of the difference is less then  $Q/6$  then the pixel is replaced with black, otherwise white is used. This seems to help reduce the amount of noise in the pictures

## Input

- ImageType rhs  
This is the image to be subtracted from 'this' image

## Output

ImageType is returned to allow chaining of subtraction

Figure 7: rotateImage Example



Figure 8: operator+ Example



#### Assumptions

It is assumed that each image have the same dimensions. However, if the images do not have the same dimensions, then a string is thrown stating that the images do not have the same dimensions. It is not necessary to have each image initialized, but it makes senses that they would each be initialized.

#### Example

See figure 9 on page 16

#### NEGATEIMAGE

```
void negateImage();
```

#### Purpose

This function simply subtracts the current pixel value from the max value of the pixel, thus negating the image

#### Input

None

#### Output

None

#### Assumptions

Nothing is assumed

#### Example

See figure 10 on page 16

### 3.2 driver.cpp

#### SHOWMENU

```
int showMenu( WINDOW *&, const char[], int, int, int, int,
             char[][NAMELEN], int, bool=false );
```

#### Purpose

This is the function which builds the scrolling menu system, this simply creates a curses window and puts all the options stored in menuStr onto the window, it then waits for the user to press UP, DOWN, or RETURN before reacting. The parameters allow menus to be different widths, heights, and locations. A few constants can be changed to change the colors of the window.

#### Input

- \*&menu  
An un-initialized window pointer.
- title[]  
A string to be the title.



Figure 9: operator- Example

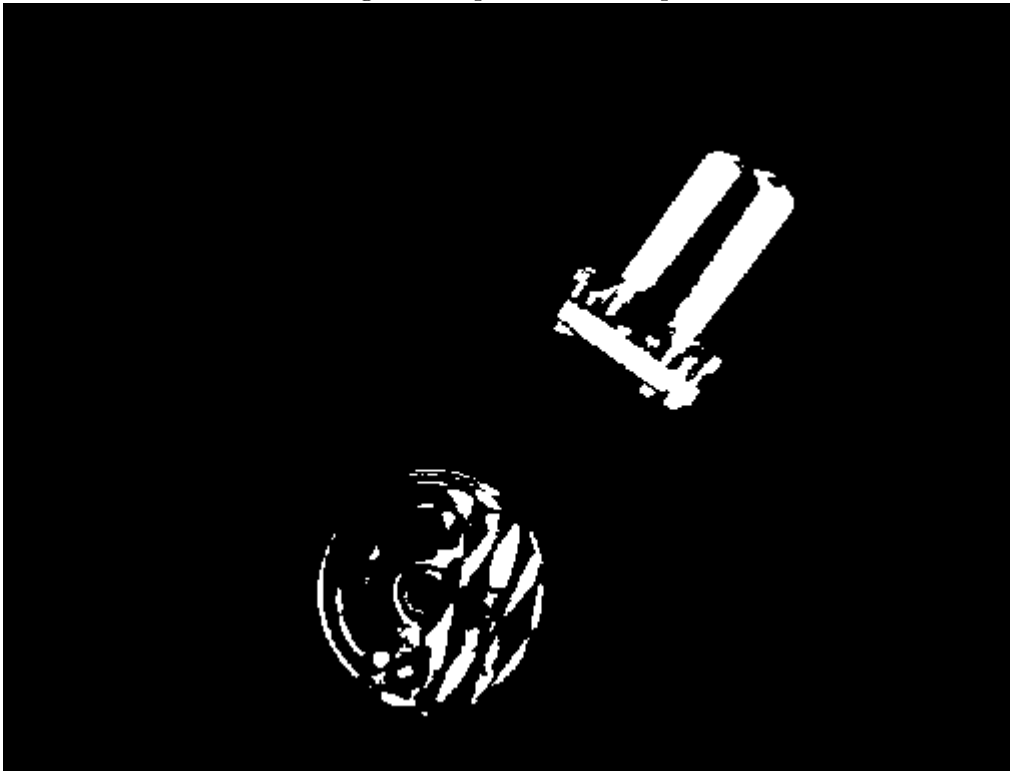


Figure 10: negateImage Example



- height and width  
The height and width of the menu.
- locY and locX  
The y and x locations of the menu's upper left corner.
- menuStr[][NAME\_LEN]  
A list of c-style strings to be used in the menu.
- choices  
The number of strings in menuStr.
- erase  
A bool value which says if the last choice is left highlighted. Default value is true.

#### Output

Display a window with menu options, let user choose and return the index of that choice.

