Game Programming in C++ with Allegro

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0.2.0 Edition

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Chapter 1: Software, Setup and Motivation

Motivation

Uh…..to make games. Seriously though, I wrote this book to be an entry level game programming book. I have scoured the Internet and bookstores for anything approaching a good entry level game programming book, but have found little to nothing. Most books come bundled with game creation software, which is great, but we want to *program* games, not only create them. The others deal with DirectX, a powerful graphics engine that eats noobs….literally. Needless to say I believe these books are not good entry points to the world of game programming. In this book you will learn basic programming concepts through game creation. My goal is that you understand basic programming concepts along with game creation.

Software

In this chapter we are going to discuss the tools we need to create a fully functional game. We will need everything from an Integrated Development Environment (IDE) to a graphics creation program . The good news is that everything we will use in this book is free and open source. Open source is defined as "of or relating to or being computer software for which the source code is freely available"[1]. Basically we will be using programs that the authors give away for free. Not only can you freely download these programs but you are also free to change and add new features to them.

Visual C++ 2008 Express Edition

OK, so the first and most important piece of software that we will need is a compiler and IDE. A compiler is a program that takes code (that we will be writing) and checks it, reports any errors, and creates an executable file for us. An executable file is a file that, well, executes (duh!). That's computer talk for a file that runs; in other words Visual C++ 2008 Express Edition is going to allow us to program and run our game. You can think of it as a Microsoft Word for programmers. Instead of typing essays, papers and books, we are typing C++ computer code. This program, like I have said previously, is completely free. You can download it from http://www.microsoft.com/express/vc/#webInstall. I recommend that you download and install his piece of software first. It can be a lengthy download and install process (it took me about 15-20 minutes).

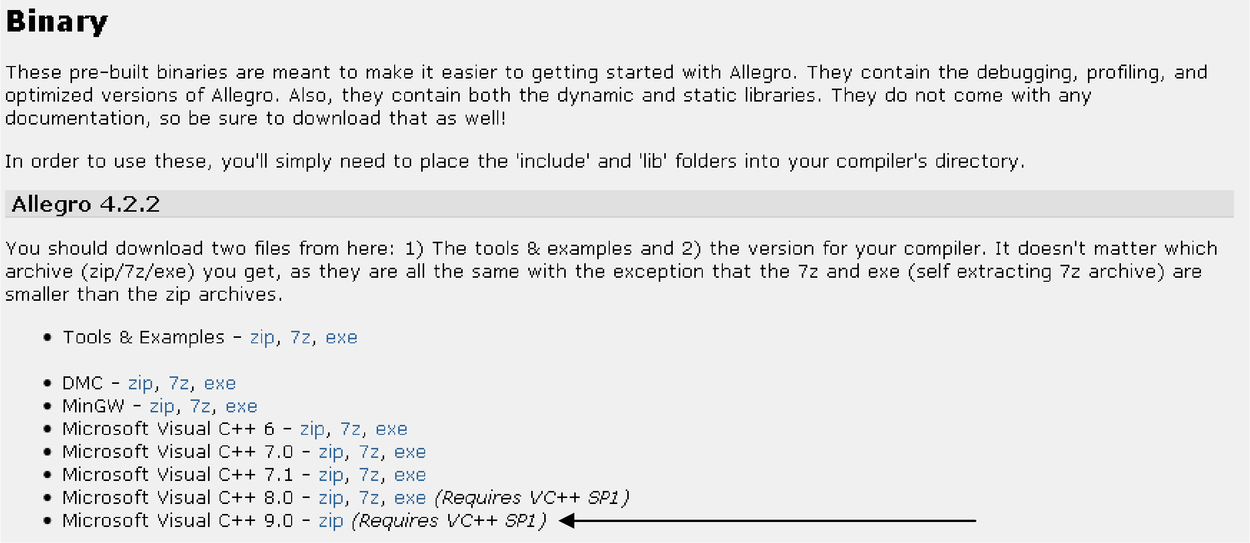
Allegro

Alright, with Visual C++ 2008 you can begin your journey into programming. However, if you want to do anything with graphics you are going to need a graphics library to help you. Most games today use the graphics library produced by Microsoft called DirectX. It is an extremely powerful library and it will work with Visual C++ 2008. But "with great power comes great responsibility"[2], and it turns out that DirectX can be confusing for new programmers (also called noobs). For this reason we will be using the graphics

[1] As defined by google.com
[2] From Spiderman, duh

library called Allegro. It has more than enough power for our purposes. Maybe someday you will be knowledgeable enough to wrestle with DirectX, but for now….baby steps.

You can download the latest stable version of Allegro (currently at 4.2.2) from http://www.allegro.cc/files/. You want to download the binary version of allegro for Microsoft Visual C++ 9.0 (as shown below in figure 1).



Binary

These pre-built binaries are meant to make it easier to getting started with Allegro. They contain the debugging, profiling, and optimized versions of Allegro. Also, they contain both the dynamic and static libraries. They do not come with any documentation, so be sure to download that as well!

In order to use these, you'll simply need to place the 'include' and 'lib' folders into your compiler's directory.

Allegro 4.2.2

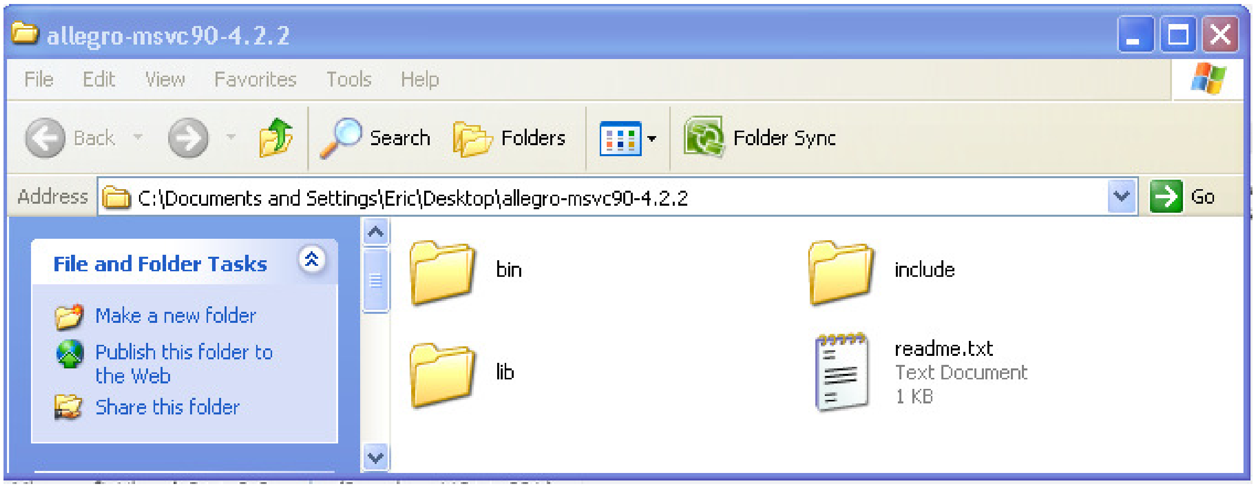
You should download two files from here: 1) The tools & examples and 2) the version for your compiler. It doesn't matter which archive (zip/7z/exe) you get, as they are all the same with the exception that the 7z and exe (self extracting 7z archive) are smaller than the zip archives.

- Tools & Examples - zip, 7z, exe

- DMC - zip, 7z, exe
- MinGW - zip, 7z, exe
- Microsoft Visual C++ 6 - zip, 7z, exe
- Microsoft Visual C++ 7.0 - zip, 7z, exe
- Microsoft Visual C++ 7.1 - zip, 7z, exe
- Microsoft Visual C++ 8.0 - zip, 7z, exe *(Requires VC++ SP1)*
- Microsoft Visual C++ 9.0 - zip *(Requires VC++ SP1)*

Figure 1: Download Microsoft Visual C++ 9.0 zip file

Now, you downloaded a zip file. Your next question probably is, what the heck to I do with that? What a noob, um, I mean, let me help you with that. You want to right click on the folder and select the option “Extract All”. Follow the onscreen guide and in the end you should end up with a folder named “allegro-msvc90-4.2.2”. Inside that folder you should have the folders “bin”, “lib”, “include” and a file named “readme” (as shown in figure 2).



Address: C:\Documents and Settings\Eric\Desktop\allegro-msvc90-4.2.2

Figure 2: The contents of the allegro-msvc90-4.4.4 after unzipped

Now, we have to correctly place these files so that when we program, our compiler can find them. Remember, without these files we will not be able to draw graphics, play sounds, read in input from the keyboard/mouse and a whole slew of other things. If Visual C++ is the car, allegro is definitely the engine. It is the library that will "power" our game.

1. Open the "lib" folder and select all the files (control+a) and copy them (control+c).
    a. Go to My Computer-> C:-> Program Files ->Microsoft Visual Studio 9.0-> VC -> lib
        i. Past the files here (control+v)
2. Open the "include" folder and select all the files (control+a) and copy them (control+c).
    a. Go to My Computer-> C:-> Program Files ->Microsoft Visual Studio 9.0-> VC -> include
        i. Past the files here (control+v)
3. Open the "bin" folder and select all the files (control+a) and copy them (control+c).
    a. Go to My Computer-> C:-> WINDOWS -> system32
        i. Past the files here (control+v)
4. Open the "lib" folder and select the file "alld42.pdb" and copy it (control+c).
    a. Go to My Computer-> C:-> WINDOWS -> system32
        i. Past the files here (control+v)

That was easy, huh? Well maybe it was difficult for some of you, especially if you are not used to navigated the directly structure inside of Windows. The good news is, your done, and hopefully you did everything correctly.

Gimpshop

Lastly, we need a program that we can create and modify our games graphics in. Gimpshop will do the job and it is free. I think I should note that I use and strongly prefer Photoshop to Gimpshop. However, Photoshop is an extremely expensive program (~700 dollars). If you program games and work with digital images a lot (like I do), it is completely worth it; it is an amazing program. But for the purposes of this book I thought it was important to keep the entry cost down to, well, nothing. Nothing beats learning game programming with a free e-book with free programs. It should also be noted that even though I may prefer other, pay products, over these free, open-source products, they are in fact very good and more than adequate for the scope of this book. Indeed, we can create some amazingly powerful and beautiful games with these free programs (as I hope you will see). You can get Gimpshop from http://www.gimpshop.com/.

Summary

Now you should have Visual C++ 9.0, allegro 4.2.2 and Gimpshop all installed and ready to go. All the potential in the world, and you have no idea what to do with it.....such a shame. Oh well, I guess you are just going to just have to read Chapter 2.

Questions/Discussions

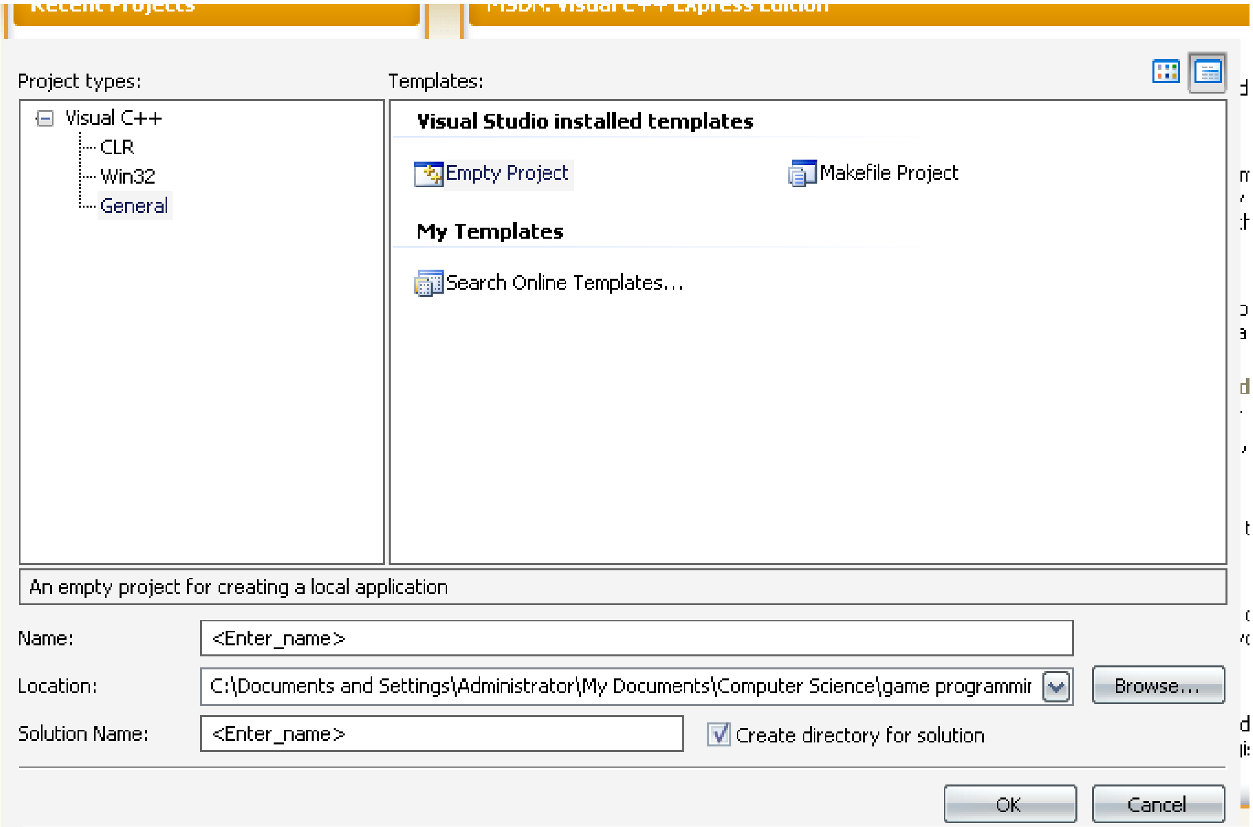
Incomplete section

Chapter 2: Beginning Game Programming

Now, you have everything installed and ready to go. It's time to start our first project….drawing a pixel onto the screen. You may be asking yourself what a pixel is. A pixel is a single point of color on the monitor. It is the smallest unit of color that the monitor can display. Needless to say, when we finish drawing the pixel on the screen, it is going to be a very small point of color.

Setting Up The Pixel Project

First, open up Visual C++ 9.0 Express Edition. Now, go to File-> New-> Project. Your screen should look like Figure 3 below.



