

A SYSTEM FOR FAST 90 DEGREE ROTATION OF BI-LEVEL IMAGES

1. Field of the Invention

The present invention relates to a digital image processing method and more particularly to a method for the fast rotation of bi-level images.

2. Description of the Prior Art

Bi-level images (also called monochrome images) are images having just two intensity levels (generally black and white or black and green) because their bi-level bitmaps contain a single bit per pixel. The entire bitmap for a screen for a resolution of 1,024 x 1,024 pixels is 2^{20} bits, or about 128,000 bytes.

Through the increasing proliferation in offices and home offices of low memory computers, such as workstations and personal computers, computer storage of office documentation, reports, forms, letters and even photographs, is becoming prevalent as a means for reducing physical storage requirements and improving accessibility to common office files.

Documents are commonly received into computer systems by optical character reader (OCR) scan, facsimile or on-line data transmission. The challenge is to take the image of a document entered into a system, for example by OCR, and be able to manipulate it quickly and efficiently, so that it can be easily viewed by the end user.

Rotating a bi-level image by 90° , 180° , and 270° with respect to its orientation on input are among the most commonly used operations during document image processing. The traditional solution is to rotate the image one pixel at time, but this operation is very time consuming.

As a result, a number of methods have been proposed in the prior art for expediting image rotation, particularly plus or

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minus 90° rotations, since these are considerably more complex than 180° rotation due to the packed internal data representation of the image pixels, wherein each byte contains eight image pixels. The rotated image must occupy the storage that contained the original image before rotation. Thus, for this type of rotation, the number of rows must be a multiple of eight, since the bits in each vertical column are packed into bytes by the rotation and a row of the output image must not end with a fraction of a byte. Consequently, placeholder data values must be added to columns that are not multiples of eight.

U.S. Patent Number 4,627,020 of IBM Corporation, sets forth a method for rotating an image by 90° that was considerably faster than the traditional method because it caused the rotation of up to 64 pixels (8 by 8 blocks) at a time, rather than just one pixel. A block of the image would be moved into temporary storage (called a look-up table) and divided into smaller groups of bytes of rotatable size. Each group that did not have the same value for all bits is then rotated. This method took advantage of the fact that large areas of most images are background colour (e.g. white), and that blocks or graphs of the image containing all one colour need not be rotated. This is an enhancement now commonly added to rotation methods. However, as will be seen, the method of the 4,627,020 patent is not as efficient as the method proposed in the present invention since it utilizes additional memory accesses and address manipulations for each byte rotated.

U.S. Patent Number 4,658,430, also of IBM Corporation, is directed to a method for rotating encoded data images that have, for example, been transmitted over a telephone line, by a multiple of 90° . The orientation of encoded data presents different problems from the rotation of the type of data to which the present invention is addressed.

U.S. Patent Number 4,837,845 of IBM Corporation is specifically directed to the problem of rotating binary image



data plus or minus 90° from its original orientation. The image data is first stored in partially transposed form in a matrix contained in eight 32-bit registers. The matrix is separated into groups of bits of rotatable size (sub-matrices of equal size), and first preselected bit positions are transposed with second preselected bit positions in each group. Rows of bits in the groups are then exchanged with second rows of bits in the groups.

Each of these IBM patents discuss, as prior art, a number of much earlier publications and references directed to solving the problems associated with image rotation, and the contents of each of these IBM patents, particularly in their sections describing the prior art, are incorporated herein by reference.

In addition to the foregoing, U.S. Patent Number 4,916,746 of International Computers Limited discloses rotating an image through 90 degrees, either clockwise or counterclockwise, using a hardware rotation circuit. The rotation circuit comprises a FIFO and shift register, where data is read out of the FIFO a word at a time and written back into the FIFO with a displacement of one bit, effecting a spiral data path. The shift register is then used to assemble the output rotated image data.

U.S. Patent Number 4,985,849 of Canon K.K. discloses an image processing system for forming a slantwise mapped or rotated modified image of an original image. The relation between the address locations of the original points of data and the output points is calculated, and these calculated values are prestored in lookup tables. The image data from the original address locations is then transferred or copied using the output address information from the lookup tables.

U.S. Patent Number 5,067,167 of Cornell Research Foundation Inc. discloses rotating a three-dimensional image by 90° by using a data processor to modify the original spacial



coordinate values of the three-dimensional image.

U.S. Patent Number 5,233,168 of Pitney Bowes Inc. discloses deskewing an image by scanning the image to capture a pixel by pixel mapped image, determining size and skew of the mapped image, performing a series of area-limited vertical pixel shifts, and performing a series of area-limited horizontal pixel shifts.

Other approaches to providing rapid image rotation have been hardware specific solutions, such as a special hardware device called a rotation buffer disclosed in U.S. Patent Number 4,947,344 of IBM Corporation or special circuitry disclosed in U.S. Patent number 4,992,960 of Yamaha Corporation. However, these types of hardware solutions require considerable costs associated with modified existing hardware, as opposed to a solution implemented in software for maximizing the existing hardware storage capabilities.

SUMMARY OF THE INVENTION

Like the methods disclosed in previous IBM patents ('020, '430, and '845), the present invention also works on 64 pixel blocks of image data at a time in expediting image rotation to orientation of 90° or 270° from its orientation on input. However, because the method of the present invention requires fewer memory accesses than the prior art methods, it has been found to be 15 to 30% faster in operation on Intel-based IBM® personal computers having 32-bit registers, which is the type of environment to which this invention is predominantly directed.

Accordingly, the invention provides, in a 32-bit operating system, a method of rotating by 90° a block of bi-level image data having 8 rows by 8 columns of pixel data bits. The method includes the computer-implemented steps of generating an intermediate matrix having 8 rows by 8 columns of pixel data bits, wherein each row from the block has been divided and translated into a paired nibble column, alternate rows from

the block being arranged transversely and lower order rows from the block being arranged on top of adjacent higher order rows in the paired nibble columns of the intermediate matrix and saving the rows of the intermediate matrix sequentially into first and second 32-bit registers. The first 32-bit register is then copied into a third 32-bit register and the second 32-bit register into a fourth 32-bit register. Each of the first and second registers is shifted by one bit in opposite directions and alternate bits from the fourth register are dynamically overlaid onto the first register while alternate bits from the third register are dynamically overlaid onto the second register.

The present invention is also directed to a system provided with means for carrying out the computer implemented steps of the method.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described in detail in association with the accompanying figures, in which:

Figure 1 is a schematic representation of a typical operating systems for practicing the present invention;

Figures 2 and 3 illustrate the display screen of a personal computer or work station showing a document oriented by a difference of 90°; and

Figure 4 is a flow diagram illustrating the computer implemented steps in rotating a image 90° clockwise or counterclockwise.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention operates in a 32-bit programming operating system environment such as IBM's OS/2® system, Posix Unix systems or Microsoft's system NT.

The elements of an operating system of this type are

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illustrated schematically in Figure 1, and would typically include a host processor 12 having a 32-bit storage registers, an image storage 14, a display terminal 16, means for receiving image data, such as an OCR-image scanner 18, and a printer 20. Other means for receiving image data into the operating system would include data transmission and facsimile. The display terminal 16, the image scanner 18 and the printer 20 each may have different requirements for reading or presentation of a document or image. Accordingly, the processor 12 in conjunction with image storage 14 will be required to manipulate the image data to meet the presentation requirements of each of the peripheral devices 16, 18 and 20.

For example, a photographic image may be scanned into the system via scanner 18 and end up as a horizontally displayed image 22 on a computer display 24, such as illustrated in Figure 2. In order for the end user to use the displayed image in any meaningful way, the orientation of the image must be rotated 90° clockwise to the position 22a shown on the computer display 24 in Figure 3.

The steps of the method of this invention are illustrated in the flow diagram of Figure 4. As discussed earlier, the present invention rotates image data in 8 by 8 pixel block segments. Thus, an 8 by 8 pixel block segment selected from the stored data of the entire image (block 50 in Figure 4) may be represented by the 64 bit matrix set forth below in Table A:



TABLE A

Row 1	A7	A6	A5	A4	A3	A2	A1	A0
Row 2	B7	B6	B5	B4	B3	B2	B1	B0
Row 3	C7	C6	C5	C4	C3	C2	C1	C0
Row 4	D7	D6	D5	D4	D3	D2	D1	D0
Row 5	E7	E6	E5	E4	E3	E2	E1	E0
Row 6	F7	F6	F5	F4	F3	F2	F1	F0
Row 7	G7	G6	G5	G4	G3	G2	G1	G0
Row 8	H7	H6	H5	H4	H3	H2	H1	H0

Where A0, A1,, H6, H7 each represent a bi-level pixel forming the matrix.

Clockwise 90° rotation of the matrix of Table A turns the matrix on its side so that Row 1 becomes the right-hand column of 8 bits, with the A0 pixel at the bottom. Counterclockwise 90° rotation turns the matrix so that Row 1 becomes the left-hand column of 8 bits, with the A0 pixel at the top. These two resulting data representations are illustrated in Tables D and E in this description.

The same general principles and functions are applied to achieve both clockwise and counterclockwise rotation according to the invention. However, as will be discussed in detail below, the functions are reversed, in many cases, to achieve counterclockwise, rather than clockwise, rotation.

The working area for transforming the image data is 32-bit registers in the processor, from which the transformed data is moved back to the memory (storage) ready for display or printing. A 64-bit matrix can be stored in two 32-bit registers.



The present invention is performed in four main steps. First, an intermediate matrix is generated that sets the foundation for dividing the matrix into two register-size rows of 4-bytes each. The intermediate matrix is stored in the two target 32-bit registers, and then copied into a further pair of 32-bit registers. The data in the four registers is then manipulated, and the four registers are finally collapsed back into the original two that now contain the rotated data image.

Throughout, only three memory accesses per byte (or 24 per block) are required, first when the byte is read in a processor register, next when the value is used to access a lookup table for generating the intermediate matrix and a final memory access to save the rotated data back in memory.

This represents a 25% reduction over the next fastest rotation method of the prior art (which requires four memory accesses per byte or 32 for a full block), and accounts for the improved speed of the present invention.

According to the preferred embodiment of the invention, the selected 8 by 8 pixel matrix or block of image data is transformed into a intermediate matrix (block 52), that is rearranged in a manner that starts the process of re-aligning the pixels to a position more proximate to their position following complete rotation. In the case of an intended 90° clockwise rotation, the intermediate matrix is as set out in Table B:



TABLE 8

Row 1	G7	G3	E7	E3	C7	C3	A7	A3
Row 2	G6	G2	E6	E2	C6	C2	A6	A2
Row 3	G5	G1	E5	E1	C5	C1	A5	A1
Row 4	G4	G0	E4	E0	C4	C0	A4	A0
Row 5	H7	H3	F7	F3	D7	D3	B7	B3
Row 6	H6	H2	F6	F2	D6	D2	B6	B2
Row 7	H5	H1	F5	F1	D5	D1	B5	B1
Row 8	H4	H0	F4	F0	D4	D0	B4	B0

The partial rearrangement for rotation effectively divides and translates each row into a pair of nibble columns. The first four rows of the intermediate matrix contain the translated paired nibble columns of the odd-numbered rows from the original block of data (i.e., rows A, C, E and G) arranged transversely. In the case of a clockwise rotation, the transverse arrangement is from right to left, with the higher order bits from each half-row arranged on top of the lower order bits. For counterclockwise rotation, it will be seen from reviewing Table E that the transverse arrangement is from left to right, with the lower order bits arranged on top of the higher order bits from each half row. The bottom four rows of the intermediate matrix contain the even-numbered rows from the original block of data (i.e., rows B, D, F, and H) in the same arrangement as the upper four rows.

In the preferred embodiment of the invention, the intermediate matrix is generated using four lookup tables, which are set out in the section titled Appendix which forms part of the present disclosure.

Each of the four lookup tables is responsible for converting two rows in the 8 by 8 pixel matrix. For clockwise rotation, Table 1 from the Appendix is used for converting Rows 1 and 2,

Table 2 for Rows 3 and 4, Table 3 for Rows 5 and 6, and Table 4 for Rows 7 and 8, and the rows are converted alternately (ie. rows 1, 3, 5 and 7, followed by rows 2, 4, 6 and 8). For counterclockwise rotation, the lookup tables are used in the reverse order, that is, Table 1 is used for converting Rows 8 and 7, Table 2 for Rows 6 and 5, Table 3 for Rows 4 and 3, and Table 4 for Rows 2 and 1.

Generation of the intermediate matrix, in the preferred embodiment, is by dynamic overlay with the results being saved immediately to two 32-bit processor registers.

Use of the lookup tables for a 90° clockwise rotation can be illustrated by the following example, starting with the bi-level 8 by 8 pixel matrix in binary notation set out in Table C.

TABLE C

Row 1	0	0	0	0	1	1	1	1
Row 2	0	0	0	0	0	0	1	1
Row 3	0	0	0	1	0	1	0	0
Row 4	0	0	0	1	0	1	0	1
Row 5	0	0	1	1	0	0	0	0
Row 6	0	1	0	1	1	1	0	0
Row 7	0	0	1	0	1	1	1	0
Row 8	0	0	1	0	0	0	1	0

First, for row 1, entry 15 of lookup table 1 is used:

**** Lookup Table 1:

	From	To
ROW	BINARY REPRESENTATION	BINARY REPRESENTATION
15	00001111	00000001 00000001 00000001 00000001

This 32-bit value is saved in register R1 as:

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	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	00000001	00000001	00000001	00000001

Next, for row 3, entry 20 of lookup table 2 is used:

**** LOOKUP TABLE 2:

	FROM	TO
ROW	BINARY REPRESENTATION	BINARY REPRESENTATION
20	00010100	00000000 00000100 00000000 00001000

This value is logical ORed, or dynamically overlaid with the 4-byte value for row 1, in which any "one" value from either 4-byte row replaces a "zero" value. The resulting revision of the first 32-bit register is:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	00000001	00000101	00000001	00001001

Next, for row 5, entry 48 of lookup table 3 is used:

**** LOOKUP TABLE 3

	FROM	TO
ROW	BINARY REPRESENTATION	BINARY REPRESENTATION
48	00110000	00000000 00000000 00100000 00100000

When this 4-byte value is logical ORed with the contents of R1 the following register value results:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	00000001	00000101	00100001	00101001

Finally, for row 7, entry 46 of lookup table 4 is used:

****LOOKUP TABLE 4:

	FROM	TO
ROW	BINARY REPRESENTATION	BINARY REPRESENTATION
46	00101110	01000000 01000000 11000000 00000000

After logical ORing R1 with the value, register R1 contains:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	01000001	01000101	11100001	00101001

Repeating the same procedures for row 2, 4, 6 and 8, using lookup table 1, 2, 3, and 4 respectively, the result is saved in R2 as:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R2	00010000	00110100	11000001	00101101





This completes the process of the intermediate matrix generation. To clarify the results, the contents of R1 and R2 may be displayed in terms of bytes with higher-order bytes on top of lower order bytes in a matrix-like format as follows:

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R1 BYTE 3      0 1 0 0 0 0 0 1
R1 BYTE 2      0 1 0 0 0 1 0 1
R1 BYTE 1      1 1 1 0 0 0 0 1
R1 BYTE 0      0 0 1 0 1 0 0 1
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R2 BYTE 3      0 0 0 1 0 0 0 0
R2 BYTE 2      0 0 1 1 0 1 0 0
R3 BYTE 1      1 1 0 0 0 0 0 1
R3 BYTE 0      0 0 1 0 1 1 0 1
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Therefore, returning to the original generic example, the first four rows (or first four-byte row) of the intermediate matrix are saved into the first 32-bit register R1 (block 54) of Figure 4, and the remaining four rows (or second four-byte row) of the matrix are saved into a second 32-bit register R2 (block 56). Thus, in a 32-bit environment, the intermediate matrix is held in the two 32-bit registers in R1 and R2 in the following representation:

R1: G7 G3 E7 E3 C7 C3 A7 A3	G6 G2 E6 E2 C6 C2 A6 A2	G5 G1 E5 E1 C5 C1 A5 A1	G4 G0 E4 E0 C4 C0 A4 A0
R2: H7 H3 F7 F3 D7 D3 B7 B3	H6 H2 F6 F2 D6 D2 B6 B2	H5 H1 F5 F1 D5 D1 B5 B1	H4 H0 F4 F0 D4 D0 B4 B0

The contents of registers R1 and R2 are then copied to two other 32-bit registers R3 and R4 respectively (block 58) to achieve the following representation.

R1: G7 G3 E7 E3 C7 C3 A7 A3 R2: H7 H3 F7 F3 D7 D3 B7 B3	G6 G2 E6 E2 C6 C2 A6 A2 H6 H2 F6 F2 D6 D2 B6 B2	G5 G1 E5 E1 C5 C1 A5 A1 H5 H1 F5 F1 D5 D1 B5 B1	G4 G0 E4 E0 C4 C0 A4 A0 H4 H0 F4 F0 D4 D0 B4 B0
R3: G7 G3 E7 E3 C7 C3 A7 A3 R4: H7 H3 F7 F3 D7 D3 B7 B3	G6 G2 E6 E2 C6 C2 A6 A2 H6 H2 F6 F2 D6 D2 B6 B2	G5 G1 E5 E1 C5 C1 A5 A1 H5 H1 F5 F1 D5 D1 B5 B1	G4 G0 E4 E0 C4 C0 A4 A0 H4 H0 F4 F0 D4 D0 B4 B0

When the rotation is an 90° clockwise rotation (block 60), the even bits R1 and R4 are zeroed out (block 62) and the odd bits of R2 and R3 are zeroed out (block 64), to yield the following changes in the registers:

R1: G7 00 E7 00 C7 00 A7 00 R2: 00 H3 00 F3 00 D3 00 B3	G6 00 E6 00 C6 00 A6 00 00 H2 00 F2 00 D2 00 B2	G5 00 E5 00 C5 00 A5 00 00 H1 00 F1 00 D1 00 B1	G4 00 E4 00 C4 00 A4 00 00 H0 00 F0 00 D0 00 B0
R3: 00 G3 00 E3 00 C3 00 A3 R4: H7 00 F7 00 D7 00 B7 00	00 G2 00 E2 00 C2 00 A2 H6 00 F6 00 D6 00 B6 00	00 G1 00 E1 00 C1 00 A1 H5 00 F5 00 D5 00 B5 00	00 G0 00 E0 00 C0 00 A0 H4 00 F4 00 D4 00 B4 00

The contents of R1 are then shifted right by one bit and the contents of R2 are shifted left by one bit (block 66), so that the contents of the four registers appears as follows:

R1: 00 G7 00 E7 00 C7 00 A7 R2: H3 00 F3 00 D3 00 B3 00	00 G6 00 E6 00 C6 00 A6 H2 00 F2 00 D2 00 B2 00	00 G5 00 E5 00 C5 00 A5 H1 00 F1 00 D1 00 B1 00	00 G4 00 E4 00 C4 00 A4 H0 00 F0 00 D0 00 B0 00
R3: 00 G3 00 E3 00 C3 00 A3 R4: H7 00 F7 00 D7 00 B7 00	00 G2 00 E2 00 C2 00 A2 H6 00 F6 00 D6 00 B6 00	00 G1 00 E1 00 C1 00 A1 H5 00 F5 00 D5 00 B5 00	00 G0 00 E0 00 C0 00 A0 H4 00 F4 00 D4 00 B4 00

Next R1 is logical ORed with R4 (block 74) and R2 is logical ORed with R3 (block 76) to achieve the following content of registers R1 and R2:

R1: H7 G7 F7 E7 D7 C7 B7 A7 R2: E3 G3 F3 E3 D3 C3 B3 A3	H6 G6 F6 E6 D6 C6 B6 A6 H2 G2 F2 E2 D2 C2 B2 A2	H5 G5 F5 E5 D5 C5 B5 A5 H1 G1 F1 E1 D1 C1 B1 A1	H4 G4 F4 E4 D4 C4 B4 A4 H0 G0 F0 E0 D0 C0 B0 A0
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In matrix formation, R1 and R2 now contain the rotated 8 by 8 pixel matrix:





TABLE D

R1:

H7	G7	F7	E7	D7	C7	B7	A7
H6	G6	F6	E6	D6	C6	B6	A6
H5	G5	F5	E5	D5	C5	B5	A5
H4	G4	F4	E4	D4	C4	B4	A4

R2:

H3	G3	F3	E3	D3	C3	B3	A3
H2	G2	F2	E2	D2	C2	B2	A2
H1	G1	F1	E1	D1	C1	B1	A1
H0	G0	F0	E0	D0	C0	B0	A0

90° counterclockwise rotation is achieved following a similar method. Generation of the intermediate matrix, as mentioned above, is performed in the preferred embodiment using the lookup tables in reverse order, to generate an intermediate matrix from Table A, as follows:

TABLE E

Row 1	A4	A0	C4	C0	E4	E0	G4	G0
Row 2	A5	A1	C5	C1	E5	E1	G5	G1
Row 3	A6	A2	C6	C2	E6	E2	G6	G2
Row 4	A7	A3	C7	C3	E7	E3	G7	G3
Row 5	B4	B0	D4	D0	F4	F0	H4	H0
Row 6	B5	B1	D5	D1	F5	F1	H5	H1
Row 7	B6	B2	D6	D2	F6	F2	H6	H2
Row 8	B7	B3	D7	D3	F7	F3	H7	H3

In a 32-bit environment, the above intermediate matrix can be

held in the two 32-bit registers R1 and R2 (blocks 54 and 56) in the following representation:

R1: A7 A3 C7 C3 E7 E3 G7 G3	A6 A2 C6 C2 E6 E2 G6 G2	A5 A1 C5 C1 E5 E1 G5 G1	A4 A0 C4 C0 E4 E0 G4 G0
R2: B7 B3 D7 D3 F7 F3 H7 H3	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0

The contents of R1 and R2 are then copied to the two other 32-bit registers R3 and R4, respectively (block 58):

R1: A7 A3 C7 C3 E7 E3 G7 G1	A6 A2 C6 C2 E6 E2 G6 G2	A5 A1 C5 C1 E5 E1 G5 G1	A4 A0 C4 C0 E4 E0 G4 G0
R2: B7 B3 D7 D3 F7 F3 H7 H3	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0
R3: A7 A3 C7 C3 E7 E3 G7 G1	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0
R4: B7 B3 D7 D3 F7 F3 H7 H3	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0

For the counterclockwise rotation (block 60), the odd bits of R1 and R4 are zeroed out (block 68) and the even bits of R2 and R3 are zeroed out (block 70). This changes the contents of the four registers as follows:

R1: 00 A3 00 C3 00 E3 00 G3	00 A2 00 C2 00 E2 00 G2	00 A1 00 C1 00 E1 00 G1	00 A0 00 C0 00 E0 00 G0
R2: B7 00 D7 00 F7 00 H7 00	B6 00 D6 00 F6 00 H6 00	B5 00 D5 00 F5 00 H5 00	B4 00 D4 00 F4 00 H4 00
R3: A7 00 C7 00 E7 00 G7 00	A6 00 C6 00 E6 00 G6 00	A5 00 C5 00 E5 00 G5 00	A4 00 C4 00 E4 00 G4 00
R4: 00 B3 00 D3 00 F3 00 H3	00 B2 00 D2 00 F2 00 H2	00 B1 00 D1 00 F1 00 H1	00 B0 00 D0 00 F0 00 H0

The contents of R1 are shifted left by 1 bit and the contents of R2 (block 72) so that the 4 registers now appear as:

R1: A3 00 C3 00 E3 00 G3 00	A2 00 C2 00 E2 00 G2 00	A1 00 C1 00 E1 00 G1 00	A0 00 C0 00 E0 00 G0 00
R2: 00 B7 00 D7 00 F7 00 H7	00 B6 00 D6 00 F6 00 H6	00 B5 00 D5 00 F5 00 H5	00 B4 00 D4 00 F4 00 H4
R3: 07 00 C7 00 E7 00 G7 00	A6 00 C6 00 E6 00 G6 00	A5 00 C5 00 E5 00 G5 00	A4 00 C4 00 E4 00 G4 00
R4: 00 B3 00 D3 00 F3 00 H3	00 B2 00 D2 00 F2 00 H2	00 B1 00 D1 00 F1 00 H1	00 B0 00 D0 00 F0 00 H0

R1 is logical ORed with R4 (block 74), and R2 with R3 (block 76). The first two registers then have the following representation:





R1: A3 B3 C3 D3 E3 F3 G3 H3	A2 B2 C2 D2 E2 F2 G2 H2	A1 B1 C1 D1 E1 F1 G1 H1	A0 B0 C0 D0 E0 F0 G0 H0
R2: A7 B7 C7 D7 E7 F7 G7 H7	A6 B6 C6 D6 E6 F6 G6 H6	A5 B5 C5 D5 E5 F5 G5 H5	A4 B4 C4 D4 E4 F4 G4 H4

R1 and R2 now contain the 8 by 8 pixel matrix rotated 90° counterclockwise from the original orientation. Presented in matrix formation, the data appears as follows:

TABLE F

R1:

A0	B0	C0	D0	E0	F0	G0	H0
A1	B1	C1	D1	E1	F1	G1	H1
A2	B2	C2	D2	E2	F2	G2	H2
A3	B3	C3	D3	E3	F3	G3	H3

R2:

A4	B4	C4	D4	E4	F4	G4	H4
A5	B5	C5	D5	E5	F5	G5	H5
A6	B6	C6	D6	E6	F6	G6	H6
A7	B7	C7	D7	E7	F7	G7	H7

In the preferred embodiment implemented on an IBM 32-bit machine, the method of the present invention runs consistently faster, and has less overhead when ported across 32-bit platforms, than previously known methods.

