

634372

FORM 1
REGULATION 9

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-1973

APPLICATION FOR A PATENT

We HUGHES AIRCRAFT COMPANY

of 7200 Hughes Terrace, Los Angeles, CALIFORNIA 90045-0066, U.S.A.

hereby apply for the grant of a Patent for an invention entitled:

IMPROVED DATA DECOMPRESSION SYSTEM AND METHOD

which is described in the accompanying complete specification. This Application is a Convention Application and is based on the Application numbered: 514,779 for a Patent or similar protection made in U.S.A. on 25 April 1990.

Our address for service is:

GRIFFITH HACK & CO
71 YORK STREET
SYDNEY NSW 2000

DATED this 10th day of April 1991

HUGHES AIRCRAFT COMPANY
By their Patent Attorney

5021054

10/04/91

GRIFFITH HACK & CO

TO: THE COMMISSIONER OF PATENTS
COMMONWEALTH OF AUSTRALIA

4338A:rk

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952 (AS AMENDED)

DECLARATION IN SUPPORT OF AN APPLICATION FOR A PATENT

In support of an Application made by: HUGHES AIRCRAFT COMPANY

for a patent for an invention entitled: IMPROVED DATA DECOMPRESSION
SYSTEM AND METHOD

I, Wanda K. Denson-Low
of 7200 Hughes Terrace
Los Angeles, California 90045-0066
United States of America

do solemnly and sincerely declare as follows:

1. I am authorised by the above mentioned applicant for the patent to make this Declaration on its behalf.
2. The name(s) and address(es) of each actual inventor(s) of the invention is as follows:

James F. Alves - 26305 West Bravo Lane, Calabasas, California 91302
United States of America

Jerry A. Burman - 4114 La Venta Drive, Westlake Village, California 91361
United States of America

and the fact(s) upon which the applicant is entitled to make this application are as follows:

An assignment by the inventor, to the applicant dated April 19, 1990

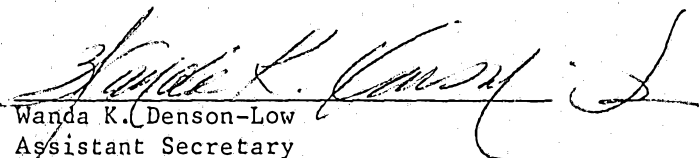
3. The basic application as defined by Section 141 of the Act was made as follows:

Country: United States of America on April 25, 1990

in the name(s) James F. Alves and Jerry A. Burman

4. The basic application referred to in the preceding paragraph of this Declaration was the first application made in a Convention country in respect of the invention the subject of this application.

Declared at Los Angeles, California, United States of America, this 7th
day of February, 1991

Signed: 

Wanda K. Denson-Low

Position: Assistant Secretary

GRIFFITH HACK & COMPANY, P.O. BOX 4164, G.P.O., SYDNEY, N.S.W. 2001
AUSTRALIA



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- (57) Claim

1. A data decompression system comprising:
an input memory adapted to store a data compressed image comprising a plurality of icons, each icon being one of a set of reference blocks of pixels representing an elemental feature of an image;
a decompression processor coupled to the input memory and adapted to generate a data compressed image in response to the plurality of icons of the data compressed image; and
image display means coupled to the decompression processor for displaying the data decompressed image.

COMMONWEALTH OF AUSTRALIA

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PATENTS ACT 1952

Form 10

COMPLETE SPECIFICATION
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TO BE COMPLETED BY APPLICANT

Name of Applicant: HUGHES AIRCRAFT COMPANY

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Complete Specification for the invention entitled:

IMPROVED DATA DECOMPRESSION SYSTEM AND METHOD

The following statement is a full description of this
invention, including the best method of performing it known
to us:-

GH&CO REF: 3782-NK:CLC:RK

4338A:rk

IMPROVED DATA DECOMPRESSION SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

Reference is made to a related patent application
entitled "Improved Data Compression System and Method,"
Serial No. 07/514,779 filed on 25th April 1990, which is
1 incorporated herein by reference and which issued as
U.S. Patent 5,048,112.

BACKGROUND

5 The present invention relates generally to data decompression, and in particu-
lar, to data decompression for images.

Conventional image data compression and decompression are used in various
systems, including database memory systems to reduce memory storage requirements
10 and in data communications systems to reduce communication bandwidth require-
ments. For such systems to provide high image fidelity, the data compression is cor-
respondingly low.

In conventional database memory systems, an image is data compressed and
the data compressed image is stored by a database memory. When the image is to be
15 displayed, the data compressed image is accessed from the database memory and is
decompressed for display.

In conventional communication systems, an image is data compressed, and
the data compressed image is communicated to a remote location. At the remote lo-
cation, the data compressed image is stored in a database memory in compressed
20 form. When the image is to be displayed at the remote location, the data compressed
image is accessed from the database memory and is decompressed for display.



SUMMARY OF THE INVENTION

The present invention is an improvement in data decompression for images, using relatively simple processing to restore an image and to provide improved data compression relative to the fidelity achieved. A preferred embodiment of the present invention is particularly appropriate for decompression of an image that has been data compressed in accordance with the teachings of the U.S. Patent No. 5,048,112. It reverses the data compression operations taught therein by reconstructing blocks of pixels from orthogonal icons and the related attributes. It is particularly effective in reconstructing orthogonal features occurring in the original image. These advantages are achieved by reconstructing a plurality of relatively small independent blocks of pixels into which the image was partitioned by the data compression processing. Each block of pixels is reconstructed by converting edge locations, dimensions, and intensities that are implicit in the stored icon and the attributes for that block of pixels into areas of constant intensity separated by intensity transitions or edges.

Orthogonal decompression, implemented by reconstructing small blocks of pixels along principal axes of intensity edges, reconstructs orthogonal features with good fidelity. The use of an optimum set of orthogonal icons and an optimum set of attributes for each icon further improves data decompression and fidelity.