An empty project for creating a local application

Name: <Enter_name>

Location: C:\Documents and Settings\Administrator\My Documents\Computer Science\game programmir

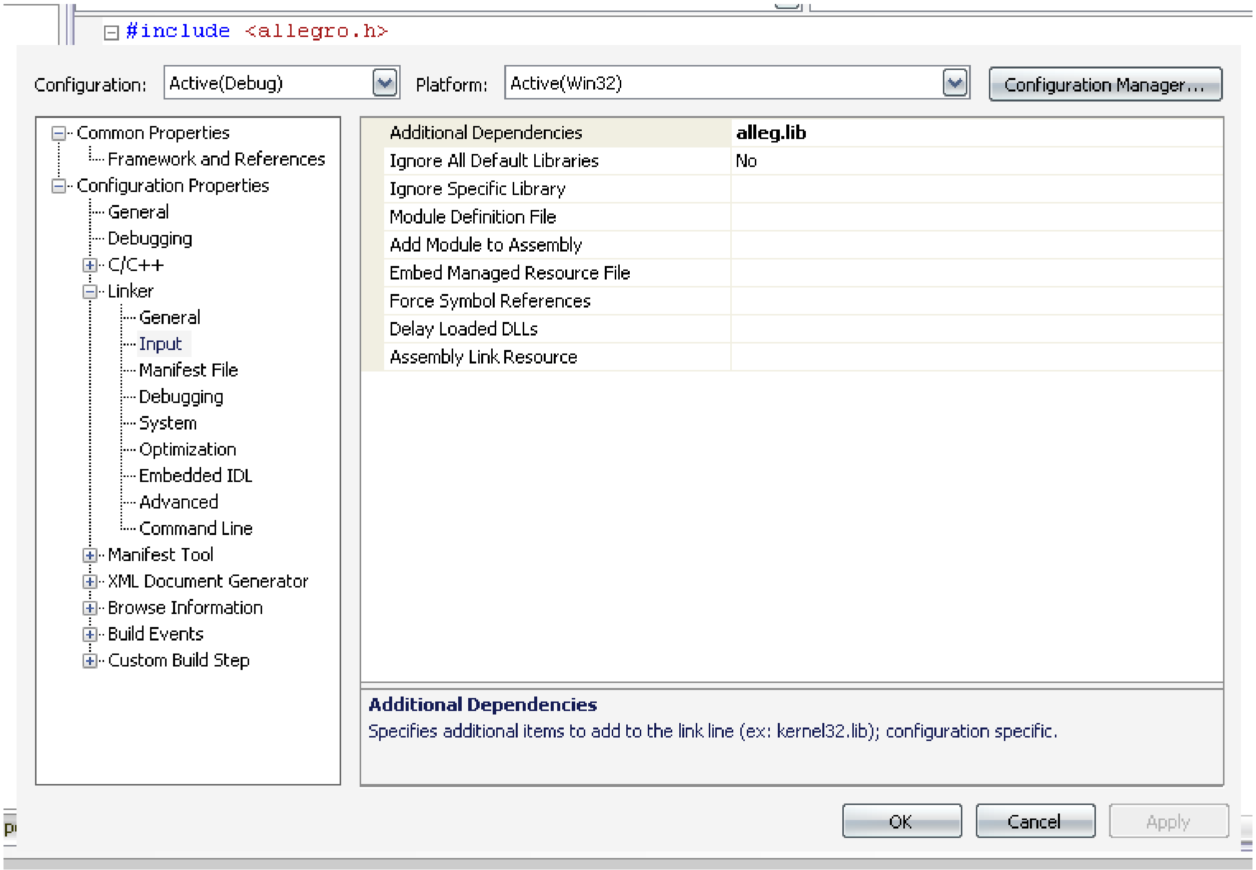
Solution Name: <Enter_name>

☑ Create directory for solution

Figure 3: Starting a New Project

Choose the "General" project type and the "Empty Project" template. Now, for the name type "Pixel" and choose a location like "My Documents" or "Desktop" (anywhere really, your choice). Click "OK". You now have an empty project! Oh, the fun.

Now we need to set the project properties to recognize the allegro library, so that we can use it. To do this go to Project-> Pixel Properties. Now go to Configuration Properties-> Linker-> Input. For Additional Dependencies add “alleg.lib”. It should exactly like Figure 4 below.



```
#include <allegro.h>
```

Configuration: Active(Debug)
Platform: Active(Win32)

Additional Dependencies	alleg.lib
Ignore All Default Libraries	No
Ignore Specific Library	
Module Definition File	
Add Module to Assembly	
Embed Managed Resource File	
Force Symbol References	
Delay Loaded DLLs	
Assembly Link Resource	

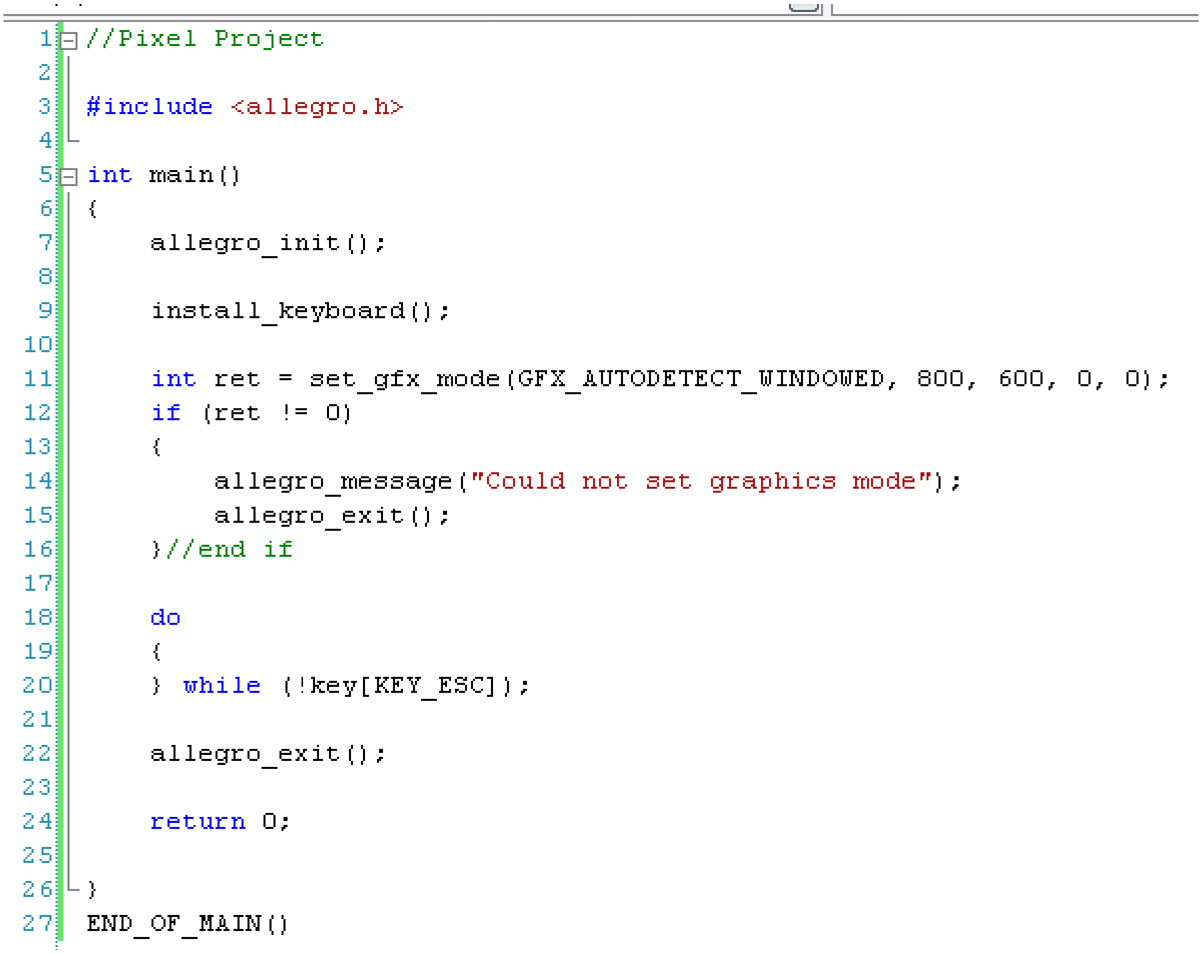
Additional Dependencies
Specifies additional items to add to the link line (ex: kernel32.lib); configuration specific.

Figure 4: Adding the Allegro library to Additional Dependencies

Now, we need to add a blank source file that we can write code on. To do this go to Project-> Add New Item. Choose the “Code” category and select the “C++ File (.cpp)”. Finally, for the name enter “main.cpp” and click the “Add” button. You should see a blank “sheet” of paper on which you can type and edit code. Good, we can finally get down to writing some code.

Creating a Window

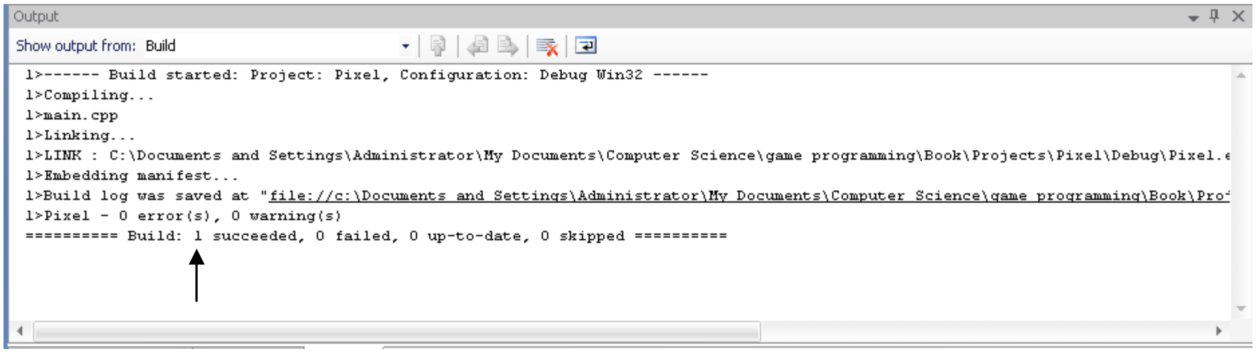
Type the program code below (We will examine what each line does and discuss how to run the program next).



```
//Pixel Project

#include <allegro.h>

int main()
{
    allegro_init();

    install_keyboard();

    int ret = set_gfx_mode(GFX_AUTODETECT_WINDOWED, 800, 600, 0, 0);
    if (ret != 0)
    {
        allegro_message("Could not set graphics mode");
        allegro_exit();
    }//end if

    do
    {
    } while (!key[KEY_ESC]);

    allegro_exit();

    return 0;

}
END_OF_MAIN()
```

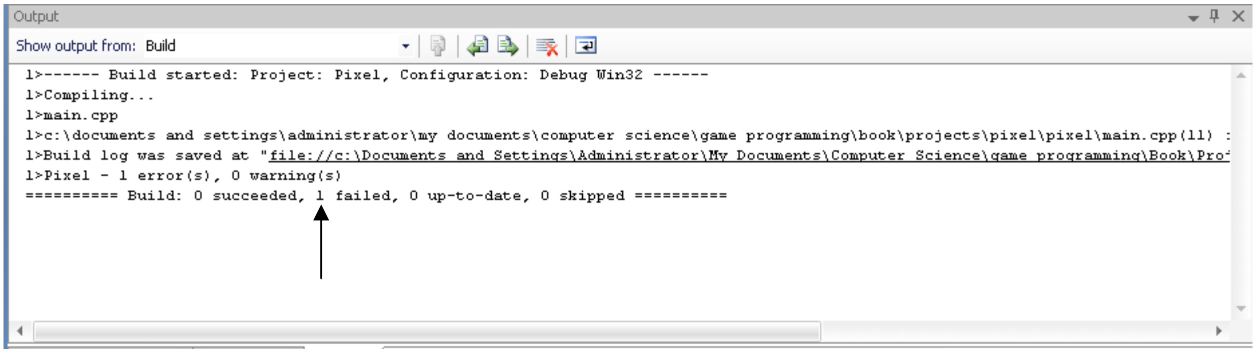
Figure 5: Opening a Window for Pixel Program

Now, you must first compile the program. Compiling takes the code you wrote and translates it into something the computer can understand and run (binary). This step may result in the computer not creating anything at all but instead "yelling" at you for the errors and mistakes that you made. You will see the results of the compile command in the output window at the bottom of the screen. See the figures below for an example of a successful compilation and one that resulted in errors.



```
1>------ Build started: Project: Pixel, Configuration: Debug Win32 ------
1>Compiling...
1>main.cpp
1>Linking...
1>LINK : C:\Documents and Settings\Administrator\My Documents\Computer Science\game programming\Book\Projects\Pixel\Debug\Pixel.e
1>Embedding manifest...
1>Build log was saved at "file://c:\Documents and Settings\Administrator\My Documents\Computer Science\game programming\Book\Pro
1>Pixel - 0 error(s), 0 warning(s)
========== Build: 1 succeeded, 0 failed, 0 up-to-date, 0 skipped ==========
```

Figure 6: A Successful compilation



```
1>------ Build started: Project: Pixel, Configuration: Debug Win32 ------
1>Compiling...
1>main.cpp
1>c:\documents and settings\administrator\my documents\computer science\game programming\book\projects\pixel\pixel\main.cpp(11) :
1>Build log was saved at "file://c:\Documents and Settings\Administrator\My Documents\Computer Science\game programming\Book\Pro
1>Pixel - 1 error(s), 0 warning(s)
========== Build: 0 succeeded, 1 failed, 0 up-to-date, 0 skipped ==========
```

Figure 7: Errors as a result of compilation

If you have errors you must fix them before moving on. Fixing errors, or "debugging" as it is known in programming, is an extremely important skill. The best of programmers spend tons of time debugging their code. In short, get used to it, a lot of your time will be spent debugging code you have already written, rather than writing new code. Visual C++ gives you a description of the error and will take you to it if you double click the error description. Programming is a precise art, as you will find out, and any small omission (like a semicolon) will result in an error message and an unsuccessful compilation. To be a great programmer you need to be a great debugger; end of story. You can compile your program by either going to Build-> Build Solution or pressing F7.

Now that you have successfully compiled your project, it is time to run it and see the results. You can run the project by either going to Debug-> Start Without Debugger or pressing control+F5. You should see a blank window as a result of running the project like in figure 8.

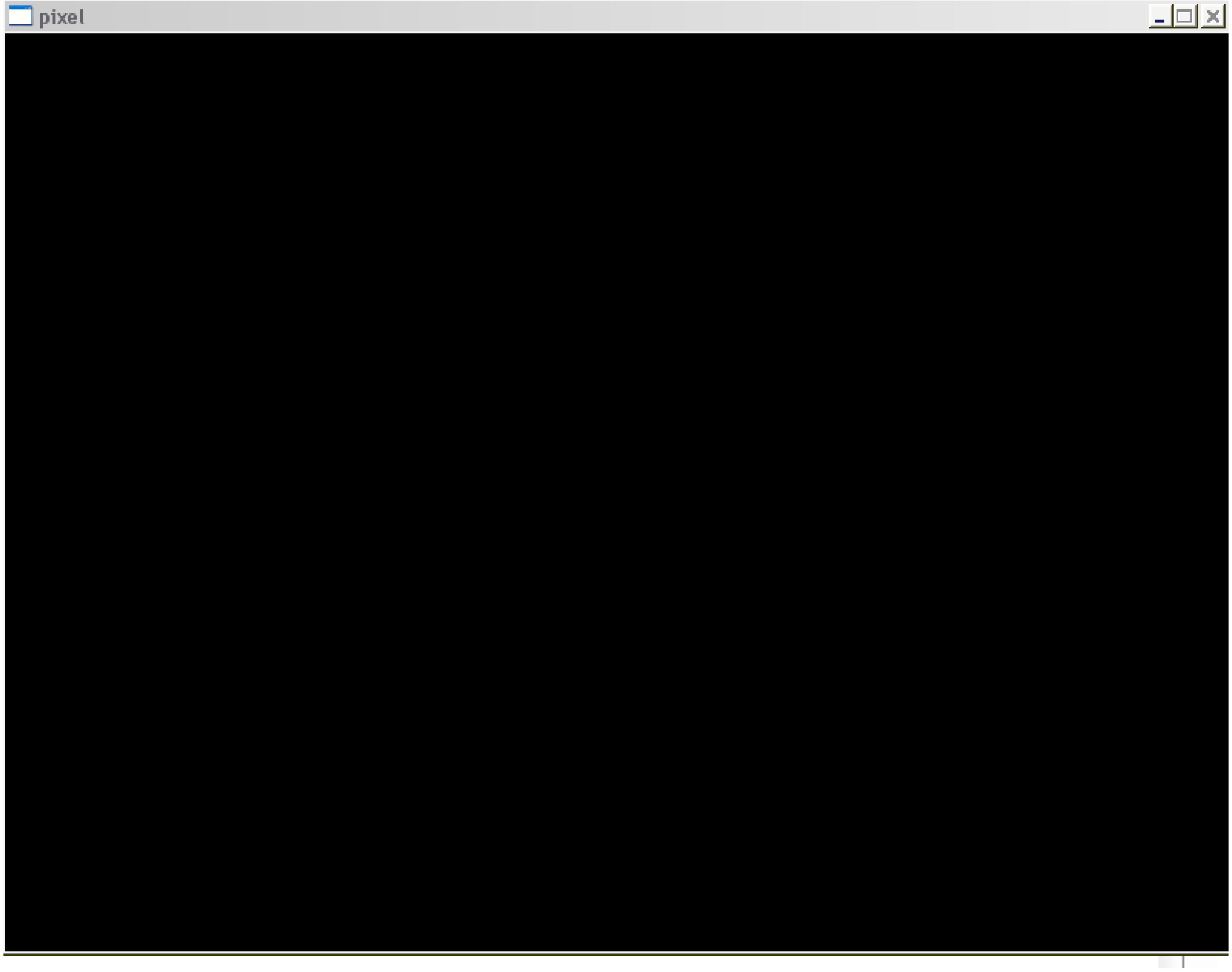


Figure 8: The blank window of our Pixel project

Now, let's examine the code line by line and see what each line is responsible for.