Test results have indicated that the present method is over 30% faster on Intel-based IBM PC computers, and the result would be even better if cache memories were used.

Modifications of the preferred embodiments described herein which would be obvious to one skilled in the art are intended to be covered by the appended claims.



LOOKUP TABLE 1 :

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00000000	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 00000001
2	00000010	00000000 00000000 00000001 00000000
3	00000011	00000000 00000000 00000001 00000001
4	00000100	00000000 00000001 00000000 00000000
5	00000101	00000000 00000001 00000000 00000001
6	00000110	00000000 00000001 00000001 00000000
7	00000111	00000000 00000001 00000001 00000001
8	00001000	00000001 00000000 00000000 00000000
9	00001001	00000001 00000000 00000000 00000001
10	00001010	00000001 00000000 00000001 00000000
11	00001011	00000001 00000000 00000001 00000001
12	00001100	00000001 00000001 00000000 00000000
13	00001101	00000001 00000001 00000000 00000001
14	00001110	00000001 00000001 00000001 00000000
15	00001111	00000001 00000001 00000001 00000001
16	00010000	00000000 00000000 00000000 00000010
17	00010001	00000000 00000000 00000000 00000011
18	00010010	00000000 00000000 00000001 00000010
19	00010011	00000000 00000000 00000001 00000011
20	00010100	00000000 00000001 00000000 00000010
21	00010101	00000000 00000001 00000000 00000011
22	00010110	00000000 00000001 00000001 00000010
23	00010111	00000000 00000001 00000001 00000011
24	00011000	00000001 00000000 00000000 00000010
25	00011001	00000001 00000000 00000000 00000011
26	00011010	00000001 00000000 00000001 00000010
27	00011011	00000001 00000000 00000001 00000011
28	00011100	00000001 00000001 00000000 00000010
29	00011101	00000001 00000001 00000000 00000011
30	00011110	00000001 00000001 00000001 00000010
31	00011111	00000001 00000001 00000001 00000011
32	00100000	00000000 00000000 00000010 00000000
33	00100001	00000000 00000000 00000010 00000001
34	00100010	00000000 00000000 00000011 00000000
35	00100011	00000000 00000000 00000011 00000001
36	00100100	00000000 00000001 00000010 00000000
37	00100101	00000000 00000001 00000010 00000001
38	00100110	00000000 00000001 00000011 00000000
39	00100111	00000000 00000001 00000011 00000001

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40	00101000	00000001 00000000 00000010 00000000
41	00101001	00000001 00000000 00000010 00000001
42	00101010	00000001 00000000 00000011 00000000
43	00101011	00000001 00000000 00000011 00000001
44	00101100	00000001 00000001 00000010 00000000
45	00101101	00000001 00000001 00000010 00000001
46	00101110	00000001 00000001 00000011 00000000
47	00101111	00000001 00000001 00000011 00000001
48	00110000	00000000 00000000 00000010 00000010
49	00110001	00000000 00000000 00000010 00000011
50	00110010	00000000 00000000 00000011 00000010
51	00110011	00000000 00000000 00000011 00000011
52	00110100	00000000 00000001 00000010 00000010
53	00110101	00000000 00000001 00000010 00000011
54	00110110	00000000 00000001 00000011 00000010
55	00110111	00000000 00000001 00000011 00000011
56	00111000	00000001 00000000 00000010 00000010
57	00111001	00000001 00000000 00000010 00000011
58	00111010	00000001 00000000 00000011 00000010
59	00111011	00000001 00000000 00000011 00000011
60	00111100	00000001 00000001 00000010 00000010
61	00111101	00000001 00000001 00000010 00000011
62	00111110	00000001 00000001 00000011 00000010
63	00111111	00000001 00000001 00000011 00000011
64	01000000	00000000 00000010 00000000 00000000
65	01000001	00000000 00000010 00000000 00000001
66	01000010	00000000 00000010 00000001 00000000
67	01000011	00000000 00000010 00000001 00000001
68	01000100	00000000 00000011 00000000 00000000
69	01000101	00000000 00000011 00000000 00000001
70	01000110	00000000 00000011 00000001 00000000
71	01000111	00000000 00000011 00000001 00000001
72	01001000	00000001 00000010 00000000 00000000
73	01001001	00000001 00000010 00000000 00000001
74	01001010	00000001 00000010 00000001 00000000
75	01001011	00000001 00000010 00000001 00000001
76	01001100	00000001 00000011 00000000 00000000
77	01001101	00000001 00000011 00000000 00000001
78	01001110	00000001 00000011 00000001 00000000
79	01001111	00000001 00000011 00000001 00000001
80	01010000	00000000 00000010 00000000 00000010
81	01010001	00000000 00000010 00000000 00000011
82	01010010	00000000 00000010 00000001 00000010
83	01010011	00000000 00000010 00000001 00000011
84	01010100	00000000 00000011 00000000 00000010
85	01010101	00000000 00000011 00000000 00000011
86	01010110	00000000 00000011 00000001 00000010
87	01010111	00000000 00000011 00000001 00000011



88	01011000	00000001 00000010 00000000 00000010
89	01011001	00000001 00000010 00000000 00000011
90	01011010	00000001 00000010 00000001 00000010
91	01011011	00000001 00000010 00000001 00000011
92	01011100	00000001 00000011 00000000 00000010
93	01011101	00000001 00000011 00000000 00000011
94	01011110	00000001 00000011 00000001 00000010
95	01011111	00000001 00000011 00000001 00000011
96	01100000	00000000 00000010 00000010 00000000
97	01100001	00000000 00000010 00000010 00000001
98	01100010	00000000 00000010 00000011 00000000
99	01100011	00000000 00000010 00000011 00000001
100	01100100	00000000 00000011 00000010 00000000
101	01100101	00000000 00000011 00000010 00000001
102	01100110	00000000 00000011 00000011 00000000
103	01100111	00000000 00000011 00000011 00000001
104	01101000	00000001 00000010 00000010 00000000
105	01101001	00000001 00000010 00000010 00000001
106	01101010	00000001 00000010 00000011 00000000
107	01101011	00000001 00000010 00000011 00000001
108	01101100	00000001 00000011 00000010 00000000
109	01101101	00000001 00000011 00000010 00000001
110	01101110	00000001 00000011 00000011 00000000
111	01101111	00000001 00000011 00000011 00000001
112	01110000	00000000 00000010 00000010 00000010
113	01110001	00000000 00000010 00000010 00000011
114	01110010	00000000 00000010 00000011 00000010
115	01110011	00000000 00000010 00000011 00000011
116	01110100	00000000 00000011 00000010 00000010
117	01110101	00000000 00000011 00000010 00000011
118	01110110	00000000 00000011 00000011 00000010
119	01110111	00000000 00000011 00000011 00000011
120	01111000	00000001 00000010 00000010 00000010
121	01111001	00000001 00000010 00000010 00000011
122	01111010	00000001 00000010 00000011 00000010
123	01111011	00000001 00000010 00000011 00000011
124	01111100	00000001 00000011 00000010 00000010
125	01111101	00000001 00000011 00000010 00000011
126	01111110	00000001 00000011 00000011 00000010
127	01111111	00000001 00000011 00000011 00000011
128	10000000	00000010 00000000 00000000 00000000
129	10000001	00000010 00000000 00000000 00000001
130	10000010	00000010 00000000 00000001 00000000
131	10000011	00000010 00000000 00000001 00000001
132	10000100	00000010 00000001 00000000 00000000
133	10000101	00000010 00000001 00000000 00000001
134	10000110	00000010 00000001 00000001 00000000
135	10000111	00000010 00000001 00000001 00000001



136	10001000	00000011 00000000 00000000 00000000
137	10001001	00000011 00000000 00000000 00000001
138	10001010	00000011 00000000 00000001 00000000
139	10001011	00000011 00000000 00000001 00000001
140	10001100	00000011 00000001 00000000 00000000
141	10001101	00000011 00000001 00000000 00000001
142	10001110	00000011 00000001 00000001 00000000
143	10001111	00000011 00000001 00000001 00000001
144	10010000	00000010 00000000 00000000 00000010
145	10010001	00000010 00000000 00000000 00000011
146	10010010	00000010 00000000 00000001 00000010
147	10010011	00000010 00000000 00000001 00000011
148	10010100	00000010 00000001 00000000 00000010
149	10010101	00000010 00000001 00000000 00000011
150	10010110	00000010 00000001 00000001 00000010
151	10010111	00000010 00000001 00000001 00000011
152	10011000	00000011 00000000 00000000 00000010
153	10011001	00000011 00000000 00000000 00000011
154	10011010	00000011 00000000 00000001 00000010
155	10011011	00000011 00000000 00000001 00000011
156	10011100	00000011 00000001 00000000 00000010
157	10011101	00000011 00000001 00000000 00000011
158	10011110	00000011 00000001 00000001 00000010
159	10011111	00000011 00000001 00000001 00000011
160	10100000	00000010 00000000 00000010 00000000
161	10100001	00000010 00000000 00000010 00000001
162	10100010	00000010 00000000 00000011 00000000
163	10100011	00000010 00000000 00000011 00000001
164	10100100	00000010 00000001 00000010 00000000
165	10100101	00000010 00000001 00000010 00000001
166	10100110	00000010 00000001 00000011 00000000
167	10100111	00000010 00000001 00000011 00000001
168	10101000	00000011 00000000 00000010 00000000
169	10101001	00000011 00000000 00000010 00000001
170	10101010	00000011 00000000 00000011 00000000
171	10101011	00000011 00000000 00000011 00000001
172	10101100	00000011 00000001 00000010 00000000
173	10101101	00000011 00000001 00000010 00000001
174	10101110	00000011 00000001 00000011 00000000
175	10101111	00000011 00000001 00000011 00000001
176	10110000	00000010 00000000 00000010 00000010
177	10110001	00000010 00000000 00000010 00000011
178	10110010	00000010 00000000 00000011 00000010
179	10110011	00000010 00000000 00000011 00000011
180	10110100	00000010 00000001 00000010 00000010
181	10110101	00000010 00000001 00000010 00000011
182	10110110	00000010 00000001 00000011 00000010
183	10110111	00000010 00000001 00000011 00000011



184	10111000	00000011 00000000 00000010 00000010
185	10111001	00000011 00000000 00000010 00000011
186	10111010	00000011 00000000 00000011 00000010
187	10111011	00000011 00000000 00000011 00000011
188	10111100	00000011 00000001 00000010 00000010
189	10111101	00000011 00000001 00000010 00000011
190	10111110	00000011 00000001 00000011 00000010
191	10111111	00000011 00000001 00000011 00000011
192	11000000	00000010 00000010 00000000 00000000
193	11000001	00000010 00000010 00000000 00000001
194	11000010	00000010 00000010 00000001 00000000
195	11000011	00000010 00000010 00000001 00000001
196	11000100	00000010 00000011 00000000 00000000
197	11000101	00000010 00000011 00000000 00000001
198	11000110	00000010 00000011 00000001 00000000
199	11000111	00000010 00000011 00000001 00000001
200	11001000	00000011 00000010 00000000 00000000
201	11001001	00000011 00000010 00000000 00000001
202	11001010	00000011 00000010 00000001 00000000
203	11001011	00000011 00000010 00000001 00000001
204	11001100	00000011 00000011 00000000 00000000
205	11001101	00000011 00000011 00000000 00000001
206	11001110	00000011 00000011 00000001 00000000
207	11001111	00000011 00000011 00000001 00000001
208	11010000	00000010 00000010 00000000 00000010
209	11010001	00000010 00000010 00000000 00000011
210	11010010	00000010 00000010 00000001 00000010
211	11010011	00000010 00000010 00000001 00000011
212	11010100	00000010 00000011 00000000 00000010
213	11010101	00000010 00000011 00000000 00000011
214	11010110	00000010 00000011 00000001 00000010
215	11010111	00000010 00000011 00000001 00000011
216	11011000	00000011 00000010 00000000 00000010
217	11011001	00000011 00000010 00000000 00000011
218	11011010	00000011 00000010 00000001 00000010
219	11011011	00000011 00000010 00000001 00000011
220	11011100	00000011 00000011 00000000 00000010
221	11011101	00000011 00000011 00000000 00000011
222	11011110	00000011 00000011 00000001 00000010
223	11011111	00000011 00000011 00000001 00000011
224	11100000	00000010 00000010 00000010 00000000
225	11100001	00000010 00000010 00000010 00000001
226	11100010	00000010 00000010 00000011 00000000
227	11100011	00000010 00000010 00000011 00000001
228	11100100	00000010 00000011 00000010 00000000
229	11100101	00000010 00000011 00000010 00000001
230	11100110	00000010 00000011 00000011 00000000
231	11100111	00000010 00000011 00000011 00000001



232	11101000	00000011 00000010 00000010 00000000
233	11101001	00000011 00000010 00000010 00000001
234	11101010	00000011 00000010 00000011 00000000
235	11101011	00000011 00000010 00000011 00000001
236	11101100	00000011 00000011 00000010 00000000
237	11101101	00000011 00000011 00000010 00000001
238	11101110	00000011 00000011 00000011 00000000
239	11101111	00000011 00000011 00000011 00000001
240	11110000	00000010 00000010 00000010 00000010
241	11110001	00000010 00000010 00000010 00000011
242	11110010	00000010 00000010 00000011 00000010
243	11110011	00000010 00000010 00000011 00000011
244	11110100	00000010 00000011 00000010 00000010
245	11110101	00000010 00000011 00000010 00000011
246	11110110	00000010 00000011 00000011 00000010
247	11110111	00000010 00000011 00000011 00000011
248	11111000	00000011 00000010 00000010 00000010
249	11111001	00000011 00000010 00000010 00000011
250	11111010	00000011 00000010 00000011 00000010
251	11111011	00000011 00000010 00000011 00000011
252	11111100	00000011 00000011 00000010 00000010
253	11111101	00000011 00000011 00000010 00000011
254	11111110	00000011 00000011 00000011 00000010
255	11111111	00000011 00000011 00000011 00000011



LOOKUP TABLE 2 :

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00000000	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 00000100
2	00000010	00000000 00000000 00000100 00000000
3	00000011	00000000 00000000 00000100 00000100
4	00000100	00000000 00000100 00000000 00000000
5	00000101	00000000 00000100 00000000 00000100
6	00000110	00000000 00000100 00000100 00000000
7	00000111	00000000 00000100 00000100 00000100
8	00001000	00000100 00000000 00000000 00000000
9	00001001	00000100 00000000 00000000 00000100
10	00001010	00000100 00000000 00000100 00000000
11	00001011	00000100 00000000 00000100 00000100
12	00001100	00000100 00000100 00000000 00000000
13	00001101	00000100 00000100 00000000 00000100
14	00001110	00000100 00000100 00000100 00000000
15	00001111	00000100 00000100 00000100 00000100
16	00010000	00000000 00000000 00000000 00001000
17	00010001	00000000 00000000 00000000 00001100
18	00010010	00000000 00000000 00000100 00001000
19	00010011	00000000 00000000 00000100 00001100
20	00010100	00000000 00000100 00000000 00001000
21	00010101	00000000 00000100 00000000 00001100
22	00010110	00000000 00000100 00000100 00001000
23	00010111	00000000 00000100 00000100 00001100
24	00011000	00000100 00000000 00000000 00001000
25	00011001	00000100 00000000 00000000 00001100
26	00011010	00000100 00000000 00000100 00001000
27	00011011	00000100 00000000 00000100 00001100
28	00011100	00000100 00000100 00000000 00001000
29	00011101	00000100 00000100 00000000 00001100
30	00011110	00000100 00000100 00000100 00001000
31	00011111	00000100 00000100 00000100 00001100
32	00100000	00000000 00000000 00001000 00000000
33	00100001	00000000 00000000 00001000 00000100
34	00100010	00000000 00000000 00001100 00000000
35	00100011	00000000 00000000 00001100 00000100
36	00100100	00000000 00000100 00001000 00000000
37	00100101	00000000 00000100 00001000 00000100
38	00100110	00000000 00000100 00001100 00000000
39	00100111	00000000 00000100 00001100 00000100

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40	00101000	00000100 00000000 00001000 00000000
41	00101001	00000100 00000000 00001000 00000100
42	00101010	00000100 00000000 00001100 00000000
43	00101011	00000100 00000000 00001100 00000100
44	00101100	00000100 00000100 00001000 00000000
45	00101101	00000100 00000100 00001000 00000100
46	00101110	00000100 00000100 00001100 00000000
47	00101111	00000100 00000100 00001100 00000100
48	00110000	00000000 00000000 00001000 00001000
49	00110001	00000000 00000000 00001000 00001100
50	00110010	00000000 00000000 00001100 00001000
51	00110011	00000000 00000000 00001100 00001100
52	00110100	00000000 00000100 00001000 00001000
53	00110101	00000000 00000100 00001000 00001100
54	00110110	00000000 00000100 00001100 00001000
55	00110111	00000000 00000100 00001100 00001100
56	00111000	00000100 00000000 00001000 00001000
57	00111001	00000100 00000000 00001000 00001100
58	00111010	00000100 00000000 00001100 00001000
59	00111011	00000100 00000000 00001100 00001100
60	00111100	00000100 00000100 00001000 00001000
61	00111101	00000100 00000100 00001000 00001100
62	00111110	00000100 00000100 00001100 00001000
63	00111111	00000100 00000100 00001100 00001100
64	01000000	00000000 00001000 00000000 00000000
65	01000001	00000000 00001000 00000000 00000100
66	01000010	00000000 00001000 00000100 00000000
67	01000011	00000000 00001000 00000100 00000100
68	01000100	00000000 00001100 00000000 00000000
69	01000101	00000000 00001100 00000000 00000100
70	01000110	00000000 00001100 00000100 00000000
71	01000111	00000000 00001100 00000100 00000100
72	01001000	00000100 00001000 00000000 00000000
73	01001001	00000100 00001000 00000000 00000100
74	01001010	00000100 00001000 00000100 00000000
75	01001011	00000100 00001000 00000100 00000100
76	01001100	00000100 00001100 00000000 00000000
77	01001101	00000100 00001100 00000000 00000100
78	01001110	00000100 00001100 00000100 00000000
79	01001111	00000100 00001100 00000100 00000100
80	01010000	00000000 00001000 00000000 00001000
81	01010001	00000000 00001000 00000000 00001100
82	01010010	00000000 00001000 00000100 00001000
83	01010011	00000000 00001000 00000100 00001100
84	01010100	00000000 00001100 00000000 00001000
85	01010101	00000000 00001100 00000000 00001100
86	01010110	00000000 00001100 00000100 00001000
87	01010111	00000000 00001100 00000100 00001100

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88	01011000	00000100 00001000 00000000 00001000
89	01011001	00000100 00001000 00000000 00001100
90	01011010	00000100 00001000 00000100 00001000
91	01011011	00000100 00001000 00000100 00001100
92	01011100	00000100 00001100 00000000 00001000
93	01011101	00000100 00001100 00000000 00001100
94	01011110	00000100 00001100 00000100 00001000
95	01011111	00000100 00001100 00000100 00001100
96	01100000	00000000 00001000 00001000 00000000
97	01100001	00000000 00001000 00001000 00000100
98	01100010	00000000 00001000 00001100 00000000
99	01100011	00000000 00001000 00001100 00000100
100	01100100	00000000 00001100 00001000 00000000
101	01100101	00000000 00001100 00001000 00000100
102	01100110	00000000 00001100 00001100 00000000
103	01100111	00000000 00001100 00001100 00000100
104	01101000	00000100 00001000 00001000 00000000
105	01101001	00000100 00001000 00001000 00000100
106	01101010	00000100 00001000 00001100 00000000
107	01101011	00000100 00001000 00001100 00000100
108	01101100	00000100 00001100 00001000 00000000
109	01101101	00000100 00001100 00001000 00000100
110	01101110	00000100 00001100 00001100 00000000
111	01101111	00000100 00001100 00001100 00000100
112	01110000	00000000 00001000 00001000 00001000
113	01110001	00000000 00001000 00001000 00001100
114	01110010	00000000 00001000 00001100 00001000
115	01110011	00000000 00001000 00001100 00001100
116	01110100	00000000 00001100 00001000 00001000
117	01110101	00000000 00001100 00001000 00001100
118	01110110	00000000 00001100 00001100 00001000
119	01110111	00000000 00001100 00001100 00001100
120	01111000	00000100 00001000 00001000 00001000
121	01111001	00000100 00001000 00001000 00001100
122	01111010	00000100 00001000 00001100 00001000
123	01111011	00000100 00001000 00001100 00001100
124	01111100	00000100 00001100 00001000 00001000
125	01111101	00000100 00001100 00001000 00001100
126	01111110	00000100 00001100 00001100 00001000
127	01111111	00000100 00001100 00001100 00001100
128	10000000	00001000 00000000 00000000 00000000
129	10000001	00001000 00000000 00000000 00000100
130	10000010	00001000 00000000 00000100 00000000
131	10000011	00001000 00000000 00000100 00000100
132	10000100	00001000 00000100 00000000 00000000
133	10000101	00001000 00000100 00000000 00000100
134	10000110	00001000 00000100 00000100 00000000
135	10000111	00001000 00000100 00000100 00000100

