University of Nevada, Reno

CS 302 — Data Structures

Assignment 1

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Contents

List of Figures

1 Introduction

In this assignment, the students were asked to make an image class that manipulated a Portable Gray Map (PGM) image in various ways. This was to be accomplished using dynamic 2D arrays and other tools that were learned in previous CS courses.

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.

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. Dynamic 2D arrays was a new tool for the students' C++ repertoire, but the students soon came to understand the benefits of dynamic 2D arrays.

The assignment also required the use of constructors, destructors, copy constructors, and operator overloading, These topics were review from CS 202, but the use of them refreshed the students minds on how they work and to their purposes.

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 realize 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 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. 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 manipulating them 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.

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

DESCTRUCTOR

```
~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& );
```

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& operator= ( const ImageType& );
```

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 obejct 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, int);
```

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

```
void 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& );
```

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 8

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( int , const ImageType&, bool=true );
```

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.

Figure 1: subImage Example

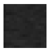
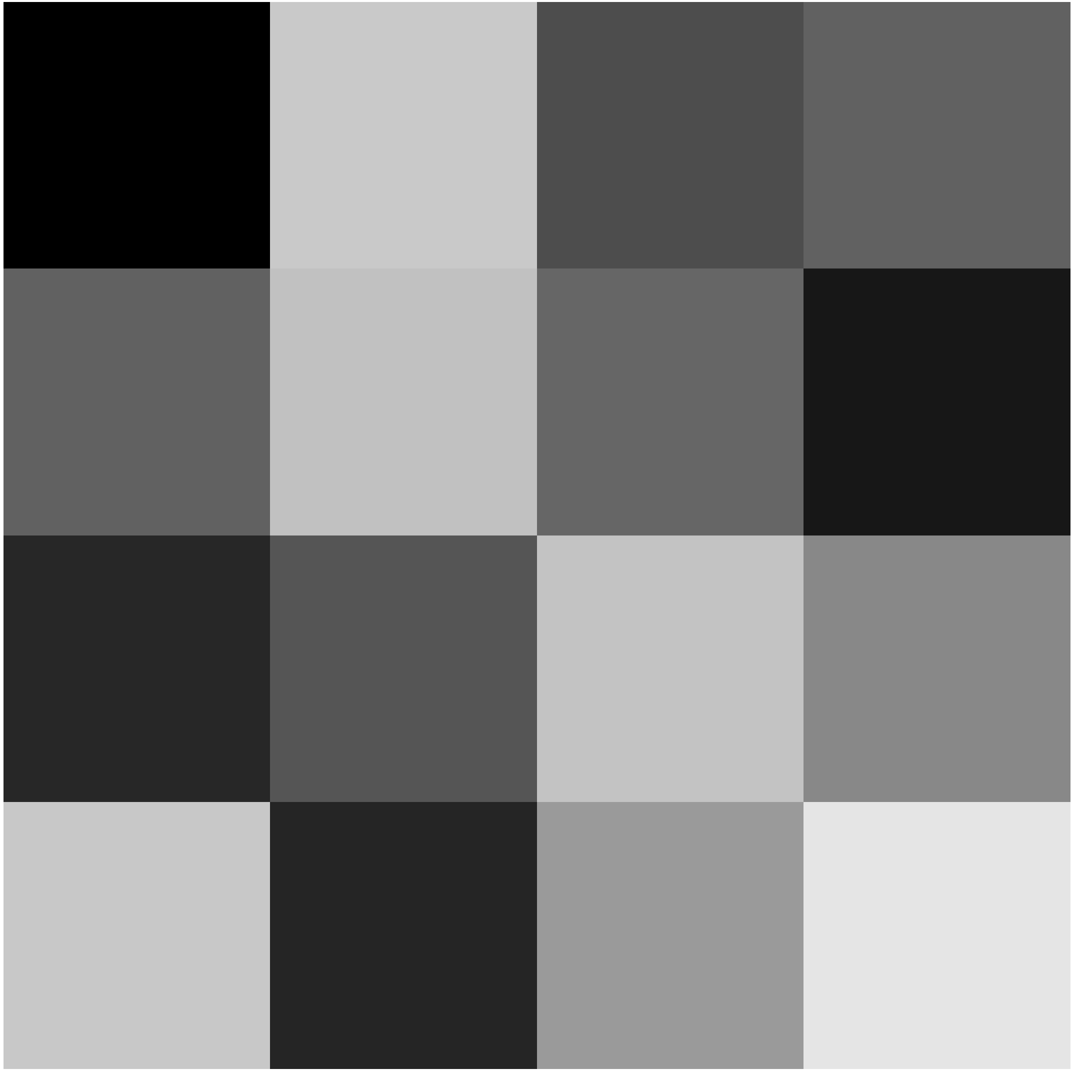


Figure 2: Cubic Enlarge Example

Figure 3: Standard Enlarge Example



Example

See figure 2 on page 8

See figure 3 on page 9

shrinkImage

