

EasyBMP User Manual (Version 0.66)

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Abstract

We define and document a simple, easy-to-use, cross-platform/cross-architecture Windows bitmap (BMP) library written in C++. The EasyBMP library will work for input and output on uncompressed 1-bit, 4-bit, 8-bit, 24-bit, and 32-bit Windows BMP files in just about any operating system on just about any 32-bit or higher architecture. EasyBMP has been tested on both little-endian (Pentium 3, Pentium 4, Celeron, Celeron M, Pentium M) and big-endian (Sun Sparc4) machines in Linux, Solaris, and Windows.

EasyBMP is licensed under the GNU Library General Public (LGPL) license version 2.1. If you use this library in your application, it is the author's request that you notify him.

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1 What's New in this Release (Version 0.66)

Several major changes have been made since Version 0.64. First, in the interest of improved robustness, the `Pixels` and `Colors` data members of the `BMP` class have been made private. To this end, `GetColor(int)` and `SetColor(int,RGBAPixel)` were introduced as member functions of `BMP` to provide a safe means to access `Colors`. (For instance, these functions will not allow one to access a non-existent color table or a color outside the allowed range, e.g., accessing color number 17 in a 4-bit image.) The `CreateStandardColorTable` function was moved to be a member function of `BMP`. The `CreateGreyscaleColorTable` was revised to use the new functions and moved to `EasyBMP_VariousBMPUtilities.h`. It was also renamed to `CreateGrayscaleColorTable`. The file `EasyBMP_StandardColorTables.h` was removed from the library, as it is no longer necessary.

The most recent revisions of `EasyBMP` also continue the drive towards an eventual separation of code from function declarations. Any functions that were previously implemented inside a class were moved outside.

Lastly, the error messages in `EasyBMP` were revised for clarity.

2 Introduction to the EasyBMP Library

During my studies at the University of Minnesota and the University of California, I needed a simple method to create and modify images. Because the Windows BMP file format is nearly universally readable, flexible, and simple, I decided to work with this format. (No compression to worry about, potential for 8 bits per color channel, etc.)

There are many excellent open- and closed-source BMP and image libraries available, and in no way do I claim that anything here is even equal to those libraries. However, as I looked about I noticed that quite a few existing libraries had one or more of the following properties:

- too feature-rich (and accordingly more difficult to learn);
- required extensive installation;
- relied upon Linux or Windows libraries for simple functions;
- were too poorly documented for the novice programmer;
- required programming changes when moving code from one platform to another.

At that point, I decided to create my `EasyBMP` library. My goals included easy inclusion in C++ projects, ease of use, no dependence upon other libraries (totally self-contained), and cross-platform compatibility.

2.1 Sample Application: Converting a Color Image to Grayscale

Here, we give a first sample application using the [EasyBMP](#) library. Notice that inclusion of the library is simple: we include the `EasyBMP.h` file. In this application, we see a simple example of opening an existing BMP file, reading its RGB information, and manipulating and writing that information to another BMP file. The commands are pretty straightforward. This example should illustrate how easy the library is for even the novice programmer.

```
#include "EasyBMP.h"
using namespace std;

int main( int argc, char* argv[] )
{
    if( argc != 3 )
    {
        cout << "Usage: ColorBMPtoGrayscale <input_filename> <output_filename>\n\n";
        return 1;
    }

    // declare and read the bitmap
    BMP Input;
    Input.ReadFromFile( argv[1] );

    // convert each pixel to grayscale
    for( int j=0 ; j < Input.TellHeight() ; j++)
    {
        for( int i=0 ; i < Input.TellWidth() ; i++)
        {
            int Temp = IntSquare( Input(i,j)->Red ) +
                      IntSquare( Input(i,j)->Green ) +
                      IntSquare( Input(i,j)->Blue );
            Temp = (int) floor( sqrt( Temp / 3.0 ) );
            Input(i,j)->Red   = (BYTE) Temp;
            Input(i,j)->Green = (BYTE) Temp;
            Input(i,j)->Blue  = (BYTE) Temp;
        }
    }

    // Create a grayscale color table if necessary
    if( Input.TellBitDepth() < 24 )
    { CreateGrayscaleColorTable( Input ); }

    // write the output file
    Input.WriteToFile( argv[2] );

    return 0;
}
```