#### Assumptions

Assumes that window is un-initialized and will be destructed by calling function.

#### Example

See figure 11 on page 18

#### SHOWREGS

```
void showRegs( WINDOW *amp, const bool[],
               const char[][NAMELEN] );
```

#### Purpose

Display a window of registers next to the main menu (or wherever the constants dictate).

#### Input

- \*&regWin  
An un-initialized window pointer.
- loaded[]  
A list of bools representing which registers are loaded.
- names[][NAMES\_LEN]  
A list of the names of each register.

#### Output

Displays a window next to main of all the registers.

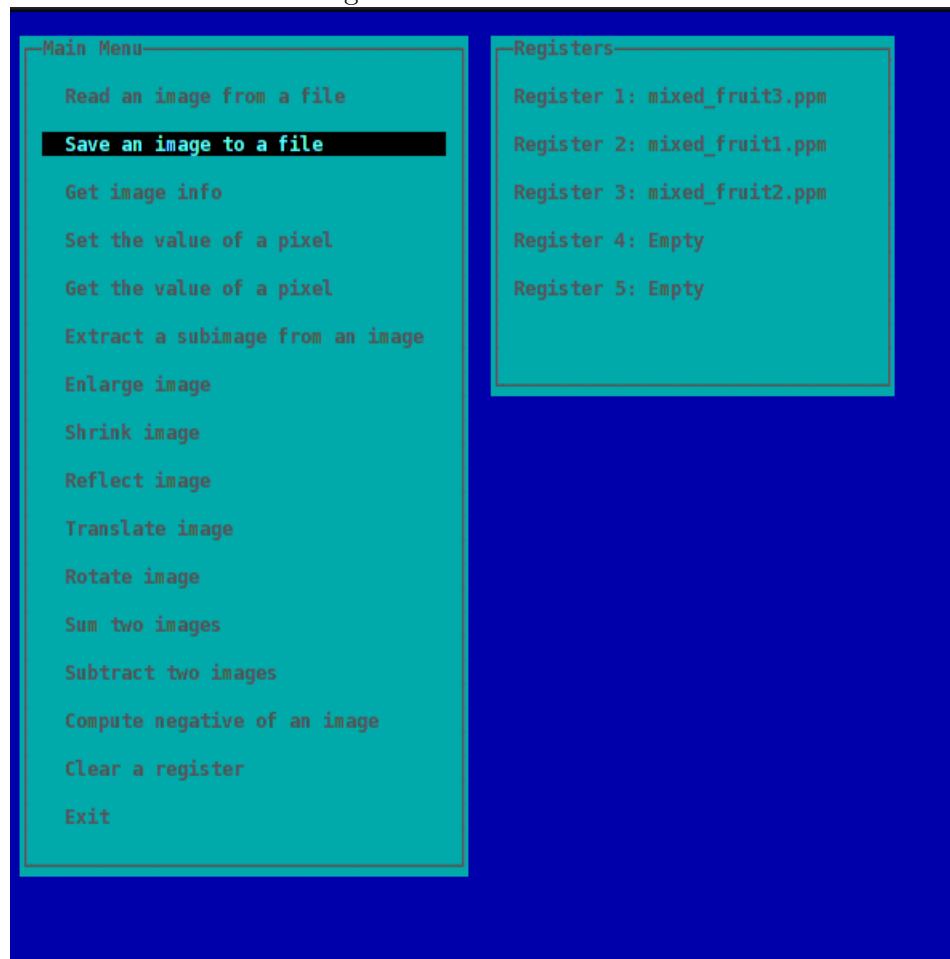
#### Assumptions

This allocates memory for a WINDOW but it doesn't delete it.

#### DRAWWINDOW

```
void drawWindow( WINDOW *amp, const char[],
                 int, int, int, int, short=MENU_BACKGROUND,
                 short=MENU_FOREGROUND );
```

Figure 11: The Main Menu



### Purpose

This function simply draws an empty window with a given title, height, width, x, and y locations. The colors have default values but can be changed if oddly colored windows are wanted.

### Input

- \*&win  
An un-initialized window pointer.
- title[]  
A c-style string.
- height and width  
The height and width of the desired window.
- y and x  
The y and x locations of the upper left corner.
- bgColor and fgColor  
The background and foreground colors, both have default values equal to the menu colors defined as constants.

### Output

Displays a empty window with a border and title using the given parameters.

### Assumptions

This allocates memory for a WINDOW but it doesn't delete it.