Line 1:

```
//Pixel Project
```

This line is known as a comment, and end-of-line comment to be exact. Comments always start with two forward slashes (//) and are ignored by the compiler. That means, the computer doesn't care about comments at all. So, why do we use comments; to help document the program for ourselves and others. We may want to put our name, date, version number or other information that may be important to us, but not the computer. It results in absolutely nothing, used only for the purposes of writing notes to ourselves in our code.

Line 3:

```
#include <allegro.h>
```

Line 3 is known as a preprocessor directive. In other words, this line is processed BEFORE the program actually begins to execute. This specific line is an include statement. Include statements allow us to include other libraries (or code) into our programs to help us. In this case, we are including the Allegro library which is going to help us draw images, play sounds and obtain input.

Line 5

```
int main()
```

This is a very important line of code. This is the main function declaration. This line is the start of program execution. You can think of this line as a sort of bookmark for the computer. The computer will seek out this line and begin execution from this point. It can conceivable be anywhere in a project, even if it spans thousands of lines of code, or hundreds of separate files; all that matters is that it exists somewhere in your code. The computer will run everything in the body of the main function which is delimited (started and ended with) the open brace on line 6 and the close brace on line 26. That means that the instructions that actual run are found between lines 7 and 25 (the body of function main).

Line 7

```
allegro_init();
```

This line of code initializes the allegro library. Recall that the allegro library is going to help us with graphics, sounds and input. This line is required; it tells allegro to ready itself for use.

Line 9

```
install_keyboard();
```

This one is a tough one. This instruction installs the keyboard, getting it ready for use. What? You knew that? Man, you are a quick learner. This line tells the computer that we will be using the keyboard for input, allowing us to check what keys are being pressed and when they are being pressed.

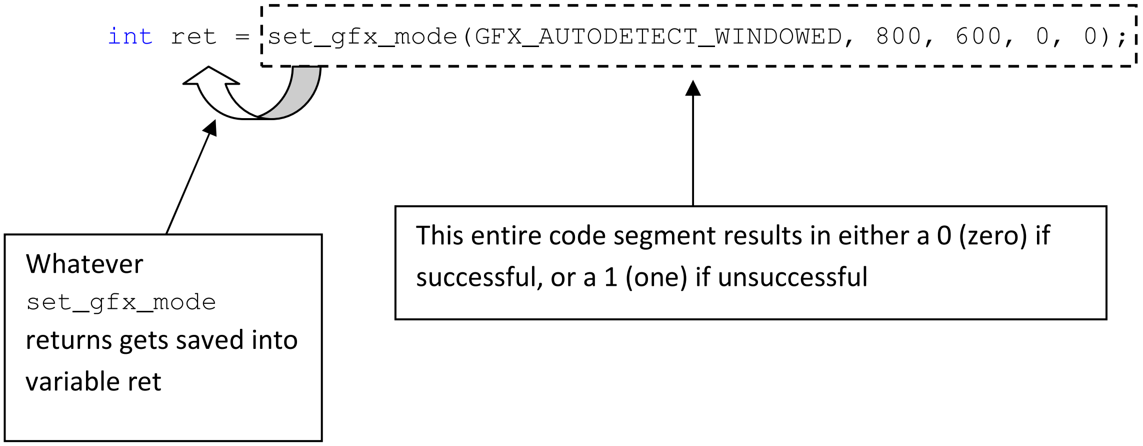
Line 11

```
int ret = set_gfx_mode(GFX_AUTODETECT_WINDOWED, 800, 600, 0, 0);
```

This line tells the computer to open a window of size 800x600. We can change this line to produce a smaller or larger window, as well as creating a full screen game. Each value in the parenthesis is known as an argument and changing its value will change the resulting window. Look at the table below for a description as to what each argument does and possible values for each.

Argument number	Value	Description
Argument 1	GFX_AUTODETECT_WINDOWED	Tells the computer to open a window
	GFX_AUTODETECT_FULLSCREEN	Tells the computer to create a full screen window (without title bar).
Argument 2	800	The window will be 800 pixels wide
	1280	The window will be 1280 pixels wide
Argument 3	600	The window will be 600 pixels in height
	1024	The window will be 1024 pixels in height
Argument 4	0	Virtual Screen width (discussed later). Just leave 0 all the time for now.
Argument 5	0	Virtual Screen height (discussed later). Just leave 0 all the time for now.

Finally, there may be some problems that arise as a result of this line. For example, trying to open a window in a resolution (the width and height combined) that is not supported. Imagine trying to open a window on a cell phone that is in 1280x1024 resolution. Problem is, no cell phone supports that resolution; they operate in resolutions much smaller than that. In cases like these we have a problem. For that reason, the instruction `set_gfx_mode` returns an integer value after attempting to open the window. It returns a 0 (zero) if the window was successfully created and a 1 (one) if something went wrong when attempting to create the window. We save this integer value in a variable we named ret.



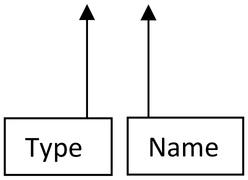
```
int ret = set_gfx_mode(GFX_AUTODETECT_WINDOWED, 800, 600, 0, 0);
```

Whatever `set_gfx_mode` returns gets saved into variable ret

This entire code segment results in either a 0 (zero) if successful, or a 1 (one) if unsuccessful

This line introduces us to variable declarations. Variables are locations in memory where we can store values. In this line we created a variable named ret to be of type int (integer). Recall from your elementary math classes that an integer is any whole number (no decimals, no fractions). It turns out that in C++ we can create variables to hold all kinds of different types of data, but we must specify what type of data each variable will hold. When we declare a variable we need to provide C++ with two pieces of information: (1) variable type and (2) variable name.

```
int ret = set_gfx_mode(GFX_AUTODETECT_WINDOWED, 800, 600, 0, 0);
```



For now we will be working only with integer variables, but we will take a look at other variable types in a later chapter. Now, for naming your variable there are a couple of rules. You can name you variables anything you want as long as you follow the following rules:

- Must start with a letter
- Cannot contain any spaces
- Cannot contain any special symbols
- May contain underscores

Here are some examples of valid and invalid variable names

Invalid	Valid
5num	num5
max health	maxHealth
hit#	hit_number

Finally anytime you see an equal sign (=), that statement is called an assignment statement. An assignment statement is a fancy way of saying that a variables value changed. For example, I can declare a variable and assign it a value at the same time by writing a single statement like:

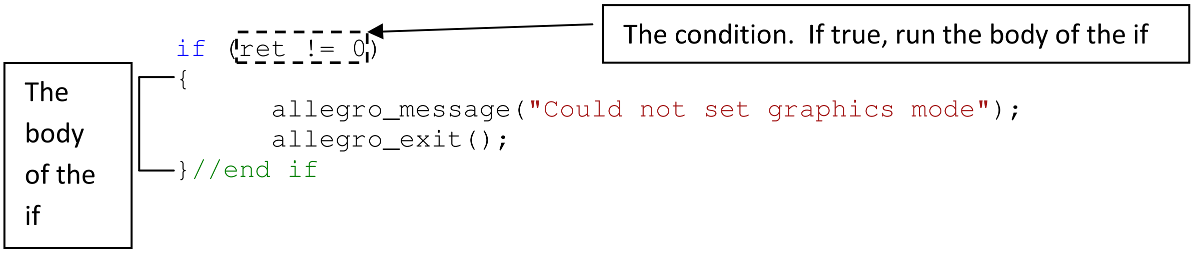
```
int x = 5;
```

Every time you see the equal sign (an assignment statement), the value of the variable has changed to be whatever is on the right hand side. We will examine other ways to use assignment statements in an upcoming section.

Line 12-16

```
        if (ret != 0)
        {
                allegro_message("Could not set graphics mode");
                allegro_exit();
        }//end if
```

Lines 12-16 are collectively known as an if statement. If statements specify a block of code that runs only if some condition (true/false statement) is true. The condition in this case is `ret != 0`, which means variable `ret` not equal to 0. If variable `ret` is not equal to zero, then the body of the if will execute. The body of the if is the block of code delimited by (started and ended with) the open brace on line 13 and the close brace on line 16. Recall that variable `ret` is equal to whatever is returned by `set_gfx_mode`. In this case it will either be a zero if the window was successfully created or a one if there was a problem creating the window. This if starts off by saying if variable ret is not equal to zero then run the body of the if. When would the variable ret not equal zero? When there was a problem creating the window. If there was a problem creating the window then there is obviously no point on going on with the program. The body of the if says to pop up a message that says “Could not set Graphics mode” and then to exit allegro, essentially ending our game. Notice how the end brace has an end of line comment after it. I believe it is always a good idea to comment end braces so you know exactly what they are ending. When we get to more complicated and longer programs, it will save you some time and grief if you know what every end brace is ending.



```
        if (ret != 0)
        {
                allegro_message("Could not set graphics mode");
                allegro_exit();
        }//end if
```

Lines 18-20

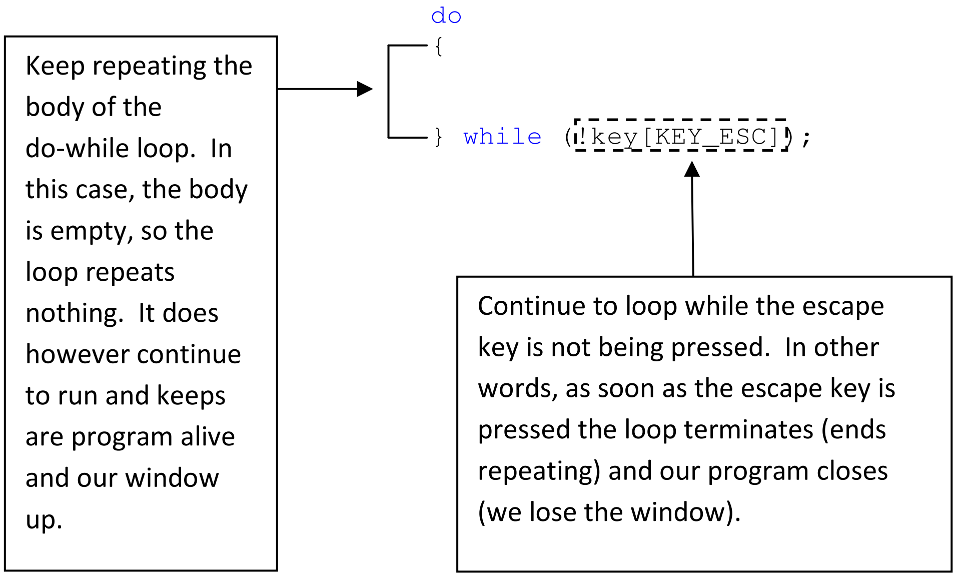
```
do
{
} while (!key[KEY_ESC]);
```

Lines 18 through 20 are known collectively as a do-while loop. Do-while loops repeat the instructions in the body of the loop until some condition (true/false statement) becomes false. In this case the body of the do-while loop is empty (there are no statements between the start brace on line 19 and the end brace on line 20), which essentially means the do-while loop repeats nothing. The purpose of these lines is to keep the window we created up until the escape key on the keyboard is pressed. Eventually we will add code inside the body of the do-while loop, but for now it serves its purpose by running (and spinning its wheels, after all it does nothing!) until the escape key is pressed, thereby keeping our program alive and our window on the screen.

This also gives us an opportunity to see the code to test for key presses. Notice the `!key[KEY_ESC]` line, which tests to see if the escape key is not being pressed (because of the exclamation point, which means "not" in programming). You can test for other key presses by substituting that code for any one of the following:

```
KEY_A - KEY_Z,
KEY_0 - KEY_9,
KEY_0_PAD - KEY_9_PAD,
KEY_F1 - KEY_F12,

KEY_ESC, KEY_TILDE, KEY_MINUS, KEY_EQUALS,
KEY_BACKSPACE, KEY_TAB, KEY_OPENBRACE, KEY_CLOSEBRACE,
KEY_ENTER, KEY_COLON, KEY_QUOTE, KEY_BACKSLASH,
KEY_BACKSLASH2, KEY_COMMA, KEY_STOP, KEY_SLASH,
KEY_SPACE,

KEY_INSERT, KEY_DEL, KEY_HOME, KEY_END, KEY_PGUP,
KEY_PGDN, KEY_LEFT, KEY_RIGHT, KEY_UP, KEY_DOWN,

KEY_SLASH_PAD, KEY_ASTERISK, KEY_MINUS_PAD,
KEY_PLUS_PAD, KEY_DEL_PAD, KEY_ENTER_PAD,

KEY_PRTSCR, KEY_PAUSE,

KEY_ABNT_C1, KEY_YEN, KEY_KANA, KEY_CONVERT, KEY_NOCONVERT,
KEY_AT, KEY_CIRCUMFLEX, KEY_COLON2, KEY_KANJI,

KEY_LSHIFT, KEY_RSHIFT,
KEY_LCONTROL, KEY_RCONTROL,
KEY_ALT, KEY_ALTGR,
KEY_LWIN, KEY_RWIN, KEY_MENU,
KEY_SCRLOCK, KEY_NUMLOCK, KEY_CAPSLOCK

KEY_EQUALS_PAD, KEY_BACKQUOTE, KEY_SEMICOLON, KEY_COMMAND
```

Take a look at the diagram below which explains how the do-while loop works.



```
do
{

} while (!key[KEY_ESC]);
```

Keep repeating the body of the do-while loop. In this case, the body is empty, so the loop repeats nothing. It does however continue to run and keeps are program alive and our window up.

Continue to loop while the escape key is not being pressed. In other words, as soon as the escape key is pressed the loop terminates (ends repeating) and our program closes (we lose the window).

Line 22

```
allegro_exit();
```

Our program is essentially done at this point. All that is left to do is to shutdown everything we have been using. In this case, we need to exit allegro before a program is done.

Line 24

```
return 0;
```

Finally this statement ends our main function. Remember that our main function is the only thing that executes, so `return 0` is the programming equivalent to saying "we are done".

Line 26-27

```
        }
        END_OF_MAIN()
```

Line 26 and 27 end the body of the main function (previously discussed).

Congratulations you now have programmed and understand how to program an application that does absolutely nothing! Good for you. On a serious note, we have the foundation upon which we can now draw pixels.