Additional code samples are available for download at

<http://easybmp.sourceforge.net>

3 What's EasyBMP Good for?

Lots of things! Okay, so we're a little biased. :-) EasyBMP was first used to easily load textures in a homebrew raytracer. Later on, however, its focus shifted to being a simple, intuitive way to get image data in and out of programs, particularly scientific applications. Some sample application ideas include:

1. If you have a scientific computation that runs for hours, days, or weeks, you could add a quick routine that outputs a snapshot of the simulation after every time step. This would provide an easy way to check the status of your long-running simulation without the overhead of starting up Matlab, Tecplot, etc. With X-forwarding, you could even check your simulation snapshot remotely over an SSH shell on free WiFi at Panera! :-)
2. You could write a small program that generates animation frames from your simulation data. Then, remotely start the program over a command line shell, let it run on its own, and collect the results later. Again, no overhead of Tecplot or Matlab, and no user interaction required!
3. Import patient data (e.g., MRI imagery) into a patient-tailored simulation or for medical analysis.
4. Create arbitrary starting shapes for level set methods based on your own hand-drawn BMP files. This eliminates the artificial restriction of only being able to simulate shapes whose level set functions that can readily be described with a formula.
5. Interface your science applications with imaging equipment.
6. Use EasyBMP as a quick testbed for new image processing ideas.
7. Import snapshots from a webcam, compare them, and use EasyBMP to remotely detect changes in a room.
8. Import textures for raytracing and OpenGL programs.
9. Save screenshots of OpenGL programs. Or an X program. Or ...
10. Create nice graphics for a system monitoring utility.

4 Installing and Using the EasyBMP Library

Installing the EasyBMP library is easy. Simply copy all the *.h files to the directory of your project. Alternatively, copy all the header files anywhere in your compiler's path. You should have the following files:

1. EasyBMP.h
2. EasyBMP_DataStructures.h
3. EasyBMP_BMP.h
4. EasyBMP_VariousBMPutilities.h

To use the EasyBMP library, simply include the EasyBMP.h file via

```
#include "EasyBMP.h"
```

Note that if you have copied all the **EasyBMP** header files to your compiler path, you may not need the quotes, but rather brackets:

```
#include <EasyBMP.h>
```

Compile your source code as you normally would; you don't have to link to anything. For instance, to compile the code example above with `g++`, use

```
g++ -o ColorBMPtoGrayscale ColorBMPtoGrayscale.cpp
```

5 A Few Words on the BMP file format

Any BMP file begins with a *file header*, which contains information on the file size and data location. The file header is followed by an *info header*, which has information on the dimensions and color depth of the file. All this information is stored in the first 54 bytes of the file.

After that, the data is stored. There are two basic storage schemes for BMP files. If the bit depth is 8 or less (256 colors or fewer), the colors are stored in a table of (red,green,blue,alpha) values immediately after the info header. In this *indexed* format, each pixel in the image refers to the position of a color in the color table. In essence, this storage technique is “painting by number.” The benefit is that each pixel requires little space, but each of the 256 colors can attain the full range allowed on modern machines. (One of 8^3 colors with 256 values of transparency.)

The other scheme involves storing the red, green, and blue data at every pixel, along with (possibly) the alpha value. This format is very intuitive and allows for the full range of colors for all pixels. However, the resulting files are substantially larger than for 1-, 4- and 8-bit files.

EasyBMP internally converts all files to 32-bits for ease and consistency of handling. In particular, this makes it easy to write add-on functions that work on all bit-depth files. **EasyBMP** converts back to the original bit depth when saving the file.

The coordinate system of a BMP file has its origin in the top left corner of the image. The $(i, j)^{\text{th}}$ pixel is i pixels from the left and j pixels from the top. **EasyBMP** indexes pixels with the same coordinate system. See Figure 1.