```
void shrinkImage( int , const ImageType& );
```

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 11

reflectImage

```
void reflectImage( bool , const ImageType& );
```

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
- 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 11

Figure 4: shrinkImage Example

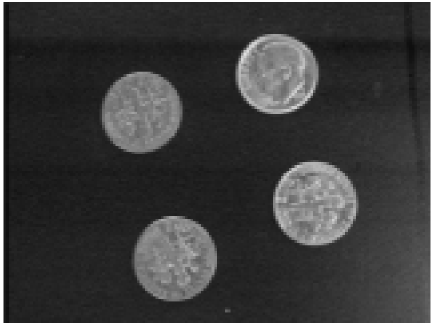
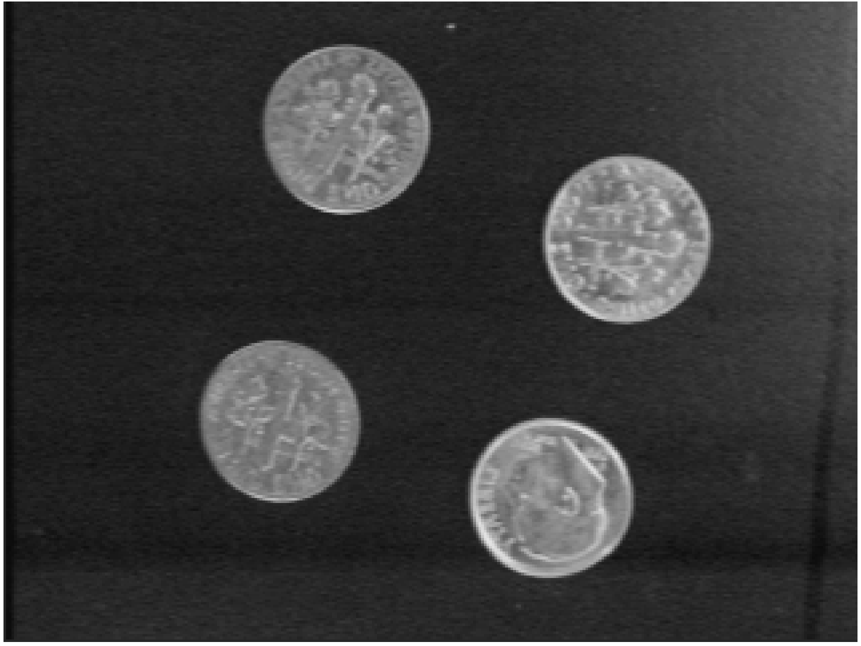


Figure 5: reflectImage Example



translateImage

```
void translateImage( int , const ImageType& );
```

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 13

rotateImage