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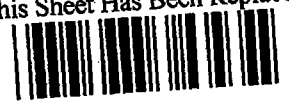
136	10001000	00001100 00000000 00000000 00000000
137	10001001	00001100 00000000 00000000 00000100
138	10001010	00001100 00000000 00000100 00000000
139	10001011	00001100 00000000 00000100 00000100
140	10001100	00001100 00000100 00000000 00000000
141	10001101	00001100 00000100 00000000 00000100
142	10001110	00001100 00000100 00000100 00000000
143	10001111	00001100 00000100 00000100 00000100
144	10010000	00001000 00000000 00000000 00001000
145	10010001	00001000 00000000 00000000 00001100
146	10010010	00001000 00000000 00000100 00001000
147	10010011	00001000 00000000 00000100 00001100
148	10010100	00001000 00000100 00000000 00001000
149	10010101	00001000 00000100 00000000 00001100
150	10010110	00001000 00000100 00000100 00001000
151	10010111	00001000 00000100 00000100 00001100
152	10011000	00001100 00000000 00000000 00001000
153	10011001	00001100 00000000 00000000 00001100
154	10011010	00001100 00000000 00000100 00001000
155	10011011	00001100 00000000 00000100 00001100
156	10011100	00001100 00000100 00000000 00001000
157	10011101	00001100 00000100 00000000 00001100
158	10011110	00001100 00000100 00000100 00001000
159	10011111	00001100 00000100 00000100 00001100
160	10100000	00001000 00000000 00001000 00000000
161	10100001	00001000 00000000 00001000 00000100
162	10100010	00001000 00000000 00001100 00000000
163	10100011	00001000 00000000 00001100 00000100
164	10100100	00001000 00000100 00001000 00000000
165	10100101	00001000 00000100 00001000 00000100
166	10100110	00001000 00000100 00001100 00000000
167	10100111	00001000 00000100 00001100 00000100
168	10101000	00001100 00000000 00001000 00000000
169	10101001	00001100 00000000 00001000 00000100
170	10101010	00001100 00000000 00001100 00000000
171	10101011	00001100 00000000 00001100 00000100
172	10101100	00001100 00000100 00001000 00000000
173	10101101	00001100 00000100 00001000 00000100
174	10101110	00001100 00000100 00001100 00000000
175	10101111	00001100 00000100 00001100 00000100
176	10110000	00001000 00000000 00001000 00001000
177	10110001	00001000 00000000 00001000 00001100
178	10110010	00001000 00000000 00001100 00001000
179	10110011	00001000 00000000 00001100 00001100
180	10110100	00001000 00000100 00001000 00001000
181	10110101	00001000 00000100 00001000 00001100
182	10110110	00001000 00000100 00001100 00001000
183	10110111	00001000 00000100 00001100 00001100

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184	10111000	00001100 00000000 00001000 00001000
185	10111001	00001100 00000000 00001000 00001100
186	10111010	00001100 00000000 00001100 00001000
187	10111011	00001100 00000000 00001100 00001100
188	10111100	00001100 00000100 00001000 00001000
189	10111101	00001100 00000100 00001000 00001100
190	10111110	00001100 00000100 00001100 00001000
191	10111111	00001100 00000100 00001100 00001100
192	11000000	00001000 00001000 00000000 00000000
193	11000001	00001000 00001000 00000000 00000100
194	11000010	00001000 00001000 00000100 00000000
195	11000011	00001000 00001000 00000100 00000100
196	11000100	00001000 00001100 00000000 00000000
197	11000101	00001000 00001100 00000000 00000100
198	11000110	00001000 00001100 00000100 00000000
199	11000111	00001000 00001100 00000100 00000100
200	11001000	00001100 00001000 00000000 00000000
201	11001001	00001100 00001000 00000000 00000100
202	11001010	00001100 00001000 00000100 00000000
203	11001011	00001100 00001000 00000100 00000100
204	11001100	00001100 00001100 00000000 00000000
205	11001101	00001100 00001100 00000000 00000100
206	11001110	00001100 00001100 00000100 00000000
207	11001111	00001100 00001100 00000100 00000100
208	11010000	00001000 00001000 00000000 00001000
209	11010001	00001000 00001000 00000000 00001100
210	11010010	00001000 00001000 00000100 00001000
211	11010011	00001000 00001000 00000100 00001100
212	11010100	00001000 00001100 00000000 00001000
213	11010101	00001000 00001100 00000000 00001100
214	11010110	00001000 00001100 00000100 00001000
215	11010111	00001000 00001100 00000100 00001100
216	11011000	00001100 00001000 00000000 00001000
217	11011001	00001100 00001000 00000000 00001100
218	11011010	00001100 00001000 00000100 00001000
219	11011011	00001100 00001000 00000100 00001100
220	11011100	00001100 00001100 00000000 00001000
221	11011101	00001100 00001100 00000000 00001100
222	11011110	00001100 00001100 00000100 00001000
223	11011111	00001100 00001100 00000100 00001100
224	11100000	00001000 00001000 00001000 00000000
225	11100001	00001000 00001000 00001000 00000100
226	11100010	00001000 00001000 00001100 00000000
227	11100011	00001000 00001000 00001100 00000100
228	11100100	00001000 00001100 00001000 00000000
229	11100101	00001000 00001100 00001000 00000100
230	11100110	00001000 00001100 00001100 00000000
231	11100111	00001000 00001100 00001100 00000100

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232	11101000	00001100 00001000 00001000 00000000
233	11101001	00001100 00001000 00001000 00000100
234	11101010	00001100 00001000 00001100 00000000
235	11101011	00001100 00001000 00001100 00000100
236	11101100	00001100 00001100 00001000 00000000
237	11101101	00001100 00001100 00001000 00000100
238	11101110	00001100 00001100 00001100 00000000
239	11101111	00001100 00001100 00001100 00000100
240	11110000	00001000 00001000 00001000 00001000
241	11110001	00001000 00001000 00001000 00001100
242	11110010	00001000 00001000 00001100 00001000
243	11110011	00001000 00001000 00001100 00001100
244	11110100	00001000 00001100 00001000 00001000
245	11110101	00001000 00001100 00001000 00001100
246	11110110	00001000 00001100 00001100 00001000
247	11110111	00001000 00001100 00001100 00001100
248	11111000	00001100 00001000 00001000 00001000
249	11111001	00001100 00001000 00001000 00001100
250	11111010	00001100 00001000 00001100 00001000
251	11111011	00001100 00001000 00001100 00001100
252	11111100	00001100 00001100 00001000 00001000
253	11111101	00001100 00001100 00001000 00001100
254	11111110	00001100 00001100 00001100 00001000
255	11111111	00001100 00001100 00001100 00001100



LOOKUP TABLE 3 :

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00000000	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 00010000
2	00000010	00000000 00000000 00010000 00000000
3	00000011	00000000 00000000 00010000 00010000
4	00000100	00000000 00010000 00000000 00000000
5	00000101	00000000 00010000 00000000 00010000
6	00000110	00000000 00010000 00010000 00000000
7	00000111	00000000 00010000 00010000 00010000
8	00001000	00010000 00000000 00000000 00000000
9	00001001	00010000 00000000 00000000 00010000
10	00001010	00010000 00000000 00010000 00000000
11	00001011	00010000 00000000 00010000 00010000
12	00001100	00010000 00010000 00000000 00000000
13	00001101	00010000 00010000 00000000 00010000
14	00001110	00010000 00010000 00010000 00000000
15	00001111	00010000 00010000 00010000 00010000
16	00010000	00000000 00000000 00000000 00100000
17	00010001	00000000 00000000 00000000 00110000
18	00010010	00000000 00000000 00010000 00100000
19	00010011	00000000 00000000 00010000 00110000
20	00010100	00000000 00010000 00000000 00100000
21	00010101	00000000 00010000 00000000 00110000
22	00010110	00000000 00010000 00010000 00100000
23	00010111	00000000 00010000 00010000 00110000
24	00011000	00010000 00000000 00000000 00100000
25	00011001	00010000 00000000 00000000 00110000
26	00011010	00010000 00000000 00010000 00100000
27	00011011	00010000 00000000 00010000 00110000
28	00011100	00010000 00010000 00000000 00100000
29	00011101	00010000 00010000 00000000 00110000
30	00011110	00010000 00010000 00010000 00100000
31	00011111	00010000 00010000 00010000 00110000
32	00100000	00000000 00000000 00100000 00000000
33	00100001	00000000 00000000 00100000 00010000
34	00100010	00000000 00000000 00110000 00000000
35	00100011	00000000 00000000 00110000 00010000
36	00100100	00000000 00010000 00100000 00000000
37	00100101	00000000 00010000 00100000 00010000
38	00100110	00000000 00010000 00110000 00000000
39	00100111	00000000 00010000 00110000 00010000

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40	00101000	00010000 00000000 00100000 00000000
41	00101001	00010000 00000000 00100000 00010000
42	00101010	00010000 00000000 00110000 00000000
43	00101011	00010000 00000000 00110000 00010000
44	00101100	00010000 00010000 00100000 00000000
45	00101101	00010000 00010000 00100000 00010000
46	00101110	00010000 00010000 00110000 00000000
47	00101111	00010000 00010000 00110000 00010000
48	00110000	00000000 00000000 00100000 00100000
49	00110001	00000000 00000000 00100000 00110000
50	00110010	00000000 00000000 00110000 00100000
51	00110011	00000000 00000000 00110000 00110000
52	00110100	00000000 00010000 00100000 00100000
53	00110101	00000000 00010000 00100000 00110000
54	00110110	00000000 00010000 00110000 00100000
55	00110111	00000000 00010000 00110000 00110000
56	00111000	00010000 00000000 00100000 00100000
57	00111001	00010000 00000000 00100000 00110000
58	00111010	00010000 00000000 00110000 00100000
59	00111011	00010000 00000000 00110000 00110000
60	00111100	00010000 00010000 00100000 00100000
61	00111101	00010000 00010000 00100000 00110000
62	00111110	00010000 00010000 00110000 00100000
63	00111111	00010000 00010000 00110000 00110000
64	01000000	00000000 00100000 00000000 00000000
65	01000001	00000000 00100000 00000000 00010000
66	01000010	00000000 00100000 00010000 00000000
67	01000011	00000000 00100000 00010000 00010000
68	01000100	00000000 00110000 00000000 00000000
69	01000101	00000000 00110000 00000000 00010000
70	01000110	00000000 00110000 00010000 00000000
71	01000111	00000000 00110000 00010000 00010000
72	01001000	00010000 00100000 00000000 00000000
73	01001001	00010000 00100000 00000000 00010000
74	01001010	00010000 00100000 00010000 00000000
75	01001011	00010000 00100000 00010000 00010000
76	01001100	00010000 00110000 00000000 00000000
77	01001101	00010000 00110000 00000000 00010000
78	01001110	00010000 00110000 00010000 00000000
79	01001111	00010000 00110000 00010000 00010000
80	01010000	00000000 00100000 00000000 00100000
81	01010001	00000000 00100000 00000000 00110000
82	01010010	00000000 00100000 00010000 00100000
83	01010011	00000000 00100000 00010000 00110000
84	01010100	00000000 00110000 00000000 00100000
85	01010101	00000000 00110000 00000000 00110000
86	01010110	00000000 00110000 00010000 00100000
87	01010111	00000000 00110000 00010000 00110000



88	01011000	00010000 00100000 00000000 00100000
89	01011001	00010000 00100000 00000000 00110000
90	01011010	00010000 00100000 00010000 00100000
91	01011011	00010000 00100000 00010000 00110000
92	01011100	00010000 00110000 00000000 00100000
93	01011101	00010000 00110000 00000000 00110000
94	01011110	00010000 00110000 00010000 00100000
95	01011111	00010000 00110000 00010000 00110000
96	01100000	00000000 00100000 00100000 00000000
97	01100001	00000000 00100000 00100000 00010000
98	01100010	00000000 00100000 00110000 00000000
99	01100011	00000000 00100000 00110000 00010000
100	01100100	00000000 00110000 00100000 00000000
101	01100101	00000000 00110000 00100000 00010000
102	01100110	00000000 00110000 00110000 00000000
103	01100111	00000000 00110000 00110000 00010000
104	01101000	00010000 00100000 00100000 00000000
105	01101001	00010000 00100000 00100000 00010000
106	01101010	00010000 00100000 00110000 00000000
107	01101011	00010000 00100000 00110000 00010000
108	01101100	00010000 00110000 00100000 00000000
109	01101101	00010000 00110000 00100000 00010000
110	01101110	00010000 00110000 00110000 00000000
111	01101111	00010000 00110000 00110000 00010000
112	01110000	00000000 00100000 00100000 00100000
113	01110001	00000000 00100000 00100000 00110000
114	01110010	00000000 00100000 00110000 00100000
115	01110011	00000000 00100000 00110000 00110000
116	01110100	00000000 00110000 00100000 00100000
117	01110101	00000000 00110000 00100000 00110000
118	01110110	00000000 00110000 00110000 00100000
119	01110111	00000000 00110000 00110000 00110000
120	01111000	00010000 00100000 00100000 00100000
121	01111001	00010000 00100000 00100000 00110000
122	01111010	00010000 00100000 00110000 00100000
123	01111011	00010000 00100000 00110000 00110000
124	01111100	00010000 00110000 00100000 00100000
125	01111101	00010000 00110000 00100000 00110000
126	01111110	00010000 00110000 00110000 00100000
127	01111111	00010000 00110000 00110000 00110000
128	10000000	00100000 00000000 00000000 00000000
129	10000001	00100000 00000000 00000000 00010000
130	10000010	00100000 00000000 00010000 00000000
131	10000011	00100000 00000000 00010000 00010000
132	10000100	00100000 00010000 00000000 00000000
133	10000101	00100000 00010000 00000000 00010000
134	10000110	00100000 00010000 00010000 00000000
135	10000111	00100000 00010000 00010000 00010000



136	10001000	00110000 00000000 00000000 00000000
137	10001001	00110000 00000000 00000000 00010000
138	10001010	00110000 00000000 00010000 00000000
139	10001011	00110000 00000000 00010000 00010000
140	10001100	00110000 00010000 00000000 00000000
141	10001101	00110000 00010000 00000000 00010000
142	10001110	00110000 00010000 00010000 00000000
143	10001111	00110000 00010000 00010000 00010000
144	10010000	00100000 00000000 00000000 00100000
145	10010001	00100000 00000000 00000000 00110000
146	10010010	00100000 00000000 00010000 00100000
147	10010011	00100000 00000000 00010000 00110000
148	10010100	00100000 00010000 00000000 00100000
149	10010101	00100000 00010000 00000000 00110000
150	10010110	00100000 00010000 00010000 00100000
151	10010111	00100000 00010000 00010000 00110000
152	10011000	00110000 00000000 00000000 00100000
153	10011001	00110000 00000000 00000000 00110000
154	10011010	00110000 00000000 00010000 00100000
155	10011011	00110000 00000000 00010000 00110000
156	10011100	00110000 00010000 00000000 00100000
157	10011101	00110000 00010000 00000000 00110000
158	10011110	00110000 00010000 00010000 00100000
159	10011111	00110000 00010000 00010000 00110000
160	10100000	00100000 00000000 00100000 00000000
161	10100001	00100000 00000000 00100000 00010000
162	10100010	00100000 00000000 00110000 00000000
163	10100011	00100000 00000000 00110000 00010000
164	10100100	00100000 00010000 00100000 00000000
165	10100101	00100000 00010000 00100000 00010000
166	10100110	00100000 00010000 00110000 00000000
167	10100111	00100000 00010000 00110000 00010000
168	10101000	00110000 00000000 00100000 00000000
169	10101001	00110000 00000000 00100000 00010000
170	10101010	00110000 00000000 00110000 00000000
171	10101011	00110000 00000000 00110000 00010000
172	10101100	00110000 00010000 00100000 00000000
173	10101101	00110000 00010000 00100000 00010000
174	10101110	00110000 00010000 00110000 00000000
175	10101111	00110000 00010000 00110000 00010000
176	10110000	00100000 00000000 00100000 00100000
177	10110001	00100000 00000000 00100000 00110000
178	10110010	00100000 00000000 00110000 00100000
179	10110011	00100000 00000000 00110000 00110000
180	10110100	00100000 00010000 00100000 00100000
181	10110101	00100000 00010000 00100000 00110000
182	10110110	00100000 00010000 00110000 00100000
183	10110111	00100000 00010000 00110000 00110000



184	10111000	00110000 00000000 00100000 00100000
185	10111001	00110000 00000000 00100000 00110000
186	10111010	00110000 00000000 00110000 00100000
187	10111011	00110000 00000000 00110000 00110000
188	10111100	00110000 00010000 00100000 00100000
189	10111101	00110000 00010000 00100000 00110000
190	10111110	00110000 00010000 00110000 00100000
191	10111111	00110000 00010000 00110000 00110000
192	11000000	00100000 00100000 00000000 00000000
193	11000001	00100000 00100000 00000000 00010000
194	11000010	00100000 00100000 00010000 00000000
195	11000011	00100000 00100000 00010000 00010000
196	11000100	00100000 00110000 00000000 00000000
197	11000101	00100000 00110000 00000000 00010000
198	11000110	00100000 00110000 00010000 00000000
199	11000111	00100000 00110000 00010000 00010000
200	11001000	00110000 00100000 00000000 00000000
201	11001001	00110000 00100000 00000000 00010000
202	11001010	00110000 00100000 00010000 00000000
203	11001011	00110000 00100000 00010000 00010000
204	11001100	00110000 00110000 00000000 00000000
205	11001101	00110000 00110000 00000000 00010000
206	11001110	00110000 00110000 00010000 00000000
207	11001111	00110000 00110000 00010000 00010000
208	11010000	00100000 00100000 00000000 00100000
209	11010001	00100000 00100000 00000000 00110000
210	11010010	00100000 00100000 00010000 00100000
211	11010011	00100000 00100000 00010000 00110000
212	11010100	00100000 00110000 00000000 00100000
213	11010101	00100000 00110000 00000000 00110000
214	11010110	00100000 00110000 00010000 00100000
215	11010111	00100000 00110000 00010000 00110000
216	11011000	00110000 00100000 00000000 00100000
217	11011001	00110000 00100000 00000000 00110000
218	11011010	00110000 00100000 00010000 00100000
219	11011011	00110000 00100000 00010000 00110000
220	11011100	00110000 00110000 00000000 00100000
221	11011101	00110000 00110000 00000000 00110000
222	11011110	00110000 00110000 00010000 00100000
223	11011111	00110000 00110000 00010000 00110000
224	11100000	00100000 00100000 00100000 00000000
225	11100001	00100000 00100000 00100000 00010000
226	11100010	00100000 00100000 00110000 00000000
227	11100011	00100000 00100000 00110000 00010000
228	11100100	00100000 00110000 00100000 00000000
229	11100101	00100000 00110000 00100000 00010000
230	11100110	00100000 00110000 00110000 00000000
231	11100111	00100000 00110000 00110000 00010000

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232	11101000	00110000 00100000 00100000 00000000
233	11101001	00110000 00100000 00100000 00010000
234	11101010	00110000 00100000 00110000 00000000
235	11101011	00110000 00100000 00110000 00010000
236	11101100	00110000 00110000 00100000 00000000
237	11101101	00110000 00110000 00100000 00010000
238	11101110	00110000 00110000 00110000 00000000
239	11101111	00110000 00110000 00110000 00010000
240	11110000	00100000 00100000 00100000 00100000
241	11110001	00100000 00100000 00100000 00110000
242	11110010	00100000 00100000 00110000 00100000
243	11110011	00100000 00100000 00110000 00110000
244	11110100	00100000 00110000 00100000 00100000
245	11110101	00100000 00110000 00100000 00110000
246	11110110	00100000 00110000 00110000 00100000
247	11110111	00100000 00110000 00110000 00110000
248	11111000	00110000 00100000 00100000 00100000
249	11111001	00110000 00100000 00100000 00110000
250	11111010	00110000 00100000 00110000 00100000
251	11111011	00110000 00100000 00110000 00110000
252	11111100	00110000 00110000 00100000 00100000
253	11111101	00110000 00110000 00100000 00110000
254	11111110	00110000 00110000 00110000 00100000
255	11111111	00110000 00110000 00110000 00110000

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LOOKUP TABLE 4 :

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00000000	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 01000000
2	00000010	00000000 00000000 01000000 00000000
3	00000011	00000000 00000000 01000000 01000000
4	00000100	00000000 01000000 00000000 00000000
5	00000101	00000000 01000000 00000000 01000000
6	00000110	00000000 01000000 01000000 00000000
7	00000111	00000000 01000000 01000000 01000000
8	00001000	01000000 00000000 00000000 00000000
9	00001001	01000000 00000000 00000000 01000000
10	00001010	01000000 00000000 01000000 00000000
11	00001011	01000000 00000000 01000000 01000000
12	00001100	01000000 01000000 00000000 00000000
13	00001101	01000000 01000000 00000000 01000000
14	00001110	01000000 01000000 01000000 00000000
15	00001111	01000000 01000000 01000000 01000000
16	00010000	00000000 00000000 00000000 10000000
17	00010001	00000000 00000000 00000000 11000000
18	00010010	00000000 00000000 01000000 10000000
19	00010011	00000000 00000000 01000000 11000000
20	00010100	00000000 01000000 00000000 10000000
21	00010101	00000000 01000000 00000000 11000000
22	00010110	00000000 01000000 01000000 10000000
23	00010111	00000000 01000000 01000000 11000000
24	00011000	01000000 00000000 00000000 10000000
25	00011001	01000000 00000000 00000000 11000000
26	00011010	01000000 00000000 01000000 10000000
27	00011011	01000000 00000000 01000000 11000000
28	00011100	01000000 01000000 00000000 10000000
29	00011101	01000000 01000000 00000000 11000000
30	00011110	01000000 01000000 01000000 10000000
31	00011111	01000000 01000000 01000000 11000000
32	00100000	00000000 00000000 10000000 00000000
33	00100001	00000000 00000000 10000000 01000000
34	00100010	00000000 00000000 11000000 00000000
35	00100011	00000000 00000000 11000000 01000000
36	00100100	00000000 01000000 10000000 00000000
37	00100101	00000000 01000000 10000000 01000000
38	00100110	00000000 01000000 11000000 00000000
39	00100111	00000000 01000000 11000000 01000000

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40	00101000	01000000 00000000 10000000 00000000
41	00101001	01000000 00000000 10000000 01000000
42	00101010	01000000 00000000 11000000 00000000
43	00101011	01000000 00000000 11000000 01000000
44	00101100	01000000 01000000 10000000 00000000
45	00101101	01000000 01000000 10000000 01000000
46	00101110	01000000 01000000 11000000 00000000
47	00101111	01000000 01000000 11000000 01000000
48	00110000	00000000 00000000 10000000 10000000
49	00110001	00000000 00000000 10000000 11000000
50	00110010	00000000 00000000 11000000 10000000
51	00110011	00000000 00000000 11000000 11000000
52	00110100	00000000 01000000 10000000 10000000
53	00110101	00000000 01000000 10000000 11000000
54	00110110	00000000 01000000 11000000 10000000
55	00110111	00000000 01000000 11000000 11000000
56	00111000	01000000 00000000 10000000 10000000
57	00111001	01000000 00000000 10000000 11000000
58	00111010	01000000 00000000 11000000 10000000
59	00111011	01000000 00000000 11000000 11000000
60	00111100	01000000 01000000 10000000 10000000
61	00111101	01000000 01000000 10000000 11000000
62	00111110	01000000 01000000 11000000 10000000
63	00111111	01000000 01000000 11000000 11000000
64	01000000	00000000 10000000 00000000 00000000
65	01000001	00000000 10000000 00000000 01000000
66	01000010	00000000 10000000 01000000 00000000
67	01000011	00000000 10000000 01000000 01000000
68	01000100	00000000 11000000 00000000 00000000
69	01000101	00000000 11000000 00000000 01000000
70	01000110	00000000 11000000 01000000 00000000
71	01000111	00000000 11000000 01000000 01000000
72	01001000	01000000 10000000 00000000 00000000
73	01001001	01000000 10000000 00000000 01000000
74	01001010	01000000 10000000 01000000 00000000
75	01001011	01000000 10000000 01000000 01000000
76	01001100	01000000 11000000 00000000 00000000
77	01001101	01000000 11000000 00000000 01000000
78	01001110	01000000 11000000 01000000 00000000
79	01001111	01000000 11000000 01000000 01000000
80	01010000	00000000 10000000 00000000 10000000
81	01010001	00000000 10000000 00000000 11000000
82	01010010	00000000 10000000 01000000 10000000
83	01010011	00000000 10000000 01000000 11000000
84	01010100	00000000 11000000 00000000 10000000
85	01010101	00000000 11000000 00000000 11000000
86	01010110	00000000 11000000 01000000 10000000
87	01010111	00000000 11000000 01000000 11000000