6 Basic Bitmap Operations

As of Version 0.55, **EasyBMP** has a unified interface for all bit depths. To initialize a new BMP object, simply declare it:

```
Example:  
  
// Declare a new bitmap object  
BMP AnImage;
```

When you declare a BMP image, you will have a 1×1 blank 24-bit bitmap image. Next, set the size and bit depth of the image. You can do this either by reading an existing bitmap image or setting this information manually, as below:

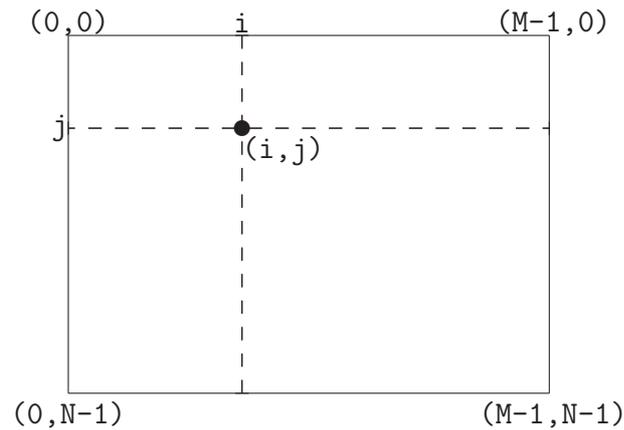


Figure 1: Coordinate system for an $M \times N$ BMP image. The black circle indicates the $(i, j)^{\text{th}}$ pixel in the coordinate system.

Example:

```
BMP AnImage;
// Set size to 640 x 480
AnImage.SetSize(640,480);
// Set its color depth to 8-bits
AnImage.SetBitDepth(8);
// Declare another BMP image
BMP AnotherImage;
// Read from a file
AnotherImage.ReadFromFile("sample.bmp");
```

To check the bit depth, width, and height of a BMP object, use:

Example:

```
BMP AnImage;
AnImage.ReadFromFile("sample.bmp");
cout << "File info:\n";
cout << AnImage.TellWidth() << " x " << AnImage.TellHeight()
    << " at " << AnImage.TellBitDepth() << " bits\n";
```

EasyBMP also provides a simple routine to compute and display the number of colors:

Example:

```
BMP AnImage;
AnImage.ReadFromFile("sample.bmp");
cout << "colors: " << AnImage.TellNumberOfColors() << "\n";
```

Note that for a 32-bit file, we don't regard two colors that differ only in the alpha channel as different colors; this function will state that 32-bit and 24-bit files have the same number of colors.

The bit depth and dimensions of a bitmap can be changed at any time:

Example:

```
BMP AnImage;
AnImage.ReadFromFile("sample.bmp");
// Change the bit-depth
AnImage.SetBitDepth(8);
AnImage.SetBitDepth(24);
// Change the size
AnImage.SetSize(1024,768);
```

Note that whenever the bit depth is changed, any existing color table is erased. Likewise, whenever the size is changed, all pixels are deleted.

To access pixels, use `RGPApixel* operator()(int,int):`

Example:

```
BMP AnImage;
AnImage.ReadFromFile("sample.bmp");
// show the color of pixel (14,18)
cout << "(" << (int) AnImage(14,18)->Red << ", "
      << (int) AnImage(14,18)->Green << ", "
      << (int) AnImage(14,18)->Blue << ", "
      << (int) AnImage(14,18)->Alpha << ")\n";
// Change this pixel to a blue-grayish color
AnImage(14,18)->Red = 50;
AnImage(14,18)->Green = 50;
AnImage(14,18)->Blue = 192;
AnImage(14,18)->Alpha = 0;
```

Lastly, to save to a file, use `WriteToFile(char*)`:

Example:

```
BMP AnImage;
AnImage.ReadFromFile("sample.bmp");
AnImage.WriteToFile("copied.bmp");
```

7 Advanced Usage: Modifying the Color Table

In **EasyBMP**, the `BMP` class will automatically generate a “Windows standard” color table whenever one is required (for 1-bit, 4-bit, and 8-bit files). However, it is possible to access and modify individual colors in the color table. If you want to see what the n^{th} color in the color table and change another, use the following:

Example:

```
BMP SomeImage;
// Set the bit depth to 8-bits
SomeImage.SetBitDepth(8);
// Get the 40th color
RGBApixel SomeColor = SomeImage.GetColor(40);
// Display the color
cout << (int) SomeColor.Red   << ", "
      << (int) SomeColor.Green << ", "
      << (int) SomeColor.Blue  << ", "
      << (int) SomeColor.Alpha << "\n";
// Change the 14th color to red
RGBApixel NewColor;
NewColor.Red   = 255;
NewColor.Green = 0;
NewColor.Blue  = 0;
NewColor.Alpha = 0;
SomeImage.SetColor(14,NewColor);
```

You can reset the color table to the “Windows standard” color table at any time:

Example:

```
BMP SomeImage;
// Set the bit depth to 8-bits
SomeImage.SetBitDepth(8);
// Change the 14th color to red
RGBApixel NewColor;
NewColor.Red   = 255;
NewColor.Green = 0;
NewColor.Blue  = 0;
NewColor.Alpha = 0;
SomeImage.SetColor(14,NewColor);
// Reset the color table
SomeImage.CreateStandardColorTable();
```

To maintain previously-provided functionality, [EasyBMP](#) still provides a grayscale color table generator:

Example:

```
BMP SomeImage;
// Set the bit depth to 8-bits
SomeImage.SetBitDepth(8);
// Create a grayscale color table
CreateGrayscaleColorTable( SomeImage );
```

Notice that in the example, the argument is a BMP object.

If you want to modify a color table for a BMP file, you can do so by using the `SetColor(int,RGBapixel)` member function. To avoid messy error messages, any color table operation should do nothing when applied to a 24-bit or 32-bit file. Consider this example:

Example:

```
void CreateRedColorTable( BMP& InputImage )
{
    int BitDepth = InputImage.TellBitDepth();
    if( BitDepth != 1 && BitDepth != 4 && BitDepth != 8 ){ return; }
    int NumberOfColors = IntPow(2,BitDepth); int i;
    BYTE StepSize;
    if( BitDepth != 1 )
    { StepSize = 255/(NumberOfColors-1); }
    else
    { StepSize = 255; }
    for( i=0 ; i < NumberOfColors ; i++)
    {
        RGBapixel Temp;
        Temp.Red    = i*StepSize;
        Temp.Green  = 0;
        Temp.Blue   = 0;
        Temp.Alpha  = 0;
        InputImage.SetColor(i,Temp);
    }
}
```

To call this new function, you would do this:

Example:

```
BMP RedImage;
RedImage.ReadFromFile("sample.bmp");
CreateRedColorTable( RedImage );
```

8 Extra Goodies: Various Bitmap Utilities

We have provided several sample utilities to make the library more immediately useful. We shall detail some of these goodies here. :-).

The first several utilities deal with getting file information from existing files.

- `void DisplayBitmapInfo(char* szFileNameIn)`: This routine displays the bitmap information from an existing bitmap. All information is given. (width and height of image, bit depth, etc.)
- `BMFH GetBMFH(char* szFileNameIn)`: This returns a BMFH based on the file. See Section A for more information on the data structure.

- `BMIH GetBMIH(char* szFileNameIn)`: This returns a BMIH based on the file. See Section A for more information on the data structure.
- `int GetBitmapColorDepth(char* szFileNameIn)`: This routine returns the bit depth of the file.

The other provided functions are “cut ‘n’ paste” functions: they copy pixels from one BMP object to another, with or without transparency.

- `void PixelToPixelCopy(BMP& From, int FromX, int FromY,
 BMP& To, int ToX, int ToY)`

This function copies the (FromX,FromY) pixel of the BMP object From to pixel (ToX,ToY) of the BMP object To.