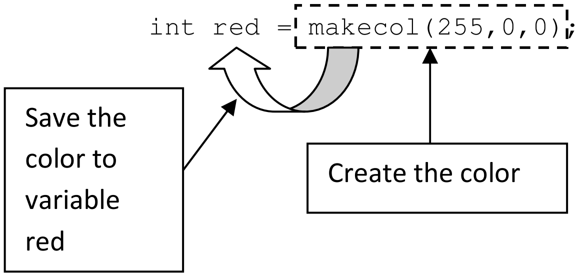
Drawing a Pixel

Drawing a pixel it easy, once you understand how color and the screen coordinate system works. Problem is, we need to know how color and the screen coordinate system works; bet you didn't see that coming. So let's first talk about color, and how computers represent color.

Color, to the computer, is a combination of red, green and blue values. Each of these values can be anywhere from 0 (no color) to 255 (lots of color). Remember that white light is a combination of all colors (it's how a rainbow works). This color system is called RGB (Red, Green, Blue) because of the three colors it uses to produce the range of all colors. In order to make a color we need to use the instruction `makecol`, and abbreviation of make color. Let's take a look at some common colors, and some not so common, and how we would create them in code.

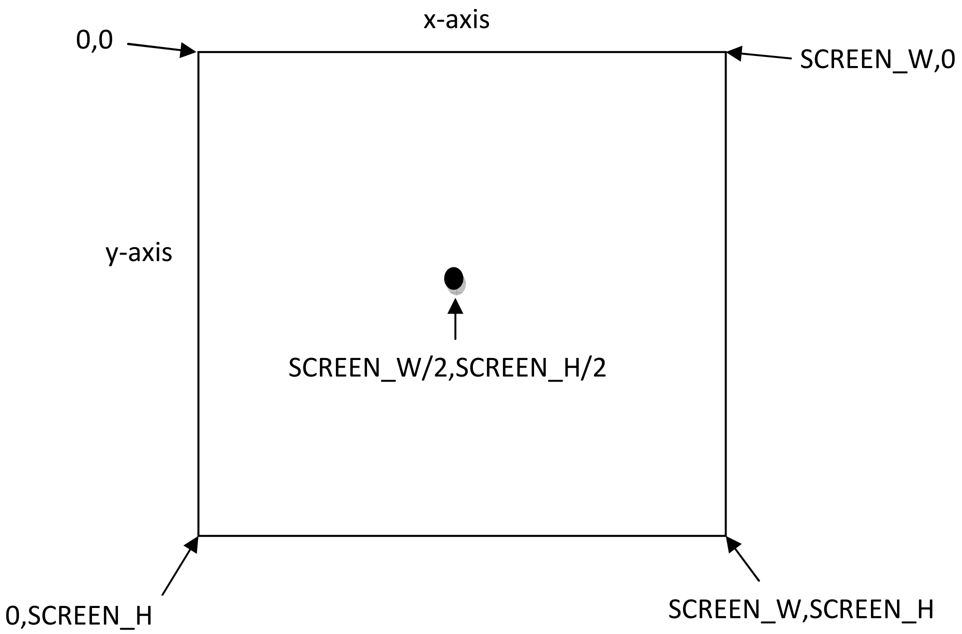
```
        int red = makecol(255,0,0); //lots of red, no green, no blue
        int green = makecol(0, 255, 0); //no red, lots of green, no blue
        int blue = makecol(0, 0, 255); //no red, no green, lots of blue
        int white = makecol(255,255,255); //all colors combined make white
        int black = makecol(0, 0, 0); //the absence of color is black
        int yellow = makecol(255,255,0); //red and blue combined make yellow
        int blueGrey = makecol(163,218,226); //a more complicated color combo
```

It turns out that using the RGB system gives us 255*255*255 possibilities; that's nearly 16.8 million different color combinations, which is more than the human eye can even see! Put plainly, the RGB color system is capable of producing any color you could possibly want. Notice that in the previous examples I saved the color I created to an integer variable.



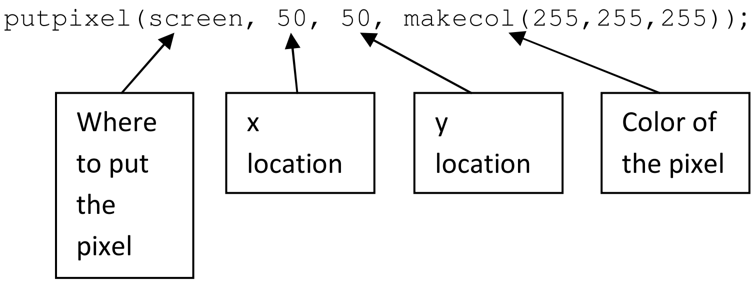
It may at first seem odd so save a color in an integer variable, I know it did to me at first. After all a color is, well a color and not a number. Upon further thought (yes, think!) it makes sense though, because a color is just a combination of RGB intensity values which are numbers themselves. If you think about it for long enough, it will make sense, trust me.

Now we need to understand the screen's coordinate system. The coordinate system is pictured below.



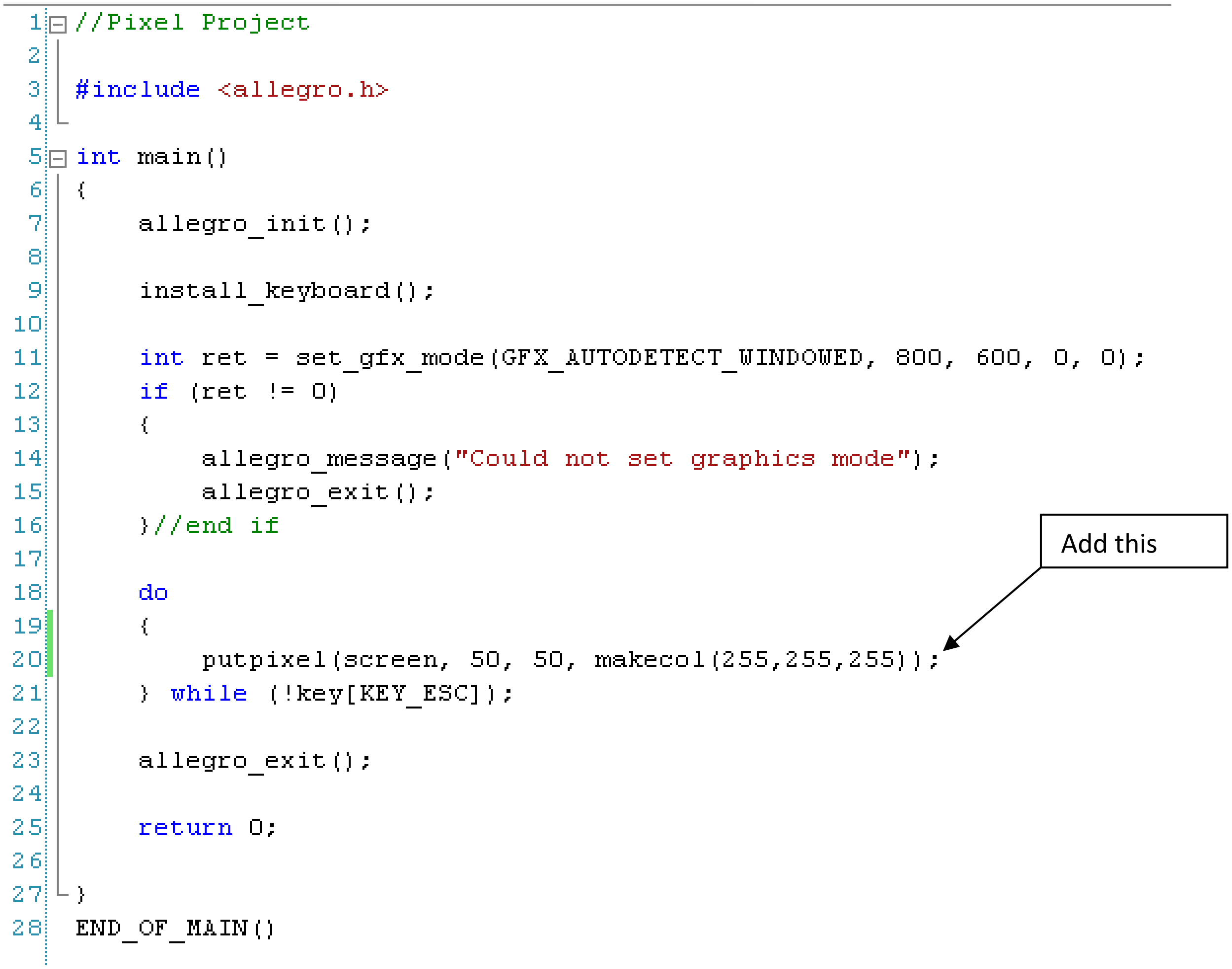
One big problem I see with new programmers is the assumption that the screen coordinate system works exactly like the coordinate system we all learned in math. This assumption is obviously wrong. The screen coordinate system only has positive x and y values. The top left corner of the screen is (0,0), the top right corner is (screen width, 0), the bottom left corner is (0, screen height), the bottom right corner is (screen width, screen height) and the middle point is (screen width divided by 2, screen height divided by 2). Recall that the screen width and height of our window is 800x600 right now. Essentially that means that the x-axis works exactly like you remember from math, but the y-axis is reversed; moving down the screen the y values get larger, while moving up the screen they get smaller.

Now, we can finally draw a pixel on the screen. Let's take a look at the instruction and dissect it's arguments.



```
putpixel(screen, 50, 50, makecol(255,255,255));
```

This instruction then would put a single pixel on the screen at (50, 50) in white. By adding this code to our do-while loop we can see the result; which is a white pixel in the top left corner of the screen. Look closely, some new programmers underestimate how small a pixel actually is. Below is the complete program listing, you just need to add the one line to your code.



```
//Pixel Project

#include <allegro.h>

int main()
{
    allegro_init();

    install_keyboard();

    int ret = set_gfx_mode(GFX_AUTODETECT_WINDOWED, 800, 600, 0, 0);
    if (ret != 0)
    {
        allegro_message("Could not set graphics mode");
        allegro_exit();
    }//end if

    do
    {
        putpixel(screen, 50, 50, makecol(255,255,255));
    } while (!key[KEY_ESC]);

    allegro_exit();

    return 0;

}
END_OF_MAIN()
```

Add this

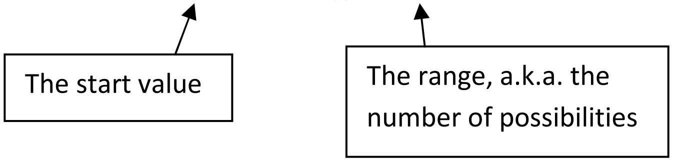
Modifying The Pixel Program

As exciting as our pixel program is (sarcasm), I think we need to do some things to liven it up. In order to add some excitement to our program we need to look at random number generation.

Random Number Generation

Random number generation is an extremely important topic to understand when it comes to game programming. We will be using random number generation in every single project that we write, so it is important that you take the time to understand it thoroughly, so that you have a solid foundation upon which we can build. Random number generation does exactly what you think it would: generates random numbers. The key to random number generation is to be able to control the range of numbers being produced. For example if we want to create a random amount of red, green or blue we would want to generate random numbers between 0 (no color) and 255 (a ton of color). Let's take a look at a random number generation statement and dissect it.

```
1 + rand() % 6
```



The statement above will produce random number between 1 and 6. It does this because the start value is 1 and the range is 6 (the number of possibilities). Let's take a look at another statement:

```
5 + rand() % 3
```

What numbers will this produce? It turns out that this equation produces numbers between 5 and 7. Why? Well starting at 5 count 3 times (the range) and you get 5, 6, 7. Therefore, this statement produces numbers between 5 and 7. How about his one?

```
8 + rand() % 10
```

Most new programmers would answer 8 – 18; but as I'm sure you have concluded by now, they are wrong. Let's examine this; starting at 8 count 10 times (the range): 8, 9, 10, 11, 12, 13, 14, 15, 16, 17. That's your answer, this equation generates numbers between 8 and 17. Now, how would we generate a random amount of red, green and blue and then create a random color based on those values? Well, we need to know the start value and the range in order to write a random number generation statement. What is the lowest value red, green and blue can be? Correct, zero. And the highest value red, green and blue can be? Correct, 255. Now, for the tricky part. What is the range between 0-255, that is, how many numbers are there between 0 and 255? The answer is 256 (trust me). Now, understanding that, let's take a look at how we would create a random color:

```
    int red = 0 + rand() % 256;
    int green = 0 + rand() % 256;
    int blue = 0 + rand() % 256;
    int color = makecol(red, green, blue);
```

Notice that I am creating variables to store the random numbers in (`red`, `green`, `blue`) and then using those variables to create a new color. It may be perplexing at first (that means confusing, duh) to see that a color can be stored inside an integer variable (`color`). But we must remember that computers are really only good at one thing: numbers. Therefore, the computer prefers to assign a unique number to every single possible color.

Now that we have a random color to use for our pixel, let's also choose a random location to place it (x, y). A random x location can range from 0 to the width of the window (800 in this case) and a random y location can range from 0 to the height of the window (600 in this case). It is always good programming practice to not use numbers when you program, because numbers change. For example, it would be a bad idea to randomly choose an x and y value in the following way:

```
int x = 0 + rand() % 800;
int y = 0 + rand() % 600;
```

The 800 and 600 values, the width and height respectively, can change. For example, we may want to make this game full screen later. If we do that then we would have to find every 800 and 600 value in the code and replace them with the new values. So, instead we use to constants that allegro provides us, by using these we can change the size of the window at any time and our code would automatically scale correctly. The new, better, lines of code can be found below (notice also that I removed the 0 for obvious reasons).