A preferred embodiment of a data compression system comprises an input memory employed to store a data compressed image having a plurality of icons. A decompression processor is coupled to the input memory and is adapted to generate a data decompressed image in response to the plurality of icons thereof. A display monitor is coupled to the decompression processor for displaying the data decompressed image.



According to one aspect of the present invention there is provided a data decompression system comprising:

an input memory adapted to store a data compressed image comprising a plurality of icons, each icon being one of a set of reference blocks of pixels representing an elemental feature of an image;

a decompression processor coupled to the input memory and adapted to generate a data compressed image in response to the plurality of icons of the data compressed image; and

image display means coupled to the decompression processor for displaying the data decompressed image.

According to another aspect of the present invention there is provided a database memory system comprising:

an image input circuit adapted to generate an input image comprising a plurality of pixels;

a data compression processor coupled to the image input circuit and adapted to generate a data compressed image having a plurality of icons in response to the input image, each icon being one of a set of reference blocks of pixels representing an elemental feature of an image;

a database memory coupled to the data compression processor and adapted to store the data compressed image having the plurality of icons;

a decompression processor coupled to the database memory and adapted to generate a data decompressed image having a plurality of pixels in response to the data compressed image having the plurality of icons; and

image display means coupled to the decompression processor for displaying the data decompressed image.



BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the present invention will now be described by way of example only with reference to the accompanying drawings wherein like reference numerals
5 designate like structural elements, and in which:

Fig. 1A is a block diagram representation of a communication system using data decompression in accordance with the principles of the present invention;

Fig. 1B is a block diagram representation of a database memory system using data decompression in accordance with the principles of the present invention;

10 Fig. 1C is a block diagram representation of a data decompression subsystem in accordance with the principles of the present invention;

Fig. 2 is a diagram of a block of pixels having a ribbon icon that is decompressed in accordance with the principles of the present invention;

Fig. 3 is a diagram of symbolic icon types and the related attributes; and

15 Fig. 4, comprising Figs. 4A and 4B, is a detailed flow diagram of decompression operations.

DETAILED DESCRIPTION

A communication system 110 in accordance with the principles of the present invention is shown in Fig. 1A. A data compression subsystem 112 is coupled to a
20 communication subsystem 116 to communicate a data compressed image to a remote location. At the remote location, the communication subsystem 116 is coupled to a data decompression subsystem 120 which in turn is coupled to a display monitor 124. The data compression subsystem 112 data compresses an image in accordance with
25 the orthogonal compression arrangement and method described in US Patent No. 5,048,112.

The data compressed image is shown generated as a data compressed image signal 114 and is communicated to the remote location by the communication subsystem 116 as a communication signal 118. At the remote location, the communication signal 118 is decompressed by the data decompression subsystem 120, which generates
30 a decompressed image signal 122 and which is displayed by the display monitor 124.

A database memory system 130 in accordance with the principles of the present invention is shown in Fig. 1B. A data compression subsystem 112 is coupled to a database memory subsystem 136, which in turn is coupled a data decompression subsystem 120, and which in turn is coupled to a display monitor 124 in accordance
35 with the present invention. The data compression subsystem 112 data compresses an



1 image in accordance with the orthogonal compression arrangement and method de-
 scribed in the cross referenced patent application. The data compressed image is
 stored as a table of orthogonal icons and related attributes by the database memory
 subsystem 136. The image is displayed by accessing the data compressed image
 5 from the database memory 136 as signal 118 that is input to the data decompression
 subsystem 120, which generates a decompressed image signal 122. The display
 monitor 124 then displays the decompressed image in response to the decompressed
 image signal 122.

10 A decompression subsystem 120 in accordance with the principles of the
 present invention is shown in Fig. 1C. A compressed data memory 154 is coupled to
 a decompression processor 158. The decompression processor 158 is coupled to an
 image memory 162, which in turn is coupled to the display monitor 124 in accor-
 dance with the present invention. In the communication system 110 (Fig. 1A), the
 compressed image 118 received from the communication subsystem 116 is stored as
 15 a table of icons and related attributes in the compressed data memory 154 that is in-
 cluded in the data decompression subsystem 120. In a database memory system 130
 (Fig. 1B), the compressed image 118 is received from the database memory sub-
 system 136 is stored as a table of icons and related attributes in the compressed data
 memory 154. The compressed data memory 154 may be included in the data decom-
 20 pression subsystem 120 and is typically implemented as a buffer memory that stores
 data compressed image data.

The decompression processor 158 processes a data compressed image signal
 156 from the compressed data memory 154 and generates a decompressed image in-
 25 tensity signal 160 to be stored in the image memory 162 under control of two dimen-
 sional memory mapped row and column addresses 161. The decompression proces-
 sor 158 generates two dimensional memory mapped addresses to store the two di-
 mensional image into the image memory 162. The display monitor 124 is refreshed
 with refresh signal 122 from the image memory 162 to display the decompressed
 image.

30 The compressed data memory 154 is sequentially addressed to access the
 table of data compressed icons and related attributes in sequential tabular form. The
 image memory 162 is addressed in two dimensional memory map form to access a
 two dimensional image stored as columns and rows of pixels.

35 The image memory 162, operating under control of addresses 161 generated
 by the decompression processor 158, is implemented as a two dimensional memory
 map for storing a two dimensional image having 1,000 rows by 1,000 columns of

pixels (1,000,000 pixels). The image is partitioned into 10,000 blocks of pixels arranged in a two dimensional memory map array of 100 rows by 100 columns of blocks of pixels with each block of pixels having a two dimensional array of 10 rows by 10 columns of pixels. The block partitioning is implicit in the generating of each 10 by 10 array of pixels by the decompression processor 158. This two dimensional pixel and block addressing arrangement is discussed in more detail hereinafter.