88	01011000	01000000 10000000 00000000 10000000
89	01011001	01000000 10000000 00000000 11000000
90	01011010	01000000 10000000 01000000 10000000
91	01011011	01000000 10000000 01000000 11000000
92	01011100	01000000 11000000 00000000 10000000
93	01011101	01000000 11000000 00000000 11000000
94	01011110	01000000 11000000 01000000 10000000
95	01011111	01000000 11000000 01000000 11000000
96	01100000	00000000 10000000 10000000 00000000
97	01100001	00000000 10000000 10000000 01000000
98	01100010	00000000 10000000 11000000 00000000
99	01100011	00000000 10000000 11000000 01000000
100	01100100	00000000 11000000 10000000 00000000
101	01100101	00000000 11000000 10000000 01000000
102	01100110	00000000 11000000 11000000 00000000
103	01100111	00000000 11000000 11000000 01000000
104	01101000	01000000 10000000 10000000 00000000
105	01101001	01000000 10000000 10000000 01000000
106	01101010	01000000 10000000 11000000 00000000
107	01101011	01000000 10000000 11000000 01000000
108	01101100	01000000 11000000 10000000 00000000
109	01101101	01000000 11000000 10000000 01000000
110	01101110	01000000 11000000 11000000 00000000
111	01101111	01000000 11000000 11000000 01000000
112	01110000	00000000 10000000 10000000 10000000
113	01110001	00000000 10000000 10000000 11000000
114	01110010	00000000 10000000 11000000 10000000
115	01110011	00000000 10000000 11000000 11000000
116	01110100	00000000 11000000 10000000 10000000
117	01110101	00000000 11000000 10000000 11000000
118	01110110	00000000 11000000 11000000 10000000
119	01110111	00000000 11000000 11000000 11000000
120	01111000	01000000 10000000 10000000 10000000
121	01111001	01000000 10000000 10000000 11000000
122	01111010	01000000 10000000 11000000 10000000
123	01111011	01000000 10000000 11000000 11000000
124	01111100	01000000 11000000 10000000 10000000
125	01111101	01000000 11000000 10000000 11000000
126	01111110	01000000 11000000 11000000 10000000
127	01111111	01000000 11000000 11000000 11000000
128	10000000	10000000 00000000 00000000 00000000
129	10000001	10000000 00000000 00000000 01000000
130	10000010	10000000 00000000 01000000 00000000
131	10000011	10000000 00000000 01000000 01000000
132	10000100	10000000 01000000 00000000 00000000
133	10000101	10000000 01000000 00000000 01000000
134	10000110	10000000 01000000 01000000 00000000
135	10000111	10000000 01000000 01000000 01000000



136	10001000	11000000 00000000 00000000 00000000
137	10001001	11000000 00000000 00000000 01000000
138	10001010	11000000 00000000 01000000 00000000
139	10001011	11000000 00000000 01000000 01000000
140	10001100	11000000 01000000 00000000 00000000
141	10001101	11000000 01000000 00000000 01000000
142	10001110	11000000 01000000 01000000 00000000
143	10001111	11000000 01000000 01000000 01000000
144	10010000	10000000 00000000 00000000 10000000
145	10010001	10000000 00000000 00000000 11000000
146	10010010	10000000 00000000 01000000 10000000
147	10010011	10000000 00000000 01000000 11000000
148	10010100	10000000 01000000 00000000 10000000
149	10010101	10000000 01000000 00000000 11000000
150	10010110	10000000 01000000 01000000 10000000
151	10010111	10000000 01000000 01000000 11000000
152	10011000	11000000 00000000 00000000 10000000
153	10011001	11000000 00000000 00000000 11000000
154	10011010	11000000 00000000 01000000 10000000
155	10011011	11000000 00000000 01000000 11000000
156	10011100	11000000 01000000 00000000 10000000
157	10011101	11000000 01000000 00000000 11000000
158	10011110	11000000 01000000 01000000 10000000
159	10011111	11000000 01000000 01000000 11000000
160	10100000	10000000 00000000 10000000 00000000
161	10100001	10000000 00000000 10000000 01000000
162	10100010	10000000 00000000 11000000 00000000
163	10100011	10000000 00000000 11000000 01000000
164	10100100	10000000 01000000 10000000 00000000
165	10100101	10000000 01000000 10000000 01000000
166	10100110	10000000 01000000 11000000 00000000
167	10100111	10000000 01000000 11000000 01000000
168	10101000	11000000 00000000 10000000 00000000
169	10101001	11000000 00000000 10000000 01000000
170	10101010	11000000 00000000 11000000 00000000
171	10101011	11000000 00000000 11000000 01000000
172	10101100	11000000 01000000 10000000 00000000
173	10101101	11000000 01000000 10000000 01000000
174	10101110	11000000 01000000 11000000 00000000
175	10101111	11000000 01000000 11000000 01000000
176	10110000	10000000 00000000 10000000 10000000
177	10110001	10000000 00000000 10000000 11000000
178	10110010	10000000 00000000 11000000 10000000
179	10110011	10000000 00000000 11000000 11000000
180	10110100	10000000 01000000 10000000 10000000
181	10110101	10000000 01000000 10000000 11000000
182	10110110	10000000 01000000 11000000 10000000
183	10110111	10000000 01000000 11000000 11000000

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184	10111000	11000000 00000000 10000000 10000000
185	10111001	11000000 00000000 10000000 11000000
186	10111010	11000000 00000000 11000000 10000000
187	10111011	11000000 00000000 11000000 11000000
188	10111100	11000000 01000000 10000000 10000000
189	10111101	11000000 01000000 10000000 11000000
190	10111110	11000000 01000000 11000000 10000000
191	10111111	11000000 01000000 11000000 11000000
192	11000000	10000000 10000000 00000000 00000000
193	11000001	10000000 10000000 00000000 01000000
194	11000010	10000000 10000000 01000000 00000000
195	11000011	10000000 10000000 01000000 01000000
196	11000100	10000000 11000000 00000000 00000000
197	11000101	10000000 11000000 00000000 01000000
198	11000110	10000000 11000000 01000000 00000000
199	11000111	10000000 11000000 01000000 01000000
200	11001000	11000000 10000000 00000000 00000000
201	11001001	11000000 10000000 00000000 01000000
202	11001010	11000000 10000000 01000000 00000000
203	11001011	11000000 10000000 01000000 01000000
204	11001100	11000000 11000000 00000000 00000000
205	11001101	11000000 11000000 00000000 01000000
206	11001110	11000000 11000000 01000000 00000000
207	11001111	11000000 11000000 01000000 01000000
208	11010000	10000000 10000000 00000000 10000000
209	11010001	10000000 10000000 00000000 11000000
210	11010010	10000000 10000000 01000000 10000000
211	11010011	10000000 10000000 01000000 11000000
212	11010100	10000000 11000000 00000000 10000000
213	11010101	10000000 11000000 00000000 11000000
214	11010110	10000000 11000000 01000000 10000000
215	11010111	10000000 11000000 01000000 11000000
216	11011000	11000000 10000000 00000000 10000000
217	11011001	11000000 10000000 00000000 11000000
218	11011010	11000000 10000000 01000000 10000000
219	11011011	11000000 10000000 01000000 11000000
220	11011100	11000000 11000000 00000000 10000000
221	11011101	11000000 11000000 00000000 11000000
222	11011110	11000000 11000000 01000000 10000000
223	11011111	11000000 11000000 01000000 11000000
224	11100000	10000000 10000000 10000000 00000000
225	11100001	10000000 10000000 10000000 01000000
226	11100010	10000000 10000000 11000000 00000000
227	11100011	10000000 10000000 11000000 01000000
228	11100100	10000000 11000000 10000000 00000000
229	11100101	10000000 11000000 10000000 01000000
230	11100110	10000000 11000000 11000000 00000000
231	11100111	10000000 11000000 11000000 01000000

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232	11101000	11000000	10000000	10000000	00000000
233	11101001	11000000	10000000	10000000	01000000
234	11101010	11000000	10000000	11000000	00000000
235	11101011	11000000	10000000	11000000	01000000
236	11101100	11000000	11000000	10000000	00000000
237	11101101	11000000	11000000	10000000	01000000
238	11101110	11000000	11000000	11000000	00000000
239	11101111	11000000	11000000	11000000	01000000
240	11110000	10000000	10000000	10000000	10000000
241	11110001	10000000	10000000	10000000	11000000
242	11110010	10000000	10000000	11000000	10000000
243	11110011	10000000	10000000	11000000	11000000
244	11110100	10000000	11000000	10000000	10000000
245	11110101	10000000	11000000	10000000	11000000
246	11110110	10000000	11000000	11000000	10000000
247	11110111	10000000	11000000	11000000	11000000
248	11111000	11000000	10000000	10000000	10000000
249	11111001	11000000	10000000	10000000	11000000
250	11111010	11000000	10000000	11000000	10000000
251	11111011	11000000	10000000	11000000	11000000
252	11111100	11000000	11000000	10000000	10000000
253	11111101	11000000	11000000	10000000	11000000
254	11111110	11000000	11000000	11000000	10000000
255	11111111	11000000	11000000	11000000	11000000

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The embodiments of the invention of which an exclusive property or privilege is claimed are defined as follows:

1. In a 32-bit operating system, a method of rotating by 90^0 a block of bi-level image data having 8 rows by 8 columns of pixel data bits, comprising the computer implemented steps of:

generating an intermediate matrix having 8 rows by 8 columns of pixel data bits, wherein each row from the block is divided and translated into a paired nibble column, alternate rows from the block being arranged transversely and lower order rows from the block being arranged on top of higher order rows in the paired nibble columns of the intermediate matrix;

saving the rows of the intermediate matrix sequentially into first and second 32-bit processor registers;

copying the first 32-bit register into a third 32-bit processor register and the second 32-bit register into a fourth 32-bit processor register;

shifting each of the first and second registers by one bit in opposite directions; and

overlaying alternate bits from the fourth register onto the first register and from the third register onto the second register.

2. The method, according to claim 1, wherein the step of generating an intermediate matrix comprises generating an intermediate matrix wherein the alternate rows are arranged transversely from right to left, and wherein higher order bits from each divided row are arranged on top of lower order bits.

3. The method according to claim 2, wherein the step of shifting each of the first and second registers by one bit in opposite directions comprises shifting the first register by one bit left and shifting the second register by one bit right.

4. The method according to claim 3, wherein the step of overlaying alternate bits further comprises the steps of



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zeroing out all odd bit of the first and fourth registers and all even bits of the second and third register, and logical ORing the first register with the fourth register and the second with the third register.

5. The method according to claim 1, wherein the step of generating an intermediate matrix comprises generating an intermediate matrix wherein the alternate rows are arranged transversely from left to right, and wherein lower order bits from each divided row are arranged on top of higher order bits.

6. The method, according to claim 5, wherein the step of shifting each of the first and second register by one bit in opposite direction comprises shifting the first register by one bit right and shifting the second register by one bit left.

7. The method according to claim 6, wherein the step of overlaying alternate bits further comprises the steps of zeroing out all even bits of the first and fourth registers and all odd bits of the second and third registers, and logical ORing the first register with the fourth register and the second register with the third register.

8. The method, according to claim 1, wherein the step of generating an intermediate matrix comprises:

obtaining a first set of 4-byte values from at least one lookup table for each odd-numbered row from the block and dynamically overlaying said first set of 4-byte values in the first 32-bit register; and

obtaining a second set of 4-byte values from said at least one lookup table for each even-numbered row from the block and dynamically overlaying said second set of 4-byte values in the second 32-bit register.

9. In a 32-bit operating system, a method of rotating a bi-level image by 90^0 , comprising the computer implemented steps



of:

- a) selecting an unrotated 8 by 8 pixel matrix from the image data;
- b) generating an intermediate matrix having 8 rows by 8 columns of pixel data bits, wherein each row from the block is divided and translated into a paired nibble column, alternate rows from the block being arranged transversely and lower order rows from the block being arranged on top of higher order rows in the paired nibble columns of the intermediate matrix;
- c) saving the rows of the intermediate matrix sequentially to first and second 32-bit registers;
- d) copying the first 32-bit register into a third 32-bit register and the second 32-bit register into a fourth 32-bit register;
- e) shifting each of the first and second registers by one bit in opposite directions;
- f) overlaying alternate bits from the fourth register onto the first register and from the third register onto the second register; and
- g) repeating steps a) through f) until the image has been rotated.

10. A 32-bit operating system for rotating a block of bi-level image data having 8 rows by 8 columns of pixel data bits, comprising:

means for generating an intermediate matrix having 8 rows by 8 columns of pixel data bits from the block, wherein each row from the block is divided and translated into a paired nibble column, alternate rows from the block being arranged transversely and lower order rows from the block being arranged on top of higher order rows in the paired nibble columns of the intermediate matrix;

at least first, second, third, and fourth 32-bit processor registers, the first and third registers for saving, in duplicate, the first four rows of the intermediate matrix and the second and fourth registers for saving, in duplicate, the remaining four rows of the intermediate matrix;

means for shifting each of the first and second registers



by one bit in opposite directions; and

means for overlaying alternate bits from the fourth register onto the first register and from the third register onto the second register.

11. A system, according to claim 10, wherein the means for generating an intermediate matrix comprise at least one lookup table.

12. A system, according to claim 11, wherein said at least one lookup table comprises multiple look tables, each lookup table being adapted for generating a 4-byte value for at least one row from the block.

13. A system, according to claim 10, wherein the means for generating an intermediate matrix comprises:

four lookup tables, each lookup table being adapted for generating 4-byte values for at least two rows from the block; and

means for dynamically overlaying 4-byte values from alternate rows from the block into one of said registers.



A SYSTEM FOR FAST 90 DEGREE ROTATION OF BI-LEVEL IMAGES

ABSTRACT

A method for rotating bi-level image data plus or minus 90° . An 8×8 pixel block is selected for rotation from the image data and, using lookup tables, an intermediate matrix is generated dynamically and stored into two 32-bit registers in the processor. Generation of the intermediate matrix partially rotates and stores the odd-numbered rows from the block of data in the first 32-bit register and the even-numbered rows from the block in the second 32-bit register. The first and second registers are copied, respectively, into third and fourth 32-bit registers. The first and second registers are then shifted one bit in opposite directions. The first register is logical ORed with the fourth register, and the second register is logical ORed with the third register so that the even bits are replaced in one register and the odd bits in the other. These steps are repeated for all remaining blocks of image data.

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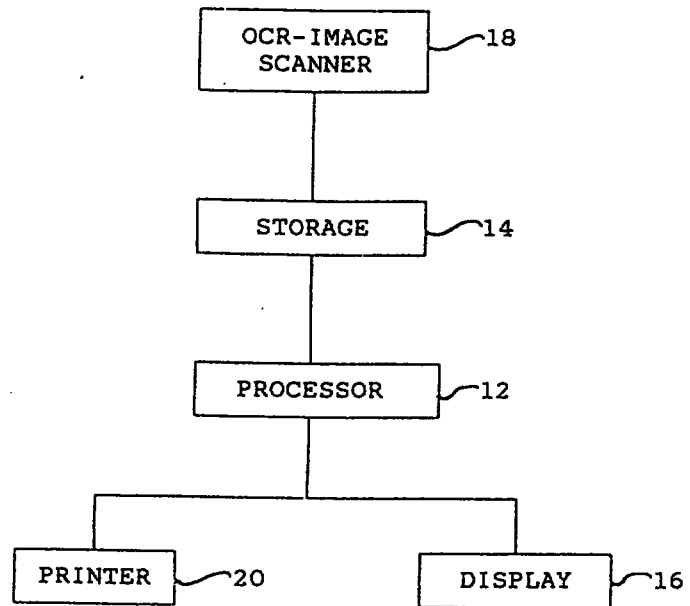


FIGURE 1

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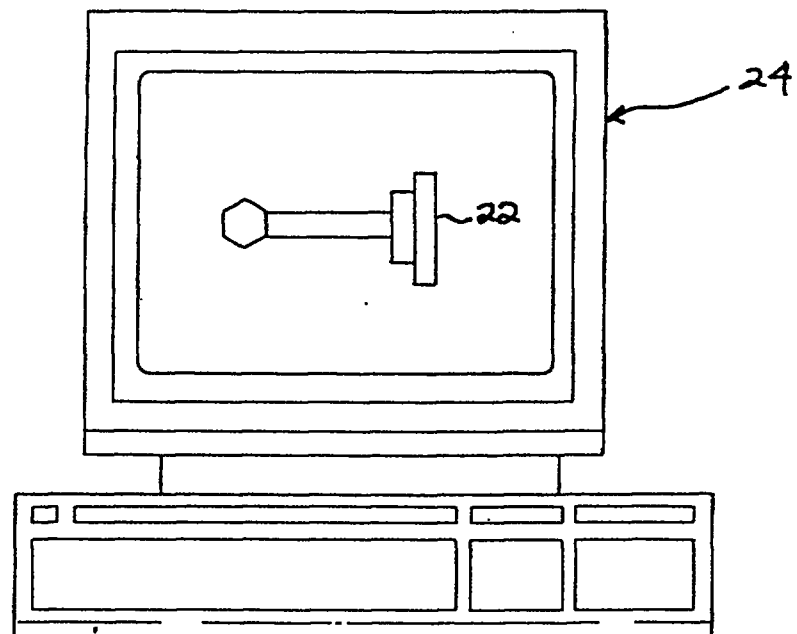


FIG. 2

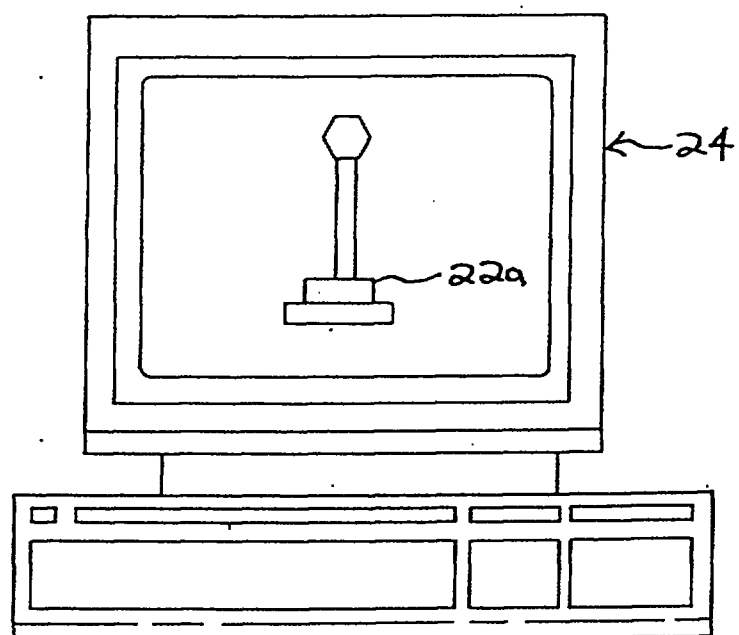


FIG. 3

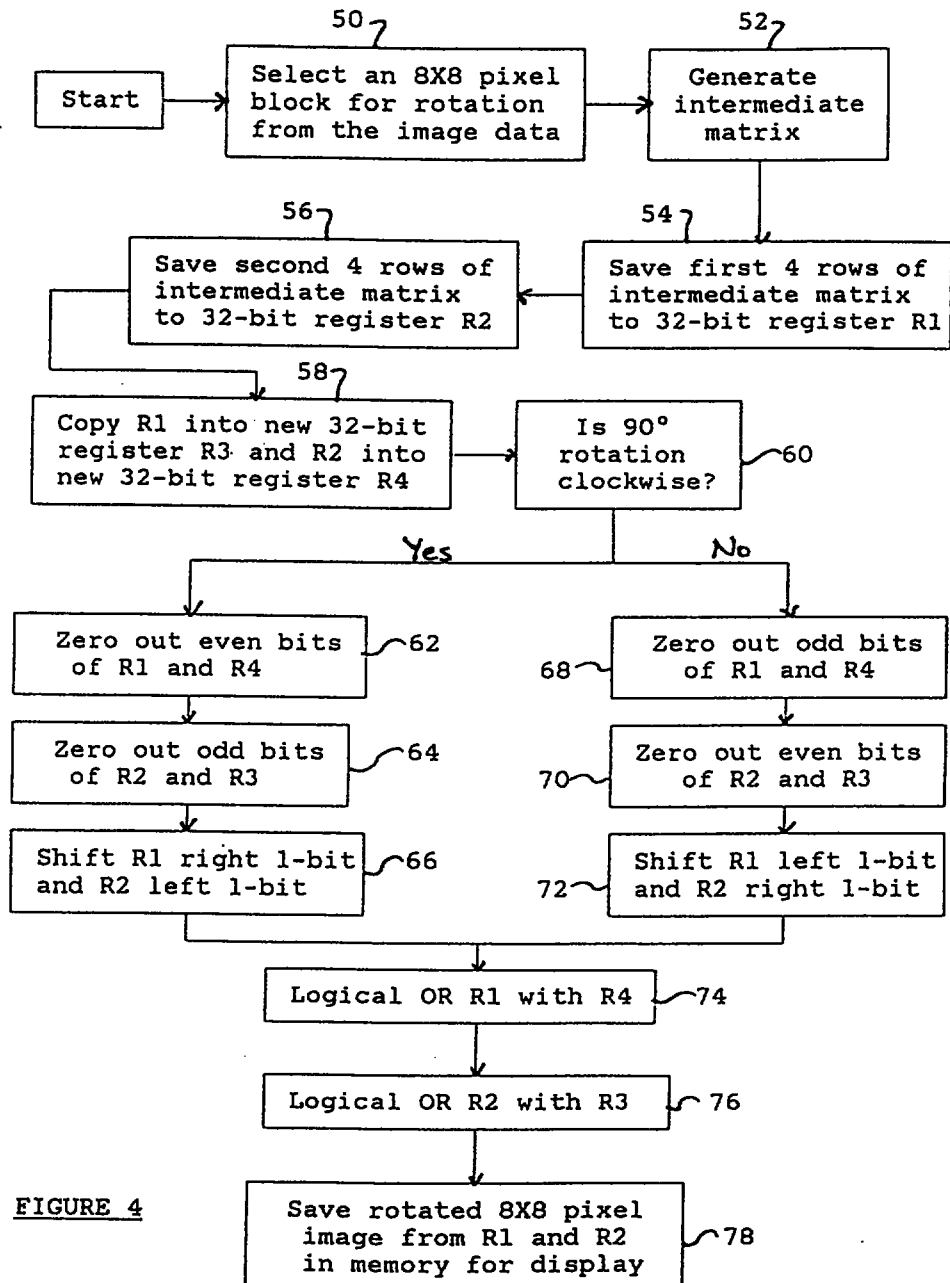


FIGURE 4

A SYSTEM FOR FAST 90 DEGREE ROTATION OF BI-LEVEL IMAGES

1. Field of the Invention

The present invention relates to a digital image processing method and more particularly to a method for the fast rotation of bi-level images.

