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A Data Conversion Program for µShape™ Binary File

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BACHELOR'S THESIS | ABSTRACT

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The work of data conversion hidden beneath the sophisticated computer world happens more often than people can ever imagine. File data is one of the most primary elements that have been "shaped" in different ways in order to fulfill a particular file purpose. If some of the data structures are obsolete or a file function needs to be altered, data conversion is taking place.

In this thesis conversion from µShape software which generates a file specific format "*.fis" to standard uncompressed bitmap file format "*.bmp" is implemented. The empirical part of conversion was conducted on a C language program c which was separated into two individual sub-programs. The first program was used to read in a fis file generated by µShape and write out a standard bitmap file. In this program, the deviation data as well as metrology needed to concrete the bitmap later can be obtained from file header information of FIS file. The second program inherits the successful achievement of first objective and arranges and modifies all the file data into a scaled color map. This is the key step to make the output of bitmap file optical observation possible, since the generated color in this case is the measurement of the surface deviation of the image.

Although the encoded way of data may vary considerably from file to file, the aim of the project is to attempt explore the conversion technique as well as to give general guidelines especially when it comes to secret specifications of a file format.

KEYWORDS:

data conversion, bitmap, BMP, FIS, RGB model, format conversion, surface deviation

Contents

Notation

BMP	bitmap file format
FIS	µshape file format
P-V	peak to valley
SF	scale factor
DIB	device independent bitmap
GDI	graphics device interface
PNG	portable network graphics
GIF	Graphic interchange format
MSDN	Microsoft developer network
Angstrom	0.1 nanometer
MTF	modulation transfer function
RGB model	red, green, blue model

1 Introduction

1.1 Data Conversion Background

Data conversion is the process of translating data from one format to another; it can be converted either from human-readable to machine-readable form or vice versa [1]. Due to the fact that the computer industry has been developed in complicated layers and dynamic process, data is also constructed in various formats to meet different standards. Therefore, data must be converted when it is needed. For example, for any enterprises the annual increment of data in a database will unveil the limitation of data construction from old software and the entire update of certain software will definitely lead to the entire update to its database. Because the storage of data in background database differs from software to software, consequently when an update occurs, data conversion is a necessity to be included. Sometimes the data conversion takes place even because the graphical user interface of software is in a transformation.

The alteration between operating systems also takes data conversion into account. Different operating systems have their own file system to handle data, and for the purpose of common files sharing, data has to be converted. Another example would be the massive data residing in hardware, even a tiny modification of certain components of the hardware will cause the occurrence of data conversion. Moreover, for software and web-based application the stylish improvement of interface or add-on of new features is implemented by data conversion. Data conversion could be carried out either in a complicated fashion or as simple as the editing of a few bits, depending on the data types. Logistically speaking, for instance, the conversion of data from a video clip is far more time-consuming than that of a text file.

The process of data conversion can be approached through different channels. Generally when it occurs with the upgrading of hardware, the data is usually converted automatically in the background, for example a hardware driver will execute the conversion when it is needed. In some other cases, certain software has the function to open a file with a variety of formats, for instance a digital image reader is able to open a number of different image file formats and save them as other desired image formats, and, that is to say, it can complete the inner data conversion without using any third party converting tools. In addition, although it is seldom to be practiced, for the maximum freedom of interoperability among different file formats, one can also always achieve the data conversion by writing his/her own sophisticated program.

1.2 Lossy Data Conversion

For perfect data conversion, all of the source data and its embedded information should be transferred into the target file. However, this can only be done if the target format does support the same features and same data structures present in the source file. [2] Conversion from a BMP image file to a JPEG image file involves loss of precision of image, because the JPEG format supports compressed images hence running a dissimilar data structure to that of the BMP format. After the conversion is completed, the difference of two image outputs can hardly be distinguished by human vision. The conversion, however, could cause unexpected confusion and malfunction.

1.3 Methodology

The lack of specification and information referring to either source format or target format is a major difficulty in data conversion, therefore reverse engineering is then necessary to be introduced. “Reverse engineering is the process of analyzing a subject system to create representations of the system at a higher level of abstraction."[3] It can also be seen as "going backwards through the development cycle". [4] Reverse engineering is re-building unknown specifications very closely to the original file. But the progress of research is based upon hypothesis and analysis, which the whole conversion will not be a copy work. Instead, some unpredictable errors or uncompleted constructions or missing features will be generated and remaining in tolerant level.

To be specific about the conversion program in this project, the secret specifications of source file makes the programmer reverse-engineered throughout the conversion process.

2. Bitmap File

2.1 Introduction

The bitmap standard file is one of the digital image storage formats widely used on Microsoft Windows and other OS/2 systems. The file extension for a bitmap file is ".BMP". The bitmap image structure could be reflected plainly from its name: a collection of bits that form an image. Note the linguistic ambiguous use of pixmap which should not be mixed up with bitmap. "Strictly speaking, the term bitmap applies only to 1-bit-per-pixel bilevel systems; for multiple-bit-per-pixel systems, we use the more general term pixmap (short for pixel map)." [5] Prior to Windows 3.0, the bitmap file was device-dependent. However, Microsoft decided to adopt the bitmap alteration as Device-Independent Bitmap (DIB) after the release of Windows 3.0 in order to make the bitmap file compatible with display devices of any kind in the market at the time. Usually, bitmap files are uncompressed images and the size of them is rather large, which causes intensive occupation of the memory. As a result, its Web application tends to use more light weight image formats, such as JPEG, PNG, and GIF due to the fact lossy compression is allowed in those formats. The main disadvantage of bitmap files is that they are not supported by Web browsers or Web-based languages. [6] In the Microsoft scheme, it has been designed as one of the GDI objects.