## DELETEMENU

```
void deleteMenu( WINDOW *& );
```

### Purpose

This basically clears the entire screen after deleting the window that is passed.

### Input

- \*&menu  
A window pointer which has been initialized.

### Output

De-allocate memory for the window pointer and refresh the main screen.

### Assumptions

Assumes WINDOW object is initialized before calling.

## PROCESSEENTRY

```
void processEntry( ImageType<pType>[], bool [],  
                  char[][NAMELEN], int );
```

### Purpose

This is the function that decides where to go depending on the choice in the main menu. The reason it has all the parameters is for passing to the subsequent functions that will be using them.

### Input

- `img[]`  
A list of images that are stored in the registers.
- `loaded[]`  
A list of bools that represent if each register is loaded.
- `name[][NAME_LEN]`  
The names of all the registers as c strings.
- `choice`  
The choice the user made at the main menu.

### Output

Depending on the value of choice, call a function to do some image manipulation.

### Assumptions

Assumes value  $\geq 0$  and  $< \text{MENU\_OPTIONS}$ , not that anything will crash if its not true, but nothing will happen, also assumes that names contain valid c strings.

## STDWINDOW

```
void stdWindow( WINDOW *&, const char [ ] );
```

### Purpose

This just builds the window used for message box, this function is just to simplify the plethora of other functions that use this.

### Input

- `newWin`  
An un-initialized window pointer.
- `title[]`  
A c style string.

### Output

Displays a window in the standard text box location with the title and a border.

### Assumptions

The window object is initialized here but not deleted, this is left up to the calling function.

## PROMPTFORREG

```
int promptForReg( bool [ ] , char [ ][NAME_LEN] ,  
                 const bool = true , int=1, int=MENU_WIDTH+3 );
```

### Purpose

This is the function that calls the menu for the register prompt, it can be called in different locations (like in addImg and subImg) but has a default defined by some global constants. The function creates a list of registers and adds the "Back" option as the final option, this way the user has the option to cancel choosing a register. Although in the program it looks like the register display and register choosing window are the same, this menu overlaps the other menu to make it seem like control is transferring to another window.

### Input

- loaded[]  
A list of flags indicating which registers are loaded.
- name[][NAME\_LEN]  
A list of names of each register.
- check  
A flag used to indicate whether registers that aren't loaded are valid.
- y and x  
The y and x locations of the menu, default values are defined for this.

### Output

Display a menu with the registers in it, allowing user to choose a register.

### Assumptions

Assumes that names are already set to valid c strings.

## PROMPTFORFILENAME

```
int promptForFilename( const char [],  
                      const char [], char [] );
```

### Purpose

Create a message box and prompt the user for a string value with given prompt.

### Input

- title[]  
The title of the prompt window as a c style string.
- prompt[]  
The prompting message.
- str[]  
A string in which to store output into.

### Output

Sets the final parameter equal to the file name the user chooses and returns the length.

### Assumptions

Assumes first 2 parameters are valid c strings and that the final parameter is a string of at least length 16 plus the length of the file path declared as a constant.

## PROMPTFORLOC

```
void promptForLoc( const char [] , ImageType<pType>&,
                  int&, int& );
```

## Purpose

This function prompts the user for a location (both row and column) and sets the valid points equal to row or col. If -1 is returned in either location it means user choose to cancel the prompt. The validity of the points is calculated by the image object it is passed. The image properties are calculated and then used to determine the bounds of row and column.

## Input

- title[]  
The title of the prompt window as a c style string.
- &img  
This is just so the dimensions of the image can be obtained.
- &row and &col  
Used to store the user's input values.

## Output

Sets two reference parameters equal to row and column of users choice.

## Assumptions

Assumes image is initialized and has a valid height and width also that first parameter is a valid c string.

## PROMPTFORPIXVALUE

```
int promptForPixValue( const char [] , const char [] , int );
```

## Purpose

Prompt for a pixel value which is from 0 to maxVal, if not display message box and re-prompt user until valid choice is made.

## Input

- title[]  
The title of the prompt window as a c style string.
- prompt[]  
The prompting message.
- maxVal  
The maximum value allowed to input.

## Output

Prompts user in message window and returns the value when the user inputs a valid value(-1 indicates cancel).

---

Assumptions

Assumes that first 2 parameters are valid c strings.

## PROMPTFORSCALEVALUE

```
int promptForScaleValue( const char[], const char[], int );
```

## Purpose

This function prompts the user for a scale value and checks to make sure it is not greater than maxVal and not less than 2. This is used in the enlarge and shrink functions.