2. Description of the Prior Art

Bi-level images (also called monochrome images) are images having just two intensity levels (generally black and white or black and green) because their bi-level bitmaps contain a single bit per pixel. The entire bitmap for a screen for a resolution of 1,024 x 1,024 pixels is 2^{20} bits, or about 128,000 bytes.

Through the increasing proliferation in offices and home offices of low memory computers, such as workstations and personal computers, computer storage of office documentation, reports, forms, letters and even photographs, is becoming prevalent as a means for reducing physical storage requirements and improving accessibility to common office files.

Documents are commonly received into computer systems by optical character reader (OCR) scan, facsimile or on-line data transmission. The challenge is to take the image of a document entered into a system, for example by OCR, and be able to manipulate it quickly and efficiently, so that it can be easily viewed by the end user.

Rotating a bi-level image by 90° , 180° , and 270° with respect to its orientation on input are among the most commonly used operations during document image processing. The traditional solution is to rotate the image one pixel at time, but this operation is very time consuming.

As a result, a number of methods have been proposed in the prior art for expediting image rotation, particularly plus or

data plus or minus 90° from its original orientation. The image data is first stored in partially transposed form in a matrix contained in eight 32-bit registers. The matrix is separated into groups of bits of rotatable size (sub-matrices of equal size), and first preselected bit positions are transposed with second preselected bit positions in each group. Rows of bits in the groups are then exchanged with second rows of bits in the groups.

Each of these IBM patents discuss, as prior art, a number of much earlier publications and references directed to solving the problems associated with image rotation, and the contents of each of these IBM patents, particularly in their sections describing the prior art, are incorporated herein by reference.

In addition to the foregoing, U.S. Patent Number 4,916,746 of International Computers Limited discloses rotating an image through 90 degrees, either clockwise or counterclockwise, using a hardware rotation circuit. The rotation circuit comprises a FIFO and shift register, where data is read out of the FIFO a word at a time and written back into the FIFO with a displacement of one bit, effecting a spiral data path. The shift register is then used to assemble the output rotated image data.

U.S. Patent Number 4,985,849 of Canon K.K. discloses an image processing system for forming a slantwise mapped or rotated modified image of an original image. The relation between the address locations of the original points of data and the output points is calculated, and these calculated values are prestored in lookup tables. The image data from the original address locations is then transferred or copied using the output address information from the lookup tables.

U.S. Patent Number 5,067,167 of Cornell Research Foundation Inc. discloses rotating a three-dimensional image by 90° by using a data processor to modify the original spacial

coordinate values of the three-dimensional image.

U.S. Patent Number 5,233,168 of Pitney Bowes Inc. discloses deskewing an image by scanning the image to capture a pixel by pixel mapped image, determining size and skew of the mapped image, performing a series of area-limited vertical pixel shifts, and performing a series of area-limited horizontal pixel shifts.

Other approaches to providing rapid image rotation have been hardware specific solutions, such as a special hardware device called a rotation buffer disclosed in U.S. Patent Number 4,947,344 of IBM Corporation or special circuitry disclosed in U.S. Patent number 4,992,960 of Yamaha Corporation. However, these types of hardware solutions require considerable costs* associated with modified existing hardware, as opposed to a solution implemented in software for maximizing the existing hardware storage capabilities.

SUMMARY OF THE INVENTION

Like the methods disclosed in previous IBM patents ('020, '430, and '845), the present invention also works on 64 pixel blocks of image data at a time in expediting image rotation to orientation of 90° or 270° from its orientation on input. However, because the method of the present invention requires fewer memory accesses than the prior art methods, it has been found to be 15 to 30% faster in operation on Intel-based IBM® personal computers having 32-bit registers, which is the type of environment to which this invention is predominantly directed.

Accordingly, the invention provides, in a 32-bit operating system, a method of rotating by 90° a block of bi-level image data having 8 rows by 8 columns of pixel data bits. The method includes the computer-implemented steps of generating an intermediate matrix having 8 rows by 8 columns of pixel data bits, wherein each row from the block has been divided and translated into a paired nibble column, alternate rows from

the block being arranged transversely and lower order rows from the block being arranged on top of adjacent higher order rows in the paired nibble columns of the intermediate matrix and saving the rows of the intermediate matrix sequentially into first and second 32-bit registers. The first 32-bit register is then copied into a third 32-bit register and the second 32-bit register into a fourth 32-bit register. Each of the first and second registers is shifted by one bit in opposite directions and alternate bits from the fourth register are dynamically overlaid onto the first register while alternate bits from the third register are dynamically overlaid onto the second register.

The present invention is also directed to a system provided with means for carrying out the computer implemented steps of the method.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described in detail in association with the accompanying figures, in which:

Figure 1 is a schematic representation of a typical operating systems for practicing the present invention;

Figures 2 and 3 illustrate the display screen of a personal computer or work station showing a document oriented by a difference of 90°; and

Figure 4 is a flow diagram illustrating the computer implemented steps in rotating a image 90° clockwise or counterclockwise.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention operates in a 32-bit programming operating system environment such as IBM's OS/2® system, Posix Unix systems or Microsoft's system NT.

The elements of an operating system of this type are

illustrated schematically in Figure 1, and would typically include a host processor 12 having a 32-bit storage registers, an image storage 14, a display terminal 16, means for receiving image data, such as an OCR-image scanner 18, and a printer 20. Other means for receiving image data into the operating system would include data transmission and facsimile. The display terminal 16, the image scanner 18 and the printer 20 each may have different requirements for reading or presentation of a document or image. Accordingly, the processor 12 in conjunction with image storage 14 will be required to manipulate the image data to meet the presentation requirements of each of the peripheral devices 16, 18 and 20.

For example, a photographic image may be scanned into the system via scanner 18 and end up as a horizontally displayed image 22 on a computer display 24, such as illustrated in Figure 2. In order for the end user to use the displayed image in any meaningful way, the orientation of the image must be rotated 90° clockwise to the position 22a shown on the computer display 24 in Figure 3.

The steps of the method of this invention are illustrated in the flow diagram of Figure 4. As discussed earlier, the present invention rotates image data in 8 by 8 pixel block segments. Thus, an 8 by 8 pixel block segment selected from the stored data of the entire image (block 50 in Figure 4) may be represented by the 64 bit matrix set forth below in Table A:

TABLE A

Row 1	A7	A6	A5	A4	A3	A2	A1	A0
Row 2	B7	B6	B5	B4	B3	B2	B1	B0
Row 3	C7	C6	C5	C4	C3	C2	C1	C0
Row 4	D7	D6	D5	D4	D3	D2	D1	D0
Row 5	E7	E6	E5	E4	E3	E2	E1	E0
Row 6	F7	F6	F5	F4	F3	F2	F1	F0
Row 7	G7	G6	G5	G4	G3	G2	G1	G0
Row 8	H7	H6	H5	H4	H3	H2	H1	H0

Where A0, A1, , H6, H7 each represent a bi-level pixel forming the matrix.

Clockwise 90° rotation of the matrix of Table A turns the matrix on its side so that Row 1 becomes the right-hand column of 8 bits, with the A0 pixel at the bottom. Counterclockwise 90° rotation turns the matrix so that Row 1 becomes the left-hand column of 8 bits, with the A0 pixel at the top. These two resulting data representations are illustrated in Tables D and E in this description.

The same general principles and functions are applied to achieve both clockwise and counterclockwise rotation according to the invention. However, as will be discussed in detail below, the functions are reversed, in many cases, to achieve counterclockwise, rather than clockwise, rotation.

The working area for transforming the image data is 32-bit registers in the processor, from which the transformed data is moved back to the memory (storage) ready for display or printing. A 64-bit matrix can be stored in two 32-bit registers.

The present invention is performed in four main steps. First, an intermediate matrix is generated that sets the foundation for dividing the matrix into two register-size rows of 4-bytes each. The intermediate matrix is stored in the two target 32-bit registers, and then copied into a further pair of 32-bit registers. The data in the four registers is then manipulated, and the four registers are finally collapsed back into the original two that now contain the rotated data image.

Throughout, only three memory accesses per byte (or 24 per block) are required, first when the byte is read in a processor register, next when the value is used to access a lookup table for generating the intermediate matrix and a final memory access to save the rotated data back in memory.

This represents a 25% reduction over the next fastest rotation method of the prior art (which requires four memory accesses per byte or 32 for a full block), and accounts for the improved speed of the present invention.

According to the preferred embodiment of the invention, the selected 8 by 8 pixel matrix or block of image data is transformed into a intermediate matrix (block 52), that is re-arranged in a manner that starts the process of re-aligning the pixels to a position more proximate to their position following complete rotation. In the case of an intended 90° clockwise rotation, the intermediate matrix is as set out in Table B:

TABLE B

Row 1	G7	G3	E7	E3	C7	C3	A7	A3
Row 2	G6	G2	E6	E2	C6	C2	A6	A2
Row 3	G5	G1	E5	E1	C5	C1	A5	A1
Row 4	G4	G0	E4	E0	C4	C0	A4	A0
Row 5	H7	H3	F7	F3	D7	D3	B7	B3
Row 6	H6	H2	F6	F2	D6	D2	B6	B2
Row 7	H5	H1	F5	F1	D5	D1	B5	B1
Row 8	H4	H0	F4	F0	D4	D0	B4	B0

The partial rearrangement for rotation effectively divides and translates each row into a pair of nibble columns. The first four rows of the intermediate matrix contain the translated paired nibble columns of the odd-numbered rows from the original block of data (ie., rows A, C, E and G) arranged transversely. In the case of a clockwise rotation, the transverse arrangement is from right to left, with the higher order bits from each half-row arranged on top of the lower order bits. For counterclockwise rotation, it will be seen from reviewing Table E that the transverse arrangement is from left to right, with the lower order bits arranged on top of the higher order bits from each half row. The bottom four rows of the intermediate matrix contain the even-numbered rows from the original block of data (ie., rows B, D, F, and H) in the same arrangement as the upper four rows.

In the preferred embodiment of the invention, the intermediate matrix is generated using four lookup tables, which are set out in the section titled Appendix which forms part of the present disclosure.

Each of the four lookup tables is responsible for converting two rows in the 8 by 8 pixel matrix. For clockwise rotation, Table 1 from the Appendix is used for converting Rows 1 and 2,

Table 2 for Rows 3 and 4, Table 3 for Rows 5 and 6, and Table 4 for Rows 7 and 8, and the rows are converted alternately (ie. rows 1, 3, 5 and 7, followed by rows 2, 4, 6 and 8). For counterclockwise rotation, the lookup tables are used in the reverse order, that is, Table 1 is used for converting Rows 8 and 7, Table 2 for Rows 6 and 5, Table 3 for Rows 4 and 3, and Table 4 for Rows 2 and 1.

Generation of the intermediate matrix, in the preferred embodiment, is by dynamic overlay with the results being saved immediately to two 32-bit processor registers.

Use of the lookup tables for a 90° clockwise rotation can be illustrated by the following example, starting with the bi-level 8 by 8 pixel matrix in binary notation set out in Table C.

TABLE C

Row 1	0	0	0	0	1	1	1	1
Row 2.	0	0	0	0	0	0	1	1
Row 3	0	0	0	1	0	1	0	0
Row 4	0	0	0	1	0	1	0	1
Row 5	0	0	1	1	0	0	0	0
Row 6	0	1	0	1	1	1	0	0
Row 7	0	0	1	0	1	1	1	0
Row 8	0	0	1	0	0	0	1	0

First, for row 1, entry 15 of lookup table 1 is used:

**** Lookup Table 1:

	From	To
ROW	BINARY REPRESENTATION	BINARY REPRESENTATION
15	00001111	00000001 00000001 00000001 00000001

This 32-bit value is saved in register R1 as:

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	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	00000001	00000001	00000001	00000001

Next, for row 3, entry 20 of lookup table 2 is used:

**** LOOKUP TABLE 2:

ROW	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
20	00010100	00000000 00000100 00000000 00001000

This value is logical ORed, or dynamically overlaid with the 4-byte value for row 1, in which any "one" value from either 4-byte row replaces a "zero" value. The resulting revision of the first 32-bit register is:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	00000001	00000101	00000001	00001001

Next, for row 5, entry 48 of lookup table 3 is used:

**** LOOKUP TABLE 3

ROW	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
48	00110000	00000000 00000000 00100000 00100000

When this 4-byte value is logical ORed with the contents of R1 the following register value results:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	00000001	00000101	00100001	00101001

Finally, for row 7, entry 46 of lookup table 4 is used:

****LOOKUP TABLE 4:

ROW	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
46	00101110	01000000 01000000 11000000 00000000

After logical ORing R1 with the value, register R1 contains:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R1	01000001	01000101	11100001	00101001

Repeating the same procedures for row 2, 4, 6 and 8, using lookup table 1, 2, 3, and 4 respectively, the result is saved in R2 as:

	BYTE 3	BYTE 2	BYTE 1	BYTE 0
R2	00010000	00110100	11000001	00101101

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This completes the process of the intermediate matrix generation. To clarify the results, the contents of R1 and R2 may be displayed in terms of bytes with higher-order bytes on top of lower order bytes in a matrix-like format as follows:

```

R1 BYTE 3      0 1 0 0 0 0 0 1
R1 BYTE 2      0 1 0 0 0 1 0 1
R1 BYTE 1      1 1 1 0 0 0 0 1
R1 BYTE 0      0 0 1 0 1 0 0 1

R2 BYTE 3      0 0 0 1 0 0 0 0
R2 BYTE 2      0 0 1 1 0 1 0 0
R3 BYTE 1      1 1 0 0 0 0 0 1
R3 BYTE 0      0 0 1 0 1 1 0 1

```

Therefore, returning to the original generic example, the first four rows (or first four-byte row) of the intermediate matrix are saved into the first 32-bit register R1 (block 54) of Figure 4, and the remaining four rows (or second four-byte row) of the matrix are saved into a second 32-bit register R2 (block 56). Thus, in a 32-bit environment, the intermediate matrix is held in the two 32-bit registers in R1 and R2 in the following representation:

R1: G7 G3 E7 E3 C7 C3 A7 A3	G6 G2 E6 E2 C6 C2 A6 A2	G5 G1 E5 E1 C5 C1 A5 A1	G4 G0 E4 E0 C4 C0 A4 A0
R2: H7 H3 F7 F3 D7 D3 B7 B3	H6 H2 F6 F2 D6 D2 B6 B2	H5 H1 F5 F1 D5 D1 B5 B1	H4 H0 F4 F0 D4 D0 B4 B0

The contents of registers R1 and R2 are then copied to two other 32-bit registers R3 and R4 respectively (block 58) to achieve the following representation.

R1: G7 G3 E7 E3 C7 C3 A7 A3	G6 G2 E6 E2 C6 C2 A6 A2	G5 G1 E5 E1 C5 C1 A5 A1	G4 G0 E4 E0 C4 C0 A4 A0
R2: H7 H3 F7 F3 D7 D3 B7 B3	H6 H2 F6 F2 D6 D2 B6 B2	H5 H1 F5 F1 D5 D1 B5 B1	H4 H0 F4 F0 D4 D0 B4 B0
R3: G7 G3 E7 E3 C7 C3 A7 A3	G6 G2 E6 E2 C6 C2 A6 A2	G5 G1 E5 E1 C5 C1 A5 A1	G4 G0 E4 E0 C4 C0 A4 A0
R4: H7 H3 F7 F3 D7 D3 B7 B3	H6 H2 F6 F2 D6 D2 B6 B2	H5 H1 F5 F1 D5 D1 B5 B1	H4 H0 F4 F0 D4 D0 B4 B0

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When the rotation is an 90° clockwise rotation (block 60), the even bits R1 and R4 are zeroed out (block 62) and the odd bits of R2 and R3 are zeroed out (block 64), to yield the following changes in the registers:

R1: 07 00 E7 00 C7 00 A7 00 R2: 00 H3 00 F3 00 D3 00 B3	G6 00 E6 00 C6 00 A6 00 00 H2 00 F2 00 D2 00 B2	G5 00 E5 00 C5 00 A5 00 00 H1 00 F1 00 D1 00 B1	G4 00 E4 00 C4 00 A4 00 00 H0 00 F0 00 D0 00 B0
R3: 00 G3 00 E3 00 C3 00 A3 R4: H7 00 F7 00 D7 00 B7 00	00 G2 00 E2 00 C2 00 A2 H6 00 F6 00 D6 00 B6 00	00 G1 00 E1 00 C1 00 A1 H5 00 F5 00 D5 00 B5 00	00 G0 00 E0 00 C0 00 A0 H4 00 F4 00 D4 00 B4 00

The contents of R1 are then shifted right by one bit and the contents of R2 are shifted left by one bit (block 66), so that the contents of the four registers appears as follows:

R1: 00 07 00 E7 00 C7 00 A7 R2: H3 00 F3 00 D3 00 B3 00	00 G6 00 E6 00 C6 00 A6 H2 00 F2 00 D2 00 B2 00	00 G5 00 E5 00 C5 00 A5 H1 00 F1 00 D1 00 B1 00	00 G4 00 E4 00 C4 00 A4 H0 00 F0 00 D0 00 B0 00
R3: 00 G3 00 E3 00 C3 00 A3 R4: H7 00 F7 00 D7 00 B7 00	00 G2 00 E2 00 C2 00 A2 H6 00 F6 00 D6 00 B6 00	00 G1 00 E1 00 C1 00 A1 H5 00 F5 00 D5 00 B5 00	00 G0 00 E0 00 C0 00 A0 H4 00 F4 00 D4 00 B4 00

Next R1 is logical ORed with R4 (block 74) and R2 is logical ORed with R3 (block 76) to achieve the following content of registers R1 and R2:

R1: H7 G7 F7 E7 D7 C7 B7 A7 R2: H3 G3 F3 E3 D3 C3 B3 A3	H6 G6 F6 E6 D6 C6 B6 A6 H2 G2 F2 E2 D2 C2 B2 A2	H5 G5 F5 E5 D5 C5 B5 A5 H1 G1 F1 E1 D1 C1 B1 A1	H4 G4 F4 E4 D4 C4 B4 A4 H0 G0 F0 E0 D0 C0 B0 A0
--	--	--	--

In matrix formation, R1 and R2 now contain the rotated 8 by 8 pixel matrix:

TABLE D

R1:

H7	G7	F7	E7	D7	C7	B7	A7
H6	G6	F6	E6	D6	C6	B6	A6
H5	G5	F5	E5	D5	C5	B5	A5
H4	G4	F4	E4	D4	C4	B4	A4

R2:

H3	G3	F3	E3	D3	C3	B3	A3
H2	G2	F2	E2	D2	C2	B2	A2
H1	G1	F1	E1	D1	C1	B1	A1
H0	G0	F0	E0	D0	C0	B0	A0

90° counterclockwise rotation is achieved following a similar method. Generation of the intermediate matrix, as mentioned above, is performed in the preferred embodiment using the lookup tables in reverse order, to generate an intermediate matrix from Table A, as follows:

TABLE E

Row 1	A4	A0	C4	C0	E4	E0	G4	G0
Row 2	A5	A1	C5	C1	E5	E1	G5	G1
Row 3	A6	A2	C6	C2	E6	E2	G6	G2
Row 4	A7	A3	C7	C3	E7	E3	G7	G3
Row 5	B4	B0	D4	D0	F4	F0	H4	H0
Row 6	B5	B1	D5	D1	F5	F1	H5	H1
Row 7	B6	B2	D6	D2	F6	F2	H6	H2
Row 8	B7	B3	D7	D3	F7	F3	H7	H3

In a 32-bit environment, the above intermediate matrix can be

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held in the two 32-bit registers R1 and R2 (blocks 54 and 56) in the following representation:

R1: A7 A3 C7 C3 E7 E3 G7 G3	A6 A2 C6 C2 E6 E2 G6 G2	A5 A1 C5 C1 E5 E1 G5 G1	A4 A0 C4 C0 E4 E0 G4 G0
R2: B7 B3 D7 D3 F7 F3 H7 H3	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0

The contents of R1 and R2 are then copied to the two other 32-bit registers R3 and R4, respectively (block 58):

R1: A7 A3 C7 C3 E7 E3 G7 G1	A6 A2 C6 C2 E6 E2 G6 G2	A5 A1 C5 C1 E5 E1 G5 G1	A4 A0 C4 C0 E4 E0 G4 G0
R2: B7 B3 D7 D3 F7 F3 H7 H3	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0
R3: A7 A3 C7 C3 E7 E3 G7 G1	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0
R4: B7 B3 D7 D3 F7 F3 H7 H3	B6 B2 D6 D2 F6 F2 H6 H2	B5 B1 D5 D1 F5 F1 H5 H1	B4 B0 D4 D0 F4 F0 H4 H0

For the counterclockwise rotation (block 60), the odd bits of R1 and R4 are zeroed out (block 68) and the even bits of R2 and R3 are zeroed out (block 70). This changes the contents of the four registers as follows:

R1: 00 A3 00 C3 00 E3 00 G3	00 A2 00 C2 00 E2 00 G2	00 A1 00 C1 00 E1 00 G1	00 A0 00 C0 00 E0 00 G0
R2: B7 00 D7 00 F7 00 H7 00	B6 00 D6 00 F6 00 H6 00	B5 00 D5 00 F5 00 H5 00	B4 00 D4 00 F4 00 H4 00
R3: A7 00 C7 00 E7 00 G7 00	A6 00 C6 00 E6 00 G6 00	A5 00 C5 00 E5 00 G5 00	A4 00 C4 00 E4 00 G4 00
R4: 00 B3 00 D3 00 F3 00 H3	00 B2 00 D2 00 F2 00 H2	00 B1 00 D1 00 F1 00 H1	00 B0 00 D0 00 F0 00 H0

The contents of R1 are shifted left by 1 bit and the contents of R2 (block 72) so that the 4 registers now appear as:

R1: A3 00 C3 00 E3 00 G3 00	A2 00 C2 00 E2 00 G2 00	A1 00 C1 00 E1 00 G1 00	A0 00 C0 00 E0 00 G0 00
R2: 00 B7 00 D7 00 F7 00 H7	00 B6 00 D6 00 F6 00 H6	00 B5 00 D5 00 F5 00 H5	00 B4 00 D4 00 F4 00 H4
R3: 07 00 C7 00 E7 00 G7 00	A6 00 C6 00 E6 00 G6 00	A5 00 C5 00 E5 00 G5 00	A4 00 C4 00 E4 00 G4 00
R4: 00 B3 00 D3 00 F3 00 H3	00 B2 00 D2 00 F2 00 H2	00 B1 00 D1 00 F1 00 H1	00 B0 00 D0 00 F0 00 H0

R1 is logical ORed with R4 (block 74), and R2 with R3 (block 76). The first two registers then have the following representation:

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minus 90° rotations, since these are considerably more complex than 180° rotation due to the packed internal data representation of the image pixels, wherein each byte contains eight image pixels. The rotated image must occupy the storage that contained the original image before rotation. Thus, for this type of rotation, the number of rows must be a multiple of eight, since the bits in each vertical column are packed into bytes by the rotation and a row of the output image must not end with a fraction of a byte. Consequently, placeholder data values must be added to columns that are not multiples of eight.