- `void PixelToPixelCopyTransparent(BMP& From, int FromX, int FromY,
 BMP& To, int ToX, int ToY,
 RGBApixel& Transparent)`

This function copies the (FromX,FromY) pixel of the BMP object From to pixel (ToX,ToY) of the BMP object To, and it treats the input pixel as transparent if its color is Transparent. Here’s an example:

Example:

```
BMP Image1;
BMP Image2;
Image1.ReadFromFile("Blah.bmp");
Image2.SetSize(10,10);
RGBApixel TransparentColor;
TransparentColor.Red = 255;
TransparentColor.Green = 255;
TransparentColor.Blue = 255;
PixelToPixelCopyTransparent(Image1,3,5,Image2,0,0,TransparentColor);
```

Note that the alpha channel is ignored when considering transparency.

- `void RangedPixelToPixelCopy(BMP& From, int FromL , int FromR, int FromB, int FromT,
 BMP& To, int ToX, int ToY)`

This function copies a range of pixels from one image to another. It copies the rectangle [FromL , FromR] × [FromB , FromT] in image From to the rectangle whose top left corner is (ToX , ToY) in image To. When using this function, don’t forget that the top left corner of the image is (0,0) in the coordinate system! Also, FromB denotes the bottom edge of the rectangle, so FromB > FromT. However, if the algorithm detects that you accidentally reversed these numbers, it will automatically swap them for you. Lastly, if the rectangle you chose to copy from image From overlaps the boundary of image To, it will truncate the the copy selection, rather than give a nasty segmentation fault. :-)

- `void RangedPixelToPixelCopyTransparent(
 BMP& From, int FromL , int FromR, int FromB, int FromT,
 BMP& To, int ToX, int ToY ,
 RGBApixel& Transparent)`

This function does the same thing as the previous function, but with support for transparency. As in the example for the pixel-to-pixel copy above, you specify a transparent color of type `RGBapixel`.

9 Hidden Helper Functions

EasyBMP has a few helper functions that are intended primarily for internal use, but may also be helpful for your code.

- `double Square(double number)`: This routine gives the square of the double `number`. It is much faster than using the standard library `pow(double,2.0)`.
- `int IntSquare(int number)`: This does the same as the above, but with faster integer operations.
- `int IntPow(int base, int exponent)`: Instead of calling `pow(x,n)` where `x` and `n` are integers, use this function. It's much faster. Beware against using negative exponents, as they aren't supported.

10 Known Bugs and Quirks

As of Version 0.66, there are no known bugs in EasyBMP. However, there are some quirks. First, when working with a win32 project, you need to include `windows.h` before you include `EasyBMP.h`. This is because EasyBMP currently mistakenly sets the `_WINGDI_H` pragma, which tricks compilers into thinking that `wingdi.h` has already been included. This issue will be addressed in the next release of EasyBMP. In the meantime, the recommended course of action is include `windows.h` before `EasyBMP.h`.

The second quirk is that there are no copy constructors or `operator=` operators defined for the BMP class. This means that you can't do code operations like this:

Example:

```
BMP Sample1;
Sample1.ReadFromFile("sample1.bmp");
BMP Sample2;
Sample2.ReadFromFile("sample2.bmp");
Sample1 = Sample2;
```

The biggest implication of this is that you won't want to make functions that return a BMP object. Instead, if you want to modify a BMP object in a function, you should pass it by reference to the function. An example of this can be seen in the `CreateRedColorTable(BMP&)` sample function given in an earlier section.

`operator=` and copy constructor functionality may be added to EasyBMP at a later date, but only if they do not interfere with stability and robustness.

11 Future Changes

Future changes may include:

1. separating code from the *.h files into a single cpp file; (This would help for scaling EasyBMP to larger, multi-cpp projects.)
2. an optimal color table `GenerateOptimalColorTable()` generator function;
3. a “fake” indexed mode, where the user can treat the alpha channel as though it were a color index; (This would be faster for 8-bit files, for instance.)
4. eliminating the use of ceil and floor functions, as well conversions from double to int wherever possible.

12 Obtaining Support for EasyBMP or Contacting EasyBMP

If you need support, have a feature request, or have other feedback on EasyBMP, you can email Paul Macklin at macklin01@users.sourceforge.net. Paul would also love to hear back from people who have successfully used EasyBMP in their own projects.

A Classes and BMP Data Types

Here, we detail the various classes and data types and how to interface with them.