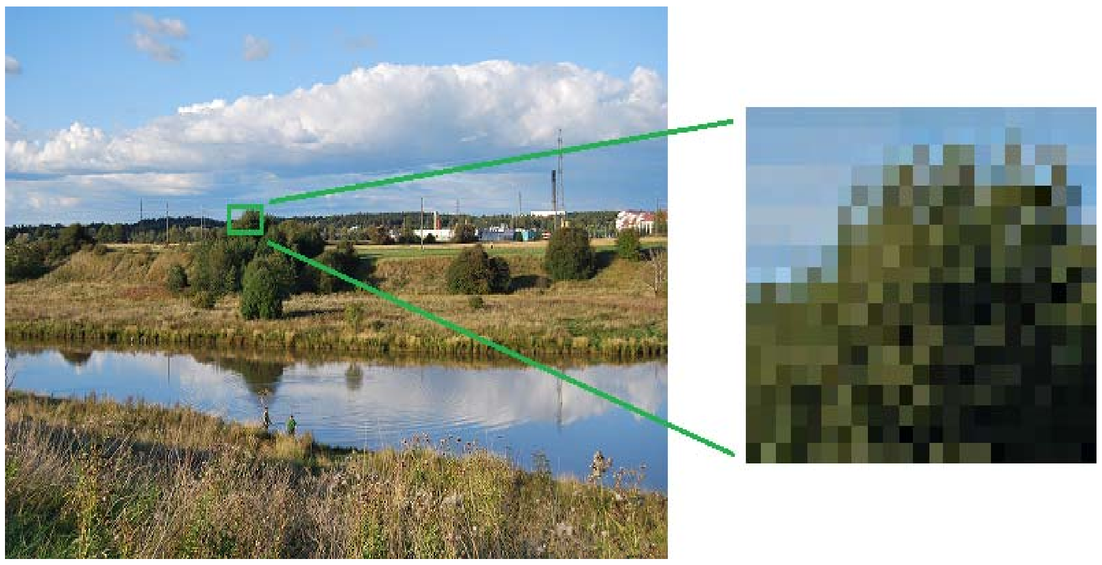


Figure 1.Typical uncompressed bitmap image and its magnified view

2.2 Bitmap Storage

As it mentioned before, the bitmap consists of a map of bits that is stored vertically as well as horizontally in the matrix with their individual color. For each of the bitmap files, the image pixels are stored with a number of bits per pixel (bpp) called color depth. Color depth is associated with the color of a single pixel thus the more bits per pixel, the more colors will be available to produce. The disk storage size of a standard bitmap file can be calculated by the formula as following:

$$\text{Fizesize (kB)} = \frac{\text{N} \times \text{M} \times \text{B}}{8 \times 1024}$$

Where N is the number of rows, M is the number of columns, B is the color depth.

2.3 BMP File Structures

In general, each bitmap file is divided into either three or four parts, a bitmap file header, a bitmap information header, an optional color table and a pixel data area that indicates bitmap bits.

Table 1.The four hierarchical layers of the BMP file

BITMAP FILE HEADER
BITMAP INFO HEADER
COLOR TABLE (PALETTE)
BITMAP ARRAY

The bitmap file header describes overall information such as file type, size, and layout of a device-independent bitmap file. According to MSDN, the header is defined as BITMAPFILEHEADER structure.

The bitmap information header, which defined as BITMAPINFOHEADER structure, contains information about the dimension, compression and color format of the bitmap file.

The color table, which is defined as an array of RGBQUARD structures, specifies how many colors are being used in red, green and blue in a bitmap file. The use of color table, however, is excluded when the color bits of a bitmap file is set to 24 because 24 bit red-green-blue (RGB) values are all the elements that constitute a pixel from the actual bitmap data area.

The colors in the table should appear in order of importance. This helps a display driver render a bitmap on a device that cannot display as many colors as there are in the bitmap. If the DIB is in Windows version 3.0 or later format, the driver can use the biClrImportant member of the BITMAPINFOHEADER structure to determine which colors are important. [7]

The storage order of pixels in the data area is considered to be upside-down, arranging from left to right, ascending row by row with a starting point at the lower left corner all the way to the upper right corner.
Note: The BMP file content can be obtained from Appendix A.

2.4 Color Depth Field

In the bits per pixel field from the BITMAPINFOHEADER structure, the actual intensities of color and pixel existing in a bitmap are able to be set by the number of bits. There are 6 different levels that the bit can be assigned to:

1. When the field is set to 1, the bitmap is monochrome. Only two values are allowed in the palette, each bit in the bitmap data builds a pixel. The color of the first value in the palette is assigned to the pixel when the bit is clear, whereas the color of the second value will be applied to the pixel when the bit is set.

2. When the field is set to 4, each pixel in the bitmap is represented by a 4-bit index into the palette. No more than 16 values are allowed in the palette, meaning that a bitmap has a maximum of 16 colors. For example, if the first byte in the bitmap is 0x1F, the byte is equal to 2 pixels. The first pixel contains the color in the second value of palette, and the second pixel contains the color in the sixteenth palette.

3. When the field is set to 8, the bitmap can have a maximum capacity of 256 colors, and the palette contains up to 256 values. At this point, each byte in the palette data area corresponds to one pixel.

4. When the field is set to 16, the bitmap can have a maximum capacity of 2^{16} colors. In this case, the palette field remains empty only if the compression field of the bitmap file is set to bi_rgb. Each pixel in 16 bit palette is built up by a unit of 4 bytes value. Five bits can depict a color from red, green or blue. The value for blue is in the least significant five bits, followed by five bits each for green and red, respectively. The most significant bit is not used. [8]

5. When the field is set to 24, the bitmap has a maximum capacity of 2^{24} colors, and no entries will be set in the palette filed. A single pixel in this case consists of 8 bytes in the bitmap data area where 3 bytes out of 8 represent respectively a color of blue, green, and red.

6. When the field is set to 32, the bitmap has a maximum capacity of 2^{32} colors. If the compression field of the bitmap is set to bi_rgb, then no values in the palette are filed. At this point, each 4 bytes represent one of the colors of blue, green, and red. The highest byte in each pixel is not used. If the compression field of the bitmap is set to bi_bitfields, the palette field contains three 4 bytes color masks that specify the red, green, and blue components, respectively, of each pixel. [8]

2.5 Line Padding

Regarding to the actual data creating, a bitmap file has an extra critical fact that needs to be taken into account. The data of each line has to be ended on a 4-byte boundary, if the data cannot make an even 4-byte boundary at the end of each line, then it has to be followed by redundant data. The official name of those redundant data is “padding” and they are all zeros. For example, if the output bitmap file from this conversion program has the dimension of 1022 × 1022, then two zeros will be padded into the end of each data line.

An example can be seen from Table 2:

Table 2.Line padding codes in outputting a BMP file

```
DataSizePerLine=fHeader->nCol*3;
int npad = 0;
while(DataSizePerLine%4!=0)   /*the pixel each line has to be the multiple of 4*/
     {
     DataSizePerLine++;
     npad++;
     }
```

Note: In order to load feasible bitmap file data, the line padding has to be manually removed from each data line.

2.6 RGB Color Model

“...the Rays to speak properly are not coloured. In them there is nothing else than a certain Power and Disposition to stir up a Sensation of this or that Colour.”- Isaac Newton [9].

According to the tristimulus theory, the human retina has three kinds of cone cells, which can perceive color through the peak sensitivity at wavelengths of about 630 nm (red), 530 nm (green) and 450 nm (blue) [10]. See Figure 2. The natural color system is far simpler than what we actually see; the capability of comparing intensities in a light source makes us have a colorful vision. In other words, “the perception of color is an entirely arbitrary creation of our nervous system, and is in no way contained in the wavelengths themselves”. [11]