U.S. Patent Number 4,627,020 of IBM Corporation, sets forth a method for rotating an image by 90° that was considerably faster than the traditional method because it caused the rotation of up to 64 pixels (8 by 8 blocks) at a time, rather than just one pixel. A block of the image would be moved into temporary storage (called a look-up table) and divided into smaller groups of bytes of rotatable size. Each group that did not have the same value for all bits is then rotated. This method took advantage of the fact that large areas of most images are background colour (e.g. white), and that blocks or graphs of the image containing all one colour need not be rotated. This is an enhancement now commonly added to rotation methods. However, as will be seen, the method of the 4,627,020 patent is not as efficient as the method proposed in the present invention since it utilizes additional memory accesses and address manipulations for each byte rotated.

U.S. Patent Number 4,658,430, also of IBM Corporation, is directed to a method for rotating encoded data images that have, for example, been transmitted over a telephone line, by a multiple of 90°. The orientation of encoded data presents different problems from the rotation of the type of data to which the present invention is addressed.

U.S. Patent Number 4,837,845 of IBM Corporation is specifically directed to the problem of rotating binary image

R1: A3 B3 C3 D3 E3 F3 G3 H3	A2 B2 C2 D2 E2 F2 G2 H2	A1 B1 C1 D1 E1 F1 G1 H1	A0 B0 C0 D0 E0 F0 G0 H0
R2: A7 B7 C7 D7 E7 F7 G7 H7	A6 B6 C6 D6 E6 F6 G6 H6	A5 B5 C5 D5 E5 F5 G5 H5	A4 B4 C4 D4 E4 F4 G4 H4

R1 and R2 now contain the 8 by 8 pixel matrix rotated 90° counterclockwise from the original orientation. Presented in matrix formation, the data appears as follows:

TABLE F

R1:

A0	B0	C0	D0	E0	F0	G0	H0
A1	B1	C1	D1	E1	F1	G1	H1
A2	B2	C2	D2	E2	F2	G2	H2
A3	B3	C3	D3	E3	F3	G3	H3

R2:

A4	B4	C4	D4	E4	F4	G4	H4
A5	B5	C5	D5	E5	F5	G5	H5
A6	B6	C6	D6	E6	F6	G6	H6
A7	B7	C7	D7	E7	F7	G7	H7

In the preferred embodiment implemented on an IBM 32-bit machine, the method of the present invention runs consistently faster, and has less overhead when ported across 32-bit platforms, than previously known methods.

Test results have indicated that the present method is over 30% faster on Intel-based IBM PC computers, and the result would be even better if cache memories were used.

Modifications of the preferred embodiments described herein which would be obvious to one skilled in the art are intended to be covered by the appended claims.



The embodiments of the invention of which an exclusive property or privilege is claimed are defined as follows:

1. In a 32-bit operating system, a method of rotating by 90° a block of bi-level image data having 8 rows by 8 columns of pixel data bits, comprising the computer implemented steps of:

generating an intermediate matrix having 8 rows by 8 columns of pixel data bits, wherein each row from the block is divided and translated into a paired nibble column, alternate rows from the block being arranged transversely and lower order rows from the block being arranged on top of higher order rows in the paired nibble columns of the intermediate matrix;

saving the rows of the intermediate matrix sequentially into first and second 32-bit processor registers;

copying the first 32-bit register into a third 32-bit processor register and the second 32-bit register into a fourth 32-bit processor register;

shifting each of the first and second registers by one bit in opposite directions; and

overlaying alternate bits from the fourth register onto the first register and from the third register onto the second register.

2. The method, according to claim 1, wherein the step of generating an intermediate matrix comprises generating an intermediate matrix wherein the alternate rows are arranged transversely from right to left, and wherein higher order bits from each divided row are arranged on top of lower order bits.

3. The method according to claim 2, wherein the step of shifting each of the first and second registers by one bit in opposite directions comprises shifting the first register by one bit left and shifting the second register by one bit right.

4. The method according to claim 3, wherein the step of overlaying alternate bits further comprises the steps of



zeroing out all odd bit of the first and fourth registers and all even bits of the second and third register, and logical ORing the first register with the fourth register and the second with the third register.

5. The method according to claim 1, wherein the step of generating an intermediate matrix comprises generating an intermediate matrix wherein the alternate rows are arranged transversely from left to right, and wherein lower order bits from each divided row are arranged on top of higher order bits.

6. The method, according to claim 5, wherein the step of shifting each of the first and second register by one bit in opposite direction comprises shifting the first register by one bit right and shifting the second register by one bit left.

7. The method according to claim 6, wherein the step of overlaying alternate bits further comprises the steps of zeroing out all even bits of the first and fourth registers and all odd bits of the second and third registers, and logical ORing the first register with the fourth register and the second register with the third register.

8. The method, according to claim 1, wherein the step of generating an intermediate matrix comprises:

obtaining a first set of 4-byte values from at least one lookup table for each odd-numbered row from the block and dynamically overlaying said first set of 4-byte values in the first 32-bit register; and

obtaining a second set of 4-byte values from said at least one lookup table for each even-numbered row from the block and dynamically overlaying said second set of 4-byte values in the second 32-bit register.

9. In a 32-bit operating system, a method of rotating a bi-level image by 90° , comprising the computer implemented steps



of:

a) selecting an unrotated 8 by 8 pixel matrix from the image data;

b) generating an intermediate matrix having 8 rows by 8 columns of pixel data bits, wherein each row from the block is divided and translated into a paired nibble column, alternate rows from the block being arranged transversely and lower order rows from the block being arranged on top of higher order rows in the paired nibble columns of the intermediate matrix;

c) saving the rows of the intermediate matrix sequentially to first and second 32-bit registers;

d) copying the first 32-bit register into a third 32-bit register and the second 32-bit register into a fourth 32-bit register;

e) shifting each of the first and second registers by one bit in opposite directions;

f) overlaying alternate bits from the fourth register onto the first register and from the third register onto the second register; and

g). repeating steps a) through f) until the image has been rotated.

10. A 32-bit operating system for rotating a block of bi-level image data having 8 rows by 8 columns of pixel data bits, comprising:

means for generating an intermediate matrix having 8 rows by 8 columns of pixel data bits from the block, wherein each row from the block is divided and translated into a paired nibble column, alternate rows from the block being arranged transversely and lower order rows from the block being arranged on top of higher order rows in the paired nibble columns of the intermediate matrix;

at least first, second, third, and fourth 32-bit processor registers, the first and third registers for saving, in duplicate, the first four rows of the intermediate matrix and the second and fourth registers for saving, in duplicate, the remaining four rows of the intermediate matrix;

means for shifting each of the first and second registers



by one bit in opposite directions; and

means for overlaying alternate bits from the fourth register onto the first register and from the third register onto the second register.

11. A system, according to claim 10, wherein the means for generating an intermediate matrix comprise at least one lookup table.

12. A system, according to claim 11, wherein said at least one lookup table comprises multiple look tables, each lookup table being adapted for generating a 4-byte value for at least one row from the block.

13. A system, according to claim 10, wherein the means for generating an intermediate matrix comprises:

four lookup tables, each lookup table being adapted for generating 4-byte values for at least two rows from the block; and

means for dynamically overlaying 4-byte values from alternate rows from the block into one of said registers.

LOOKUP TABLE 1:

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00008008	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 00000001
2	00000010	00000000 00000000 00000000 00000010
3	00000011	00000000 00000000 00000000 00000011
4	00000100	00000000 00000001 00000000 00000000
5	00000101	00000000 00000001 00000000 00000001
6	00000110	00000000 00000001 00000000 00000010
7	00000111	00000000 00000001 00000000 00000011
8	00001000	00000001 00000000 00000000 00000000
9	00001001	00000001 00000000 00000000 00000001
10	00001010	00000001 00000000 00000000 00000010
11	00001011	00000001 00000000 00000000 00000011
12	00001100	00000001 00000001 00000000 00000000
13	00001101	00000001 00000001 00000000 00000001
14	00001110	00000001 00000001 00000000 00000010
15	00001111	00000001 00000001 00000000 00000011
16	00010000	00000000 00000000 00000000 00000010
17	00010001	00000000 00000000 00000000 00000011
18	00010010	00000000 00000000 00000001 00000010
19	00010011	00000000 00000000 00000001 00000011
20	00010100	00000000 00000001 00000000 00000010
21	00010101	00000000 00000001 00000000 00000011
22	00010110	00000000 00000001 00000000 00000010
23	00010111	00000000 00000001 00000000 00000011
24	00011000	00000001 00000000 00000000 00000010
25	00011001	00000001 00000000 00000000 00000011
26	00011010	00000001 00000000 00000001 00000010
27	00011011	00000001 00000000 00000001 00000011
28	00011100	00000001 00000001 00000000 00000010
29	00011101	00000001 00000001 00000000 00000011
30	00011110	00000001 00000001 00000001 00000010
31	00011111	00000001 00000001 00000001 00000011
32	00100000	00000000 00000000 00000010 00000000
33	00100001	00000000 00000000 00000010 00000001
34	00100010	00000000 00000000 00000011 00000000
35	00100011	00000000 00000000 00000011 00000001
36	00100100	00000000 00000001 00000010 00000000
37	00100101	00000000 00000001 00000010 00000001
38	00100110	00000000 00000001 00000011 00000000
39	00100111	00000000 00000001 00000011 00000001

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40	00101000	00000001 00000000 00000010 00000000
41	00101001	00000001 00000000 00000010 00000001
42	00101010	00000001 00000000 00000011 00000000
43	00101011	00000001 00000000 00000011 00000001
44	00101100	00000001 00000001 00000010 00000000
45	00101101	00000001 00000001 00000010 00000001
46	00101110	00000001 00000001 00000011 00000000
47	00101111	00000001 00000001 00000011 00000001
48	00110000	00000000 00000000 00000010 00000010
49	00110001	00000000 00000000 00000010 00000011
50	00110010	00000000 00000000 00000011 00000010
51	00110011	00000000 00000000 00000011 00000011
52	00110100	00000000 00000001 00000010 00000010
53	00110101	00000000 00000001 00000010 00000011
54	00110110	00000000 00000001 00000011 00000010
55	00110111	00000000 00000001 00000011 00000011
56	00111000	00000001 00000000 00000010 00000010
57	00111001	00000001 00000000 00000010 00000011
58	00111010	00000001 00000000 00000011 00000010
59	00111011	00000001 00000000 00000011 00000011
60	00111100	00000001 00000001 00000010 00000010
61	00111101	00000001 00000001 00000010 00000011
62	00111110	00000001 00000001 00000011 00000010
63	00111111	00000001 00000001 00000011 00000011
64	01000000	00000000 00000010 00000000 00000000
65	01000001	00000000 00000010 00000000 00000001
66	01000010	00000000 00000010 00000001 00000000
67	01000011	00000000 00000010 00000001 00000001
68	01000100	00000000 00000011 00000000 00000000
69	01000101	00000000 00000011 00000000 00000001
70	01000110	00000000 00000011 00000001 00000000
71	01000111	00000000 00000011 00000001 00000001
72	01001000	00000001 00000010 00000000 00000000
73	01001001	00000001 00000010 00000000 00000001
74	01001010	00000001 00000010 00000001 00000000
75	01001011	00000001 00000010 00000001 00000001
76	01001100	00000001 00000011 00000000 00000000
77	01001101	00000001 00000011 00000000 00000001
78	01001110	00000001 00000011 00000001 00000000
79	01001111	00000001 00000011 00000001 00000001
80	01010000	00000000 00000010 00000000 00000010
81	01010001	00000000 00000010 00000000 00000011
82	01010010	00000000 00000010 00000001 00000010
83	01010011	00000000 00000010 00000001 00000011
84	01010100	00000000 00000011 00000000 00000010
85	01010101	00000000 00000011 00000000 00000011
86	01010110	00000000 00000011 00000001 00000010
87	01010111	00000000 00000011 00000001 00000011

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88	01011000	00000001 00000010 00000000 00000010
89	01011001	00000001 00000010 00000000 00000011
90	01011010	00000001 00000010 00000001 00000010
91	01011011	00000001 00000010 00000001 00000011
92	01011100	00000001 00000011 00000000 00000010
93	01011101	00000001 00000011 00000000 00000011
94	01011110	00000001 00000011 00000001 00000010
95	01011111	00000001 00000011 00000001 00000011
96	01100000	00000000 00000010 00000010 00000000
97	01100001	00000000 00000010 00000010 00000001
98	01100010	00000000 00000010 00000011 00000000
99	01100011	00000000 00000010 00000011 00000001
100	01100100	00000000 00000011 00000010 00000000
101	01100101	00000000 00000011 00000010 00000001
102	01100110	00000000 00000011 00000011 00000000
103	01100111	00000000 00000011 00000011 00000001
104	01101000	00000001 00000010 00000010 00000000
105	01101001	00000001 00000010 00000010 00000001
106	01101010	00000001 00000010 00000011 00000000
107	01101011	00000001 00000010 00000011 00000001
108	01101100	00000001 00000011 00000010 00000000
109	01101101	00000001 00000011 00000010 00000001
110	01101110	00000001 00000011 00000011 00000000
111	01101111	00000001 00000011 00000011 00000001
112	01110000	00000000 00000010 00000010 00000010
113	01110001	00000000 00000010 00000010 00000011
114	01110010	00000000 00000010 00000011 00000010
115	01110011	00000000 00000010 00000011 00000011
116	01110100	00000000 00000011 00000010 00000010
117	01110101	00000000 00000011 00000010 00000011
118	01110110	00000000 00000011 00000011 00000010
119	01110111	00000000 00000011 00000011 00000011
120	01111000	00000001 00000010 00000010 00000010
121	01111001	00000001 00000010 00000010 00000011
122	01111010	00000001 00000010 00000011 00000010
123	01111011	00000001 00000010 00000011 00000011
124	01111100	00000001 00000011 00000010 00000010
125	01111101	00000001 00000011 00000010 00000011
126	01111110	00000001 00000011 00000011 00000010
127	01111111	00000001 00000011 00000011 00000011
128	10000000	00000010 00000000 00000000 00000000
129	10000001	00000010 00000000 00000000 00000001
130	10000010	00000010 00000000 00000001 00000000
131	10000011	00000010 00000000 00000001 00000001
132	10000100	00000010 00000001 00000000 00000000
133	10000101	00000010 00000001 00000000 00000001
134	10000110	00000010 00000001 00000001 00000000
135	10000111	00000010 00000001 00000001 00000001

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136	10001000	00000011 00000000 00000000 00000000
137	10001001	00000011 00000000 00000000 00000001
138	10001010	00000011 00000000 00000001 00000000
139	10001011	00000011 00000000 00000001 00000001
140	10001100	00000011 00000000 00000000 00000000
141	10001101	00000011 00000001 00000000 00000000
142	10001110	00000011 00000001 00000001 00000000
143	10001111	00000011 00000001 00000001 00000001
144	10010000	00000010 00000000 00000000 00000010
145	10010001	00000010 00000000 00000000 00000011
146	10010010	00000010 00000000 00000001 00000010
147	10010011	00000010 00000000 00000001 00000011
148	10010100	00000010 00000001 00000000 00000010
149	10010101	00000010 00000001 00000000 00000011
150	10010110	00000010 00000001 00000001 00000010
151	10010111	00000010 00000001 00000001 00000011
152	10011000	00000011 00000000 00000000 00000010
153	10011001	00000011 00000000 00000000 00000011
154	10011010	00000011 00000000 00000001 00000010
155	10011011	00000011 00000000 00000001 00000011
156	10011100	00000011 00000001 00000000 00000010
157	10011101	00000011 00000001 00000000 00000011
158	10011110	00000011 00000001 00000001 00000010
159	10011111	00000011 00000001 00000001 00000011
160	10100000	00000010 00000000 00000010 00000000
161	10100001	00000010 00000000 00000010 00000001
162	10100010	00000010 00000000 00000011 00000000
163	10100011	00000010 00000000 00000011 00000001
164	10100100	00000010 00000001 00000010 00000000
165	10100101	00000010 00000001 00000010 00000001
166	10100110	00000010 00000001 00000011 00000000
167	10100111	00000010 00000001 00000011 00000001
168	10101000	00000011 00000000 00000010 00000000
169	10101001	00000011 00000000 00000010 00000001
170	10101010	00000011 00000000 00000011 00000000
171	10101011	00000011 00000000 00000011 00000001
172	10101100	00000011 00000001 00000010 00000000
173	10101101	00000011 00000001 00000010 00000001
174	10101110	00000011 00000001 00000011 00000000
175	10101111	00000011 00000001 00000011 00000001
176	10110000	00000010 00000000 00000010 00000010
177	10110001	00000010 00000000 00000010 00000011
178	10110010	00000010 00000000 00000011 00000010
179	10110011	00000010 00000000 00000011 00000011
180	10110100	00000010 00000001 00000010 00000010
181	10110101	00000010 00000001 00000010 00000011
182	10110110	00000010 00000001 00000011 00000010
183	10110111	00000010 00000001 00000011 00000011

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184	10111000	00000011 00000000 00000010 00000010
185	10111001	00000011 00000000 00000010 00000011
186	10111010	00000011 00000000 00000011 00000010
187	10111011	00000011 00000000 00000011 00000011
188	10111100	00000011 00000001 00000010 00000010
189	10111101	00000011 00000001 00000010 00000011
190	10111110	00000011 00000001 00000011 00000010
191	10111111	00000011 00000001 00000011 00000011
192	11000000	00000010 00000010 00000000 00000000
193	11000001	00000010 00000010 00000000 00000001
194	11000010	00000010 00000010 00000001 00000000
195	11000011	00000010 00000010 00000001 00000001
196	11000100	00000010 00000011 00000000 00000000
197	11000101	00000010 00000011 00000000 00000001
198	11000110	00000010 00000011 00000001 00000000
199	11000111	00000010 00000011 00000001 00000001
200	11001000	00000011 00000010 00000000 00000000
201	11001001	00000011 00000010 00000000 00000001
202	11001010	00000011 00000010 00000001 00000000
203	11001011	00000011 00000010 00000001 00000001
204	11001100	00000011 00000011 00000000 00000000
205	11001101	00000011 00000011 00000000 00000001
206	11001110	00000011 00000011 00000001 00000000
207	11001111	00000011 00000011 00000001 00000001
208	11010000	00000010 00000010 00000000 00000010
209	11010001	00000010 00000010 00000000 00000011
210	11010010	00000010 00000010 00000001 00000010
211	11010011	00000010 00000010 00000001 00000011
212	11010100	00000010 00000011 00000000 00000010
213	11010101	00000010 00000011 00000000 00000011
214	11010110	00000010 00000011 00000001 00000010
215	11010111	00000010 00000011 00000001 00000011
216	11011000	00000011 00000010 00000000 00000010
217	11011001	00000011 00000010 00000000 00000011
218	11011010	00000011 00000010 00000001 00000010
219	11011011	00000011 00000010 00000001 00000011
220	11011100	00000011 00000011 00000000 00000010
221	11011101	00000011 00000011 00000000 00000011
222	11011110	00000011 00000011 00000001 00000010
223	11011111	00000011 00000011 00000001 00000011
224	11100000	00000010 00000010 00000010 00000000
225	11100001	00000010 00000010 00000010 00000001
226	11100010	00000010 00000010 00000011 00000000
227	11100011	00000010 00000010 00000011 00000001
228	11100100	00000010 00000011 00000010 00000000
229	11100101	00000010 00000011 00000010 00000001
230	11100110	00000010 00000011 00000011 00000000
231	11100111	00000010 00000011 00000011 00000001

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232 11101000
 233 11101001
 234 11101010
 235 11101011
 236 11101100
 237 11101101
 238 11101110
 239 11101111

240 11110000
 241 11110001
 242 11110010
 243 11110011
 244 11110100
 245 11110101
 246 11110110
 247 11110111

248 11111000
 249 11111001
 250 11111010
 251 11111011
 252 11111100
 253 11111101
 254 11111110
 255 11111111

00000011 00000010 00000010 00000000
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 00000011 00000011 00000011 00000010
 00000011 00000011 00000011 00000011

LOOKUP TABLE 2 :

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00000000	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 00000100
2	00000010	00000000 00000000 00000100 00000000
3	00000011	00000000 00000000 00000100 00000100
4	00000100	00000000 00000100 00000000 00000000
5	00000101	00000000 00000100 00000000 00000100
6	00000110	00000000 00000100 00000100 00000000
7	00000111	00000000 00000100 00000100 00000100
8	00001000	00000100 00000000 00000000 00000000
9	00001001	00000100 00000000 00000000 00000100
10	00001010	00000100 00000000 00000100 00000000
11	00001011	00000100 00000000 00000100 00000100
12	00001100	00000100 00000100 00000000 00000000
13	00001101	00000100 00000100 00000000 00000100
14	00001110	00000100 00000100 00000100 00000000
15	00001111	00000100 00000100 00000100 00000100
16	00010000	00000000 00000000 00000000 00001000
17	00010001	00000000 00000000 00000000 00001100
18	00010010	00000000 00000000 00000100 00001000
19	00010011	00000000 00000000 00000100 00001100
20	00010100	00000000 00000100 00000000 00001000
21	00010101	00000000 00000100 00000000 00001100
22	00010110	00000000 00000100 00000100 00001000
23	00010111	00000000 00000100 00000100 00001100
24	00011000	00000100 00000000 00000000 00001000
25	00011001	00000100 00000000 00000000 00001100
26	00011010	00000100 00000000 00000100 00001000
27	00011011	00000100 00000000 00000100 00001100
28	00011100	00000100 00000100 00000000 00001000
29	00011101	00000100 00000100 00000000 00001100
30	00011110	00000100 00000100 00000100 00001000
31	00011111	00000100 00000100 00000100 00001100
32	00100000	00000000 00000000 00001000 00000000
33	00100001	00000000 00000000 00001000 00000100
34	00100010	00000000 00000000 00001100 00000000
35	00100011	00000000 00000000 00001100 00000100
36	00100100	00000000 00000100 00001000 00000000
37	00100101	00000000 00000100 00001000 00000100
38	00100110	00000000 00000100 00001100 00000000
39	00100111	00000000 00000100 00001100 00000100