The decompression processor 158 advances the block base address on a block-by-block basis (ten pixels at a time) for each row. As each row of blocks is accessed, it advances the block address on a block row by block row basis (ten pixels at a time) to access each row of blocks. For each block of pixels, the decompression processor 158 advances the pixel address in the selected block of pixels on a pixel-by-pixel basis (one pixel at a time) for each row of pixels. As each row of pixels is accessed, it advances the pixel address on a pixel row by pixel row basis (one pixel at a time) to access each row of pixels. Accessing of each block of pixels is accomplished by generating the same raster scan sequence of pixel addresses for each block of pixels and by indexing the pixel addresses with the block base address for the particular block of pixels. Because the present invention provides for processing of each block of pixels independent of each other block of pixels, the sequence of generating the blocks of pixels is not critical and parallel processing of independent blocks of pixels is facilitated.

A block of pixels 210 in accordance with the principles of the present invention is shown in Fig. 2. The block contains an array of 10 pixels by 10 pixels. Exterior regions of pixels 216, 218 have an exterior intensity and are separated by a ribbon region 214 having an interior intensity. The principle axis of the ribbon X axis and Y axis is defined by the angle ϕ . This ribbon icon diagram is discussed in detail hereinafter and is representative of other orthogonal icons discussed hereinafter.

A plurality of orthogonal icons 128 in accordance with the principles of the present invention are shown in Figs. 3A to 3E. Fig. 3A shows a flat icon 128a, Fig. 3B shows an edge icon 128b, Fig. 3C shows a ribbon icon 128c, Fig. 3D shows a corner icon 128d, and Fig. 3E shows a spot icon 128e. The icons 128 are shown with the principal axes at an angle of about 45 degrees to the axis of the block of pixels. The family of icons has been generated by data compression to be consistent with the types of features that they are intended to generate.

The flat icon 128a (Fig. 2A) represents a block of pixels 320 that has no discernible structure or that is roughly uniform or specular in intensity distribution. The flat icon 128a does not have any edges and hence generates a block of pixels 320

1 having a constant average exterior intensity.

The edge icon 128b (Fig. 2B) represents a block of pixels 330 whose dominant structure is a single step transition in intensity. The edge icon 128b has 1 single edge and hence generates a block of pixels 330 having two regions 332, 334 of different intensities. The position of the edge is defined by the coordinates X_0 , Y_0 of the center of the edge. The exterior intensity 332 is defined as being in the opposite direction relative to an arrow pointing from the center of the edge toward the center of the block of pixels. The interior intensity 334 is defined as being in the same direction as an arrow pointing from the center of the edge toward the center of the block of pixels.

The ribbon icon 128c (Fig. 2C) represents a block of pixels 340 whose dominant structure consists of a ribbon having two parallel edges. The ribbon icon 128c has two parallel edges and hence generates a block of pixels 340 having an exterior intensity 344, 345 split by a ribbon of interior intensity 342. The position of the ribbon is defined by the coordinates X_0 , Y_0 of the center of the inside edge of the ribbon. The width of the ribbon is defined as the length of vector 346 that is normal to the two edges and interposed between the two edges.

The corner icon 128d (Fig. 2D) represents a block of pixels 350 whose dominant structure consists of two orthogonally intersecting intensity transitions. The corner icon 128d has a four sided region of edges with one of the edges corresponding with an edge of the block of pixels 350 and hence generates a block of pixels having an exterior intensity 352 and having a corner region of interior intensity 354. The position of the corner is defined by the coordinates X_0 , Y_0 of the center of the inside edge 358 of the corner. The width of the corner is defined as the length of vector 356 that is normal to the two edges and interposed between the two edges.

The spot icon 128e (Fig. 2E) represents a block of pixels 360 whose dominant structure consists of a small area which is significantly different in intensity from the rest of the region. The spot icon 128e has a four sided region of edges and hence generates a block of pixels 360 having an exterior intensity 362 and having a spot region of interior intensity 364. The position of the spot is defined by the coordinates X_0 , Y_0 of the center of the spot. The width of the corner is defined as the magnitude of the edge 366 and the length of the corner is defined as the magnitude of the edge 368.

A flow diagram 400 of decompression operations in accordance with the principles of the present invention is shown in Figs. 4A and 4B. Figs. 4A and 4B are coupled with coupling symbols A 450, B 451, and C 452. These coupling symbols

1 450-452 have the same reference numerals in both, Fig. 4A and Fig. 4B.

The flow diagram is implemented in the decompression processor 158 by accessing icon parameters from the compressed data memory 154 and by storing blocks of pixels related thereto into the image memory 162. Each block of pixels is decom-
 5 pressed by accessing an icon and the related attributes from the compressed data memory 154, scanning a block of 100 pixels by 100 pixels into the appropriate block position in the image memory 162 in response to the icon that is related to that block of pixels, and then advancing to the next icon and block of pixels in sequence. The scanning of pixels into a block of pixels in the image memory 162 is performed in
 10 raster scan form, column by column and row by row for each of ten columns in a row of pixels and for ten rows of pixels. The sequencing of blocks of pixels into the image memory 162 is performed in raster scan form, column by column and row by row for each of ten columns in a row of blocks and for ten rows of blocks. The accessing of icons and attributes from the compressed data memory 154 is performed in
 15 sequence consistent with the block by block operations.

The program enters the decompression program through the ENTER operation 410 (Fig. 4A). The program then proceeds to the BLOCK INITIALIZATION operation 411 to initialize the block related parameters, which includes initializing the row address R_b to the zero row in the image memory 162, initializing the column
 20 address C_b to the zero column in the image memory 162, and initializing the icon address I_b to the zero icon address in the compressed data memory 154. The zero row address and the zero column address for the block of pixels in the image memory 162 identifies the corner of the image memory 162 at which the block raster scan begins.