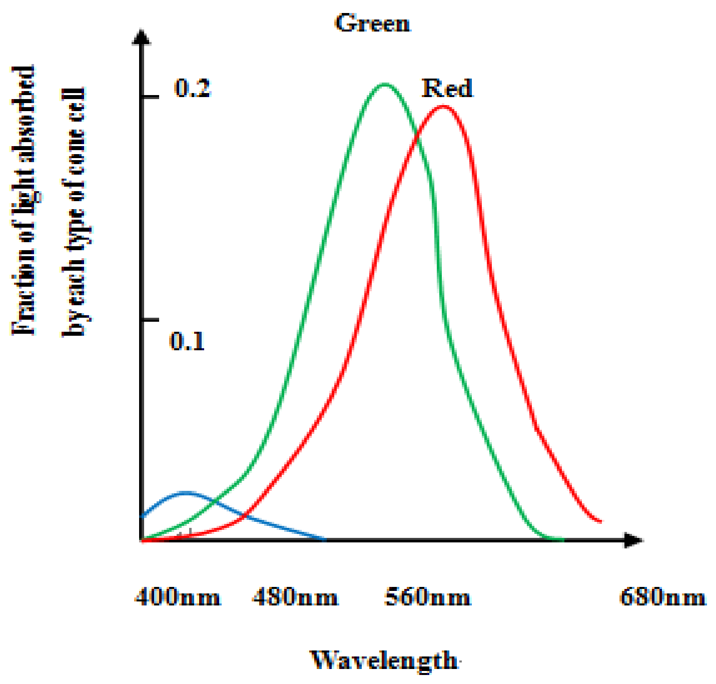


Figure 2.Spectral response curves for each cone cell. The peak points for each curve are at 450nm (blue), 530nm (green) and 630nm (red).

In computer graphics, this theory has been widely applied to display as well as manipulate a digital image by using three colors of red, green, and blue, usually referred to as the RGB color model.

The RGB model could be simulated with the unit cube defined on R, G, and B axes, as shown in Figure 3.

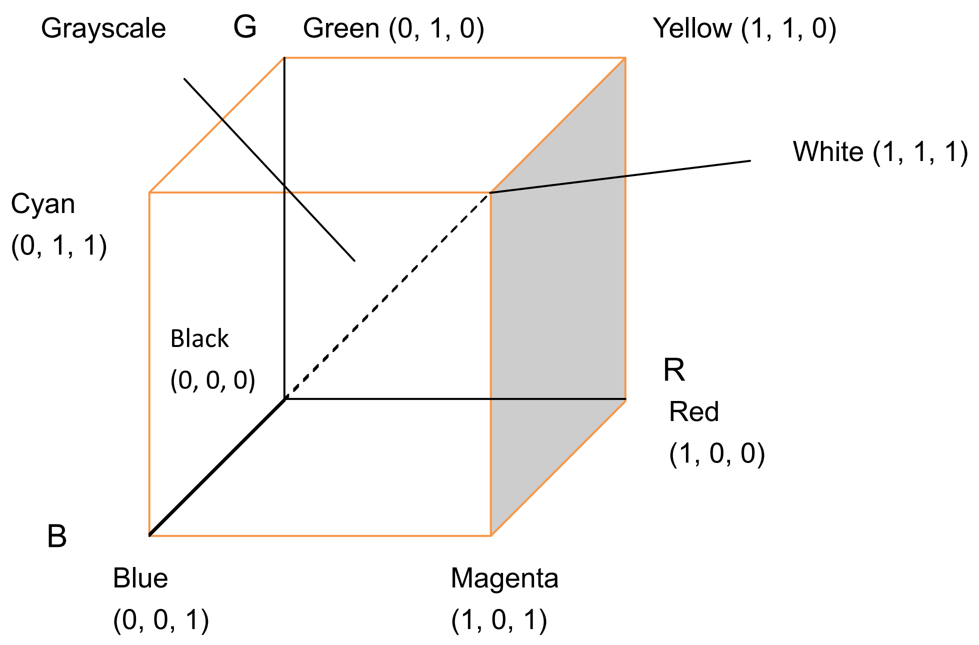


Figure 3.The RGB color model, defining colors with an additive process within the unit cube.

The origin of RGB coordinate (0, 0, 0) is black, along the grayscale, the vertex with (1, 1, 1) corresponds to white. The RGB color scheme is an additive model, as shown in Figure 3, we can obtain the cyan vertex from the sum of primary colors blue and green, which is (0, 1, 1). The white vertex at (1, 1, 1) is reproduced by adding red, green, and blue. And between black vertex and write vertex, the grey zone is at (0.5, 0.5, 0.5).

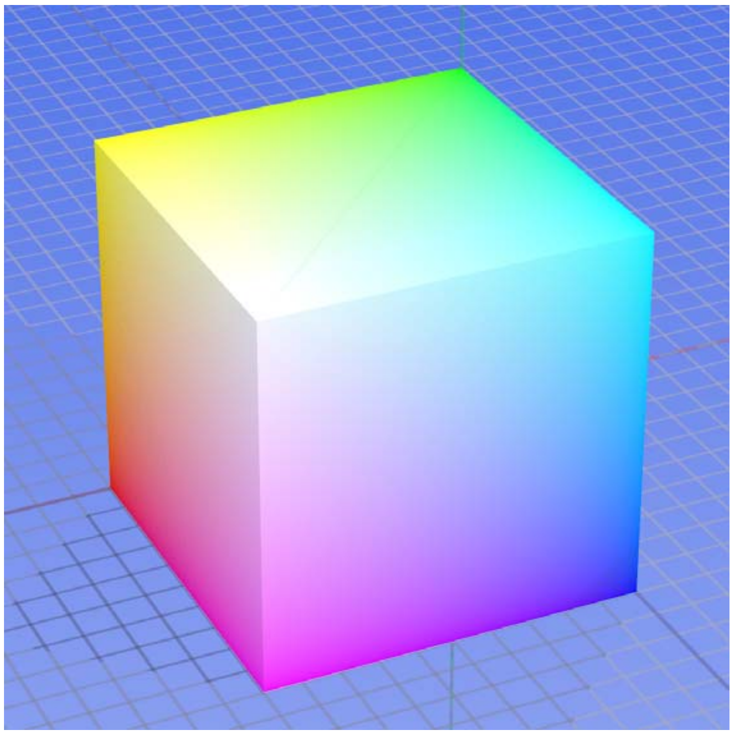
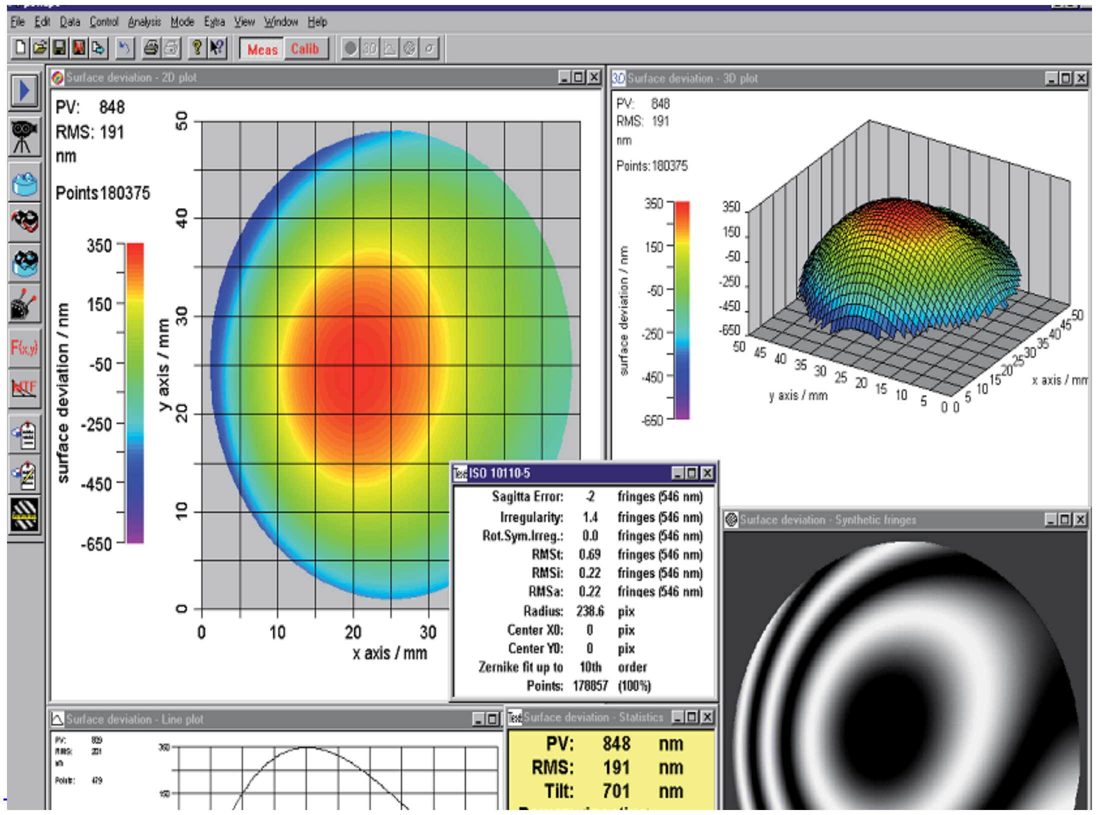