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40	00101000	00000100 00000000 00001000 00000000
41	00101001	00000100 00000000 00001000 00000100
42	00101010	00000100 00000000 00001100 00000000
43	00101011	00000100 00000000 00001100 00000100
44	00101100	00000100 00000100 00001000 00000000
45	00101101	00000100 00000100 00001000 00000100
46	00101110	00000100 00000100 00001100 00000000
47	00101111	00000100 00000100 00001100 00000100
48	00110000	00000000 00000000 00001000 00001000
49	00110001	00000000 00000000 00001000 00001100
50	00110010	00000000 00000000 00001100 00001000
51	00110011	00000000 00000000 00001100 00001100
52	00110100	00000000 00000100 00001000 00001000
53	00110101	00000000 00000100 00001000 00001100
54	00110110	00000000 00000100 00001100 00001000
55	00110111	00000000 00000100 00001100 00001100
56	00111000	00000100 00000000 00001000 00001000
57	00111001	00000100 00000000 00001000 00001100
58	00111010	00000100 00000000 00001100 00001000
59	00111011	00000100 00000000 00001100 00001100
60	00111100	00000100 00000100 00001000 00001000
61	00111101	00000100 00000100 00001000 00001100
62	00111110	00000100 00000100 00001100 00001000
63	00111111	00000100 00000100 00001100 00001100
64	01000000	00000000 00001000 00000000 00000000
65	01000001	00000000 00001000 00000000 00000100
66	01000010	00000000 00001000 00000100 00000000
67	01000011	00000000 00001000 00000100 00000100
68	01000100	00000000 00001100 00000000 00000000
69	01000101	00000000 00001100 00000000 00000100
70	01000110	00000000 00001100 00000100 00000000
71	01000111	00000000 00001100 00000100 00000100
72	01001000	00000100 00001000 00000000 00000000
73	01001001	00000100 00001000 00000000 00000100
74	01001010	00000100 00001000 00000100 00000000
75	01001011	00000100 00001000 00000100 00000100
76	01001100	00000100 00001100 00000000 00000000
77	01001101	00000100 00001100 00000000 00000100
78	01001110	00000100 00001100 00000100 00000000
79	01001111	00000100 00001100 00000100 00000100
80	01010000	00000000 00001000 00000000 00001000
81	01010001	00000000 00001000 00000000 00001100
82	01010010	00000000 00001000 00000100 00001000
83	01010011	00000000 00001000 00000100 00001100
84	01010100	00000000 00001100 00000000 00001000
85	01010101	00000000 00001100 00000000 00001100
86	01010110	00000000 00001100 00000100 00001000
87	01010111	00000000 00001100 00000100 00001100

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88	01011000	00000100 00001000 00000000 00001000
89	01011001	00000100 00001000 00000000 00001100
90	01011010	00000100 00001000 00000100 00001000
91	01011011	00000100 00001000 00000100 00001100
92	01011100	00000100 00001100 00000000 00001000
93	01011101	00000100 00001100 00000000 00001100
94	01011110	00000100 00001100 00000100 00001000
95	01011111	00000100 00001100 00000100 00001100
96	01100000	00000000 00001000 00001000 00000000
97	01100001	00000000 00001000 00001000 00000100
98	01100010	00000000 00001000 00001100 00000000
99	01100011	00000000 00001000 00001100 00000100
100	01100100	00000000 00001100 00001000 00000000
101	01100101	00000000 00001100 00001000 00000100
102	01100110	00000000 00001100 00001100 00000000
103	01100111	00000000 00001100 00001100 00000100
104	01101000	00000100 00001000 00001000 00000000
105	01101001	00000100 00001000 00001000 00000100
106	01101010	00000100 00001000 00001100 00000000
107	01101011	00000100 00001000 00001100 00000000
108	01101100	00000100 00001000 00001100 00000100
109	01101101	00000100 00001100 00001000 00000000
110	01101110	00000100 00001100 00001100 00000000
111	01101111	00000100 00001100 00001100 00000100
112	01110000	00000000 00001000 00001000 00001000
113	01110001	00000000 00001000 00001000 00001100
114	01110010	00000000 00001000 00001100 00001000
115	01110011	00000000 00001000 00001100 00001100
116	01110100	00000000 00001100 00001000 00001000
117	01110101	00000000 00001100 00001000 00001100
118	01110110	00000000 00001100 00001100 00001000
119	01110111	00000000 00001100 00001100 00001100
120	01111000	00000100 00001000 00001000 00001000
121	01111001	00000100 00001000 00001000 00001100
122	01111010	00000100 00001000 00001100 00001000
123	01111011	00000100 00001000 00001100 00001100
124	01111100	00000100 00001100 00001000 00001000
125	01111101	00000100 00001100 00001000 00001100
126	01111110	00000100 00001100 00001100 00001000
127	01111111	00000100 00001100 00001100 00001100
128	10000000	00001000 00000000 00000000 00000000
129	10000001	00001000 00000000 00000000 00000100
130	10000010	00001000 00000000 00000100 00000000
131	10000011	00001000 00000000 00000100 00000100
132	10000100	00001000 00000100 00000000 00000000
133	10000101	00001000 00000100 00000000 00000100
134	10000110	00001000 00000100 00000100 00000000
135	10000111	00001000 00000100 00000100 00000100

136	10001000	00001100 00000000 00000000 00000000
137	10001001	00001100 00000000 00000000 00000100
138	10001010	00001100 00000000 00000100 00000000
139	10001011	00001100 00000000 00000100 00000100
140	10001100	00001100 00000100 00000000 00000000
141	10001101	00001100 00000100 00000000 00000100
142	10001110	00001100 00000100 00000100 00000000
143	10001111	00001100 00000100 00000100 00000100
144	10010000	00001000 00000000 00000000 00001000
145	10010001	00001000 00000000 00000000 00001100
146	10010010	00001000 00000000 00000100 00001000
147	10010011	00001000 00000000 00000100 00001100
148	10010100	00001000 00000100 00000000 00001000
149	10010101	00001000 00000100 00000000 00001100
150	10010110	00001000 00000100 00000100 00001000
151	10010111	00001000 00000100 00000100 00001100
152	10011000	00001100 00000000 00000000 00001000
153	10011001	00001100 00000000 00000000 00001100
154	10011010	00001100 00000000 00000100 00001000
155	10011011	00001100 00000000 00000100 00001100
156	10011100	00001100 00000100 00000000 00001000
157	10011101	00001100 00000100 00000000 00001100
158	10011110	00001100 00000100 00000100 00001000
159	10011111	00001100 00000100 00000100 00001100
160	10100000	00001000 00000000 00001000 00000000
161	10100001	00001000 00000000 00001000 00000100
162	10100010	00001000 00000000 00001100 00000000
163	10100011	00001000 00000000 00001100 00000100
164	10100100	00001000 00000100 00001000 00000000
165	10100101	00001000 00000100 00001000 00000100
166	10100110	00001000 00000100 00001100 00000000
167	10100111	00001000 00000100 00001100 00000100
168	10101000	00001100 00000000 00001000 00000000
169	10101001	00001100 00000000 00001000 00000100
170	10101010	00001100 00000000 00001100 00000000
171	10101011	00001100 00000000 00001100 00000100
172	10101100	00001100 00000100 00001000 00000000
173	10101101	00001100 00000100 00001000 00000100
174	10101110	00001100 00000100 00001100 00000000
175	10101111	00001100 00000100 00001100 00000100
176	10110000	00001000 00000000 00001000 00001000
177	10110001	00001000 00000000 00001000 00001100
178	10110010	00001000 00000000 00001100 00001000
179	10110011	00001000 00000000 00001100 00001100
180	10110100	00001000 00000100 00001000 00001000
181	10110101	00001000 00000100 00001000 00001100
182	10110110	00001000 00000100 00001100 00001000
183	10110111	00001000 00000100 00001100 00001100

184	10111000	00001100 00000000 00001000 00001000
185	10111001	00001100 00000000 00001000 00001100
186	10111010	00001100 00000000 00001100 00001000
187	10111011	00001100 00000000 00001100 00001100
188	10111100	00001100 00000100 00001000 00001000
189	10111101	00001100 00000100 00001000 00001100
190	10111110	00001100 00000100 00001100 00001000
191	10111111	00001100 00000100 00001100 00001100
192	11000000	00001000 00001000 00000000 00000000
193	11000001	00001000 00001000 00000000 00000100
194	11000010	00001000 00001000 00000100 00000000
195	11000011	00001000 00001000 00000100 00000100
196	11000100	00001000 00001100 00000000 00000000
197	11000101	00001000 00001100 00000000 00000100
198	11000110	00001000 00001100 00000100 00000000
199	11000111	00001000 00001100 00000100 00000100
200	11001000	00001100 00001000 00000000 00000000
201	11001001	00001100 00001000 00000000 00000100
202	11001010	00001100 00001000 00000100 00000000
203	11001011	00001100 00001000 00000100 00000100
204	11001100	00001100 00001100 00000000 00000000
205	11001101	00001100 00001100 00000000 00000100
206	11001110	00001100 00001100 00000100 00000000
207	11001111	00001100 00001100 00000100 00000100
208	11010000	00001000 00001000 00000000 00001000
209	11010001	00001000 00001000 00000000 00001100
210	11010010	00001000 00001000 00000100 00001000
211	11010011	00001000 00001000 00000100 00001100
212	11010100	00001000 00001100 00000000 00001000
213	11010101	00001000 00001100 00000000 00001100
214	11010110	00001000 00001100 00000100 00001000
215	11010111	00001000 00001100 00000100 00001100
216	11011000	00001100 00001000 00000000 00001000
217	11011001	00001100 00001000 00000000 00001100
218	11011010	00001100 00001000 00000100 00001000
219	11011011	00001100 00001000 00000100 00001100
220	11011100	00001100 00001100 00000000 00001000
221	11011101	00001100 00001100 00000000 00001100
222	11011110	00001100 00001100 00000100 00001000
223	11011111	00001100 00001100 00000100 00001100
224	11100000	00001000 00001000 00001000 00000000
225	11100001	00001000 00001000 00001000 00000100
226	11100010	00001000 00001000 00001100 00000000
227	11100011	00001000 00001000 00001100 00000100
228	11100100	00001000 00001100 00001000 00000000
229	11100101	00001000 00001100 00001000 00000100
230	11100110	00001000 00001100 00001100 00000000
231	11100111	00001000 00001100 00001100 00000100

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232	11101000	00001100 00001000 00001000 00000000
233	11101001	00001100 00001000 00001000 00000100
234	11101010	00001100 00001000 00001100 00000000
235	11101011	00001100 00001000 00001100 00000100
236	11101100	00001100 00001100 00001000 00000000
237	11101101	00001100 00001100 00001000 00000100
238	11101110	00001100 00001100 00001100 00000000
239	11101111	00001100 00001100 00001100 00000100
240	11110000	00001000 00001000 00001000 00001000
241	11110001	00001000 00001000 00001000 00001100
242	11110010	00001000 00001000 00001100 00001000
243	11110011	00001000 00001000 00001100 00001100
244	11110100	00001000 00001100 00001000 00001000
245	11110101	00001000 00001100 00001000 00001100
246	11110110	00001000 00001100 00001100 00001000
247	11110111	00001000 00001100 00001100 00001100
248	11111000	00001100 00001000 00001000 00001000
249	11111001	00001100 00001000 00001000 00001100
250	11111010	00001100 00001000 00001100 00001000
251	11111011	00001100 00001000 00001100 00001100
252	11111100	00001100 00001100 00001000 00001000
253	11111101	00001100 00001100 00001000 00001100
254	11111110	00001100 00001100 00001100 00001000
255	11111111	00001100 00001100 00001100 00001100

Date: **21 NOV 1995****LOOKUP TABLE 3 :**

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00000000	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 00010000
2	00000010	00000000 00000000 00010000 00000000
3	00000011	00000000 00000000 00010000 00010000
4	00000100	00000000 00010000 00000000 00000000
5	00000101	00000000 00010000 00000000 00010000
6	00000110	00000000 00010000 00010000 00000000
7	00000111	00000000 00010000 00010000 00010000
8	00001000	00010000 00000000 00000000 00000000
9	00001001	00010000 00000000 00000000 00010000
10	00001010	00010000 00000000 00010000 00000000
11	00001011	00010000 00000000 00010000 00010000
12	00001100	00010000 00010000 00000000 00000000
13	00001101	00010000 00010000 00000000 00010000
14	00001110	00010000 00010000 00010000 00000000
15	00001111	00010000 00010000 00010000 00010000
16	00010000	00000000 00000000 00000000 00100000
17	00010001	00000000 00000000 00000000 00110000
18	00010010	00000000 00000000 00010000 00100000
19	00010011	00000000 00000000 00010000 00110000
20	00010100	00000000 00010000 00000000 00100000
21	00010101	00000000 00010000 00000000 00110000
22	00010110	00000000 00010000 00010000 00100000
23	00010111	00000000 00010000 00010000 00110000
24	00011000	00010000 00000000 00000000 00100000
25	00011001	00010000 00000000 00000000 00110000
26	00011010	00010000 00000000 00010000 00100000
27	00011011	00010000 00000000 00010000 00110000
28	00011100	00010000 00010000 00000000 00100000
29	00011101	00010000 00010000 00000000 00110000
30	00011110	00010000 00010000 00010000 00100000
31	00011111	00010000 00010000 00010000 00110000
32	00100000	00000000 00000000 00100000 00000000
33	00100001	00000000 00000000 00100000 00010000
34	00100010	00000000 00000000 00110000 00000000
35	00100011	00000000 00000000 00110000 00010000
36	00100100	00000000 00010000 00100000 00000000
37	00100101	00000000 00010000 00100000 00010000
38	00100110	00000000 00010000 00110000 00000000
39	00100111	00000000 00010000 00110000 00010000

40	00101000	00010000 00000000 00100000 00000000
41	00101001	00010000 00000000 00100000 00010000
42	00101010	00010000 00000000 00110000 00000000
43	00101011	00010000 00000000 00110000 00010000
44	00101100	00010000 00010000 00100000 00000000
45	00101101	00010000 00010000 00100000 00010000
46	00101110	00010000 00010000 00110000 00000000
47	00101111	00010000 00010000 00110000 00010000
48	00110000	00000000 00000000 00100000 00100000
49	00110001	00000000 00000000 00100000 00110000
50	00110010	00000000 00000000 00110000 00100000
51	00110011	00000000 00000000 00110000 00110000
52	00110100	00000000 00010000 00100000 00100000
53	00110101	00000000 00010000 00100000 00110000
54	00110110	00000000 00010000 00110000 00100000
55	00110111	00000000 00010000 00110000 00110000
56	00111000	00010000 00000000 00100000 00100000
57	00111001	00010000 00000000 00100000 00110000
58	00111010	00010000 00000000 00110000 00100000
59	00111011	00010000 00000000 00110000 00110000
60	00111100	00010000 00010000 00100000 00100000
61	00111101	00010000 00010000 00100000 00110000
62	00111110	00010000 00010000 00110000 00100000
63	00111111	00010000 00010000 00110000 00110000
64	01000000	00000000 00100000 00000000 00000000
65	01000001	00000000 00100000 00000000 00010000
66	01000010	00000000 00100000 00010000 00000000
67	01000011	00000000 00100000 00010000 00010000
68	01000100	00000000 00110000 00000000 00000000
69	01000101	00000000 00110000 00000000 00010000
70	01000110	00000000 00110000 00010000 00000000
71	01000111	00000000 00110000 00010000 00010000
72	01001000	00010000 00100000 00000000 00000000
73	01001001	00010000 00100000 00000000 00010000
74	01001010	00010000 00100000 00010000 00000000
75	01001011	00010000 00100000 00010000 00010000
76	01001100	00010000 00110000 00000000 00000000
77	01001101	00010000 00110000 00000000 00010000
78	01001110	00010000 00110000 00010000 00000000
79	01001111	00010000 00110000 00010000 00010000
80	01010000	00000000 00100000 00000000 00100000
81	01010001	00000000 00100000 00000000 00110000
82	01010010	00000000 00100000 00010000 00100000
83	01010011	00000000 00100000 00010000 00110000
84	01010100	00000000 00110000 00000000 00100000
85	01010101	00000000 00110000 00000000 00110000
86	01010110	00000000 00110000 00010000 00100000
87	01010111	00000000 00110000 00010000 00110000

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88	01011000	00010000 00100000 00000000 00100000
89	01011001	00010000 00100000 00000000 00110000
90	01011010	00010000 00100000 00010000 00100000
91	01011011	00010000 00100000 00010000 00110000
92	01011100	00010000 00110000 00000000 00100000
93	01011101	00010000 00110000 00000000 00110000
94	01011110	00010000 00110000 00010000 00100000
95	01011111	00010000 00110000 00010000 00110000
96	01100000	00000000 00100000 00100000 00000000
97	01100001	00000000 00100000 00100000 00010000
98	01100010	00000000 00100000 00110000 00000000
99	01100011	00000000 00100000 00110000 00010000
100	01100100	00000000 00110000 00100000 00000000
101	01100101	00000000 00110000 00100000 00010000
102	01100110	00000000 00110000 00110000 00000000
103	01100111	00000000 00110000 00110000 00010000
104	01101000	00010000 00100000 00100000 00000000
105	01101001	00010000 00100000 00100000 00010000
106	01101010	00010000 00100000 00110000 00000000
107	01101011	00010000 00100000 00110000 00010000
108	01101100	00010000 00110000 00100000 00000000
109	01101101	00010000 00110000 00100000 00010000
110	01101110	00010000 00110000 00110000 00000000
111	01101111	00010000 00110000 00110000 00010000
112	01110000	00000000 00100000 00100000 00100000
113	01110001	00000000 00100000 00100000 00110000
114	01110010	00000000 00100000 00110000 00100000
115	01110011	00000000 00100000 00110000 00110000
116	01110100	00000000 00110000 00100000 00100000
117	01110101	00000000 00110000 00100000 00110000
118	01110110	00000000 00110000 00110000 00100000
119	01110111	00000000 00110000 00110000 00110000
120	01111000	00010000 00100000 00100000 00100000
121	01111001	00010000 00100000 00100000 00110000
122	01111010	00010000 00100000 00110000 00100000
123	01111011	00010000 00100000 00110000 00110000
124	01111100	00010000 00110000 00100000 00100000
125	01111101	00010000 00110000 00100000 00110000
126	01111110	00010000 00110000 00110000 00100000
127	01111111	00010000 00110000 00110000 00110000
128	10000000	00100000 00000000 00000000 00000000
129	10000001	00100000 00000000 00000000 00010000
130	10000010	00100000 00000000 00010000 00000000
131	10000011	00100000 00000000 00010000 00010000
132	10000100	00100000 00010000 00000000 00000000
133	10000101	00100000 00010000 00000000 00010000
134	10000110	00100000 00010000 00010000 00000000
135	10000111	00100000 00010000 00010000 00010000

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136	10001000	00110000 00000000 00000000 00000000
137	10001001	00110000 00000000 00000000 00010000
138	10001010	00110000 00000000 00010000 00000000
139	10001011	00110000 00000000 00010000 00010000
140	10001100	00110000 00010000 00000000 00000000
141	10001101	00110000 00010000 00000000 00010000
142	10001110	00110000 00010000 00010000 00000000
143	10001111	00110000 00010000 00010000 00010000
144	10010000	00100000 00000000 00000000 00100000
145	10010001	00100000 00000000 00000000 00110000
146	10010010	00100000 00000000 00010000 00100000
147	10010011	00100000 00000000 00010000 00110000
148	10010100	00100000 00010000 00000000 00100000
149	10010101	00100000 00010000 00000000 00110000
150	10010110	00100000 00010000 00010000 00100000
151	10010111	00100000 00010000 00010000 00110000
152	10011000	00110000 00000000 00000000 00100000
153	10011001	00110000 00000000 00000000 00110000
154	10011010	00110000 00000000 00010000 00100000
155	10011011	00110000 00000000 00010000 00110000
156	10011100	00110000 00010000 00000000 00100000
157	10011101	00110000 00010000 00000000 00110000
158	10011110	00110000 00010000 00010000 00100000
159	10011111	00110000 00010000 00010000 00110000
160	10100000	00100000 00000000 00100000 00000000
161	10100001	00100000 00000000 00100000 00010000
162	10100010	00100000 00000000 00110000 00000000
163	10100011	00100000 00000000 00110000 00010000
164	10100100	00100000 00010000 00100000 00000000
165	10100101	00100000 00010000 00100000 00010000
166	10100110	00100000 00010000 00110000 00000000
167	10100111	00100000 00010000 00110000 00010000
168	10101000	00110000 00000000 00100000 00000000
169	10101001	00110000 00000000 00100000 00010000
170	10101010	00110000 00000000 00110000 00000000
171	10101011	00110000 00000000 00110000 00010000
172	10101100	00110000 00010000 00100000 00000000
173	10101101	00110000 00010000 00100000 00010000
174	10101110	00110000 00010000 00110000 00000000
175	10101111	00110000 00010000 00110000 00010000
176	10110000	00100000 00000000 00100000 00100000
177	10110001	00100000 00000000 00100000 00110000
178	10110010	00100000 00000000 00110000 00100000
179	10110011	00100000 00000000 00110000 00110000
180	10110100	00100000 00010000 00100000 00100000
181	10110101	00100000 00010000 00100000 00110000
182	10110110	00100000 00010000 00110000 00100000
183	10110111	00100000 00010000 00110000 00110000

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184	10111000	00110000 00000000 00100000 00100000
185	10111001	00110000 00000000 00100000 00110000
186	10111010	00110000 00000000 00110000 00100000
187	10111011	00110000 00000000 00110000 00110000
188	10111100	00110000 00010000 00100000 00100000
189	10111101	00110000 00010000 00100000 00110000
190	10111110	00110000 00010000 00110000 00100000
191	10111111	00110000 00010000 00110000 00110000
192	11000000	00100000 00100000 00000000 00000000
193	11000001	00100000 00100000 00000000 00010000
194	11000010	00100000 00100000 00010000 00000000
195	11000011	00100000 00100000 00010000 00010000
196	11000100	00100000 00110000 00000000 00000000
197	11000101	00100000 00110000 00000000 00010000
198	11000110	00100000 00110000 00010000 00000000
199	11000111	00100000 00110000 00010000 00010000
200	11001000	00110000 00100000 00000000 00000000
201	11001001	00110000 00100000 00000000 00010000
202	11001010	00110000 00100000 00010000 00000000
203	11001011	00110000 00100000 00010000 00010000
204	11001100	00110000 00110000 00000000 00000000
205	11001101	00110000 00110000 00000000 00010000
206	11001110	00110000 00110000 00010000 00000000
207	11001111	00110000 00110000 00010000 00010000
208	11010000	00100000 00100000 00000000 00100000
209	11010001	00100000 00100000 00000000 00110000
210	11010010	00100000 00100000 00010000 00100000
211	11010011	00100000 00100000 00010000 00110000
212	11010100	00100000 00110000 00000000 00100000
213	11010101	00100000 00110000 00000000 00110000
214	11010110	00100000 00110000 00010000 00100000
215	11010111	00100000 00110000 00010000 00110000
216	11011000	00110000 00100000 00000000 00100000
217	11011001	00110000 00100000 00000000 00110000
218	11011010	00110000 00100000 00010000 00100000
219	11011011	00110000 00100000 00010000 00110000
220	11011100	00110000 00110000 00000000 00100000
221	11011101	00110000 00110000 00000000 00110000
222	11011110	00110000 00110000 00010000 00100000
223	11011111	00110000 00110000 00010000 00110000
224	11100000	00100000 00100000 00100000 00000000
225	11100001	00100000 00100000 00100000 00010000
226	11100010	00100000 00100000 00110000 00000000
227	11100011	00100000 00100000 00110000 00010000
228	11100100	00100000 00110000 00100000 00000000
229	11100101	00100000 00110000 00100000 00010000
230	11100110	00100000 00110000 00110000 00000000
231	11100111	00100000 00110000 00110000 00010000

232 11101000
 233 11101001
 234 11101010
 235 11101011
 236 11101100
 237 11101101
 238 11101110
 239 11101111

240 11110000
 241 11110001
 242 11110010
 243 11110011
 244 11110100
 245 11110101
 246 11110110
 247 11110111

248 11111000
 249 11111001
 250 11111010
 251 11111011
 252 11111100
 253 11111101
 254 11111110
 255 11111111

00110000 00100000 00100000 00000000
 00110000 00100000 00100000 00010000
 00110000 00100000 00110000 00000000
 00110000 00100000 00110000 00010000
 00110000 00110000 00100000 00000000
 00110000 00110000 00100000 00010000
 00110000 00110000 00110000 00000000
 00110000 00110000 00110000 00010000