## Input

- title[]  
The title of the prompt window as a c style string.
- prompt[]  
The prompting message.
- maxVal  
The maximum value allowed to input.

## Output

Prompts user in message window and returns the value when the user inputs a valid value(-1 indicates cancel).

## Assumptions

Assumes that first 2 parameters are valid c strings.

## PROMPTFORMIRROR

```
char promptForMirror( const char[], const char[] );
```

## Purpose

Prompt the user for the characters h, v, or c (not case sensitive) and return the value as soon as one of the 3 is pressed.

## Input

- title[]  
The title of the prompt window as a c style string.
- prompt[]  
The prompting message.

## Output

Returns users choice as a char.

## Assumptions

Both parameters are valid c strings.

## PROMPTFORANGLE



```
int promptForAngle( const char[] , const char[] );
```

#### Purpose

Prompt user for a valid angle using a message box, make sure input is between 0 and 360, if not display a message box and then re-prompt.

#### Input

- title[]  
The title of the prompt window as a c style string.
- prompt[]  
The prompting message.

#### Output

Returns the user angle choice.

#### Assumptions

Both parameters are valid c strings.

#### MESSAGEBOX

```
void messageBox( const char[] , const char[] );
```

#### Purpose

Displays a message box in the center of the screen with the message displayed in it.

#### Input

- title[]  
The title of the window as a c style string.
- msg[]  
The message to be displayed in the message box.

#### Output

Displays a message box in the center of the screen with the message displayed in it, then waits for the user to press return before continuing.

#### Assumptions

Assumes both parameters are valid c strings.

#### FILLREGS

```
void fillRegs( ImageType<pType>[] , bool[] ,  
              char[][NAMELEN] , int , char** );
```

#### Purpose

This displays a simple message box to the screen with the given title and msg inside of it, it waits for the user to press RETURN before returning to calling function.

---

Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.
- `argc`  
The number of strings in `argv`.
- `**argv`  
The parameters passed to `main`.

## Output

Sets valid arguments to registers (loading images) and clears the rest of the registers.

## Assumptions

Assumes that `char**` is a valid list of strings with `int` rows.

## CLEARREGISTERS

```
void clearRegister( ImageType[] , bool[] ,  
                  char[][NAME_LEN] );
```

## Purpose

Prompt for a register that is filled and then clear it.

## Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

## Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

## Assumptions

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

## LOADIMAGE

```
void loadImage( ImageType<int >[],
               bool [], char[][NAMELEN] );

void loadImage( ImageType<rgb >[],
               bool [], char[][NAMELEN] );
```

#### Purpose

Prompt the user for a register to load to, then let them choose from a list of the .pgm or .ppm files in the local images directory (defined as a constant).

#### Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAMELEN]`  
A list of names of every register.

#### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

#### Assumptions

Assumes all names in the c string list are valid c strings and the bools coincide with the image types that reference the same index.

#### SAVEIMAGE

```
void saveImage( ImageType<int >[],
               bool [], char[][NAMELEN] );

void saveImage( ImageType<rgb >[],
               bool [], char[][NAMELEN] );
```

#### Purpose

Save image from a register to the local images directory, prompting user for register and file name.

#### Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAMELEN]`  
A list of names of every register.

### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in ImageType that will allow the image in that register to be manipulated.

### Assumptions

Assumes all names in the c string list are valid c strings and the bools coincide with the image types that reference the same index.

### GETIMAGEINFO

```
void getImageInfo( ImageType<int>[],
                  bool [], char[][NAMELEN] );

void getImageInfo( ImageType<rgb>[],
                  bool [], char[][NAMELEN] );
```

### Purpose

Simply retrieve image information and display to a window below the registers The data being displayed is the Register number, Image Height, Width, Q value, and average color value.

### Input

- img[]  
A list of all the images stored in the registers.
- loaded[]  
A list of bools representing if each register is loaded.
- name[][NAMELEN]  
A list of names of every register.

### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in ImageType that will allow the image in that register to be manipulated.

### Assumptions

Assumes all names in the c string list are valid c strings and the bools coincide with the image types that reference the same index.

### SETPIXEL

```
void setPixel( ImageType<int>[],
              bool [], char[][NAMELEN] );

void setPixel( ImageType<rgb>[],
              bool [], char[][NAMELEN] );
```

---

**Purpose**

Prompt user for a register then a pixel location (row, col) and then the pixel value(s) to change that pixel to.