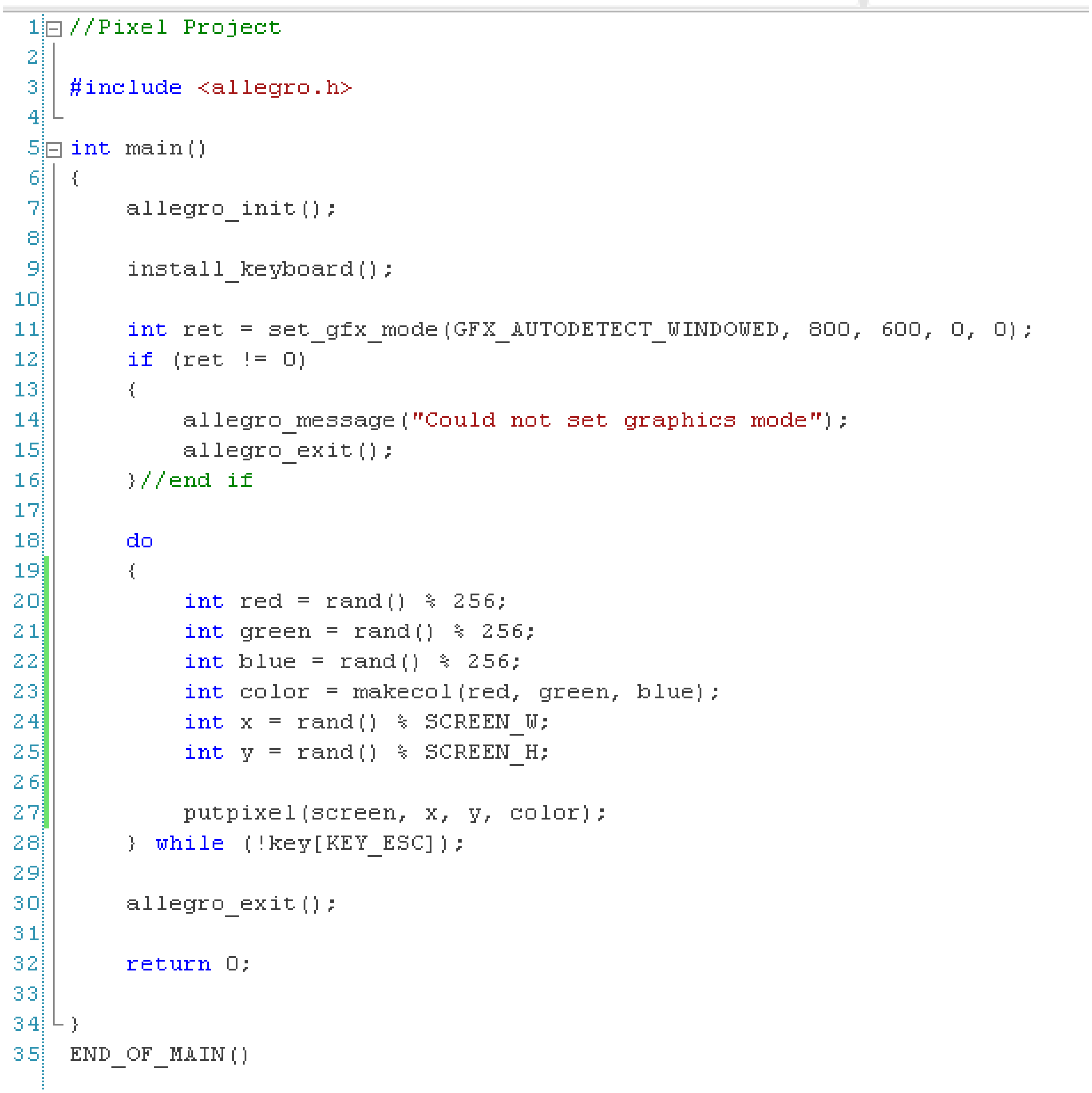
```
int x = rand() % SCREEN_W;
int y = rand() % SCREEN_H;
```

Now, we have randomly created a color and a location, all that is left to do is draw the pixel on the screen at the random location in the random color (below).

```
putpixel(screen, x, y, color);
```

Notice that I used variables `x`, `y` and `color`, all of which are randomly chosen. I literally have no idea where this pixel will appear or what color it will be (it is randomly chosen by the computer). Now, where does this code actually go? Let's take a look at the complete code listing.

Pixel Explosion



```
//Pixel Project

#include <allegro.h>

int main()
{
    allegro_init();

    install_keyboard();

    int ret = set_gfx_mode(GFX_AUTODETECT_WINDOWED, 800, 600, 0, 0);
    if (ret != 0)
    {
        allegro_message("Could not set graphics mode");
        allegro_exit();
    }//end if

    do
    {
        int red = rand() % 256;
        int green = rand() % 256;
        int blue = rand() % 256;
        int color = makecol(red, green, blue);
        int x = rand() % SCREEN_W;
        int y = rand() % SCREEN_H;

        putpixel(screen, x, y, color);
    } while (!key[KEY_ESC]);

    allegro_exit();

    return 0;

}
END_OF_MAIN()
```

I like to call this program “Pixel Explosion” because, well, it results in an explosion of pixels. Why does it result in an explosion of pixels? Let’s examine the do-while loop.

Recall that the body of the loop repeats over and over again. In this case, each time through the loop we choose a new amount of red, green, blue, create a new color and chose new random values for x and y. Finally, we place a pixel at this new location with this new color. The result is that each time through the loop we get a new pixel, in a new location, in a new color. This loop continues to repeat until the escape key is pressed, resulting in pixels showing up on the screen until the program ends.

```
do
{
        int red = rand() % 256;
        int green = rand() % 256;
        int blue = rand() % 256;
        int color = makecol(red, green, blue);
        int x = rand() % SCREEN_W;
        int y = rand() % SCREEN_H;

        putpixel(screen, x, y, color);

} while (!key[KEY_ESC]);
```

Choose random color and random location

Draw the pixel at random location with random color

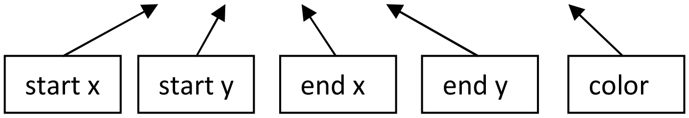
Repeat until the escape key is pressed

Drawing Other Primitives

Pixels are known as primitives because of how simple they are compared with other graphics. There are other graphics primitives that we can draw: lines, rectangles, circles and triangles. Let's take a quick look at the code we would need to draw these primitives.

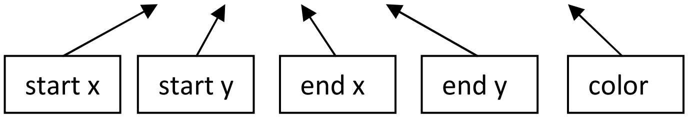
Lines

```
line(screen, 20, 50, 100, 200, makecol(255,255,255));
```



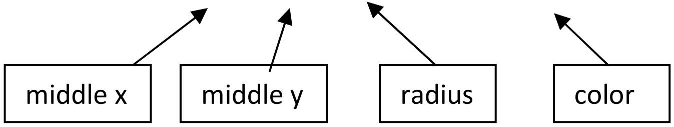
Rectangles

```
rectfill(screen, 20, 20, 100, 100, makecol(255,255,255));

rect(screen, 20, 20, 100, 100, makecol(255,255,255));
```



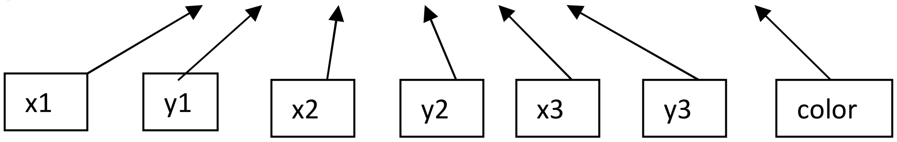
Circles

```
circlefill(screen, 400, 400, 50, makecol(255,255,255));

circle(screen, 400, 400, 50, makecol(255,255,255));
```



Triangles

```
triangle(screen, 40, 40, 100, 200, 60, 100, makecol(255,255,255));
```



For both rectangles and circles you have two options. To draw only an outline of the shape or to draw the shape filled. I suggest you try each of these out, changing the numbers to get a feel for what each does and how they look on the screen.

Summary

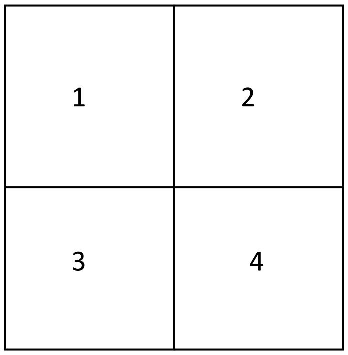
You now have a working program that puts pixels on the screen. It's not much, but it's a good start. The best advice I can give you now is to try to do some of the exercises and programming projects. Programming is really both a skill and art, and the only way to get better at it is to program.

Exercises and Programming Projects

Exercises

1. Describe what is meant by "debugging" in programming.
2. (Extra Effort) There are three types of programming errors: Compilation errors, run-time errors and logic errors. List and describe each type of error.
3. What capabilities does the `allegro.h` library give our programs when we include it?
4. The allegro game library needs to be initialized before it can be used. Write the line of code that initializes allegro.
5. We must tell the computer that we want to use the keyboard for our games. Write the line of code that readies the keyboard for use.
6. Describe what screen resolution is. Why is it important in game programming?
7. Write the line of code that will create a full screen window in a 1280x1024 resolution.
8. Declare an integer variable named red.
9. Declare an integer variable named blue.
10. Declare an integer variable named age.
11. Declare an integer variable named grade and initialize it (using an assignment statement) to 16.
12. Declare an integer variable named count and initialize it (using an assignment statement) to 10.
13. Which of the following variable names are invalid, explain why.
    ```
    a. number_5
    b. sum
    c. sum!
    d. my number
    e. 5number
    f. my_num_5
    g. my#5
    ```
14. Identify what color the following statements create (you may need to plug these into an actual program to figure them out).
    ```
    a. makecol(255,255,255)
    b. makecol(255, 0, 0)
    c. makecol(0,255,0)
    d. makecol(0,0,255)
    e. makecol(0,0,0)
    f. makecol(255,255,0)
    g. makecol(0,255,255)
    h. makecol(255,0,255)
    ```

15. Consider a screen which is broken up into four quadrants like below, with a screen resolution of 800x600:



Which quadrant will the following x, y values be in?

   a. 0, 0
   b. 800, 600
   c. 800, 0
   d. 0, 600
   e. 200, 500
   f. 100, 100
   g. 500, 0
   h. 500, 400
   i. 50, 500

16. List and describe the arguments of function `putpixel`.
17. What two constants does allegro provide for the width and height of the screen?
18. What range of random numbers is produced by the following random number generation statements?

```
a. 1 + rand() % 6
b. rand() + 6
c. 4 + rand() % 4
d. 3 + rand() % 2
e. 7 + rand() % 5
f. 100 + rand() % 14
g. 14 + rand() % 1
```

19. Write a random number generation statement to achieve the following:
   a. Produce numbers between 5 – 10
   b. Produce numbers between 3 – 6
   c. Produce numbers between 14 – 20
   d. Produce numbers between 1 – 8
   e. Produce numbers between 4 and 50
   f. Produce a random amount of red and store it into variable `red` (using an assignment statement).

g. Produce a random amount of blue and store it into variable `blue` (using an assignment statement).

h. Produce a random amount of green and store it into variable `green` (using an assignment statement).

i. Create an integer variable `color` and set it equal to a color combining the `red`, `green` and `blue` values you created in questions f, g and h.

j. Produce a random x coordinate and store it in an integer variable x for a screen in an 800x600 resolution.

k. Produce a random x coordinate and store it in an integer variable x for a screen in an 1280x1024 resolution.

l. Produce a random y coordinate and store it in an integer variable y for a screen in an 800x600 resolution.

m. Produce a random y coordinate and store it in an integer variable y for a screen in an 1280x1024 resolution.

Projects

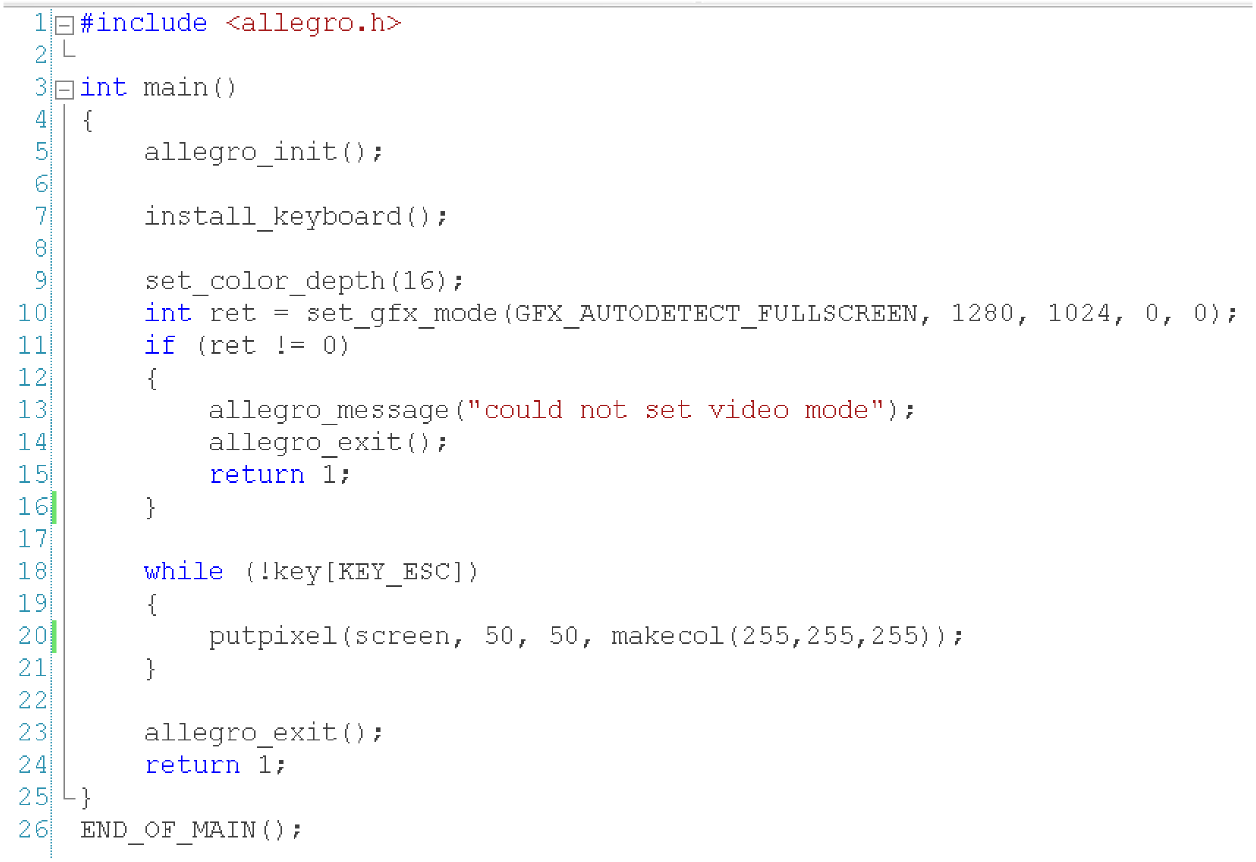
1. Create a “line explosion” program, similar to our pixel explosion program, only instead of drawing random pixels, you will draw random lines. (Hint: lines take different information to be drawn than pixels. Make sure you declare and randomly generate all the values a line function requires.)
2. Create a “rectangle explosion” program, similar to our pixel explosion program, only instead of drawing random pixels, you will draw random rectangles.
3. Create a “circle explosion” program, similar to our pixel explosion program, only instead of drawing random pixels, you will draw random circles.
4. Create a “triangle explosion” program, similar to our pixel explosion program, only instead of drawing random pixels, you will draw random triangles.
5. Combine all the draw function we know (pixels, lines, rectangles, circles and triangles) and create an image on the screen. (Hint: you do not want anything to be random in this program).

Chapter 3: Input

This chapter deals with everything you need to know about keyboard and mouse input. That is, it discusses how to read key presses from the keyboard and track movement and button presses for the mouse.

Etcha Sketcha: The Beginning

We will begin to look at key presses from the keyboard. I think the best way to learn about the keyboard and mouse is to develop a project that uses them. Our starting point will be a simple program that draws a single pixel onto the screen (shown below). You should create a new project and add the following code.