A.1 Miscellany

Some of the data types that are used in the construction of more complex data types are:

Type:	Info:
BYTE	an unsigned character of 8 bits
WORD	an unsigned short of 16 bits
DWORD	an unsigned long of 32 bits
BMFH	a specific header format for a BMP file
BMIH	provides additional information on the BMP file

For additional information on the BMFH and BMIH classes, I highly recommend that you visit

<http://www.fortunecity.com/skyscraper/windows/364/bmpffrmt.html>.

A.2 RGBAPixel

This data structure is exactly as their its suggests: a single pixel of (red,green,blue,alpha) data. This data structure is used both for individual pixels within an image and the color table in the palette. Here are the details on the data structure:

Member:	Function:
Blue	blue pixel info of type BYTE
Green	green pixel info of type BYTE
Red	red pixel info of type BYTE
Alpha	alpha pixel info of type BYTE

A.3 BMP

The `BMP` class consists of all the necessary pixel information for a Windows bitmap file, along with file I/O routines.

- `int BitDepth`: This gives the number of bits per pixel, i.e., the color depth. This data member is private and can only be accessed through `TellBitDepth` and `SetBitDepth`.
- `int Width`: This gives the width of the bitmap in pixels. This data member is private and can only be accessed through `TellWidth` and `SetSize`.
- `int Height`: This gives the height of the bitmap in pixels. This data member is private and can only be accessed through `TellHeight` and `SetSize`.
- `RGBApixel** Pixels`: This is the actual `Width × Height` array of `RGBApixel`'s. This data member is private and can only be accessed through `operator()`.
- `RGBApixel* Colors`: This is the table of colors, stored as `RGBApixel`'s. If the `BMP` object is 24-bits or 32-bits, then `Colors = NULL`. This data member is private and can only be accessed through `GetColor` and `SetColor`.
- `int TellBitDepth(void)`: This function outputs the bit depth of the `BMP` object.
- `int TellWidth(void)`: This function outputs the width of the `BMP` object.
- `int TellHeight(void)`: This function outputs the height of the `BMP` object.
- `int TellNumberOfColors(void)`: This function outputs the number of colors of the `BMP` object.
- `BMP()`: This constructor creates a `1 × 1`, 24-bit `BMP` object.
- `~BMP()`: This is the destructor. You should never call this; it is automatically called when a `BMP` object goes out of scope.
- `RGBApixel* operator()(int i, int j)`: This returns a pointer to the `(i, j)` pixel.

Example:

```
BMP Sample;
Sample.SetSize(10,10);
Sample(3,4)->Red = 255;
Sample(3,4)->Alpha = 0;
Sample(3,4)->Blue = Sample(3,4)->Red;
```

If `operator()` is used on a pixel that is out of range, it warns the user and automatically truncates the range.

- `void SetSize(int NewWidth, int NewHeight)`: Use this to change the size of the object to `NewWidth × NewHeight`. See the example above. If `NewWidth` or `NewHeight` is non-positive, this function gives a warning and does nothing.
- `void SetBitDepth(int NewDepth)`: This function changes the bit depth to `NewDepth` bits per pixel. It also automatically creates and/or resizes the color table, if necessary. If `NewDepth` is not one of 1, 4, 8, 24, or 32, the function gives an error and does nothing.
- `void WriteToFile(char* FileName)`: This function writes the current `BMP` object to the file `FileName`.

- void ReadFromFile(char* FileName): This function reads the file `FileName` into the current BMP object.
- RGBapixel GetColor(int ColorNumber): This function returns color number `ColorNumber` in the color table of the current BMP object. If `ColorNumber` is out of range or the BMP does not have a color table (e.g., in the case of a 24-bit file), this function gives a warning and returns a black pixel.
- void SetColor(int ColorNumber , RGBapixel NewColor): This function sets color number `ColorNumber` in the color table of the current BMP object to `NewColor`. If `ColorNumber` is out of range or the BMP does not have a color table (e.g., in the case of a 24-bit file), this function gives a warning and does nothing.
- void CreateStandardColorTable(void): This function creates a “Windows standard” color table for the BMP object. If the bit depth is 24 or 32, the function gives a warning and does nothing.