Figure 4.The typical view of the RGB color cube, along the grayscale diagonal from white to black.

3. FIS file

3.1 Introduction

The ".FIS" file is a device dependent file which is generated by an interferometry measuring and analysis software called µShape. The FIS file is also a binary image file that displays the analysis information and measurement result within the µShape™ software. The µShape software is a sophisticated tool for measuring the topography of flat and spherical lens surfaces or wave fronts. It is a professional software application for optical integrated quality management. µShape™ controls and displays the measurement results, stores and documents all measurement raw data and ensures maximum transparency.


File Edit Data Control Analysis Mode Extra View Window Help
Meas
Calib
Surface deviation - 2D plot
surface deviation / nm
y axis / mm
x axis / mm
Surface deviation - 3D plot
surface deviation / nm
y axis / mm
x axis / mm
Surface deviation - Synthetic fringes
Surface deviation - Line plot
Surface deviation - Statistics

PV: 848
RMS: 191
nm
Points 180375

ISO 10110-5

Sagitta Error:	-2	fringes (546 nm)
Irregularity:	1.4	fringes (546 nm)
Rot.Sym.Irreg.:	0.0	fringes (546 nm)
RMSt:	0.69	fringes (546 nm)
RMSi:	0.22	fringes (546 nm)
RMSa:	0.22	fringes (546 nm)
Radius:	238.6	pix
Center X0:	0	pix
Center Y0:	0	pix
Zernike fit up to	10th	order
Points:	178057	(100%)

PV:	848	nm
RMS:	191	nm
Tilt:	701	nm

Figure 5.The workspace window of µShape 6.0

In the context of this thesis work, the FIS file is the converting object that will be later converted into a standard uncompressed bitmap file. Only the structure of the FIS file as well as binary data inside is going to be introduced and manipulated. The output optical analysis of the object (a lens) will not be discussed as it is beyond the scope of this research.

3.2 FIS file structures

FIS is a binary file format. This format is recommended for transferring data to customer programs.

Due to the reason that the µShape software is merely specific to the professional optical metrology field for the use of scientific research, people rarely have much knowledge of it, nor does the product itself have sufficient information on how its image file is structured. The following are the pieces of description concerning a FIS file header:

Table 3.Specification of FIS file header

Field	Size (byte)	Content
Data type	1	Identifier for data type
Row	4	Number of rows in FIS file, values in integer
Columns	4	Number of columns in FIS file, values in integer
Non-aperture	4	Identifier for non-aperture, values in integer
Comment length	4	The number of comment characters, values in integer
Comment	N	The actual comment, with a size corresponding to the comment length

One of the 5 different data types will be identified by the very first byte in FIS file.

1. If the byte is set to 1, the output image is for surface deviations map (values in Angstrom as 4-byte integer values).
2. If the byte is set to 2, the output image is for wave aberration map (values in Angstrom as 4-byte integer values).
3. If the byte is set to 3, the output image is for raw phase data map (values in 2p/1024 as 4-byte integer values).
4. If the byte is set to 4, the output image is for intensity map (in gray values as positive 4-byte-integer values).
5. If the byte is set to 21, the output image is for MTF map (as positive 8-byte-double values).

The header in the FIS file is composed of 17 constant bytes that define the panoramic construction of how data is organized and a consecution of bytes from the 18th byte that serve as comment to the file. The comment length is pre-defined from 14th to 17th byte. After the FIS header, the pointer comes directly to the image data area called data map. The quantity of data map is the product value of the number of rows and columns. The data is starting from the upper left corner row by row downwards to the lower right corner. In contrast, the data arrangement of bitmap file is sheer opposite to that of the FIS file.

4. The Conversion

4.1 Tools of Conversion

The FIS to BMP file conversion project was written by using the C programming language. The Microsoft Visual C++ 6.0 is the main complier for running and debugging codes.

Visual C++ is a powerful Windows-based tool for software developing. Since 1993 when the first edition of visual C++1.0 has been released, more and more professional programmers use the Visual C++ and its follow-up versions as their primary developing tools. Visual C++ 6.0 was released in 1998 [12] and is famous of its friendly user interface, easy operation, and swift response. The Develop Studio featured in Visual C++ 6.0 contains four components: compiler, debugger, class wizard and app wizard, as a result it makes the development environment more integrated (IDE).

4.2 Pre RGB module conversion

In order to simplify the conversion, the codes were broken down into two steps. The first step focuses on byte to byte data converting; no color pixels will be allocated as well as edited in this section. The second step is based on the successful data conversion between the FIS and bitmap files. A set of scaling range and color map were introduced at this stage. Because the test FIS file according to what it has converted in Step one, it is considered not complete in terms of scientific observation, thus arranging and modifying all the file data into a scaled color map is sensible in order to enable the output of bitmap file observation

4.2.1 Reading Data from FIS file

First of all, a given FIS file “testfile.FIS” has the data samples after the FIS header as shown in Table 4:

Table 4.The range of actual FIS data after heading, decimal values are in Angstrom

Hexadecimal	Decimal (Angstrom)
00 00 00 80	-2147483648
00 00 80 FF	-8388608
FF FF FF FF	-1
00 00 00 00	0
01 00 00 00	1
FF FF 7F 00	+8388607
FF FF FF 7F	+2147483647

.