**Input**

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

**Output**

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

**Assumptions**

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

**GETPIXEL**

```
void getPixel( ImageType<int > [],
               bool [], char[][NAME_LEN] );

void getPixel( ImageType<rgb > [],
               bool [], char[][NAME_LEN] );
```

**Purpose**

Return the value(s) of a pixel in a selected image to the user.

**Input**

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

**Output**

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

**Assumptions**

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

## EXTRACTSUB

```
void extractSub( ImageType<pType>[],
                bool [], char[][NAME_LEN] );
```

## Purpose

After getting the image to manipulate, prompt for two corners to make a subimage out of, if the lower right corner is above or left of the upper right corner re-prompt for valid points

## Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

## Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

## Assumptions

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

## ENLARGEIMG

```
void enlargeImg( ImageType<pType>[],
                 bool [], char[][NAME_LEN] );
```

## Purpose

This function prompts the user for a scale value to enlarge an image by, it makes sure the scale value does not make the image larger than `MAX_IMG` value because it may cause a stack overflow.

## Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

## Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

---

### Assumptions

Assumes all names in the c string list are valid c strings and the bools coincide with the image types that reference the same index.

### SHRINKIMG

```
void shrinkImg ( ImageType<pType> [],
                 bool [], char[][NAME_LEN] );
```

### Purpose

The same as enlarge except it shrinks the image making sure it never gets smaller than MIN\_IMG. This is because some image viewers won't open images as small as 2x2 (xv for example).

### Input

- img[]  
A list of all the images stored in the registers.
- loaded[]  
A list of bools representing if each register is loaded.
- name[][NAME\_LEN]  
A list of names of every register.

### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in ImageType that will allow the image in that register to be manipulated.

### Assumptions

Assumes all names in the c string list are valid c strings and the bools coincide with the image types that reference the same index.

### REFLECTIMG

```
void reflectImg ( ImageType<pType> [],
                  bool [], char[][NAME_LEN] );
```

### Purpose

Prompt user for a direction to reflect an image then reflect the image and store it back in the original register image.

### Input

- img[]  
A list of all the images stored in the registers.
- loaded[]  
A list of bools representing if each register is loaded.
- name[][NAME\_LEN]  
A list of names of every register.

### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in ImageType that will allow the image in that register to be manipulated.

### Assumptions

Assumes all names in the c string list are valid c strings and the bools coincide with the image types that reference the same index.

### TRANSLATEIMG

```
void translateImg( ImageType<pType>[] ,
                  bool [] , char[][NAMELEN] );
```

### Purpose

This prompts the user for how far to translate the image, then calls the translate function which moves the image down to the right 't' number of pixels. Also Won't let user choose t value that would move image totally off the screen.

### Input

- img[]  
A list of all the images stored in the registers.
- loaded[]  
A list of bools representing if each register is loaded.
- name[][NAMELEN]  
A list of names of every register.

### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in ImageType that will allow the image in that register to be manipulated.

### Assumptions

Assumes all names in the c string list are valid c strings and the bools coincide with the image types that reference the same index.

### ROTATEIMG

```
void rotateImg( ImageType<pType>[] ,
                bool [] , char[][NAMELEN] );
```

### Purpose

This prompts the user for an angle theta which will rotate the image counter clockwise by theta degrees. The input is only valid from 0 to 360 which should cover all possibilities.

### Input

- img[]  
A list of all the images stored in the registers.



- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

#### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

#### Assumptions

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

### SUMIMG

```
void sumImg( ImageType<pType>[] ,
             bool [] , char[][NAME_LEN] );
```

#### Purpose

Prompt for 2 images and attempt to sum them, there is no size checking because operator+ will throw a string which will be handled by main if sizes of the two images are different.

#### Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

#### Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

#### Assumptions

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

### SUBTRACTIMG

```
void subtractImg( ImageType<pType>[] ,
                  bool [] , char[][NAME_LEN] );
```

#### Purpose

Prompt for 2 images and attempt to calculate the difference, there's no size checking here for the same reason `sumImg` doesn't do size checking

---

Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

## Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

## Assumptions

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

## NEGATE IMG

```
void negateImg( ImageType<pType> [],  
               bool [], char[][NAME_LEN] );
```

## Purpose

Prompt user for which image to negate and negate it, pretty simple function.

## Input

- `img[]`  
A list of all the images stored in the registers.
- `loaded[]`  
A list of bools representing if each register is loaded.
- `name[][NAME_LEN]`  
A list of names of every register.

## Output

Prompt the user for which register to use, then if necessary prompt for additional information and call the function in `ImageType` that will allow the image in that register to be manipulated.