```
void rotateImage( int , const ImageType& );
```

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
- ImnageType old
  The image to be rotated

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 13

Figure 6: translateImage Example

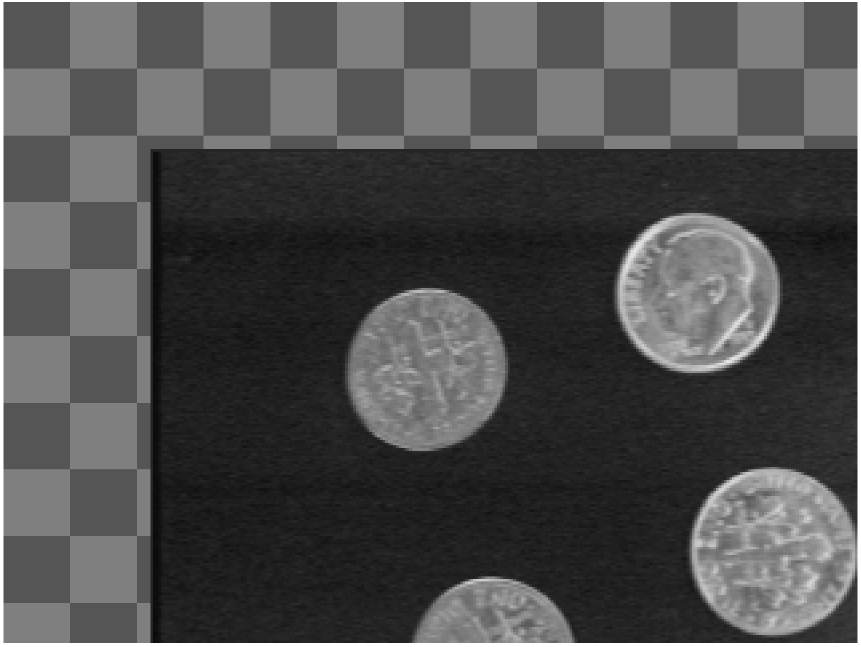
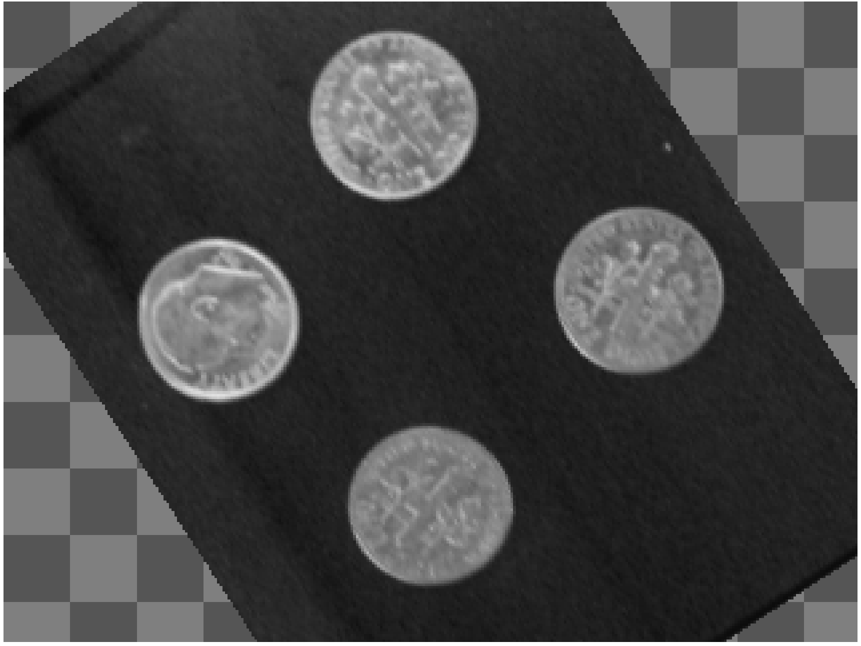


Figure 7: rotateImage Example



operator+

```
ImageType& operator+ ( const ImageType& );
```

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 15

operator-

```
ImageType& operator- ( const ImageType& );
```

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

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 15

negateImage