According to the structure of the FIS file we discussed in Chapter 3, the header code can be defined as:

Table 5.Structure of FIS header in codes

```
typedef struct tagFISHeader       /* To define FIS header structure */
{
    BYTE    id;
    DWORD nRow;
    DWORD nCol;
    DWORD iNonaperture;
    DWORD cLength;
}FISHeader;
```

After the binary FIS file is open, the first operation would be loading the header information by allocating the memory, and then extracting the data type identifier, number of rows and columns, and ending up with comments.

From the debug output, the data type identifier is displayed as 1, which means this image should serve as surface deviation picture. Moreover, the number of rows is 1024 and that of columns is 1020. Next, the value of non-aperture (background image where light is not reachable) is 2147483648. At last, the comment length was acquired as 16, this can either be verified as soon as the content of comment shows: “Pixel Size=0.0313” that matches the number of the comment length.

4.2.2 Writing Data to the BMP File

Based on the scale of data samples of the FIS file, the BMP file data after the header must follow the dimension of 1024 rows and 1020 columns for the purpose of untwisted image output.

Table 6.The actual pixel sequence of red, green and blue in the BMP file.

Hexadecimal	Decimal(Angstrom)	Color
00 00 00	-8388608	Black
80 00 00	0	None
FF FF FF	+8388607	White

B	G	R
80	00	00

Because the data in bitmap file starting at the lower right corner moving upwards row by row to the upper left corner. The actual RGB sequence of pixel is shown in Table 6 above.

As it has been introduced in Chapter 2, prior to the actual pixel data, the bitmap file header and the bitmap info header should be structured using the syntax below:

Table 7.Structures of BMP files header and info header in codes.

```
typedef struct tagBITMAPFILEHEADER
{
    WORD bfType;     /*BMP file signature, 0x4D42('BM') but not support os/2 bitmap*/
    DWORD bfSize;     /*size of whole file(in byte)*/
    WORD bfReserved1;     /*0*/
    WORD bfReserved2;     /*0*/
    DWORD bfOffBits;     /*offset from file start to pixel array*/
} BITMAPFILEHEADER;

typedef struct tagBITMAPINFOHEADER
{
    DWORD biSize;     /* sizeof(BITMAPINFOHEADER)*/
    DWORD biWidth;     /* pixel width*/
    DWORD biHeight;     /* pixel height+orientation*/
    WORD biPlanes;     /* number of planes,must be 1*/
    WORD biBitCount;     /*number of bits per pixel*/
    DWORD biCompression;     /*compression scheme*/
    DWORD biSizeImage;      /*size of pixel array*/
    DWORD biXPelsPerMeter;      /*horizontal resolution*/
    DWORD biYPelsPerMeter;      /*vertical resolution*/
    DWORD biClrUsed;      /*number of colors in the colortable*/
    DWORD biClrImportant;      /*number of entries needed to display*/
} BITMAPINFOHEADER;
```

In the bitmap file in this program, the bits per pixel field is set equal to 24, meaning the bitmap has a maximum of 2^{24} colors and the palette field does not contain any entries. A single pixel in the data area is formed by the blue, green, and red color that each of them is corresponds to only 1 byte. And in the 24 bit mode, no color look-up table will be used. The code is shown in Table 8:

Table 8.RGB bit define and bus switch

```
#define BITCOUNT 24
#define BMPINFOSIZEHEADER 40
#define FISHEADERSIZE 17
#define BUS32 1               /*32/16 bit bus switch*/
#define DEBUG 0       /*debug switch*/
#if BUS32
    typedef short WORD;
    typedef int DWORD;
#else
    typedef int WORD;
    typedef long DWORD;
```

Although the conversion codes were complied through Visual C++ 6.0, the program might be running across various compliers by different programmers.

Due to the fact the memory allocation of compliers does differ from one to another even in the same programming language, for example, the C language. The BUS32 switch was thus produced as compatibility tool aiming to make the program compatible externally. In Visual C++ 6.0, the BUS32 switch is registered to 1.

During the process of the bitmap file header setting, the bitmap file type identifier was registered to 0x4d42 i.e. ‘BM’, the output bitmap file is a regular Microsoft Windows BMP file, no OS/2 operating system is included in this conversion program.

The data reading from FIS will be automatically operated by correct programming codes. Before entering the FIS dimension loops, the initial writing cursor of bitmap file must be precisely positioned to the end of file in order to avoid the upside down bitmap image.

The traditional method of conversion would be to first obtain a decimal value of each 4 bytes unit pixel data from the FIS file and then convert those decimal values into the 3-byte triplet pixel data bitmap file. Consequently a three-step-conversion program was initiated at the beginning of the project. However, very soon it proved to become extremely complicated when dealing with the conversion from minus decimal values to minus hexadecimal values or vice versa. (See Appendix B) Furthermore, it is not professional to have such redundant codes included in the program body. Fortunately, there is a more simple way to shorten this three-step-conversion to one step.

As all values in both files are given in Angstrom and stored in hexadecimal form, the conversion then is not even necessary to go through decimal values. From the FIS file identifier, we can find that 00 00 00 80 => -2147483648 is non-aperture, which does not to do the conversion but modifies the non-aperture value into white color as background color. Additionally, the bitmap file only allows 3-byte triplet data to build up a single pixel which means there would be 3 out of 4 bytes binary data needed to be converted from FIS file. Thus, the highest byte from each pixel in FIS file could simply be omitted. The reason for the elimination of highest bit in FIS file is that a bitmap file only initiates data from the opposite position to the FIS file in order to keep the independence of the single pixel, one last byte must be picked out. Now the FIS file data has the following attributes shown in Table 9.

Table 9.The highest bit from the FIS file has been removed in order to meet the pixel structure of BMP file.

FIS Hex (Modified)
00 00 00
00 00 80
FF FF FF
00 00 00
01 00 00
FF FF 7F
FF FF FF

The programmer so far is able to obtain raw FIS pixels which match the specification of the bitmap pixels but leaving the integer values incompatible.

The next step is to manipulate the highest byte out of an individual FIS pixel by AND, an offset value in hexadecimal for producing the same integer value as that of bitmap file. In this case, an offset value of 80 will fulfill the conversion. For example, the FIS file has the individual pixel below:

00 00 80 (FF) => -8388608

Now taking hex 80 (the highest byte from the FIS file) AND hex 80 (the constant offset value), the result turns to 00. And in the bitmap file the single pixel decimal value of 00 00 00 equals to -8388608. In this case by using an offset of 80, the hexadecimal value is converted from FIS file to BMP file, where the decimal value of the single pixel remains the same.

Here is another instance, the FIS file has the individual pixel below:

FF FF 7F (00) => +8388607

This time we take 7F AND 80 = FF which is identical to FF FF FF => +8388607 the pixel in BMP file. The alteration is only applied to hexadecimal values, and we always keep the decimal values equivalent.

We need to taken into consideration that when making logistic AND calculation between two hexadecimal values, no carrying bit shall be kept. For instance, if hex 80 AND hex 80 = 100, we only take the higher bytes 00 to match the bitmap pixel structure.