The program then proceeds to the BLOCK LOOP of operations 441 which is
 25 executed iteratively, once for each block of pixels within an image. The BLOCK LOOP 441 commences with the ACCESS ICON operation 412 where the icon is accessed from the I_b address in the compressed data memory 154. The program then proceeds to the PIXEL INITIALIZATION operation 413 to initialize the pixel related parameters in the selected block of pixels addressed by the current values of C_b and R_b , as initialized in the BLOCK INITIALIZATION operation 411 above and as
 30 updated in the UPDATE BLOCK COLUMN operation 430 and in the UPDATE BLOCK ROW operation 434 below. In the PIXEL INITIALIZATION operation 413, the row address R_p is initialized to the zero row in the selected block and the column address C_p is initialized to the zero column in the selected block. The zero row address and the zero column address for the pixel in the selected block identifies the
 35 corner of the selected block at which the pixel raster scan begins.

The program then proceeds to the PIXEL LOOP of operations 442 which is executed iteratively, once for each pixel within a block. The PIXEL LOOP 442 commences with the ICON TEST operation 415 which tests the icon accessed in the ACCESS ICON operation 412 and calculates a position parameter associated with the current pixel in one of the CALCULATE operations 420, 430, 440, 450, or 460. The sign of the position parameter is indicative of whether the pixel is an interior pixel, as indicated by a negative sign, or an exterior pixel, as indicated by a positive sign.

Various equations used in the CALCULATE operations 420, 430, 440, 450, 460 are discussed below. In these equations the $F(C_P, R_P)$ term is the sign and magnitude of the pixel position parameter for the current pixel in the block of pixels, the $g(C_P, R_P)$ term and the $h(C_P, R_P)$ term are the signs and magnitudes of intermediate position parameters, the ϕ term is the angle of the principle axes, the C_P and R_P terms are the coordinates of the current pixel in the block, the $ABS[]$ term means the absolute magnitude of the bracketed term, the $Sn[]$ term means the sign of the bracketed term, and the OR term means a logical OR operation.

When a flat icon 128a is detected in the ICON TEST operation 415, the program branches along the FLAT path from the ICON TEST operation 415 to the

CALCULATE FLAT INTENSITY operation 420 where the position parameter polarity is set to be positive. This is because all pixel intensities in a flat icon block of pixels have the same intensity, which intensity is stored as an exterior intensity attribute.

When an edge icon 128b is detected in the ICON TEST operation 415, the program branches along the EDGE path from the ICON TEST operation 415 to the CALCULATE EDGE INTENSITY operation 430. Therein, the sign and magnitude of the pixel position parameter are calculated from the equation:

$F(C_P, R_P) = \cos(\phi)(C_P - X_0) + \sin(\phi)(R_P - Y_0)$, where the X_0 and Y_0 terms are the coordinates of the center position of the edge, as shown in Fig. 3B.

When a ribbon icon 128c is detected in the ICON TEST operation 415, the program branches along the RIBBON path from the ICON TEST operation 415 to the CALCULATE RIBBON INTENSITY operation 440. Therein, the sign and magnitude of the pixel position parameter are calculated from the equation:

$F(C_P, R_P) = ABS[\cos(\phi)(C_P - X_0) + \sin(\phi)(R_P - Y_0)] - \text{Width}/2$, where the X_0 and Y_0 terms are the coordinates of the center position of the ribbon and the Width term is the width of the ribbon 246 in a direction orthogonal to the length of the ribbon, as shown in Fig. 3C.

1 When a corner icon 128d is detected in the ICON TEST operation 415, the program branches along the CORNER path from the ICON TEST operation 415 to the CALCULATE CORNER INTENSITY operation 450 where the sign and magnitude of the pixel position parameter are calculated from the equations:

$$5 \quad g(C_P, R_P) = \text{ABS}[\text{Cos}(\phi)(C_P - X_0) + \text{Sin}(\phi)(R_P - Y_0)] - \text{Width}/2,$$

$$h(C_P, R_P) = \text{Cos}(\phi)(C_P - X_0) - \text{Sin}(\phi)(R_P - Y_0), \text{ and}$$

$$\text{Sn}[F(C_P, R_P)] = \text{Sn}[g(C_P, R_P)] \text{ OR } \text{Sn}[h(C_P, R_P)].$$

The X_0 and Y_0 terms are the coordinates of the center position of the corner and the Width term is the width of the corner 356, as shown in Fig. 3D. The $\text{Sn}[F(C_P, R_P)]$ equation means the sign of the $F(C_P, R_P)$ term is positive (implying an exterior intensity) when either the $g(C_P, R_P)$ term or the $h(C_P, R_P)$ term is positive and the sign of the $F(C_P, R_P)$ term is negative (implying an interior intensity) when both the $g(C_P, R_P)$ term and the $h(C_P, R_P)$ term are negative.

15 When a spot icon 128e is detected in the ICON TEST operation 415, the program branches along the SPOT path from the ICON TEST operation 415 to the CALCULATE SPOT INTENSITY operation 460 where the sign and magnitude of the pixel position parameter are calculated from the equations:

$$g(C_P, R_P) = \text{ABS}[\text{Cos}(\phi)(C_P - X_0) + \text{Sin}(\phi)(R_P - Y_0)] - \text{Width}/2,$$

$$h(C_P, R_P) = \text{ABS}[\text{Cos}(\phi)(R_P - Y_0) - \text{Sin}(\phi)(C_P - X_0)] - \text{Length}/2, \text{ and}$$

$$20 \quad \text{Sn}[F(C_P, R_P)] = \text{Sn}[g(C_P, R_P)] \text{ OR } \text{Sn}[h(C_P, R_P)].$$

The X_0 and Y_0 terms are the coordinates of the center position of the spot, the Width term is the width 366 of the spot in a first principle axis direction, and the Length term is the length 368 of the spot in a second principle axis direction. The $\text{Sn}[F(C_P, R_P)]$ equation means the sign of the $F(C_P, R_P)$ term is positive (implying an exterior intensity) when either the $g(C_P, R_P)$ term or the $h(C_P, R_P)$ term is positive and the sign of the $F(C_P, R_P)$ term is negative (implying an interior intensity) when both the $g(C_P, R_P)$ term and the $h(C_P, R_P)$ term are negative.