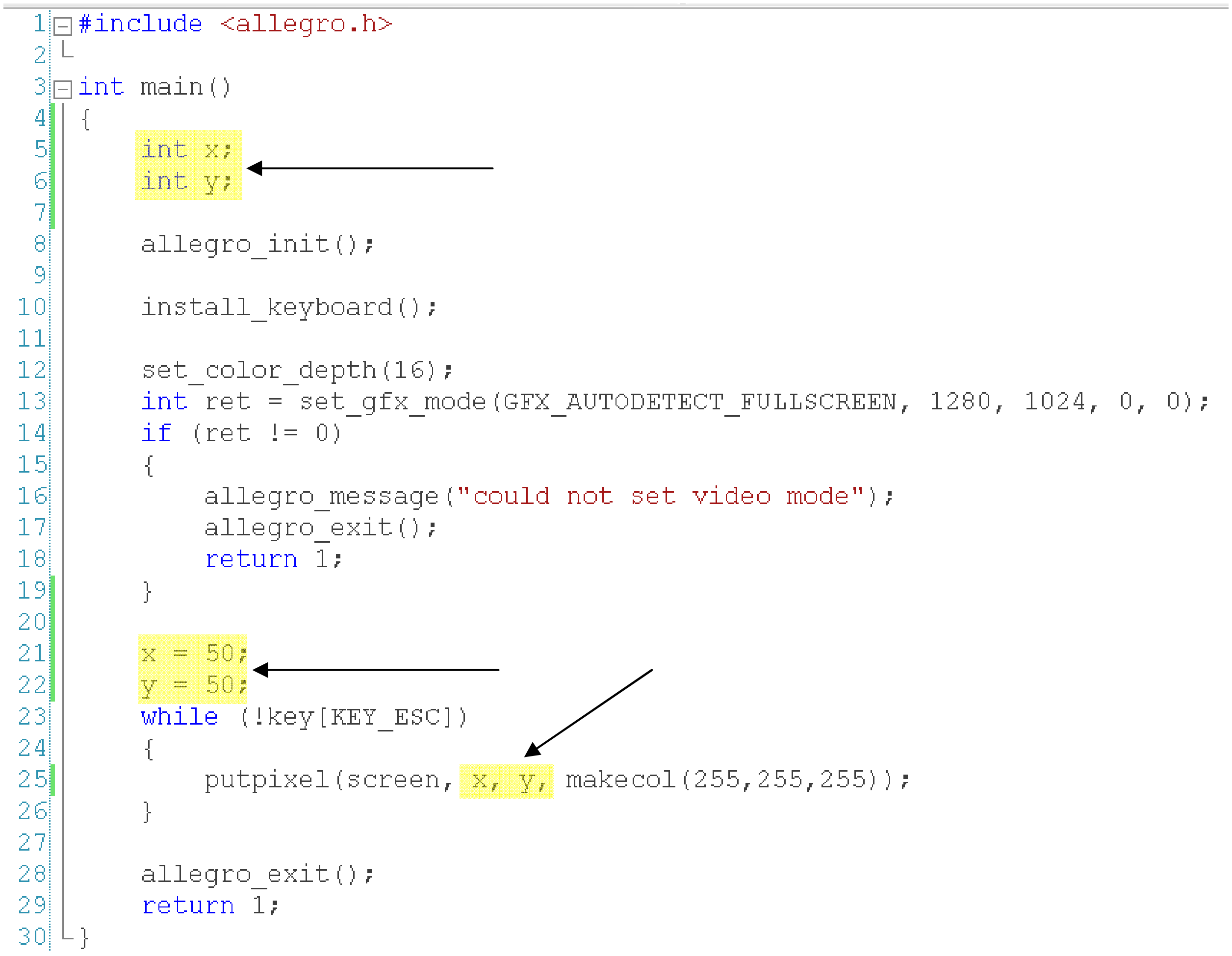


```
#include <allegro.h>

int main()
{
    allegro_init();

    install_keyboard();

    set_color_depth(16);
    int ret = set_gfx_mode(GFX_AUTODETECT_FULLSCREEN, 1280, 1024, 0, 0);
    if (ret != 0)
    {
        allegro_message("could not set video mode");
        allegro_exit();
        return 1;
    }

    while (!key[KEY_ESC])
    {
        putpixel(screen, 50, 50, makecol(255,255,255));
    }

    allegro_exit();
    return 1;
}
END_OF_MAIN();
```

This should be a review so I am not going to discuss how the program works or what each line is accomplishing. If you need help with this program I suggest you re-read chapter 2 of the book, or perhaps read chapter 2 of the book (for those of you who skipped it completely, yeah, I'm talking to you!).

Etcha Sketcha: Adding Variables

I am calling this project "Etcha Sketcha" because it is going to make our computer screen act like an etcha sketch (that toy you may have played with when growing up). The first step to creating this project is to add variables for the location of the pixel. Recall that a variable is some piece of data that *changes*, and we certainly want the location of our pixel to be able to change because we are going to be moving it all over the screen. Look at the code listing below to see the changes (which I have highlighted for your convenience, aren't I nice? Don't answer that.).



```
#include <allegro.h>

int main()
{
    int x;
    int y;

    allegro_init();

    install_keyboard();

    set_color_depth(16);
    int ret = set_gfx_mode(GFX_AUTODETECT_FULLSCREEN, 1280, 1024, 0, 0);
    if (ret != 0)
    {
        allegro_message("could not set video mode");
        allegro_exit();
        return 1;
    }

    x = 50;
    y = 50;
    while (!key[KEY_ESC])
    {
        putpixel(screen, x, y, makecol(255,255,255));
    }

    allegro_exit();
    return 1;
}
```

Now, compile and run the project. Ah, isn't that nice, nothing has changed. I love doing some work and seeing no result, don't you? Unfortunately you need to get used to it, it is pretty common that you have to add a lot of code to an existing project before you will "see" any changes. Let's take a look at the new lines and see what had changed, as far as the code is concerned at least.

Lines 5 and 6

```
int x;
int y;
```

You should recognize these two lines as being variable declarations. Here I have created two variables named x and y respectively that can each hold a single integer value. It should be noted, as it very important, that these variables currently hold some unknown integer (usually a very large positive or negative number). You can only use these variables after they have been initialized using an assignment statement (a statement using the = sign). I have named these two variables x and y because they will hold the current x and y position of my pixel on the screen.

Lines 21 and 22

```
x = 50;
y = 50;
```

These two lines initialize variables x and y to each hold the integer value of 50. Now that these variables have been initialized (given a start value) I can use them. In other words, everywhere you see the variable names x and y, the computer sees the value 50.

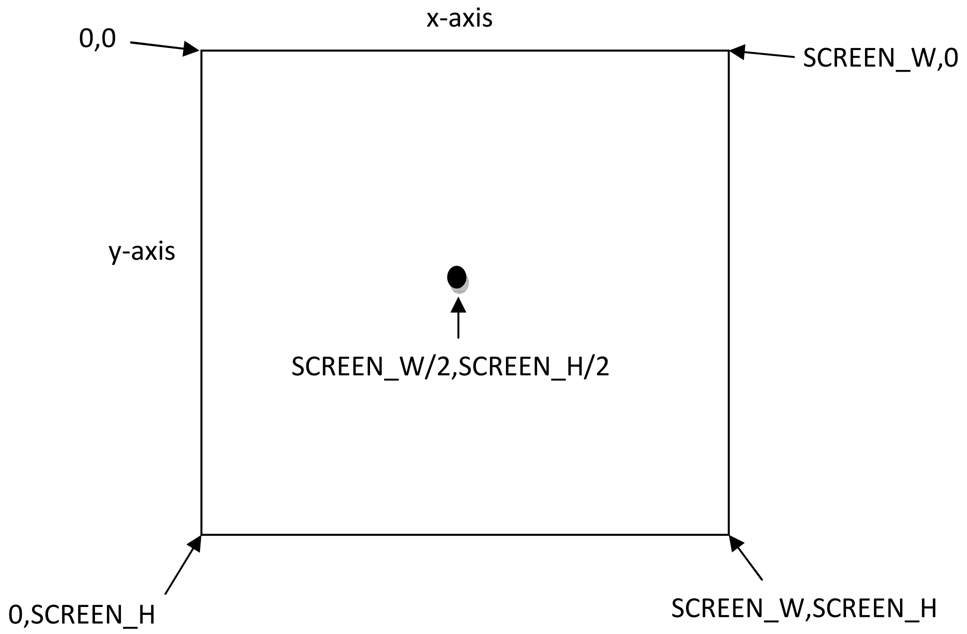
Line 25

```
putpixel(screen, x, y, makecol(255,255,255));
```

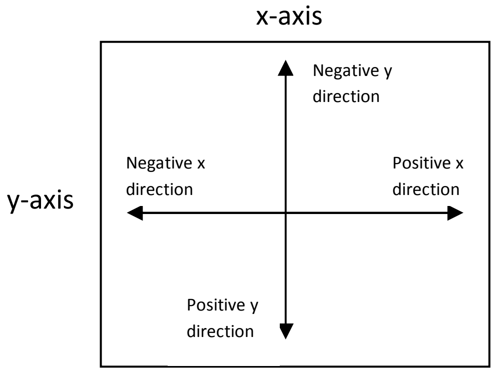
The only change in this line is the removal of the value 50 and the inclusion of variables x and y. Remember that I set variables x and y to each hold the value 50, so in actuality I have changed nothing, which is why you see no changes when the program runs. However, by putting variables for putpixel's location I am able to change where the pixel is drawn by simply changing the values of x and y. If I had left it at 50, 50 it would always be 50, 50.

Etcha Sketcha: Understanding Directional Movement

Before we can move our pixel around on the screen we need to have a complete understanding of the screens coordinate system. Remember this figure from chapter 2 (I sure hope so):



In chapter 2 we talked about the screen coordinate system and how important it is to remember that it differs from the coordinate system we are so used to from our studies in math. Below is a nifty little diagram (yea, I said nifty, don't judge me!!) to help you learn and remember how movement will work on the computer screen. Remember that movement will always be in terms of an x, y position.

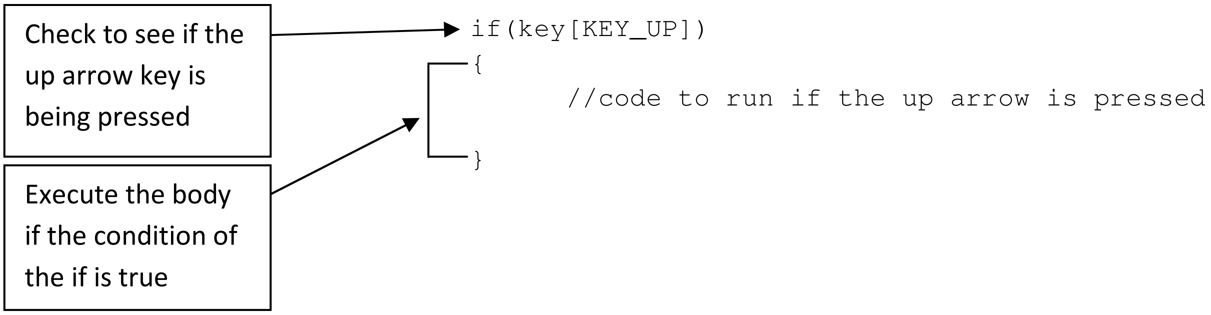


Etcha Sketcha: Reading Key Presses

We briefly discussed reading key presses in Chapter 2 but we are going to make extensive use of reading key presses in this project. Recall that each key has the following code association with it:

```
KEY_A - KEY_Z,
KEY_0 - KEY_9,
KEY_0_PAD - KEY_9_PAD,
KEY_F1 - KEY_F12,

KEY_ESC, KEY_TILDE, KEY_MINUS, KEY_EQUALS,
KEY_BACKSPACE, KEY_TAB, KEY_OPENBRACE, KEY_CLOSEBRACE,
KEY_ENTER, KEY_COLON, KEY_QUOTE, KEY_BACKSLASH,
KEY_BACKSLASH2, KEY_COMMA, KEY_STOP, KEY_SLASH,
KEY_SPACE,

KEY_INSERT, KEY_DEL, KEY_HOME, KEY_END, KEY_PGUP,
KEY_PGDN, KEY_LEFT, KEY_RIGHT, KEY_UP, KEY_DOWN,

KEY_SLASH_PAD, KEY_ASTERISK, KEY_MINUS_PAD,
KEY_PLUS_PAD, KEY_DEL_PAD, KEY_ENTER_PAD,

KEY_PRTSCR, KEY_PAUSE,

KEY_ABNT_C1, KEY_YEN, KEY_KANA, KEY_CONVERT, KEY_NOCONVERT,
KEY_AT, KEY_CIRCUMFLEX, KEY_COLON2, KEY_KANJI,

KEY_LSHIFT, KEY_RSHIFT,
KEY_LCONTROL, KEY_RCONTROL,
KEY_ALT, KEY_ALTGR,
KEY_LWIN, KEY_RWIN, KEY_MENU,
KEY_SCRLOCK, KEY_NUMLOCK, KEY_CAPSLOCK

KEY_EQUALS_PAD, KEY_BACKQUOTE, KEY_SEMICOLON, KEY_COMMAND
```

To check for key presses all we have to do is make use of an if statement (discussed in detail in Chapter 2). Look at the code below for a template:



Check to see if the up arrow key is being pressed

Execute the body if the condition of the if is true

```
if(key[KEY_UP])
{
        //code to run if the up arrow is pressed
}
```

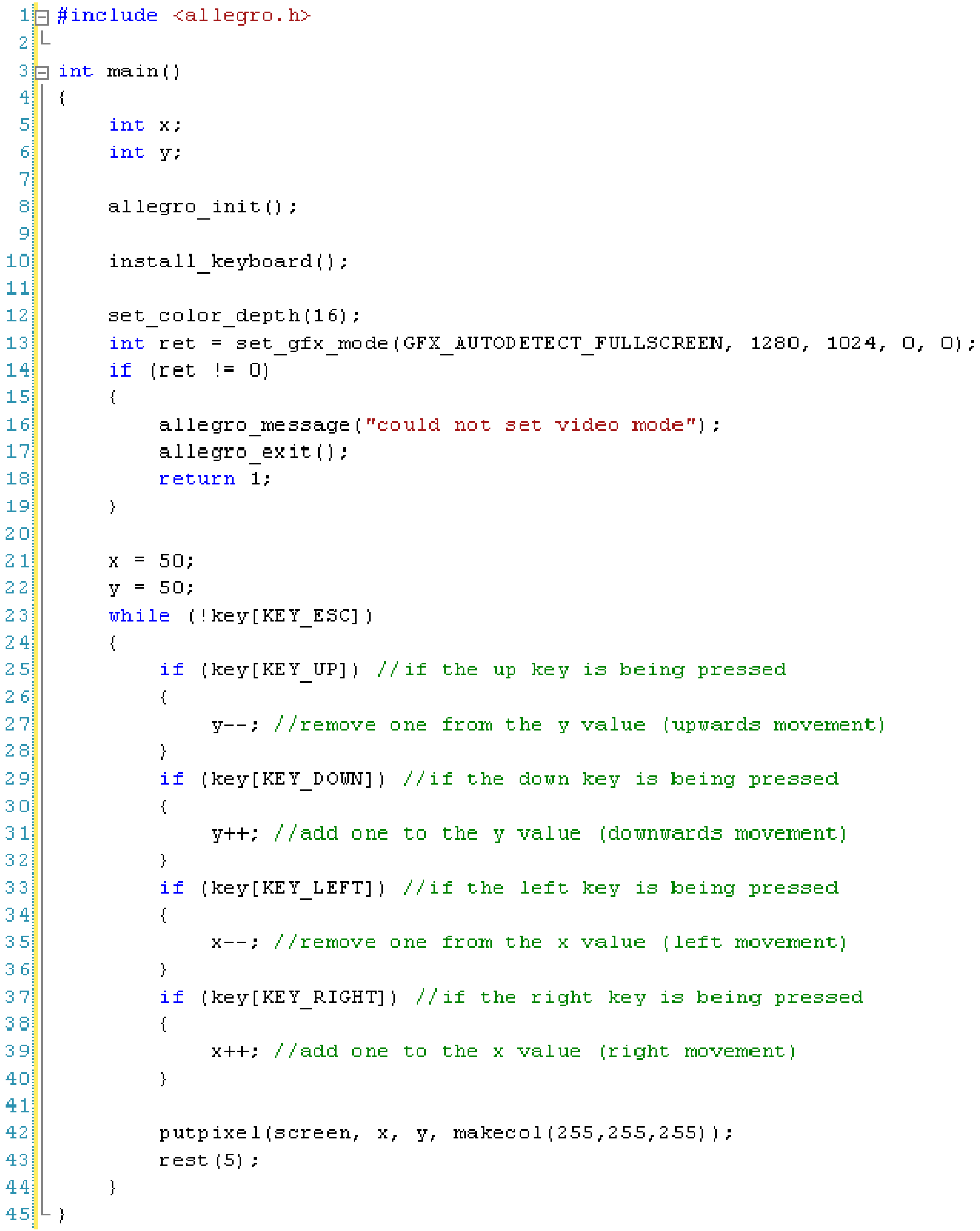
Now, let's take a look at what we do for our etcha sketcha program when certain keys are being pressed. I am going to use the arrow keys to move the pixel around on the screen but you can easily choose your own keys and type their corresponding key code (see the table of key codes above). Now, what do we want to actually do if the up, down, left and right key are being pressed? In order to answer this question we need to know what direction the pixel should move when certain keys are being pressed. Looking at the figure on page 31 I have come up with the following ifs.

```
if (key[KEY_UP]) //if the up key is being pressed
{
     y--; //remove one from the y value (upwards movement)
}
if (key[KEY_DOWN]) //if the down key is being pressed
{
     y++; //add one to the y value (downwards movement)
}
if (key[KEY_LEFT]) //if the left key is being pressed
{
     x--; //remove one from the x value (left movement)
}
if (key[KEY_RIGHT]) //if the right key is being pressed
{
     x++; //add one to the x value (right movement)
}
```