The above description can be verified from Table 10:

Table 10.The conversion code from FIS pixel to BMP pixel

```
if(*buf3&0x80)
            {
                *buf3=*buf3&0x7F;    /* prevent from carrying bit */
            }
            else
            {
                *buf3=*buf3|0x80;
            }
```

This piece of code is put at the end of loops and is followed by the command of writing bitmap data. After the successful writing data into the BMP file, the converted image is shown in Figure 6:

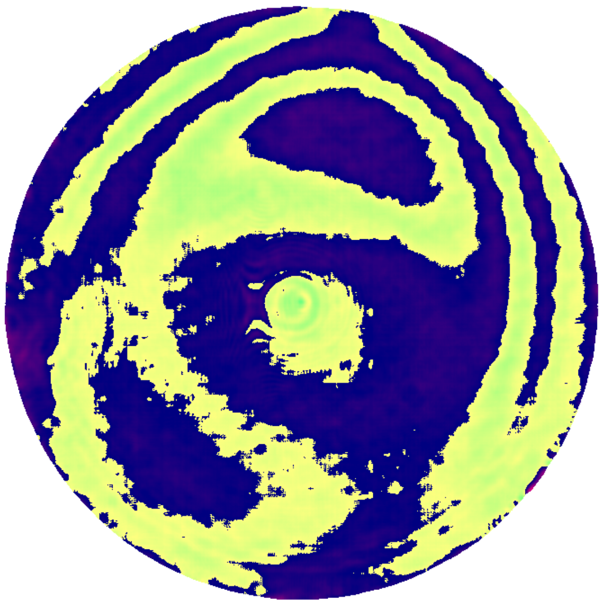


Figure 6.BMP image converted from the file with no RGB model applied

Figure 6 shows a successful byte to byte conversion with no distorted or twisted image generated. However, without the use of the RGB color model, still the output of conversion remains deviational observation unachievable since the information of surface deviation from the image is acquired through color distributions.

4.3 RGB Model Conversion

In this section, the entire bitmap file for surface deviation image is generated based on the successful data conversion from the FIS file. The RGB color model will be rendered by arranging the FIS raw pixels into a certain range of color map (see Table 11). Once the rendering is completed; the bitmap output image should show a smooth as well as chromatic surface deviation.

Table 11.Decimal values of RGB color with additive tendency

	Magenta	Blue	Cyan	Green	Yellow	Red
Blue	255	255	255 →	0	0	0
Green	0	0 →	255	255	255 →	1
Red	255 →	0	0	0 →	255	255
Color Group	0	1	2	3	4	
Decimal	0	256	512	768	1024	1279

Table 11 illustrates the range of different colors that the FIS file data of each pixel could possibly fall in. In this specific bitmap file, all of the FIS file data should squeeze into the color range from 0 to 1279 in decimal. Accordingly, the amount of the FIS file data must be then adjusted to a limited scale between +639 and -640.

4.3.1 Peak to Valley Value

No matter whether the FIS file data would be increased or decreased for the purpose of capturing them to the color rendering scale range, what the programmer needs to know is the crucial parameters of the FIS pixel data, referred to as image metrology.

The concept of Peak to Valley (P-V) value is thus required to be introduced. A P-V value in terms of optics is the difference between the top and bottom area on a surface. The Peak to Valley criterion has been widely used in the optic field for the measurement of surface quality and its flatness [13]. The use of P-V value in a FIS file determines the largest deviation of pixel array. Therefore, the maximum and minimum decimal value will have to be acquired beforehand in order to calculate the P-V value (See Table 12).

Table 12.The codes demonstrate how to get polar values from a binary file

```
double convertDecimal(BYTE col1,BYTE col2,BYTE col3,BYTE col4)
{
    double sum;
    long tmp;
    tmp=(col1<<24)+(col2<<16)+(col3<<8)+(col4);
    if(tmp!=nonaperture)
    {   sum = tmp;   }
    return sum;
}
decimal=convertDecimal(col1,col2,col3,col4);
void amendPolarValue(double decimal)
{
    double max = 0;
    double min = 0;
    if(decimal>max)
    {
        max=decimal;
    }
    if(decimal<min)
    {
        min=decimal;
    }
}
```

Once the maximum and minimum decimal values are obtained, the P-V value could be simply calculated by having the deviation between them. The P-V value would always be a positive value.

4.3.2 Scale Factor

The reason for acquiring the Peak and Valley value in this conversion program is that the color map range is from 0 to 1279 where each pixel from the FIS file should be framed into the specific area, by calculating the scale factor which scales down the whole FIS data value to +639 and -640.

The P-V value divided by 1280 is the scale factor. If the deviation lies between +639 and -640, then the scale factor is 1. The code is shown at Table 13.

Table 13.The function shows how to acquire scale factor for the FIS file

```
double getScaleFactor(double pv)
{
        if(pv>1280)
        {sf = (pv/1280);}
        else if(pv<1280)
        {sf = (pv/1280);}
        else
        {sf = 1;}

     return sf;}
```

The next step is to ensure that the pixel data have been trapped in the range from +639 to -640 by taking all the pixel values divided by scale factor. It is worth noting that while the scale factor extends or curtails the pixel bytes of the FIS file, it also decreases the precision of the output image in bitmap file; however, the surface deviation still remains observational.

At this stage of data modification, all the compressed pixel values will have to shift into the range from 0 to 1279 to match the Pseudo-color scale. The codes can be seen from Table 14:

Table 14.The functions illustrate how to shift all the data to 0-1279

```
int trapDecimal(double decimal,double sf)
{

    return (int)(decimal/sf) ;
}
int min1 = (int)(min/sf) ;
int shiftDecimal(int val1,int min1)
{
    if( (min<0) | (min >0))
    { val1 = val1-min1; }
    else
    val1 ;
    return val1;
}
```

4.3.3 RGB Color Rendering

The final step is to operate a serial of pixel byte to byte modification according to the color map table (See Table 11). The code in Table 15 below enables every single edited pixel to write into the bitmap file.

Table 15.This function depicts RGB color rendering for each pixel from converted FIS data

```
pixel *getPixel(int val)
{
    pixel *pxl=NULL;
    pxl=(pixel *)malloc(sizeof(struct pixelDef));

    if(NULL==pxl)
    {
        printf("Fail to allocate appointed memory\n");
        exit(1);
    }
    if(val>=0 && val<256)
    {
        pxl->blue=255;
        pxl->green=0;
        pxl->red=255-val;
    }
    else if(val>=256 && val<512)
    {
        pxl->blue=255;
        pxl->green=val-256;
        pxl->red=0;
    }
    else if(val>=512 && val<768)
    {
        pxl->blue=767-val; /* 255-(val-512) */
        pxl->green=255;
        pxl->red=0;
    }
    else if(val>=768 && val<1024)
    {
        pxl->blue=0;
        pxl->green=255;
        pxl->red=val-768;
    }
    else if(val>=1024 && val<1279)
    {
        pxl->blue=0;
        pxl->green=1279-val;    /* 255-(val-1024) */
        pxl->red=255;
    }
    else
    {
        pxl->blue=0;
        pxl->green=1;
        pxl->red=255;
    }
    return pxl;
}
```

When RGB model rendering is completed successfully, the actual converted bitmap output file as surface deviation image should look as in Figure 7.