30 The program then proceeds from the selected one of the CALCULATE operations 420, 430, 440, 450, 460 to the SIGN TEST operation 417 where the sign of the position parameter is tested. If the sign of the position parameter is positive, then the program proceeds along the POSITIVE path to the STORE EXTERIOR INTENSITY operation 416, where the exterior intensity attribute for the current icon is stored in a pixel location in the image memory 162 addressed by the concatenated total column address C_T and total row address R_T in memory map form. If the sign of the position parameter is negative, then the program proceeds along the NEGATIVE path to the STORE INTERIOR INTENSITY operation 419, where the interior intensity

1 attribute for the current icon is stored in a pixel location in the image memory 162
addressed by the concatenated total column address C_T and total row address R_T in
memory map form. The total addresses are calculated from the sum of the block ad-
resses and the pixel addresses from the equations: $C_T = C_B + C_P$, and $R_T = R_B + R_P$.

5 This arrangement of keeping the pixel addresses and the block addresses sep-
arate and then combining them in the STORE EXTERIOR INTENSITY operation
416 and in the STORE INTERIOR INTENSITY operation 419 facilitates the selec-
tion of the blocks of pixels in raster scan form and the scanning of pixel intensities
into each block of pixels in raster scan form.

10 The program is coupled from Fig. 4A to Fig. 4B through coupling symbol A
450 (Fig. 4A and Fig. 4B). The program completes the current iteration through the
PIXEL LOOP 442. The program proceeds to the $C_P = C_{P_{MAX}}$ TEST operation 418
from the STORE EXTERIOR INTENSITY operation 416 or from the STORE INTE-
RIOR INTENSITY operation 419 to test if the scanout of the row of pixels has been
15 completed. If C_P is not equal to $C_{P_{MAX}}$, then the scanout of the row of pixels has not
yet been completed, where the program proceeds along the NO path from the $C_P = C_{P_{MAX}}$
TEST operation 418 to the UPDATE PIXEL COLUMN operation 428. In the
UPDATE PIXEL COLUMN operation 428, the C_P address is incremented to the next
pixel in the row of pixels and the R_P address is preserved. The program then loops
20 back in the PIXEL LOOP 442 from coupling symbol C 452 (Fig. 4B) to coupling
symbol C 452 (Fig. 4A) and then to the ICON TEST operation 415 to process the
next pixel in the current block of pixels. If C_P is equal to $C_{P_{MAX}}$, as determined in the
 $C_P = C_{P_{MAX}}$ TEST operation 418, then the scanout of the row of pixels has been com-
pleted, where the program proceeds along the YES path from the $C_P = C_{P_{MAX}}$ TEST
25 operation 418 to the $R_P = R_{P_{MAX}}$ TEST operation 422 to invoke processing for a new
row of pixels.

The program then proceeds to the $R_P = R_{P_{MAX}}$ TEST operation 422 from the $C_P = C_{P_{MAX}}$ TEST operation 418 to test if the last row of pixels has been completed. If
 R_P is not equal to $R_{P_{MAX}}$, then the row of pixels that has just been completed is not the
30 last row of pixels, where the program proceeds along the NO path from the $R_P = R_{P_{MAX}}$
TEST operation 422 to the UPDATE PIXEL ROW operation 426. In the UP-
DATE PIXEL ROW operation 426, the R_P address is incremented to the next row
and the C_P address is set to zero, which is the start of the next row. The program then
loops back in the PIXEL LOOP 442 to the ICON TEST operation 415 to process the
35 next pixel in the current block of pixels. If R_P is equal to $R_{P_{MAX}}$, as determined in the
 $R_P = R_{P_{MAX}}$ TEST operation 422, then the scanout of the last row of pixels has been

1 completed, where the program proceeds along the YES path from the $R_P = R_{P\text{ MAX}}$ TEST operation 422 to the $C_B = C_{B\text{ MAX}}$ TEST operation 424, exiting the PIXEL LOOP 442 and continuing in the BLOCK LOOP 441.

5 The program then completes the current iteration through the BLOCK LOOP 441. The program proceeds to the $C_B = C_{B\text{ MAX}}$ TEST operation 424 from the $R_P = R_{P\text{ MAX}}$ TEST operation 422 to test if the processing of the current row of blocks of pixels has been completed. If C_B is not equal to $C_{B\text{ MAX}}$, then the processing of the current row of blocks of pixels has not been completed, where the program proceeds along the NO path from the $C_B = C_{B\text{ MAX}}$ TEST operation 424 to the UPDATE BLOCK COLUMN operation 430. In the UPDATE BLOCK COLUMN operation 430, the C_B address is incremented to the next block in the row of blocks and the R_B address is preserved. The program then loops back in the BLOCK LOOP 441 from coupling symbol B 451 (Fig. 4B) to coupling symbol B 451 (Fig. 4A) and then to the ACCESS ICON operation 412 to process the next block of pixels in the image. If C_B is equal to $C_{B\text{ MAX}}$, as determined in the $C_B = C_{B\text{ MAX}}$ TEST operation 424, then the processing of the current row blocks of pixels has been completed, where the program proceeds along the YES path from the $C_B = C_{B\text{ MAX}}$ TEST operation 424 to the $R_B = R_{B\text{ MAX}}$ TEST operation 432 to invoke processing for a new row of blocks of pixels.