## Assumptions

Assumes all names in the `c` string list are valid `c` strings and the bools coincide with the image types that reference the same index.

## CLEARREGISTER

```
void clearRegister( ImageType<pType> [],  
                   bool [], char[][NAME_LEN] );
```

## Purpose

Prompt for a register that is filled and then clear it.

---

Input

- `img[]`  
The array with the images loaded
- `loaded[]`  
The bool array to set that the array is empty
- `name[][NAME_LEN]`  
The array with the names of the images

## Output

None

## Assumptions

Nothing is assumed, but it makes sense to call this only if there is something to clear.

## FINDLOCALPGM

```
int findLocalPGM( char **&filenames );
```

## Purpose

A somewhat brittle function that reads all the .pgm files from a local directory (defined as a constant) and places them into a dynamically allocated c style string array.

## Input

- `**filenames`  
A double char pointer that is uninitialized.

## Output

Allocates enough memory for a list of all the ".pgm" files in the local path specified by the FILELOC constant. It then copies the file names to the array and returns the number of rows in the array.

## Assumptions

Pointer parameter is not initialized, but will be in the function this means it needs to be de-allocated later.

## FINDLOCALPPM

```
int findLocalPPM( char **&filenames );
```

## Purpose

A somewhat brittle function that reads all the .ppm files from a local directory (defined as a constant) and places them into a dynamically allocated c style string array.

## Input

- `**filenames`  
A double char pointer that is uninitialized.

**Output**

Allocates enough memory for a list of all the ".ppm" files in the local path specified by the FILELOC constant. It then copies the file names to the array and returns the number of rows in the array.

**Assumptions**

Pointer parameter is not initialized, but will be in the function this means it needs to be de-allocated later.

### 3.3 cubicspline.h

**CONSTRUCTOR**

```
cubicSpline();
```

**Purpose**

Initialize everything to NULL and 0.

**Input**

None

**Output**

None

**Assumptions**

After this runs, all variables are zero.

**CONSTRUCTOR WITH PARAMETERS**

```
cubicSpline( int [], int );
```

**Purpose**

Let object be initialized and create a linear and cubic spline based on the parameters.

**Input**

- points[]  
The array of points to be interpolated.
- num  
The number of points in the array.

**Output**

Sets the variables for both cubic and linear splines in the object.

**Assumptions**

It is assumed that there are at least 3 points, otherwise cubic splines can't be created with this algorithm.

**DESTRUCTOR**

```
~cubicSpline();
```

**Purpose**

Delete all dynamically allocated memory before object is removed.

**Input**

None

**Output**

None

**Assumptions**

None

**CREATE**

```
void create( int [], int );
```

**Purpose**

Using the points make it possible to calculate a location along the piecewise function at a later time. Creates a linear spline function.

**Input**

- `points[]`  
A list of points to be used to interpolate.
- `num`  
The number of points.

**Output**

Sets the object up so that linear approximations of intermediate values between the points can be obtained using the `getVal()` function.

**Assumptions**

There is at least 1 point.

**CREATECUBIC**

```
void createCubic( int [], int );
```

**Purpose**

Using the points make it possible to calculate a location along the piecewise function at a later time. Creates a cubic spline function.

**Input**

- `points[]`  
A list of points to be used to interpolate.

- num  
The number of points.

#### Output

Sets the object up so that cubic approximations of intermediate values between the points can be obtained using the `getCubicVal()` function.

#### Assumptions

It is assumed that 3 or more points exist.

#### GETVAL

```
double getVal( double );
```

#### Purpose

Returns an estimated value along the function, the spline function assumes that the first point lies at 0.0 and the final point lies at 100.0 with each point equally spaced. Uses a linear spline.

#### Input

- x  
A floating point value of the desired location along the function.

#### Output

Returns the value of the intermediate approximation between the points.

#### Assumptions

Assumes a linear spline has been defined. a.k.a. the function `create()` has been called, initializing the spline.

#### GETCUBICVAL

```
double getCubicVal( double );
```

#### Purpose

Returns an estimated value along the function, the spline function assumes that the first point lies at 0.0 and the final point lies at 100.0 with each point equally spaced. Uses a cubic spline.

#### Input

- x  
A floating point value of the desired location along the function.

#### Output

Returns the value of the intermediate approximation between the points.

#### Assumptions

Assumes a cubic spline has been defined. a.k.a. the function `createCubic()` has been called, initializing the spline.