```
void negateImage();
```

Figure 8: operator+ Example

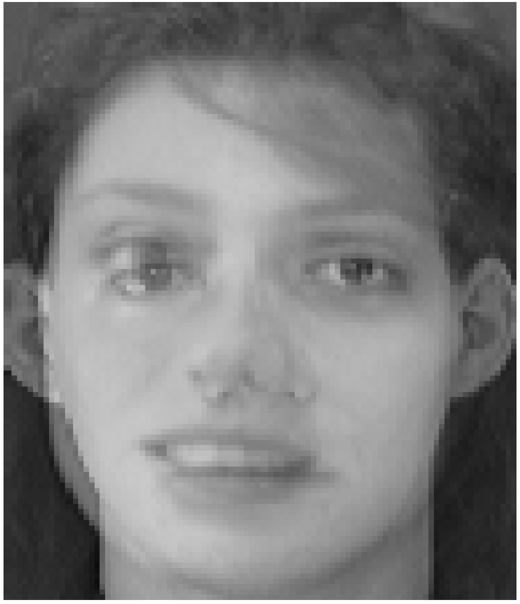
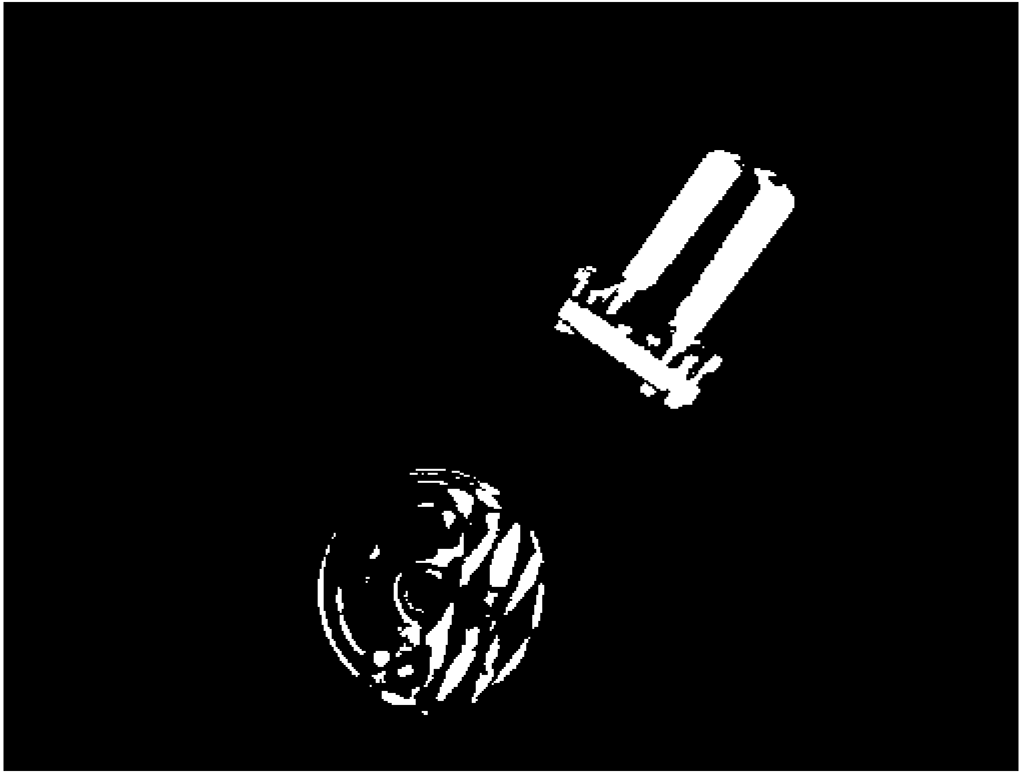


Figure 9: operator- Example



Purpose

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

Input

None

Output

None

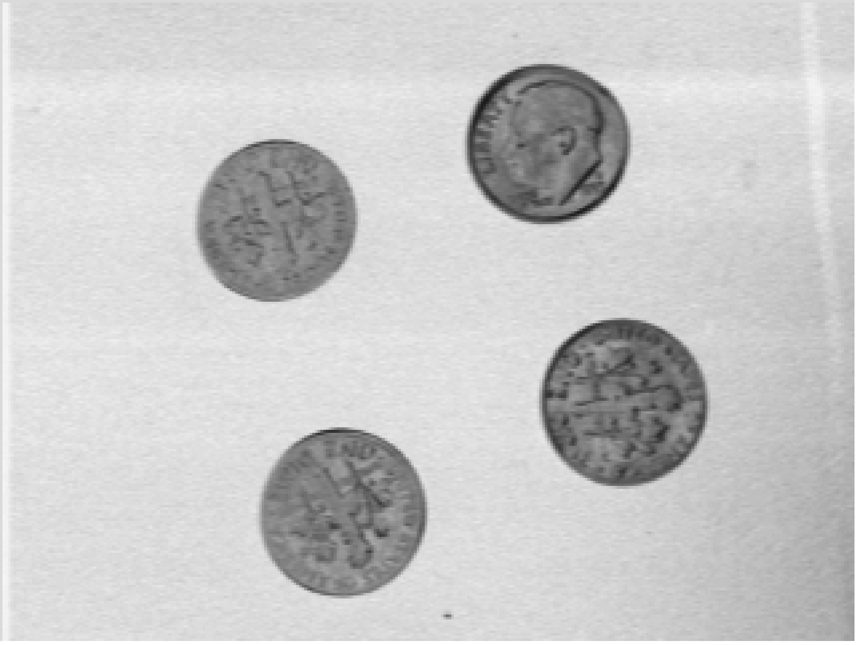
Assumptions

Nothing is assumed

Example

See figure 10 on page 16

Figure 10: negateImage Example



3.2 driver.cpp

SHOWMENU