00100000 00100000 00100000 00100000
 00100000 00100000 00100000 00110000
 00100000 00100000 00110000 00100000
 00100000 00100000 00110000 00110000
 00100000 00110000 00100000 00100000
 00100000 00110000 00100000 00110000
 00100000 00110000 00110000 00100000
 00100000 00110000 00110000 00110000

00110000 00100000 00100000 00100000
 00110000 00100000 00100000 00110000
 00110000 00100000 00110000 00100000
 00110000 00100000 00110000 00110000
 00110000 00110000 00100000 00100000
 00110000 00110000 00100000 00110000
 00110000 00110000 00110000 00100000
 00110000 00110000 00110000 00110000

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LOOKUP TABLE 4 :

ENTRY	FROM BINARY REPRESENTATION	TO BINARY REPRESENTATION
0	00000000	00000000 00000000 00000000 00000000
1	00000001	00000000 00000000 00000000 01000000
2	00000010	00000000 00000000 01000000 00000000
3	00000011	00000000 00000000 01000000 01000000
4	00000100	00000000 01000000 00000000 00000000
5	00000101	00000000 01000000 00000000 01000000
6	00000110	00000000 01000000 01000000 00000000
7	00000111	00000000 01000000 01000000 01000000
8	00001000	01000000 00000000 00000000 00000000
9	00001001	01000000 00000000 00000000 01000000
10	00001010	01000000 00000000 01000000 00000000
11	00001011	01000000 00000000 01000000 01000000
12	00001100	01000000 01000000 00000000 00000000
13	00001101	01000000 01000000 00000000 01000000
14	00001110	01000000 01000000 01000000 00000000
15	00001111	01000000 01000000 01000000 01000000
16	00010000	00000000 00000000 00000000 10000000
17	00010001	00000000 00000000 00000000 11000000
18	00010010	00000000 00000000 01000000 10000000
19	00010011	00000000 00000000 01000000 11000000
20	00010100	00000000 01000000 00000000 10000000
21	00010101	00000000 01000000 00000000 11000000
22	00010110	00000000 01000000 01000000 10000000
23	00010111	00000000 01000000 01000000 11000000
24	00011000	01000000 00000000 00000000 10000000
25	00011001	01000000 00000000 00000000 11000000
26	00011010	01000000 00000000 01000000 10000000
27	00011011	01000000 00000000 01000000 11000000
28	00011100	01000000 01000000 00000000 10000000
29	00011101	01000000 01000000 00000000 11000000
30	00011110	01000000 01000000 01000000 10000000
31	00011111	01000000 01000000 01000000 11000000
32	00100000	00000000 00000000 10000000 00000000
33	00100001	00000000 00000000 10000000 01000000
34	00100010	00000000 00000000 11000000 00000000
35	00100011	00000000 00000000 11000000 01000000
36	00100100	00000000 01000000 10000000 00000000
37	00100101	00000000 01000000 10000000 01000000
38	00100110	00000000 01000000 11000000 00000000
39	00100111	00000000 01000000 11000000 01000000

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40	00101000	01000000 00000000 10000000 00000000
41	00101001	01000000 00000000 10000000 01000000
42	00101010	01000000 00000000 11000000 00000000
43	00101011	01000000 00000000 11000000 01000000
44	00101100	01000000 01000000 10000000 00000000
45	00101101	01000000 01000000 10000000 01000000
46	00101110	01000000 01000000 11000000 00000000
47	00101111	01000000 01000000 11000000 01000000
48	00110000	00000000 00000000 10000000 10000000
49	00110001	00000000 00000000 10000000 11000000
50	00110010	00000000 00000000 11000000 10000000
51	00110011	00000000 00000000 11000000 11000000
52	00110100	00000000 01000000 10000000 10000000
53	00110101	00000000 01000000 10000000 11000000
54	00110110	00000000 01000000 11000000 10000000
55	00110111	00000000 01000000 11000000 11000000
56	00111000	01000000 00000000 10000000 10000000
57	00111001	01000000 00000000 10000000 11000000
58	00111010	01000000 00000000 11000000 10000000
59	00111011	01000000 00000000 11000000 11000000
60	00111100	01000000 01000000 10000000 10000000
61	00111101	01000000 01000000 10000000 11000000
62	00111110	01000000 01000000 11000000 10000000
63	00111111	01000000 01000000 11000000 11000000
64	01000000	00000000 10000000 00000000 00000000
65	01000001	00000000 10000000 00000000 01000000
66	01000010	00000000 10000000 01000000 00000000
67	01000011	00000000 10000000 01000000 01000000
68	01000100	00000000 11000000 00000000 00000000
69	01000101	00000000 11000000 00000000 01000000
70	01000110	00000000 11000000 01000000 00000000
71	01000111	00000000 11000000 01000000 01000000
72	01001000	01000000 10000000 00000000 00000000
73	01001001	01000000 10000000 00000000 01000000
74	01001010	01000000 10000000 01000000 00000000
75	01001011	01000000 10000000 01000000 01000000
76	01001100	01000000 11000000 00000000 00000000
77	01001101	01000000 11000000 00000000 01000000
78	01001110	01000000 11000000 01000000 00000000
79	01001111	01000000 11000000 01000000 01000000
80	01010000	00000000 10000000 00000000 10000000
81	01010001	00000000 10000000 00000000 11000000
82	01010010	00000000 10000000 01000000 10000000
83	01010011	00000000 10000000 01000000 11000000
84	01010100	00000000 11000000 00000000 10000000
85	01010101	00000000 11000000 00000000 11000000
86	01010110	00000000 11000000 01000000 10000000
87	01010111	00000000 11000000 01000000 11000000

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88	01011000	01000000 10000000 00000000 10000000
89	01011001	01000000 10000000 00000000 11000000
90	01011010	01000000 10000000 01000000 10000000
91	01011011	01000000 10000000 01000000 11000000
92	01011100	01000000 11000000 00000000 10000000
93	01011101	01000000 11000000 00000000 11000000
94	01011110	01000000 11000000 01000000 10000000
95	01011111	01000000 11000000 01000000 11000000
96	01100000	00000000 10000000 10000000 00000000
97	01100001	00000000 10000000 10000000 01000000
98	01100010	00000000 10000000 11000000 00000000
99	01100011	00000000 10000000 11000000 01000000
100	01100100	00000000 11000000 10000000 00000000
101	01100101	00000000 11000000 10000000 01000000
102	01100110	00000000 11000000 11000000 00000000
103	01100111	00000000 11000000 11000000 01000000
104	01101000	01000000 10000000 10000000 00000000
105	01101001	01000000 10000000 10000000 01000000
106	01101010	01000000 10000000 11000000 00000000
107	01101011	01000000 10000000 11000000 01000000
108	01101100	01000000 11000000 10000000 00000000
109	01101101	01000000 11000000 10000000 01000000
110	01101110	01000000 11000000 11000000 00000000
111	01101111	01000000 11000000 11000000 01000000
112	01110000	00000000 10000000 10000000 10000000
113	01110001	00000000 10000000 10000000 11000000
114	01110010	00000000 10000000 11000000 10000000
115	01110011	00000000 10000000 11000000 11000000
116	01110100	00000000 11000000 10000000 10000000
117	01110101	00000000 11000000 10000000 11000000
118	01110110	00000000 11000000 11000000 10000000
119	01110111	00000000 11000000 11000000 11000000
120	01111000	01000000 10000000 10000000 10000000
121	01111001	01000000 10000000 10000000 11000000
122	01111010	01000000 10000000 11000000 10000000
123	01111011	01000000 10000000 11000000 11000000
124	01111100	01000000 11000000 10000000 10000000
125	01111101	01000000 11000000 10000000 11000000
126	01111110	01000000 11000000 11000000 10000000
127	01111111	01000000 11000000 11000000 11000000
128	10000000	10000000 00000000 00000000 00000000
129	10000001	10000000 00000000 00000000 01000000
130	10000010	10000000 00000000 01000000 00000000
131	10000011	10000000 00000000 01000000 01000000
132	10000100	10000000 01000000 00000000 00000000
133	10000101	10000000 01000000 00000000 01000000
134	10000110	10000000 01000000 01000000 00000000
135	10000111	10000000 01000000 01000000 01000000

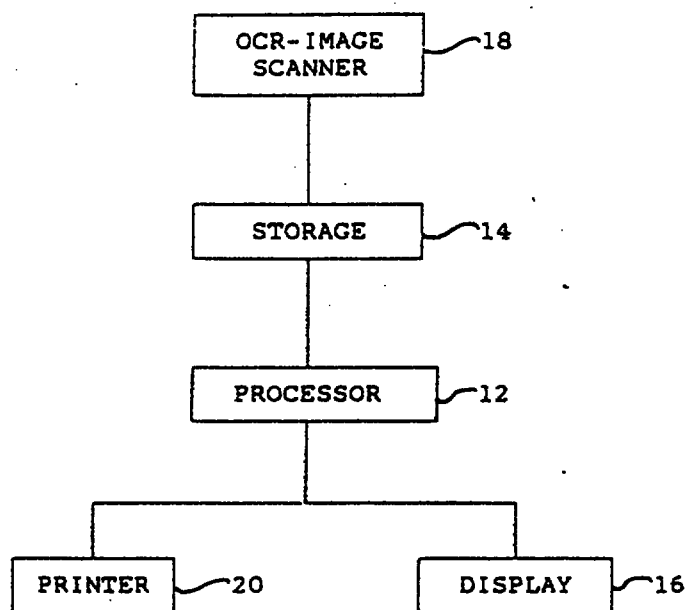
136	10001000	11000000 00000000 00000000 00000000
137	10001001	11000000 00000000 00000000 01000000
138	10001010	11000000 00000000 01000000 00000000
139	10001011	11000000 00000000 01000000 01000000
140	10001100	11000000 01000000 00000000 00000000
141	10001101	11000000 01000000 00000000 01000000
142	10001110	11000000 01000000 01000000 00000000
143	10001111	11000000 01000000 01000000 01000000
144	10010000	10000000 00000000 00000000 10000000
145	10010001	10000000 00000000 00000000 11000000
146	10010010	10000000 00000000 01000000 10000000
147	10010011	10000000 00000000 01000000 11000000
148	10010100	10000000 01000000 00000000 10000000
149	10010101	10000000 01000000 00000000 11000000
150	10010110	10000000 01000000 01000000 10000000
151	10010111	10000000 01000000 01000000 11000000
152	10011000	11000000 00000000 00000000 10000000
153	10011001	11000000 00000000 00000000 11000000
154	10011010	11000000 00000000 01000000 10000000
155	10011011	11000000 00000000 01000000 11000000
156	10011100	11000000 01000000 00000000 10000000
157	10011101	11000000 01000000 00000000 11000000
158	10011110	11000000 01000000 01000000 10000000
159	10011111	11000000 01000000 01000000 11000000
160	10100000	10000000 00000000 10000000 00000000
161	10100001	10000000 00000000 10000000 01000000
162	10100010	10000000 00000000 11000000 00000000
163	10100011	10000000 00000000 11000000 01000000
164	10100100	10000000 01000000 10000000 00000000
165	10100101	10000000 01000000 10000000 01000000
166	10100110	10000000 01000000 11000000 00000000
167	10100111	10000000 01000000 11000000 01000000
168	10101000	11000000 00000000 10000000 00000000
169	10101001	11000000 00000000 10000000 01000000
170	10101010	11000000 00000000 11000000 00000000
171	10101011	11000000 00000000 11000000 01000000
172	10101100	11000000 01000000 10000000 00000000
173	10101101	11000000 01000000 10000000 01000000
174	10101110	11000000 01000000 11000000 00000000
175	10101111	11000000 01000000 11000000 01000000
176	10110000	10000000 00000000 10000000 10000000
177	10110001	10000000 00000000 10000000 11000000
178	10110010	10000000 00000000 11000000 10000000
179	10110011	10000000 00000000 11000000 11000000
180	10110100	10000000 01000000 10000000 10000000
181	10110101	10000000 01000000 10000000 11000000
182	10110110	10000000 01000000 11000000 10000000
183	10110111	10000000 01000000 11000000 11000000

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184	10111000	11000000 00000000 10000000 10000000
185	10111001	11000000 00000000 10000000 11000000
186	10111010	11000000 00000000 11000000 10000000
187	10111011	11000000 00000000 11000000 11000000
188	10111100	11000000 01000000 10000000 10000000
189	10111101	11000000 01000000 10000000 11000000
190	10111110	11000000 01000000 11000000 10000000
191	10111111	11000000 01000000 11000000 11000000
192	11000000	10000000 10000000 00000000 00000000
193	11000001	10000000 10000000 00000000 01000000
194	11000010	10000000 10000000 01000000 00000000
195	11000011	10000000 10000000 01000000 01000000
196	11000100	10000000 11000000 00000000 00000000
197	11000101	10000000 11000000 00000000 01000000
198	11000110	10000000 11000000 01000000 00000000
199	11000111	10000000 11000000 01000000 01000000
200	11001000	11000000 10000000 00000000 00000000
201	11001001	11000000 10000000 00000000 01000000
202	11001010	11000000 10000000 01000000 00000000
203	11001011	11000000 10000000 01000000 01000000
204	11001100	11000000 11000000 00000000 00000000
205	11001101	11000000 11000000 00000000 01000000
206	11001110	11000000 11000000 01000000 00000000
207	11001111	11000000 11000000 01000000 01000000
208	11010000	10000000 10000000 00000000 10000000
209	11010001	10000000 10000000 00000000 11000000
210	11010010	10000000 10000000 01000000 10000000
211	11010011	10000000 10000000 01000000 11000000
212	11010100	10000000 11000000 00000000 10000000
213	11010101	10000000 11000000 00000000 11000000
214	11010110	10000000 11000000 01000000 10000000
215	11010111	10000000 11000000 01000000 11000000
216	11011000	11000000 10000000 00000000 10000000
217	11011001	11000000 10000000 00000000 11000000
218	11011010	11000000 10000000 01000000 10000000
219	11011011	11000000 10000000 01000000 11000000
220	11011100	11000000 11000000 00000000 10000000
221	11011101	11000000 11000000 00000000 11000000
222	11011110	11000000 11000000 01000000 10000000
223	11011111	11000000 11000000 01000000 11000000
224	11100000	10000000 10000000 10000000 00000000
225	11100001	10000000 10000000 10000000 01000000
226	11100010	10000000 10000000 11000000 00000000
227	11100011	10000000 10000000 11000000 01000000
228	11100100	10000000 11000000 10000000 00000000
229	11100101	10000000 11000000 10000000 01000000
230	11100110	10000000 11000000 11000000 00000000
231	11100111	10000000 11000000 11000000 01000000

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232	11101000	11000000 10000000 10000000 00000000
233	11101001	11000000 10000000 10000000 01000000
234	11101010	11000000 10000000 11000000 00000000
235	11101011	11000000 10000000 11000000 01000000
236	11101100	11000000 11000000 10000000 00000000
237	11101101	11000000 11000000 10000000 01000000
238	11101110	11000000 11000000 11000000 00000000
239	11101111	11000000 11000000 11000000 01000000
240	11110000	10000000 10000000 10000000 10000000
241	11110001	10000000 10000000 10000000 11000000
242	11110010	10000000 10000000 11000000 10000000
243	11110011	10000000 10000000 11000000 11000000
244	11110100	10000000 11000000 10000000 10000000
245	11110101	10000000 11000000 10000000 11000000
246	11110110	10000000 11000000 11000000 10000000
247	11110111	10000000 11000000 11000000 11000000
248	11111000	11000000 10000000 10000000 10000000
249	11111001	11000000 10000000 10000000 11000000
250	11111010	11000000 10000000 11000000 10000000
251	11111011	11000000 10000000 11000000 11000000
252	11111100	11000000 11000000 10000000 10000000
253	11111101	11000000 11000000 10000000 11000000
254	11111110	11000000 11000000 11000000 10000000
255	11111111	11000000 11000000 11000000 11000000

1FIGURE 1

2

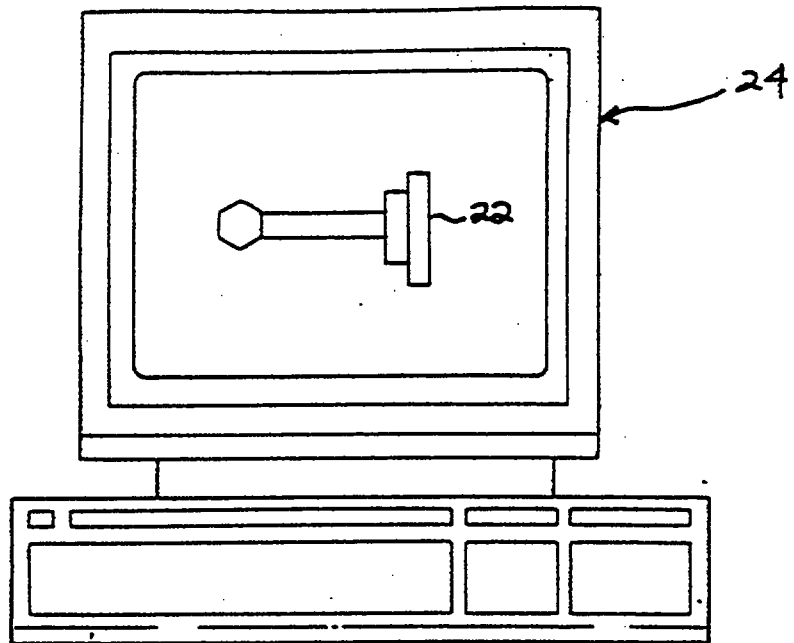


FIG. 2

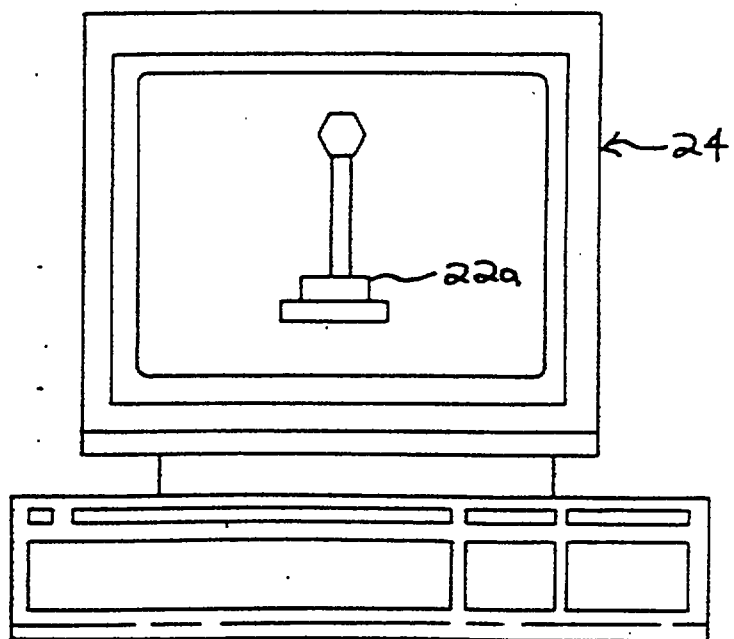


FIG. 3

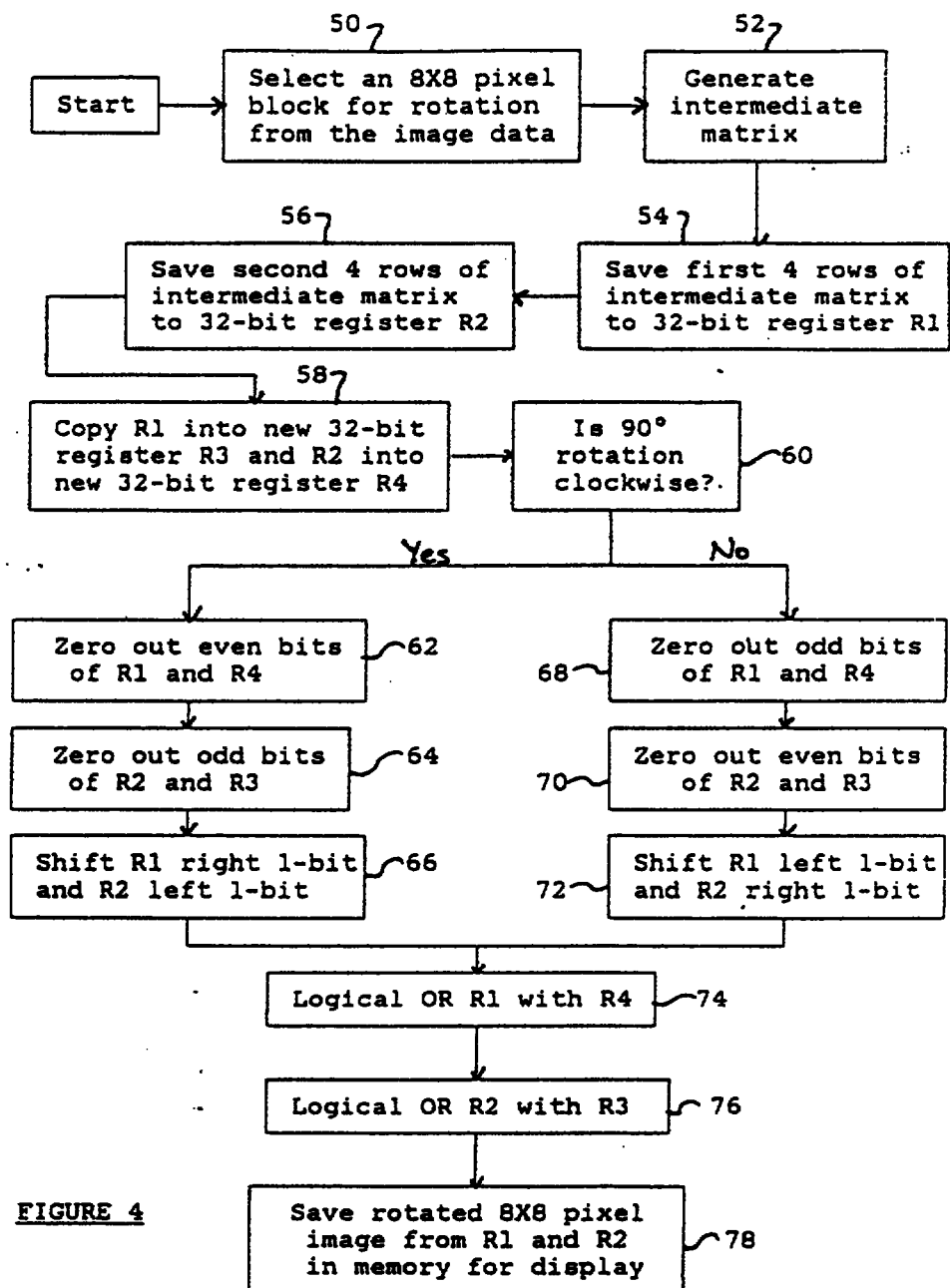


FIGURE 4

A SYSTEM FOR FAST 90 DEGREE ROTATION OF BI-LEVEL IMAGES

ABSTRACT

A method for rotating bi-level image data plus or minus 90 degrees. An 8 x 8 pixel block is selected for rotation from the image data and, using lookup tables, an intermediate matrix is generated dynamically and stored into two 32-bit registers in the processor. Generation of the intermediate matrix partially rotates and stores the odd-numbered rows from the block of data in the first 32-bit register and the even-numbered rows from the block in the second 32-bit register. The first and second registers are copied, respectively, into third and fourth 32-bit registers. The first and second registers are then shifted one bit in opposite directions.