---

### 3.4 imageIO.h

#### READIMAGEHEADER

```
void readImageHeader( const char [] , int&,
                     int&, int&, bool& );
```

##### Purpose

Reads the image header and puts them into values that are passed by reference

##### Input

- `fname[]`  
This is the name of the file stored as a C-style string
- `N`  
This is the number of rows in the image
- `M`  
This is the number of columns in the image
- `Q`  
This is the depth of the image
- `type`  
This makes sure that the file type is .pgm and not some other format

##### Output

None

##### Assumptions

Assumes that a file exists and is in pgm format

#### READIMAGE

```
void readImage(const char fname [] , ImageType<int>& image)

void readImage(const char fname [] , ImageType<int>& image)
```

##### Purpose

Reads the image (PGM or PPM) into the image object from a file

##### Input

- `fname[]`  
The C-style string to hold the image file name
- `ImageType image`  
The image object that holds the image data

##### Output

None

##### Assumptions

Assumes there is a file to be read and that the user has read access

---

WRITEIMAGE

```
void writeImage(const char fname[] , ImageType<int>& image)
void writeImage(const char fname[] , ImageType<rgb>& image)
```

**Purpose**

Writes the image (PGM or PPM) to disk

**Input**

- fname[]  
The C-style string to hold the image file name
- ImageType image  
The image object that holds the image data

**Output**

None

**Assumptions**

Assumes the user has write access to the destination folder

### 3.5 comp\_curses.h

STARTCURSES

```
void startCurses();
```

**Purpose**

This initializes the curses screen and its functions

**Input**

None

**Output**

None

**Assumptions**

No assumptions are made besides have a terminal capable of displaying curses correctly.

ENDCURSES

```
void endCurses();
```

**Purpose**

This ends the curses screen and its functions

**Input**

None



---

**Output**

None

**Assumptions**

This assumes that curses has been initialized with startCurses()

**SETCOLOR**

```
void setColor( WINDOW*, int , int );
```

**Purpose**

This sets the colors for stdscr

**Input**

- \*somewin  
This is the window pointer to set the colors to a specific window
- cf  
This is the first color (foreground) for the color pair to set in the window
- cb  
This is the second color (background) for the color pair to set in the window

**Output**

None

**Assumptions**

Assumes that screen has been initialized

**SCREENWIDTH**

```
int screenWidth();
```

**Purpose**

Returns the max screen x value

**Input**

None

**Output**

The int value of the max x value for the entire terminal

**Assumptions**

Assumes startCurses() has been run

**SCREENHEIGHT**

```
int screenHeight();
```

---

**Purpose**

Returns the max screen y value

**Input**

None

**Output**

The int value of the max y value for the entire terminal

**Assumptions**

Assumes startCurses() has been run

**PROMPTFORINT**

```
int promptForInt( WINDOW*, int , int , const char [] );
```

**Purpose**

Prompts for an int at some int at some (x,y) coordinate

**Input**

- \*somewin  
Some window to prompt for the int in
- y  
The y coordinate at which to prompt for the int
- x  
The x coordinate at which to prompt for the int
- promptString[]  
The string to display when prompting for the int

**Output**

The integer value of the user's input

**Assumptions**

It is assumed that startCurses() has been run. The function has built in error checking to prevent bad data from being input

**PROMPTFORDOUBLE**

```
double promptForDouble( WINDOW*, int , int , const char [] );
```

**Purpose**

Prompts for a double at some int at some (x,y) coordinate

**Input**

- \*somewin  
Some window to prompt for the double in

- y  
The y coordinate at which to prompt for the double
- x  
The x coordinate at which to prompt for the double
- promptString[]  
The string to display when prompting for the double

#### Output

The double value of the user's input

#### Assumptions

It is assumed that startCurses() has been run. The function has built in error checking to prevent bad data from being input (such as multiple periods)

#### PROMPTFORSTRING

```
void promptForString( WINDOW *, int , int ,  
                    const char [ ] , char [ ] , int );
```

#### Purpose

Prompts for a string at some (x,y) coordinate

#### Input

- \*somewin  
The window at which to prompt for the string
- y  
The y coordinate at which to prompt
- x  
The x coordinate at which to prompt
- promptstring  
The string to display when prompting for the string
- str[]  
The array for the string that is typed in by the user
- len  
The length of the string stored

#### Output

None

#### Assumptions

It is assumed that startCurses() has been run. The function also accounts for backspaces and makes sure that only valid input is entered.