The pixel is being drawn at location x, y (which are variables). The above code changes the values of x and y when certain keys are being pressed, which in turn changes the location the pixel is being drawn at. The result is that the pixel moves around the screen when the arrow keys are being pressed. There is one last line that we need for this program to work. The line is:

```
     rest(5);
```

This statement tells the computer to slow down and rest for 5 microseconds before continuing on with the program. If we do not include this line the program will run so fast that we will not get the intended results. You need to remember that computers execute thousands upon thousands of statements a second! What does that mean to you? Well, it means that every time you hit the up arrow, for example, the computer reads that key press hundreds of times. The result is that your pixel will "shoot" off the screen with a single key press unless you tell the computer to slow down. Go ahead and omit this line from your program and you will see exactly what I am talking about. It should also be noted that you can change the number inside the parenthesis of the rest command. Larger numbers mean a longer rest but never put this value too high or negative; you will end up with a program that doesn't do anything for a very long time. Below is the complete code listing for the modified etcha sketcha program.



```
#include <allegro.h>

int main()
{
    int x;
    int y;

    allegro_init();

    install_keyboard();

    set_color_depth(16);
    int ret = set_gfx_mode(GFX_AUTODETECT_FULLSCREEN, 1280, 1024, 0, 0);
    if (ret != 0)
    {
        allegro_message("could not set video mode");
        allegro_exit();
        return 1;
    }

    x = 50;
    y = 50;
    while (!key[KEY_ESC])
    {
        if (key[KEY_UP]) //if the up key is being pressed
        {
            y--; //remove one from the y value (upwards movement)
        }
        if (key[KEY_DOWN]) //if the down key is being pressed
        {
            y++; //add one to the y value (downwards movement)
        }
        if (key[KEY_LEFT]) //if the left key is being pressed
        {
            x--; //remove one from the x value (left movement)
        }
        if (key[KEY_RIGHT]) //if the right key is being pressed
        {
            x++; //add one to the x value (right movement)
        }

        putpixel(screen, x, y, makecol(255,255,255));
        rest(5);
    }
}
```

Notice that the code to check for key presses as well as the rest statement is all put inside the while loop. The while loop is the structure that is responsible for keeping our game window up and running. All the code for the game must eventually find its way inside the while loop.

Etcha Sketcha: Cleaning It All Up

There are just a couple of things that we really need to clean up. Foremost is the starting location of the pixel. Right now the pixel starts at location (50, 50), which is the top left part of the screen. We want to start the pixel off at the middle of the screen (at least I think that makes the most sense, and lets be honest, I'm writing the book, not you; that somehow makes me innately correct. Wow, this is a long addition in parenthesis. Now it's even longer…..ok…done). We can start the pixel off at the center of the screen by simply changing the start values of x and y on lines 21 and 22. The middle of the screen is ½ the screen width and ½ the screen height….simple enough. Make these changes to lines 21 and 22 then.

```
x = SCREEN_W / 2;
y = SCREEN_H / 2;
```

The last change we might want to institute is the color of the pixel. Right now it is white but you can change it to be anything you want by simply modifying the color parameter of the putpixel call. For example, replacing my original putpixel line with the one below will now create etcha sketcha lines in green instead of white.

```
putpixel(screen, x, y, makecol(0,255,0));
```

Etcha Sketcha: Adding Mouse Movement

This can quite possibly be the simplest addition to etcha sketcha; the ability to draw with the mouse instead of the keyboard. The reason this is so easy is because allegro handles all of the mouse movement and tracking for us! Geeze, thanks allegro! The first change you need to make is to tell allegro that you actually want to use the mouse. You do this in the same way you tell allegro that you want to use the keyboard. Below are the two statements that tell allegro you want to use the keyboard and the mouse respectively.

```
install_keyboard();
install_mouse();
```

No real magic there, those lines are pretty self explanatory (at least they should be….right….oh well, just don't tell anyone you have no idea what we're talking about).

Now that we have installed the mouse, which tells allegro we want to use it, allegro begins to track and poll the mouse for movement and button presses. Allegro gives us two variables that conveniently tell us where the mouse pointer is at any given time, they are:

```
mouse_x
mouse_y
```

Pretty easy, right? Now, all we have to do is draw the pixel at mouse_x and mouse_y and that little pixel will follow our mouse wherever it goes……cool.

```
putpixel(screen, mouse_x, mouse_y, makecol(0,255,0));
```

Exercises and Programming Projects

Exercises

1. If a graphic or primitive is moving up the screen, what direction is it moving (with respect to x,y).
2. If a graphic or primitive is moving down the screen, what direction is it moving (with respect to x,y).
3. If a graphic or primitive is moving right on the screen, what direction is it moving (with respect to x,y).
4. If a graphic or primitive is moving left on the screen, what direction is it moving (with respect to x,y).
5. If a graphic or primitive is moving left and up on the screen, what direction is it moving (with respect to x,y).
6. If a graphic or primitive is moving left and down on the screen, what direction is it moving (with respect to x,y).
7. If a graphic or primitive is moving right and up on the screen, what direction is it moving (with respect to x,y).
8. If a graphic or primitive is moving right and down on the screen, what direction is it moving (with respect to x,y).
9. Write an if statement to check if the space bar is being pressed.
10. Write an if statement to check if the w key is being pressed.
11. Write an if statement to check if the up arrow is being pressed.
12. Write an if statement to check if the 8 on the numpad is being pressed.
13. Write the code necessary to subtract one from a variable named x.
14. Write the code necessary to add one to a variable named y.
15. Write the code necessary to subtract one from a variable named health.
16. Write the code necessary to add one to a variable named score.
17. What statement allows us to “slow” our games down? Explain how it works.
18. Write the C++ statement that readies the mouse for input.
19. What two constants does allegro provide us for the location of the mouse at all times?
20. What is the key code for the left shift key?
21. What is the key code for the spacebar?
22. What is the key code for up arrow in the numpad?
23. What is the key code for the right control key?

Projects

1. Complete the etcha sketcha program with mouse movement. Allow the user to change the color of the pixel by pressing keys on the keyboard. If the ‘R’ key is pressed the pixel should change to red, ‘B’ to blue, ‘G’ to green and finally ‘W’ to white. (hint: create a color variable that will store the current color being used).
2. Modify the etcha sketcha program to allow the user to change brush type and color. The following is a set of keys that should be implemented as input:

P:	change brush to a pixel
R:	change brush to a rectangle
C:	change brush to a circle
T:	change brush to a triangle
R:	change brush color to red
B:	change brush color to blue
G:	change brush color to green
W:	change brush color to white
L:	change brush color to black

You may also implement any other colors or brush types you want, be creative!

Chapter 4: Bitmaps

What is a Bitmap?

A bitmap in the simplest terms is a picture. There are many file formats that pictures can be stored in, including the more popular file formats of JPEG, PNG and GIF. However, allegro cannot use these more popular file formats. Instead, allegro uses the BMP (Bitmap) file format. That means anytime you want to place an image in your game, whether it be a background or an avatar, it needs to be in the .bmp file format. Gimpshop is able to convert any image you want into the bmp file format, so we don't need to be worried that we cannot use certain images, we just need to convert them to the proper file format.

Creating, Loading and Displaying a Bitmap

In order to put a bitmap on the screen we need to first declare a bitmap variable (a variable which can hold a bitmap picture), then load the picture into that variable, and finally display that picture on our game window. First let's talk about how to declare a bitmap variable. Bitmap variables are declared like any other variable, with a type and a name. The type in this case is BITMAP and the name can be any valid identifier you want. Let's look at an example of a bitmap variable declaration:

```
    BITMAP *wizard;
```

Above, is a bitmap variable named `wizard`. Notice the star or asterisk that precedes the variable name. This asterisk is required and tells C++ that this variable is a pointer to an image. Pointers are a complex topic in programming, so for now just understand that you need the asterisk before your variable name for all bitmap variables. After declaring a bitmap variable we can load a bitmap image into it. It is very important to know that there is no image currently in wizard. If we attempted to use this variable now, like if we attempted to place the `wizard` variable's image on the screen, it would crash our entire program. This is a common error with new programmers. Make sure that you **ALWAYS** load a picture into a bitmap variable **BEFORE** you attempt to use it.

Now we are ready to load an image into the `wizard` variable. First thing we need is a bitmap image. This is a book on programming, not image creation. If you want to create your own image or convert an image to bmp format you can google search how to do that. I will be using an image you can find at http://mrmcelrea.com/ComputerScience/Game%20Programming/Sprites/wizard.bmp. You can use this image if you want. Finally, you **MUST** make sure that your bmp image you are going to load is in the same folder as your .cpp file; it will not load if you do otherwise. Below is the code to load an image into a bitmap variable. The code includes some lines to check to make sure the picture loaded correctly. It is always a good idea when you load pictures, sounds, fonts or anything from outside the program to check to make sure that it gets imported into the game correctly. In this case, if the picture is not loaded correctly then an error message is displayed saying "could not load the wizard image" and the game is exited.

This if checks to make sure the image was loaded correctly

```
wizard = load_bitmap(“wizard.bmp”, NULL);
if (wizard == NULL)
{
        allegro_message(“could not load the wizard image”);
        allegro_exit();
}
```

The name of the file. It must be in the same directory as your .cpp file.

Ok, we created and loaded our bitmap. The last thing to do is tell C++ to display our bmp image on the game window. Allegro will put the image on the screen for us, all we have to do is tell **allegro** where we want to place it. Below is the line of code which will display the wizard image onto the screen at (500, 500).

```
draw_sprite(screen, wizard, 500, 500);
```

That is how you put an image on the screen from creating to loading to displaying. A complete program that displays the wizard image follows:

```
#include <allegro.h>

int main()
{
        BITMAP *wizard;

        allegro_init();
        install_keyboard();

        set_color_depth(16);
        int ret = set_gfx_mode(GFX_AUTODETECT_FULLSCREEN, 1280, 1024, 0, 0);
        if (ret != 0)
        {
                allegro_message("could not set video mode");
                allegro_exit();
                return 1;
        }

        wizard = load_bitmap("wizard.bmp", NULL);
        if (wizard == NULL)
        {
                allegro_message("could not load the wizard image");
                allegro_exit();
        }

        while (!key[KEY_ESC])
        {
                draw_sprite(screen, wizard, 500, 500);
        }

        allegro_exit();
        return 1;
}
```

```
END_OF_MAIN();
```

Adding Movement to our Bitmap

Adding the abililty to move our bitmap around the screen is no different from adding the ability to move a pixel around the screen (which we did in chapter 3). We just need to create an x and y variable for the position of the wizard. We create these variables at the very beginning of function main, right below our wizard bitmap variable declaration. Let's start the position of the wizard off at (500,500).

```
double wizardX = 500;
double wizardY = 500;
```

Notice that I declared `wizardX` and `wizardY` as doubles, that is, they hold decimal values. Decimal values result in much smoother movement. Now, we just need to change the `draw_sprite` instruction to draw the `wizard` not at (500, 500) but at (`wizardX`, `wizardY`). This gives us the ability to change `wizardX` and `wizardY`, which would change his location on the screen.

```
draw_sprite(screen, wizard, wizardX, wizardY);
```

If you run the program now, nothing has changed. However, we can now add the ability to change the values of `wizardX` and `wizardY` with key presses, thereby moving the `wizard` around on the screen. We will use the arrow keys to move the wizard around on the screen. This code needs to be added inside the main while loop, that way it runs every time the game updates. You should probably put it before the wizard is drawn to the screen. I am changing the wizards position by 0.8 per key press. You may need to increase or decrease this value depending upon you preferences.

```
if (key[KEY_UP])
{
      wizardY-=0.8;
}
if (key[KEY_DOWN])
{
      wizardY+=0.8;
}
if (key[KEY_LEFT])
{
      wizardX-=0.8;
}
if (key[KEY_RIGHT])
{
      wizardX+=0.8;
}
```

Now if you run the program you can move the wizard around! But you will notice that the wizard leaves a trail everytime you move him, not exactly the effect we want. The solution is called buffering and is covered in the next section. The complete program listing for wizard movement is shown below (I also added a rest so the wizard moves a little slower):

```
#include <allegro.h>

int main()
{
    BITMAP *wizard;
    int wizardX = 500;
    int wizardY = 500;

    allegro_init();
    install_keyboard();

    set_color_depth(16);
    int ret = set_gfx_mode(GFX_AUTODETECT_FULLSCREEN, 1280, 1024, 0, 0);
    if (ret != 0)
    {
        allegro_message("could not set video mode");
        allegro_exit();
        return 1;
    }

    wizard = load_bitmap("wizard.bmp", NULL);
    if (wizard == NULL)
    {
        allegro_message("could not load the wizard image");
        allegro_exit();
    }

    while (!key[KEY_ESC])
    {
        if (key[KEY_UP])
        {
            wizardY--;
        }
        if (key[KEY_DOWN])
        {
            wizardY++;
        }
        if (key[KEY_LEFT])
        {
            wizardX--;
        }
        if (key[KEY_RIGHT])
        {
            wizardX++;
        }

        draw_sprite(screen, wizard, wizardX, wizardY);
        rest(10);
    }

    allegro_exit();
    return 1;
}
END_OF_MAIN();
```

Using a buffer

To remove the trace effect our wizard has and to improve the overall appearance of graphics on the screen, game programmers use what is called a buffer. A buffer is a virtual screen inside the game that everything is drawn to, which in turn is simply placed onto the screen. This means that everything we draw, whether it is a graphic primitive or a bitmap will be drawn to the buffer, not the screen. After we have drawn everything to the buffer we then draw the buffer to the screen. This results in a single draw to the screen instead of multiple draws which can cause some graphic anomalies. To do this we create a bitmap image named buffer to be the same size as the size of our screen (shown below):

```
BITMAP *buffer = create_bitmap(SCREEN_W, SCREEN_W);
```

We just have to make sure that we create this buffer AFTER we create our window, so that allegro and C++ know the screen width (SCREEN_W) and the screen height (SCREEN_H) of our game window. Finally, we draw everything to the buffer instead of to the screen. Then we draw the buffer to the screen and finally erase the buffer to that it is ready to be drawn on again.