```
int showMenu( WINDOW *&, const char[], int, int, int, int,
    char[][NAME_LEN], 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.
- 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 *&, const bool[] ,
const char[][NAME_LEN] );
```

Purpose

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

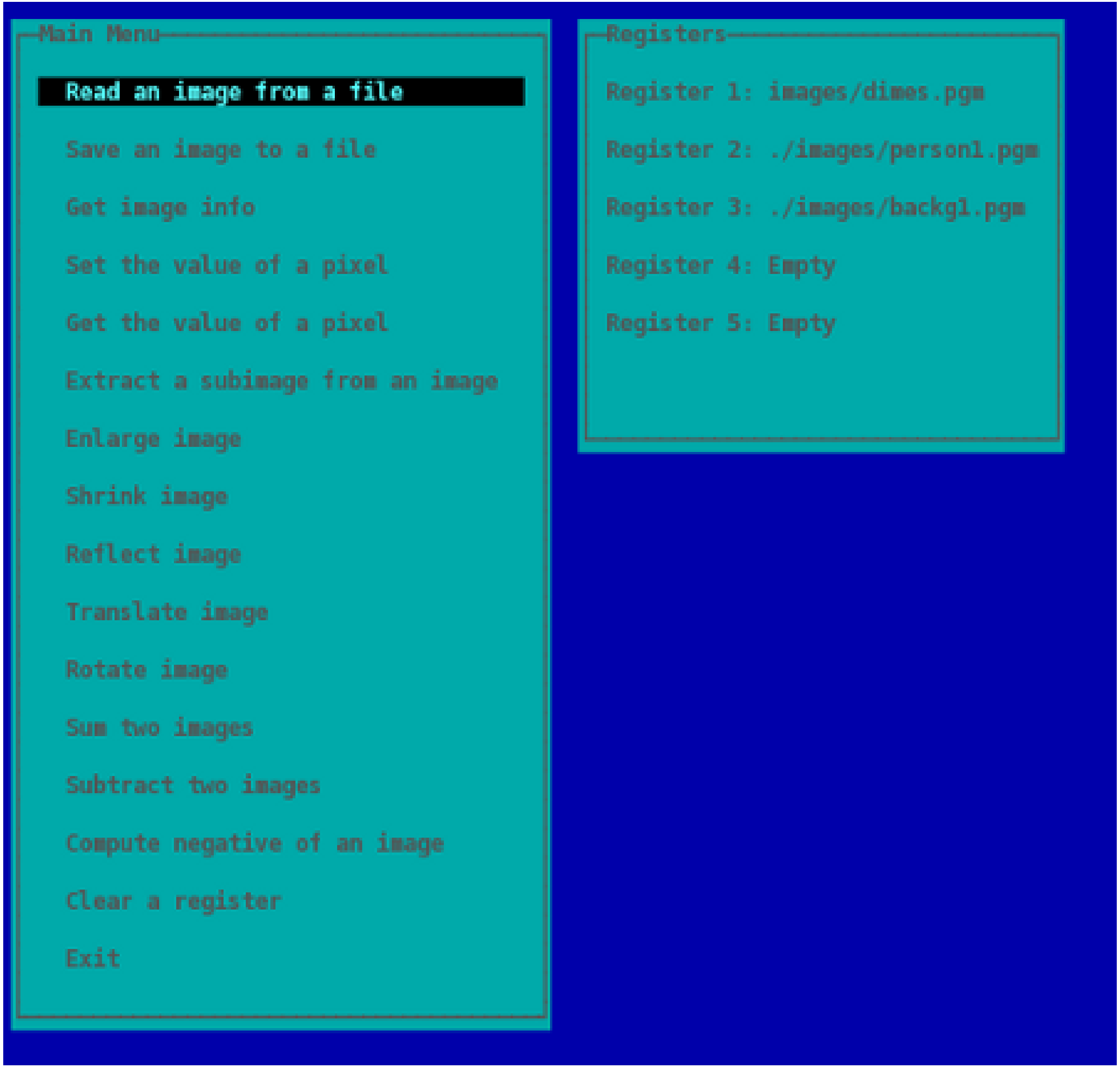
Input

- *&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.

Figure 11: The Main Menu