20 The program then proceeds to the $R_B = R_{B\text{ MAX}}$ TEST operation 432 from the $C_B = C_{B\text{ MAX}}$ TEST operation 424 to test if the last row of blocks of pixels has been completed. If R_B is not equal to $R_{B\text{ MAX}}$, then the row of blocks of pixels that has just been completed is not the last row of blocks of pixels, where the program proceeds along the NO path from the $R_B = R_{B\text{ MAX}}$ TEST operation 432 to the UPDATE BLOCK ROW operation 434. In the UPDATE BLOCK ROW operation 434, the R_B address is incremented to the next row of blocks of pixels and the C_B address is set to zero, which is the start of the next row. The program then loops back in the BLOCK LOOP 441 to the ACCESS ICON operation 412 to process the next block of pixels in the image. If R_B is equal to $R_{B\text{ MAX}}$, as determined in the $R_B = R_{B\text{ MAX}}$ TEST operation 432, then the processing of the last row of blocks of pixels has been completed, where the program proceeds along the YES path from the $R_B = R_{B\text{ MAX}}$ TEST operation 432 to the EXIT operation 446, exiting the BLOCK LOOP 441 and the program routine 400. Many alternative embodiments may be implemented from the teachings herein. For example, the image memory 162 and the compressed data memory 154 may be implemented as different memories and the decompression processor 158 may be partitioned to be in separate processors or in different portions of the same processor. Also, the decompression processor 158 may be implemented in parallel.

1 processing form, in pipeline processing form, in parallel pipeline processing form, or
in other processing forms. The decompression processor 158 may be implemented
for example by a stored program processor or by a special purpose hardwired proces-
5 sors, by array processors, or by RISC processors.

Thus there had been described a new and improved image data decompres-
sion system and method. It is to be understood that the above-described embodi-
ments are illustrative of some of the many specific embodiments that represent appli-
cations of the principles of the present invention. Clearly, numerous and varied other
10 arrangements may be designed by those skilled in the art without departing from the
scope of the invention.

It is to be understood that the above-described embodiment is merely illustra-
tive of some of the many specific embodiments which represent applications of the
principles of the present invention. Clearly, numerous and other arrangements may
15 be readily devised by those skilled in the art without departing from the scope of the
invention.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A data decompression system comprising:
an input memory adapted to store a data compressed
image comprising a plurality of icons, each icon being
one of a set of reference blocks of pixels representing
an elemental feature of an image;
a decompression processor coupled to the input
memory and adapted to generate a data compressed image in
response to the plurality of icons of the data compressed
image; and
image display means coupled to the decompression
processor for displaying the data decompressed image.
2. The data decompression system of claim 1,
wherein the decompression processor is adapted to
independently process each of the plurality of icons to
generate the data decompressed image.
3. The data compression system of claim 1, wherein
the decompression processor includes a pixel block
processor adapted to generate the data decompressed image
as a plurality of decompressed blocks of pixels, each
decompressed block of pixels being generated in response
to decompression processings of one of the icons of the
data compressed image.
4. The data compression system of claim 1, wherein
each of the plurality of icons includes a principle axis
angle, wherein the decompression processor includes a
principle axis processor adapted to generate the data
decompressed image as a plurality of decompressed blocks
of pixels, each decompressed block of pixels being
generated by decompression processing of an icon about a
principle axis in response to the principle axis angle.
5. The data compression system of claim 1, wherein
the plurality of icons include orthogonal icons, wherein
the decompression processor includes an orthogonal pixel
block processor adapted to generate the data decompressed
image as a plurality of decompressed blocks of pixels
having orthogonal features in response to the orthogonal



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icons, each decompressed block of pixels being generated in response to decompression processing of one of the orthogonal icons of the data compressed image.

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1 6. The data compression system of claim 1, wherein the decompression pro-
cessor includes a pixel block processor adapted to generate the data decompressed
image as a plurality of decompressed blocks of pixel features, each decompressed
block of pixels being generated in response to decompression processing of one of
5 the icons of the data compressed image, wherein the plurality of icons includes a flat
icon, and wherein the pixel block processor includes a flat icon processor adapted to
generate at least one of the decompressed blocks of pixels as a flat image feature
block of pixels having a constant intensity in response to the flat icon.

1 7. The data compression system of claim 1, wherein the decompression pro-
cessor includes a pixel block processor adapted to generate the data decompressed
image as a plurality of decompressed blocks of pixel features, each decompressed
block of pixels being generated in response to decompression processing of one of
5 the icons of the data compressed image, wherein the plurality of icons includes an
edge icon, and wherein the pixel block processor includes an edge icon processor
adapted to generate at least one of the decompressed blocks of pixels as an edge
image feature block of pixels having a single edge separating two intensity regions,
each intensity region having an intensity that is different from the intensity of the
10 other intensity region.

1 8. The data compression system of claim 1, wherein the decompression pro-
cessor includes a pixel block processor adapted to generate the data decompressed
image as a plurality of decompressed blocks of pixel features, each decompressed
block of pixels being generated in response to decompression processing of one of
5 the icons of the data compressed image, wherein the plurality of icons includes a rib-
bon icon, and wherein the pixel block processor includes a ribbon icon processor
adapted to generate at least one of the decompressed blocks of pixels as a ribbon
image feature block of pixels having an exterior intensity ribbon and having a ribbon
of an interior intensity formed by two edges and traversing a block of pixels.

1 9. The data compression system of claim 1, wherein the decompression pro-
 5 cessor includes a pixel block processor adapted to generate the data decompressed
 image as a plurality of decompressed blocks of pixel features, each decompressed
 block of pixels being generated in response to decompression processing of one of
 the icons of the data compressed image, wherein the plurality of icons includes a cor-
 ner icon, and wherein the pixel block processor includes a corner icon processor
 adapted to generate at least one of the decompressed blocks of pixels as a corner
 image feature block of pixels having an exterior intensity and having a corner with an
 interior intensity formed by three edges within the block of pixels.

1 10. The data compression system of claim 1, wherein the decompression pro-
 5 cessor includes a pixel block processor adapted to generate the data decompressed
 image as a plurality of decompressed blocks of pixel features, each decompressed
 block of pixels being generated in response to decompression processing of one of
 the icons of the data compressed image, wherein the plurality of icons includes a spot
 icon, and wherein the pixel block processor includes a spot icon processor adapted to
 generate at least one of the decompressed blocks of pixels as a spot image feature
 block of pixels having an exterior intensity and having a spot with an interior intensi-
 ty formed by four edges within the block of pixels.