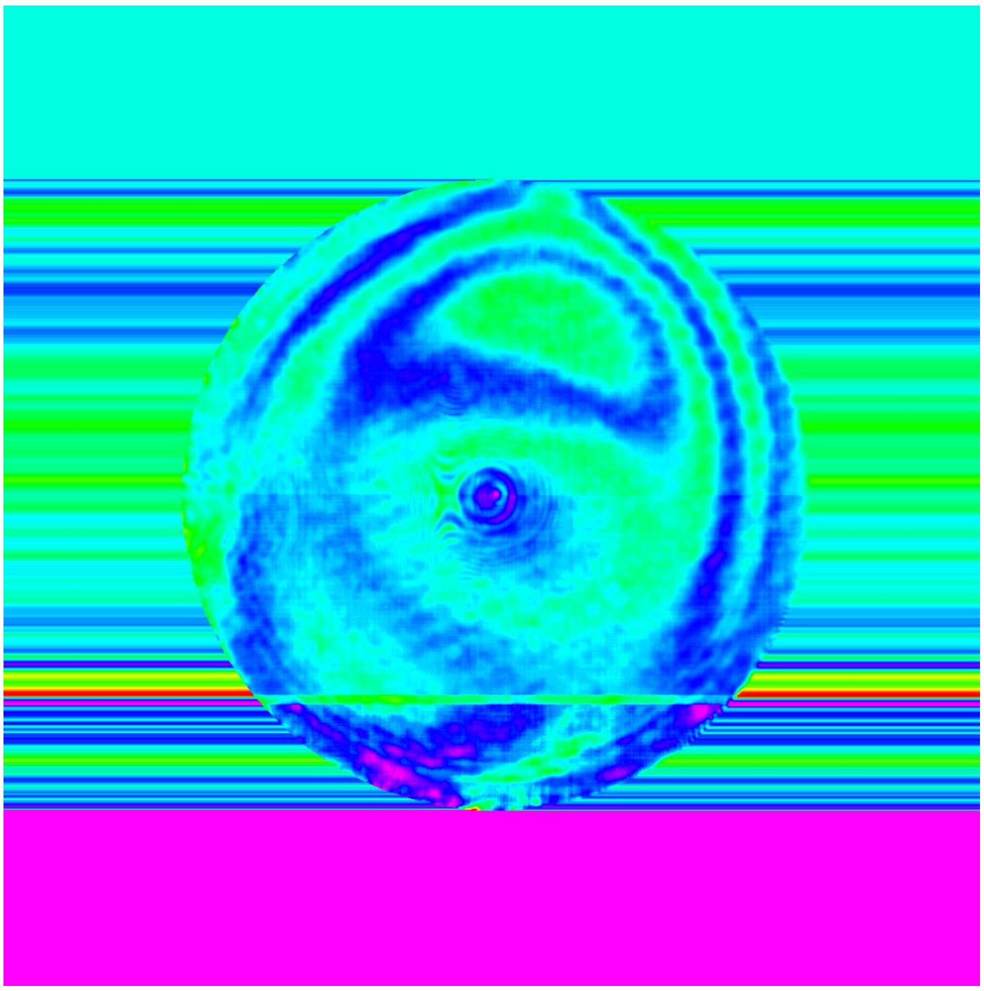


Figure 7.The conversion BMP image from the FIS file with RGB color rendering

5. Summary

This thesis systematically introduced the background knowledge of computer data conversion and general guidelines that then extend a third party program in later chapters for conversion between FIS file and BMP file. Most people have more or less experience with operating bitmap images, while few have a detailed concept of how binary data is jigsawed to form up a pixel as well as how pixels are colored to render an image. Therefore through the analysis of bitmap and FIS file, the study also explored the structure of two dedicated binary files and the color model being used in order to convert the output image as close to the original image as possible.

The empirical research was conducted by writing up a conversion program to fulfill the conversion from the FIS file to the BMP file. For the clarity of programming, two parts of code were compiled in a sequence of functionality. The first stage demonstrated the feasibility of the FIS file converted to a BMP file with data precision and its non-aperture white background. After the successful conversion, the output image is not for optical observation but proved the possibility of conversion from FIS file hexadecimal bytes to BMP file hexadecimal bytes.

The result of second stage was to create an image which should be visually smooth and make deviational observation possible. By taking advantage of scaling metrology, all the pixel values were framed in a certain range, in this case 0 to 1279. The whole process of BMP color resetting was carried out inside the range. The problem in this image was that the background color should give white. There were still tiny errors in the program when dealing with the data compression in FIS file. However, the background color editing could be excluded from the scope of this research due to it is non-aperture and senseless to the conversion as well as image observation.

References

[1] ODLIS —Online Dictionary forLibrary and Information Science [www-document]. Available at: http://lu.com/odlis/odlis_d.cfm (accessed 14 June 2010)

[2] Data Conversion [www-document].
Available at: http://en.wikipedia.org/wiki/Data_conversion (accessed 14 June 2010)

[3] Chikofsky, E.J. and J.H. Cross II, 1990, “Reverse Engineering and Design Recovery: A Taxonomy in IEEE Software”, *IEEE Computer Society*, pp. 13–17.

[4] Warden, R., 1992, “Software Reuse and Reverse Engineering in Practice”, London, England: Chapman & Hall, pp.283–305.

[5] James, D. Foley., 1995, “Computer Graphics: Principles and Practice.”, Addison-Wesley Professional, p.13.

[6] Description of the guidelines for selecting the appropriate picture format in an Office program [www-document].
Available at: http://support.microsoft.com/kb/320314 (accessed 14 June 2010)

[7] [www-document].
Available at: http://www.digicamsoft.com/BMP/BMP.html (accessed 07 May 2010)

[8] [www-document].
Available at: http://atlc.sourceforge.net/BMP.html#_toc381201082 (accessed 11 May 2010)

[9] Isaac, N., 1704/1952, “Opticks: 4th Edition”, Dover, New York, p. 247.

[10] Donald, H. and M. Pauline, B., 1997, “Computer Graphics: C Version”, New Jersey, USA: Prentice Hall, Inc., p. 572.

[11] Goldstein, E.B., 1989, “Sensation and Perception”, California, USA : Brooks/Cole, p. 86.