## 4 Bugs and Errors

During the creation of this program we ran into a multitude of bugs and errors. Some of the biggest obstacles came while implementing the main driver program. Learning how curses works

and finding way to make it do what was needed was quite a challenge but also very rewarding. One odd bug was that when the function `wattron()` was used to set to highlight for the menu options it worked fine on one computer, but when it was used on Josiah's computer the highlighting didn't show up. The fix for this involved manually inverting the colors rather than just changing the attribute. This is a good example of how a program may act differently on different computers.

Another bug that we ran into was having trouble when enlarging images too much. The way this was dealt with was to add a global constant to the main driver which limited the size allowed to scale an image. Although there weren't many actual bugs while writing the image class, there was a huge amount of testing done to try and make the program as robust as possible given the time limitation.

There was another bug the students ran into when rotating color images holes were appearing in the image. After spending quite some time searching the problem was finally discovered; Apparently the implementation of the operator overloads for the RGB class were actually changing the calling object, so if the same value was used in an equation more than once it was returning incorrect results. This problem helped both of the students understand operator overloading much better, and once this was discovered the rest of the program went smoothly.

## 5 What was Learned

The most important thing learned in this assignment was the use of templates. This was taught briefly in the previous semester of CS, so the concept of it was fairly new to the students. This challenge did not sway them though. The students quickly grasped the concepts of templates and easily implemented it into the image class to use both ints and RGB values. The students were then able to design the functions that manipulated the 2D array of ints and RGB both, that in turn manipulated the image. This was an important concept to grasp because without understanding the concepts of a template, the students would not be able to correctly develop algorithms that correctly manipulate any type of image format.

Another concept that the students learned was the knowledge of how images are stored. The students had first hand experience with an image format and this knowledge allowed the students to have a greater understanding of how computers and the data structures associated with file formats intertwine with the software developer. The students have more of an appreciation for the necessity of data structures and the implications of designing easy to use and compact data structures for the end user. The students also learned how color images can be represented in computers and gained excellent hands on experience with how they work and how to manipulate them.

One of the other concepts that the students learned was the ability to use `ncurses` in their program. This knowledge allowed the students to create a very easy-to-use menu that is capable of multiple floating and scrollable menus. While this part of the program was not needed, the students had a desire to learn more about C++ than what is being taught in the class and brought it upon themselves to learn about `ncurses`. This knowledge has greatly improved their knowledge of pointers and correct program structure because `ncurses` utilizes many pointers. The implementation of `ncurses` also becomes very complex if there is not a clean program structure implemented. There are many facets of `ncurses` that are intertwined, so the students made a clean and modular `ncurses` driver that is able to be easily read.

Since this was a group project, we felt that it would be fairly difficult to merge and maintain our code, so we decided to learn and use git. Git is a revision control program that focuses on

software development. It was developed by Linus Torvalds for the development of the Linux kernel. Git has proved to be extremely useful in the management of the source code. It did have a small learning curve, but once that was crossed, it has become one of the most valuable tools that I know of.

## 6 Division of Labor

For the requirements that were asked for, each student did an equal amount of work. The students met very early and divided up the required functions equally. Each student then implemented each function of the image and RGB class. Since the students are at different levels of programming experience, one of the students went above the required implementation to challenge himself. Josh implemented some advanced methods of manipulating the image using knowledge from a numerical methods class that he has taken in the past. Josh also wrote the driver with the help of Josiah for feedback on how to design the menu system. Both students studied and learned how the curses environment works and equally experimented with the functionality of curses and its implementation into a menu system. For the documentation, Josiah wanted to go above the normal implementation of a standard documentation and implemented a  $\text{\LaTeX}$  document that made the writing of the documentation very easy and structured. Overall, the students contributed equally for their level of programming skill.

## 7 Extras

This section isn't required but we thought that it was important to explain all the extra features that were added to this project. The biggest addition to the project was the addition of bi-cubic interpolation for `enlargeImage()`. This was done by Josh as more of a coding challenge, but worked out pretty well. The type of spline used is a natural spline calculated using a Lagrange polynomial. This method was chosen because it only has  $n-1$  unknowns, rather than a normal polynomial interpolation which has 4 times as many unknowns. It also allows a tridiagonal matrix to solve for all the unknowns, which is much faster than a normal matrix solving algorithm.

Another addition to the project was the curses driver program. This was done to make using the program a little more enjoyable and also to show some of the things that can be done with curses. All in all these extra additions were an enjoyable challenge and I hope you enjoy them.

See figure 2 and 3 on page 9 and 10

Figure 12: difference image with noise



Figure 13: difference image without noise