```
Main Menu                                  Registers

 Read an image from a file                 Register 1: images/dimes.pgm

 Save an image to a file                   Register 2: ./images/person1.pgm

 Get image info                            Register 3: ./images/backg1.pgm

 Set the value of a pixel                  Register 4: Empty

 Get the value of a pixel                  Register 5: Empty

 Extract a subimage from an image

 Enlarge image

 Shrink image

 Reflect image

 Translate image

 Rotate image

 Sum two images

 Subtract two images

 Compute negative of an image

 Clear a register

 Exit
```

Assumptions

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

DRAWWINDOW

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

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.

PROCESSENTRY

```
void processEntry( ImageType[], bool[],
char[][NAME_LEN], 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 ≥ 0 and $<$ 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 weather 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&, 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[], bool[], char[][NAME_LEN],
      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[], bool[], char[][NAME_LEN] );
```

Purpose

Prompt the user for a register to load to, then let them choose from a list of the .pgm 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[][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.

SAVEIMAGE

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

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[][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.

GETIMAGEINFO

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

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 gray 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[][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.

SETPIXEL

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

Purpose

Prompt user for a register then a pixel location (row, col) and then the pixel value 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[], bool[], char[][NAME_LEN] );
```

Purpose

Return the value 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[], 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[], 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[] , 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[] , 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[], bool[], char[][NAME_LEN] );
```

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[][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.

ROTATEIMG

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

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[], 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[], 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[], 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.

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.

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[], ImageType& );
```

Purpose

Reads the image 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[], ImageType& );
```

Purpose

Writes the image 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

SCREENHEIGTH

```
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.

5 What was Learned

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

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.

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 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 LaTeXdocument that made the writing of the documentation very easy and structured. Overall, the students contributed equally for their level of programming skill.

7 Extra Credit

7.1 Question 1

QUESTION:

The algorithm that you have to implement in this assignment to shrink an image is actually very simple and might not always produce good results. Can you think of a more effective solution?

ANSWER:

We used a method where instead of just taking samples we actually averaged all the pixel in each block that is truncated, that way no pixel is unaccounted for. For example if the scale value was 5, then blocks of 5x5 would be shrunk to 1x1. The original method made it so that only the upper left corner of the 5x5 block would be sampled.