[12] [www-document].
Available at: http://msdn.microsoft.com/en-us/vstudio/aa700918.aspx (accessed 14 June 2010)

[13] What is an optical surface figure? [www-document].
Available at: http://optical-technologies.info/?tag=peak-to-valley-vs-rms (accessed 14 June 2010)

Appendix A: Table of BMP File Content

	Offset	Field	Size (byte)	Content
Bitmap File Header	0000h	identifier	2	the characters indentifying bitmap 'BM' – windows 3.1x, 95, NT… 'BA' – os/2 bitmap array 'CI' – os/2 color icon 'CP' – os/2 color pointer 'IC' – os/2 icon 'PT' – os/2 pointer
	0002h	file size	4	complete file size in bytes
	0006h	reserved	4	reserved for later use
	000ah	bitmap data offset	4	offset from beginning of file to the beginning of the bitmap data
	000eh	bitmap header size	4	length of the bitmap info header used to describe the bitmap colors, compression, the following sizes are possible: 28h - windows 3.1x, 95, NT… 0ch - os/2 1.x f0h - os/2 2.x
	0012h	width	4	horizontal width of bitmap in pixels
	0016h	height	4	vertical height of bitmap in pixels
	001ah	planes	2	number of planes in this bitmap

Bitmap Info Header	001ch	bits per pixel	2	bits per pixel used to store palette entry information, his also identifies in an indirect way the number of possible colors. possible values are: 1 - monochrome bitmap 4 - 16 color bitmap 8 - 256 color bitmap 16 - 16bit (high color) bitmap 24 - 24bit (true color) bitmap 32 - 32bit (true color) bitmap
	001eh	compression	4	compression specifications. the following values are possible: 0 - none (also identified by bi_rgb) 1 - rle 8-bit / pixel (also identified by bi_rle4) 2 - rle 4 - bit / pixel (also identified by bi_rle8) 3 - bitfields (also identified by bi_bitfields)
	0022h	bitmap data size	4	size of the bitmap data in bytes. this number must be rounded to the next 4 byte boundary
	0026h	hresolution	4	horizontal resolution expressed in pixel per meter.
	002ah	vresolution	4	number of colors used by this bitmap. for a 8-bit / pixel bitmap this will be 100h or 256
	002eh	colors	4	number of colors used by this bitmap. for a 8-bit / pixel bitmap this will be 100h or 256

	0032h	important colors	4	number of important colors. this number will be equal to the number of colors when every color is important
Palette	0036h	palette	n×4	the palette specification. for every entry in the palette four bytes are used to describe the rgb values of the color in the following way: 1 byte for blue component 1 byte for red component 1 byte for green component 1 byte filler which is set to zero
Bitmap Array	0436h	bitmap data	x	depending on the compression specifications, this field contains all the bitmap data bytes which represent indices in the color palette

Appendix B: Conversion Codes between Hexadecimal Value and Decimal Value

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#define ERROR 1
#define FISHEXSIZE 8
#define BMPHEXSIZE 6

int hexTrans(char c);
int fisHexToDec(char *hex);
char bmpShift(char c);
int bmpHexToDec(char *hex);
void fisDecToHex(long data);
void bmpDecToHex(long data);

int main(void)
{
 char *array=(char *)malloc(FISHEXSIZE);
 array="00000080";
     fisHexToDec(array);
     /*char *array=(char *)malloc(BMPHEXSIZE);
     array="000000";
     bmpHexToDec(array);*/
     /*fisDecToHex(1);
     /*bmpDecToHex(0);*/
     return 0;
}
```

```
int hexTrans(char c)

{

if(c>='0' && c<='9')

{

        return (c-'0')%16;

}

else

{

        return (c-'A'+10)%16;

}

}


int fisHexToDec(char *hex)

{

int i;

int j;

int k;

char t1=0;

char t2=0;

long tmp=1;

long sum=0;

char buf[FISHEXSIZE];


if(hex==NULL)

{

        perror("Parameter uninitialized");

        return ERROR;

}
```

```
for(i=FISHEXSIZE-1;i>=0;i-=2)
{
        t1=*hex++;
        t2=*hex++;
        buf[i]=t2;
        buf[i-1]=t1;
}

for(i=FISHEXSIZE-1,j=0;i>=0;i--,j++)
{
        for(k=0,tmp=1;k<j;k++)
        {
                tmp<<=4;
        }
        sum=sum+tmp*hexTrans(buf[i]);
}

printf("%ld",sum);

return 0;
}

char bmpShift(char c)
{
char tmp=0;
switch(c)
{
        case '0':
        case '1':  tmp=(char)(c+8);
                        break;
```

```
case '2':  tmp='A';
           break;
case '3':  tmp='B';
           break;
case '4':  tmp='C';
           break;
case '5':  tmp='D';
           break;
case '6':  tmp='E';
           break;
case '7':  tmp='F';
           break;
case '8':  tmp='0';
           break;
case '9':  tmp='1';
           break;
case 'A':  tmp='2';
           break;
case 'B':  tmp='3';
           break;
case 'C':  tmp='4';
           break;
case 'D':  tmp='5';
           break;
case 'E':  tmp='6';
           break;
case 'F':  tmp='7';
           break;
default:   printf("bmpShift Error\n");
           exit(ERROR);
```

```
}
return tmp;
}

int bmpHexToDec(char *hex)
{
int i;
int j;
int k;
long tmp=1;
long sum=0;
char buf[BMPHEXSIZE];

if(NULL==hex)
{
    perror("Parameter uninitialized");
    return ERROR;
}

for(i=0;i<BMPHEXSIZE;i++)
{
    buf[i]=*hex++;
}

buf[0]=bmpShift(buf[0]);

for(i=BMPHEXSIZE-1,j=0;i>=0;i--,j++)
{
    for(k=0,tmp=1;k<j;k++)
    {
        tmp<<=4;
    }
    sum=sum+tmp*hexTrans(buf[i]);
}
sum&=0x00FFFFFF;

switch(buf[0])
{
    case '8':
    case '9':
    case 'A':
    case 'B':
    case 'C':
    case 'D':
    case 'E':
    case 'F': sum*=-1;
}

printf("bmp file decimal: %ld",sum);

return 0;
}

void fisDecToHex(long data)
{
int i=FISHEXSIZE-1;
int arr[FISHEXSIZE];
char hex[]={'0','1','2','3','4','5','6','7','8','9','A','B','C','D','E','F'};

memset(arr,0,FISHEXSIZE);
```

```
if(data<0)
{
        data=~data;
        data++;
}
while(1)
{
        arr[i]+=data%16; printf("\n%d:%d\n",i,arr[i]);
        data/=16;
        if(--i==0)
        {
                break;
        }
}
arr[i]+=data;printf("%d:%d\n",i,arr[1]);
for(i=FISHEXSIZE-1;i>=0;i=i-2)
        printf("%c%c",hex[arr[i-1]],hex[arr[i]]);
printf("\n");
}

void bmpDecToHex(long data)
{
int i=BMPHEXSIZE-1;
int arr[BMPHEXSIZE];
char hex[]={'0','1','2','3','4','5','6','7','8','9','A','B','C','D','E','F'};
memset(arr,0,BMPHEXSIZE);
while(1)
{
        arr[i]=data%16;
        data/=16;
```

```
            if(--i==0)
            {
                break;
            }
        }
        arr[i]=data;
        arr[0]=(arr[0]+8)%16;
        for(i=0;i<=BMPHEXSIZE-1;i++)
            printf("%c",hex[arr[i]]);
        printf("\n");
    }
```