Draw the wizard to the buffer, not the screen.

```
draw_sprite(buffer, wizard, wizardX, wizardY);
draw_sprite(screen, buffer, 0, 0);
clear_bitmap(buffer);
```

Put the buffer onto the screen. This will always be the last draw you do, no other draws can come after this.

Finally erase the buffer so that we can draw to it again.

Notice that we draw the buffer to the screen at (0,0). When you draw a bitmap to the screen the (x,y) location you provide to allegro is where you want the top left corner of you image to be (not like most new programmers think……it is not where you want the middle of the image to be). We place our buffer at (0,0) because we want the top left corner of our buffer to be exactly at the top left corner of our screen.

The complete program listing for buffering the wizard movement can be seen below:

```
#include <allegro.h>

int main()
{
        BITMAP *wizard;
        double wizardX = 500;
        double wizardY = 500;

        allegro_init();
        install_keyboard();

        set_color_depth(16);
        int ret = set_gfx_mode(GFX_AUTODETECT_FULLSCREEN, 1280, 1024, 0, 0);
        if (ret != 0)
        {
                allegro_message("could not set video mode");
                allegro_exit();
```

```
            return 1;
        }

        BITMAP *buffer = create_bitmap(SCREEN_W, SCREEN_H);

        wizard = load_bitmap("wizard.bmp", NULL);
        if (wizard == NULL)
        {
            allegro_message("could not load the wizard image");
            allegro_exit();
        }

        while (!key[KEY_ESC])
        {
            if (key[KEY_UP])
            {
                wizardY-=0.8;
            }
            if (key[KEY_DOWN])
            {
                wizardY+=0.8;
            }
            if (key[KEY_LEFT])
            {
                wizardX-=0.8;
            }
            if (key[KEY_RIGHT])
            {
                wizardX+=0.8;
            }

            draw_sprite(buffer, wizard, wizardX, wizardY);
            draw_sprite(screen, buffer, 0, 0);
            clear_bitmap(buffer);
        }

        allegro_exit();
        return 1;
    }
    END_OF_MAIN();
```

Exercises and Programming Projects

Exercises

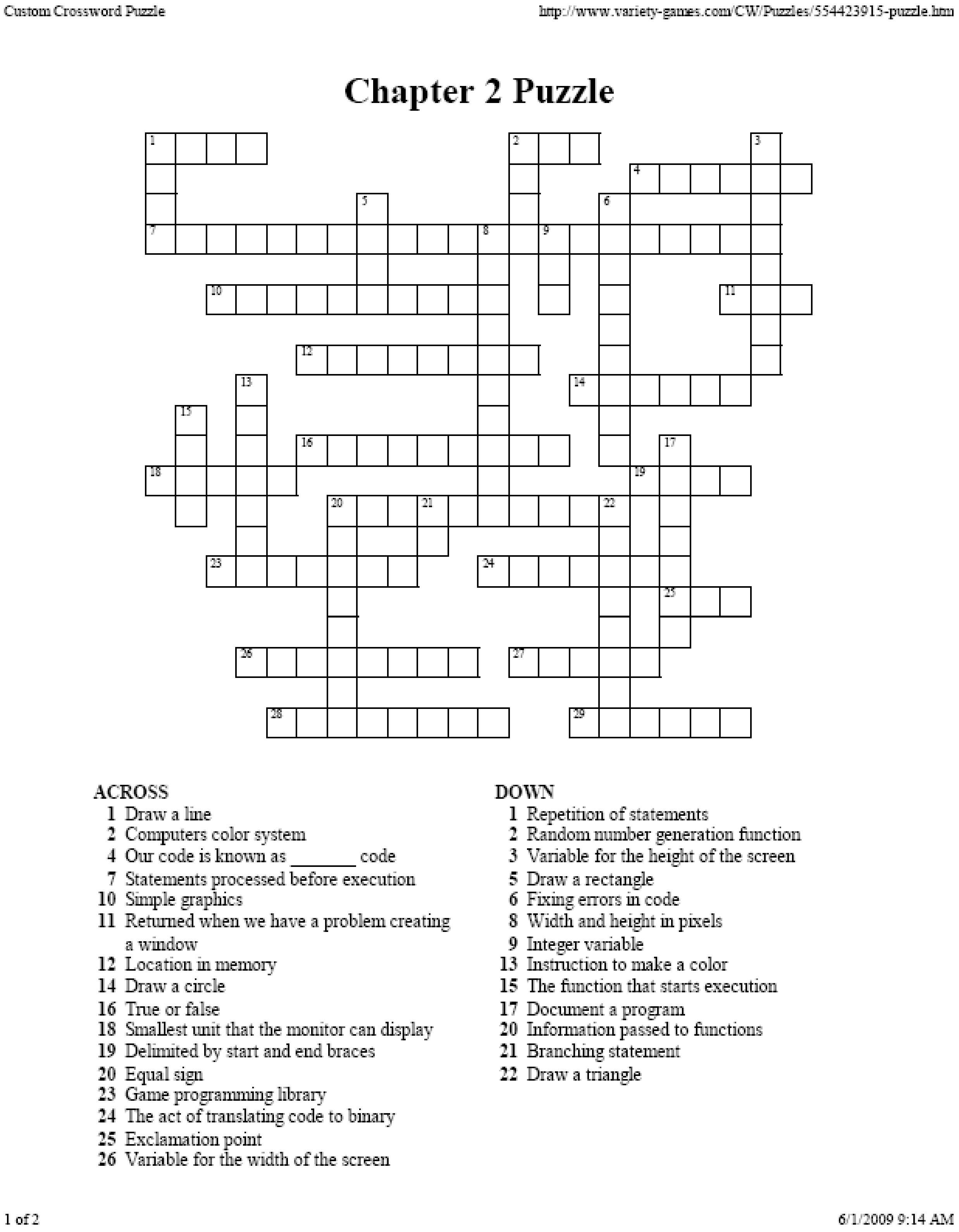
1. The JPEG file format is what most digital cameras save picture in. However, we cannot load the JPEG file format with allegro. What picture format does allegro support?
2. Write the line of code necessary to declare a bitmap variable named warrior.
3. Write the line of code necessary to declare a bitmap variable named car.
4. Write the line of code necessary to declare a bitmap variable named skeleton.
5. Write the block of code necessary to load a bitmap variable named warrior from the file “war.bmp”. Write an if to make sure the bitmap loaded successfully, if not then display an error message and exit allegro.

6. Write the block of code necessary to load a bitmap variable named car from the file “car.bmp”. Write an if to make sure the bitmap loaded successfully, if not then display an error message and exit allegro.
7. Write the block of code necessary to load a bitmap variable named skeleton from the file “skelly.bmp”. Write an if to make sure the bitmap loaded successfully, if not then display an error message and exit allegro.
8. Write the line of code necessary to draw a bitmap named warrior to the screen.
9. Write the line of code necessary to draw a bitmap named car to the screen.
10. Write the line of code necessary to draw a bitmap named skeleton to the screen.
11. Describe what buffering is. Use the Internet and define double-buffering vs. triple buffering. What are the advantages/disadvantages to using one over the other.
12. Declare a buffer and initialize it so that it is the same size as the screen.
13. Write the line of code necessary to draw a bitmap named warrior to the buffer.
14. Write the line of code necessary to draw a bitmap named car to the buffer.
15. Write the line of code necessary to draw a bitmap named skeleton to the buffer.
16. Write the line of code necessary to draw the buffer to the screen. Why do we draw the buffer at location (0, 0). Will we ever change where we draw the buffer, and why?
17. Write the line of code necessary to erase the buffer image.

Projects

1. Create or obtain a picture of a car in bmp file format. Create, load and draw the car to the screen using a buffer so that it can be moved with the W,A,S,D keys.
2. Create a project that creates loads and draws two different images to the screen using a buffer. Make one image moveable with the W,A,S,D keys and make the other moveable with the arrow keys. What happens when the two bitmaps collide? Which one goes on top of the other and why?

Appendix A: Crossword Puzzles



Custom Crossword Puzzle http://www.variety-games.com/CW/Puzzles/554423915-puzzle.htm

Chapter 2 Puzzle

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ACROSS

1 Draw a line
2 Computers color system
4 Our code is known as ________ code
7 Statements processed before execution
10 Simple graphics
11 Returned when we have a problem creating a window
12 Location in memory
14 Draw a circle
16 True or false
18 Smallest unit that the monitor can display
19 Delimited by start and end braces
20 Equal sign
23 Game programming library
24 The act of translating code to binary
25 Exclamation point
26 Variable for the width of the screen

DOWN

1 Repetition of statements
2 Random number generation function
3 Variable for the height of the screen
5 Draw a rectangle
6 Fixing errors in code
8 Width and height in pixels
9 Integer variable
13 Instruction to make a color
15 The function that starts execution
17 Document a program
20 Information passed to functions
21 Branching statement
22 Draw a triangle

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Custom Crossword Puzzle http://www.variety-games.com/CW/Puzzles/554423915-puzzle.htm

27 Number of possibilities
28 Draw a pixel
29 Ending statement

Note: For a fee, you can use Crossword Weaver to print a nice copy of this puzzle (one that doesn't look like a web page). You can check it out for free by downloading the demo from www.CrosswordWeaver.com .

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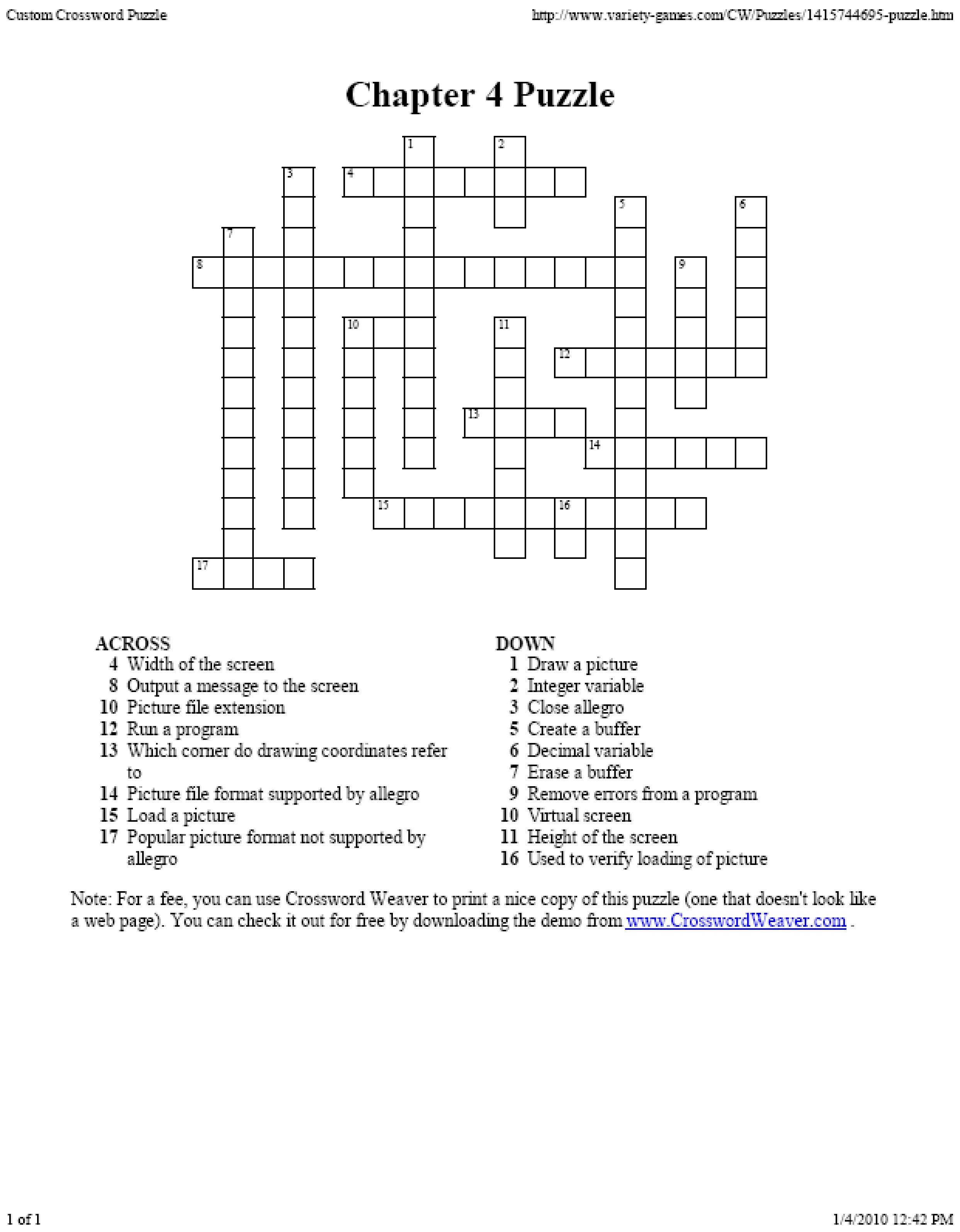

Custom Crossword Puzzle http://www.variety-games.com/CW/Puzzles/1415744695-puzzle.htm

Chapter 4 Puzzle

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ACROSS

4 Width of the screen

8 Output a message to the screen

10 Picture file extension

12 Run a program

13 Which corner do drawing coordinates refer to

14 Picture file format supported by allegro

15 Load a picture

17 Popular picture format not supported by allegro

DOWN

1 Draw a picture

2 Integer variable

3 Close allegro

5 Create a buffer

6 Decimal variable

7 Erase a buffer

9 Remove errors from a program

10 Virtual screen

11 Height of the screen

16 Used to verify loading of picture

Note: For a fee, you can use Crossword Weaver to print a nice copy of this puzzle (one that doesn't look like a web page). You can check it out for free by downloading the demo from www.CrosswordWeaver.com .

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Appendix B: Reading Guides

Chapter 2
3-Level Reading Guide

a. *Literal level: Read the* Lines. This information can be found in the text.

1. What is a pixel?
2. What is debugging? Why is it so important?
3. Describe what a comment is and its uses.
4. Where does every C++ program start execution?
5. Describe what screen resolution is.
6. What are variables?
7. What two things are required for variable declarations?
8. What is an assignment statement? How does it work?
9. What is a condition?
10. What does RGB stand for?
11. What data type does the computer use to store color?
12. List the types of primitives we can draw in allegro.

b. *Interpretive Level: Read Between the Lines*. Not only what is said, but what it means.

1. Why do projects have to be compiled before run? What does the compilation process result in?
2. How many main functions can a single program have? Support your answer.
3. What are arguments to functions?
4. What are some examples of data we can store as integers? (Hint: think of video games, web pages, desktop applications. What sorts of data do these programs keep track of?).
5. What might some common mistakes be when declaring variables?
6. Conditions are used with either relational or equality operators. List all the relational and equality operators (Hint: there should be a total of 6).
7. Explain loops in programming. What types of instructions may we want to loop (think about game programming)?
8. Besides randomly creating a color or x,y location with random number generation. What data may game programmers want to randomly generate?

c. *Applied Level: Beyond the Lines*. Not explicitly discussed or mentioned in the text.

i. There are three types of programming errors: (1)syntax, (2)logic and (3)run-time. List and describe the characteristics of each error type.

ii. You will encounter the word "function" several times during the reading. Functions in programming work much like functions in math. Research and describe how functions work in programming. It may be a good idea to brush up on your what functions are in math first.

iii. Find and list some common resolutions for the following devices: desktop displays, laptop displays, cell phone displays, iPods.

iv. If statements can be used for simple artificial intelligence (AI) in games. List some ways an if can be used in games to give the perception of intelligence.

v. The percent symbol (%) in programming is used to represent the modulus operator. Research the modulus operator and explain how it works.