7.2 Question 2

QUESTION:

We have already discussed in class two practical difficulties associated with rotation: (a) the case where the transformed pixel coordinates fall outside the image and (b) the case where the transformed pixel coordinates are not integers. In the first case, we suggested simply ignoring the transformed pixel coordinates which fall outside the range. This is probably enough in most cases. In the second case, we suggested finding the nearest integer neighbors to r and c. This approach, however, will not produce a value for every pixel in the output image. In other words, it will produce numerous ”holes” in the rotated image where no value was computed. Can you suggest a way for dealing with this problem?

ANSWER:

To make up for holes in our images, did the opposite of what was originally suggested. Instead of going from the source to the new location we took the new locations and went back to the original to see where that point should fall. This is actually much easier than it sounds as only the index values of the pixel's needed to be reversed. The one issue with this method is that instead of a counter-clockwise rotation, a clockwise rotation happens. We fixed this problem by reversing the angle before making the calculation. Another feature we added to rotate was that it estimates intermediate values so if the destination is looking for a value at (23.234, 43.23) a simple bi-linear algorithm is implemented to obtain the estimated value for that point based on the four points it falls around.

7.3 Question 3

QUESTION:

This question is regarding image subtraction. By examining the difference image, you will notice some rather small non-zero values in image areas where there is not really any change (e.g., subtract "backg1.pgm" from "backg2.pgm" and look at the values of the difference image). These differences are due to sensor noise, slight changes in illumination and various other factors. Can you suggest of a way to deal with this problem?

ANSWER:

For image subtraction there were a few idea's that we had to reduce the amount of noise, but the one we ended up going with was to simply add a difference threshold. This basically means that we made all pixels that differed by at least 43 (which is $\approx 255 \div 6$). This does show some improvements for noticing differences in images without a lot of noise, although some noise is still there.

See figures 12 and 13 on pages 45 and 45

An idea that we had, but didn't have time to implement was to look at each pixel after the threshold is made and remove any white pixel that doesn't have 3 neighbors, then run this over the image until no changes are made. I don't know how this would react but we thought it was an interesting idea.

7.4 Extras

Final Thoughts

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 8 and 9

Figure 12: difference image with noise

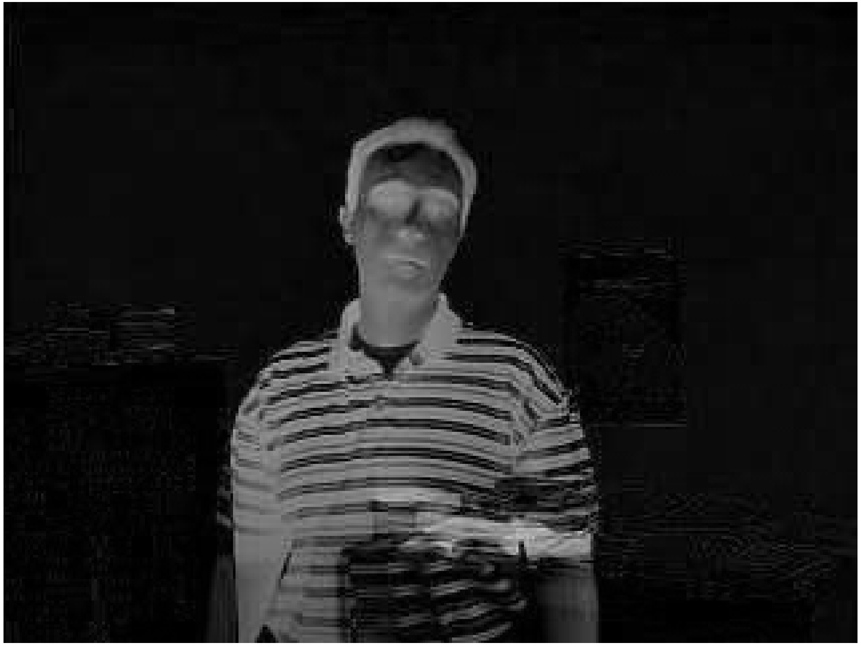


Figure 13: difference image without noise