1 11. A database memory system comprising:
 an image input circuit adapted to generate an input
 image comprising a plurality of pixels;
 a data compression processor coupled to the image
 5 input circuit and adapted to generate a data compressed
 image having a plurality of icons in response to the
 input image, each icon being one of a set of reference
 blocks of pixels representing an elemental feature of an
 image;
 10 a database memory coupled to the data compression
 processor and adapted to store the data compressed image
 having the plurality of icons;
 a decompression processor coupled to the database
 memory and adapted to generate a data decompressed image
 having a plurality of pixels in response to the data
 compressed image having the plurality of icons; and
 image display means coupled to the decompression
 processor for displaying the data decompressed image.



1 12. The database memory system of claim 11, wherein the decompression processor is adapted to independently process each of the plurality of icons to generate the data decompressed image.

1 13. The database memory system of claim 11, wherein the decompression processor includes a pixel block processor adapted to generate the data decompressed image as a plurality of decompressed blocks of pixels, each decompressed block of pixels being generated in response to decompression processing of an icon.

1 14. The database memory system of claim 11, wherein each of the plurality of icons includes a principle axis angle, wherein the decompression processor includes a principle axis processor adapted to generate the data decompressed image as a plurality of decompressed blocks of pixels, each decompressed block of pixels
5 being generated by decompression processing of an icon about a principle axis of the block of pixels in response to the principle axis angle.

1 15. A communication system comprising:
 an image input circuit adapted to generate an input image comprising a plurality of pixels;

5 a data compression processor coupled to the image input circuit and adapted to generate a data compressed image having a plurality of icons in response to the input image, each icon being one of a set of reference blocks of pixels representing an elemental feature of an image;

10 a communication subsystem coupled to the data compression processor and adapted to communicate the data compressed image having the plurality of icons to a remote location;

15 a decompression processor located at the remote location, and coupled to the communication system, and adapted to generate a data decompressed image having a plurality of pixels in response to the data compressed image having the plurality of icons; and

 image display means located at the remote location, and coupled to the decompression processor for displaying the data decompressed image.



1 16. The communication system of claim 15, wherein the decompression processor is adapted to process each of the plurality of icons independent of the processing of each of the other ones of the icons to generate the data decompressed image.

1 17. The communication system of claim 15, wherein the decompression processor includes a pixel block processor adapted to generate the data decompressed image as a plurality of decompressed blocks of pixels, each decompressed block of pixels being generated in response to decompression processing of an icon.

1 18. The communication system of claim 15, wherein each of the plurality of icons includes a principle axis angle, wherein the decompression processor includes a principle axis processor adapted to generate the data decompressed image as a plurality of decompressed blocks of pixels, each decompressed block of pixels being generated by decompression processing of an icon about a principle axis of the block of pixels in response to the principle axis angle.

1 19. A method of data decompressing an image, said method comprising the steps of:

5 storing a plurality of icons related to a data compressed image in a memory, each icon being one of a set of reference blocks of pixels representing an elemental feature of an image;

 accessing each of the plurality of icons stored in the memory;

1 generating a block of pixels in response to each of the plurality of accessed icons; and

 combining the blocks of pixels to form a decompressed image.

1 20. The method of claim 19 which further comprises the step of:

 independently processing each of the plurality of icons to generate the data decompressed image.

5 21. The method of claim 19 wherein the step of generating a block of pixels further comprises the step of:



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generating the data decompressed image as a plurality of decompressed blocks of pixels, each decompressed block of pixels being generated in response to decompression processing of one of the icons of the
5 data compressed image.



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1 22. The method of of claim 19 which further comprises the steps of:
 storing a plurality of icons wherein each of the plurality of icons includes a
 principle axes angle; and
 generating the data decompressed image as a plurality of decompressed
5 blocks of pixels by decompression processing of an icon about a principle axis in re-
 sponse to the principle axis angle.

1 23. The method of of claim 19 which further comprises the steps of:
 storing a plurality of icons wherein each of the plurality of icons includes an
 orthogonal icon; and
 generating the data decompressed image as a plurality of decompressed
5 blocks of pixels by decompression processing of one of the orthogonal icons of the
 data compressed image.

1 24. The method of of claim 19 which further comprises the steps of:
 storing a plurality of icons wherein each of the plurality of icons includes a
 flat icon; and
 generating at least one decompressed block of pixels as a flat image feature
5 block of pixels having a constant intensity in response to the flat icon.

1 25. The method of of claim 19 which further comprises the steps of:
 storing a plurality of icons wherein each of the plurality of icons includes an
 edge icon; and
 generating at least one edge image feature block of pixels having a single
5 edge separating two intensity regions, each intensity region having an intensity that is
 different from the intensity of the other intensity region.

1 26. The method of of claim 19 which further comprises the steps of:
 storing a plurality of icons wherein each of the plurality of icons includes a
 ribbon icon; and
 generating at least one of the decompressed blocks of pixels as a ribbon
5 image feature block of pixels having an exterior intensity ribbon and having a ribbon
 of an interior intensity formed by two edges and traversing a block of pixels.

1 27. The method of of claim 19 which further comprises the steps of:
 storing a plurality of icons wherein each of the plurality of icons includes a
 corner icon; and
 generating at least one of the decompressed blocks of pixels as a corner image
5 feature block of pixels having an exterior intensity and having a corner with an interi-
 or intensity formed by three edges within the block of pixels.

1 28. The method of of claim 19 which further comprises the steps of:
 storing a plurality of icons wherein each of the plurality of icons includes a
 spot icon; and
 generating at least one of the decompressed blocks of pixels as a spot image
5 feature block of pixels having an exterior intensity and having a spot with an interior
 intensity formed by four edges within the block of pixels.

 29. A method of data decompressing an image,
 substantially as hereinbefore described with reference
 to the accompanying drawings.

Dated this 10th day of April 1991

HUGHES AIRCRAFT COMPANY
By their Patent Attorney
GRIFFITH HACK & CO.

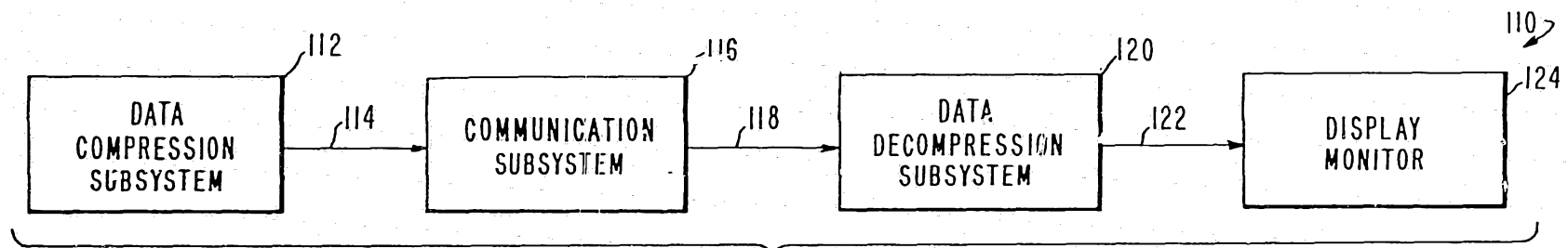


Fig. 1a.

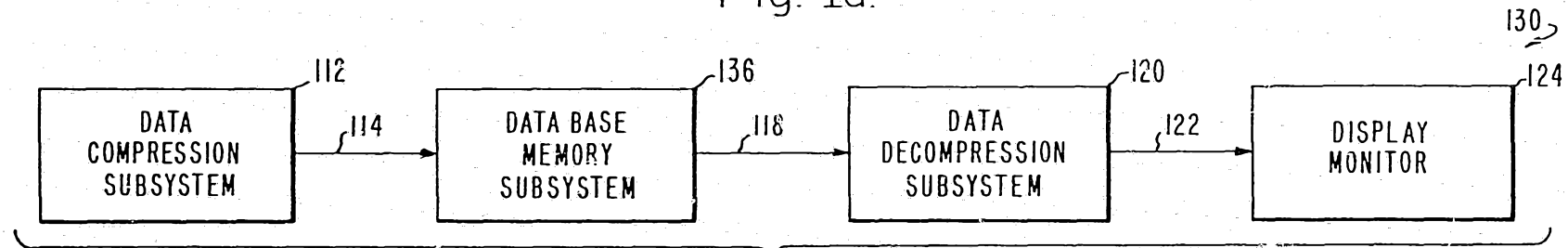


Fig. 1b.

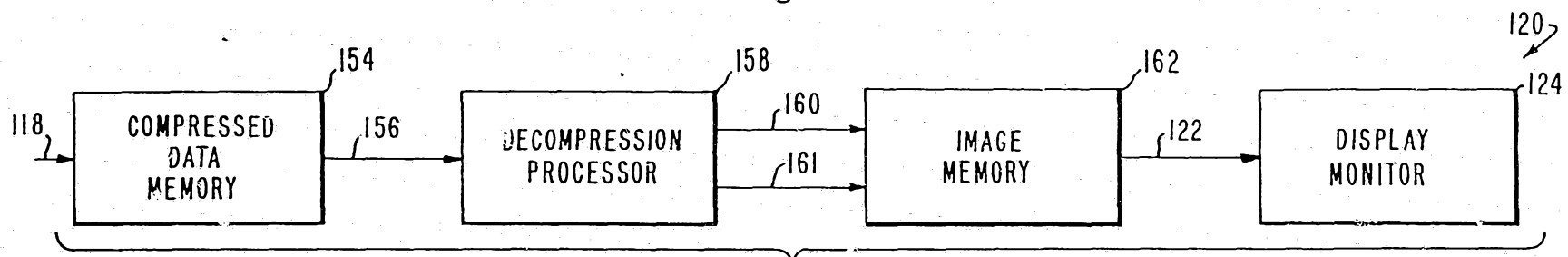


Fig. 1c.

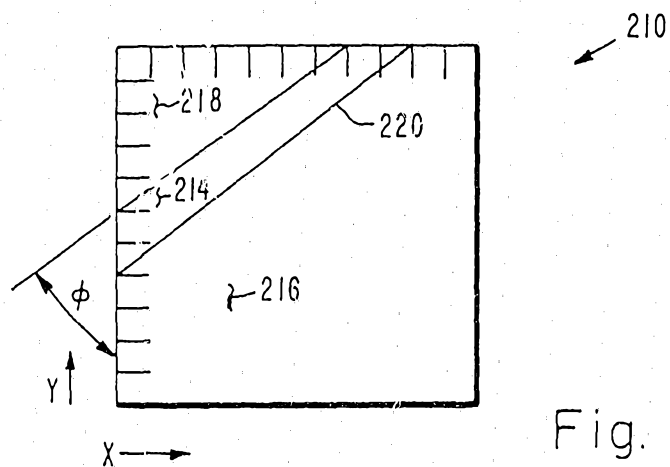


Fig. 2.

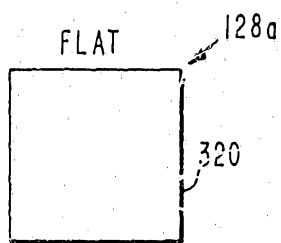


Fig. 3a.

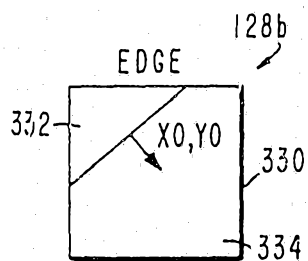


Fig. 3b.

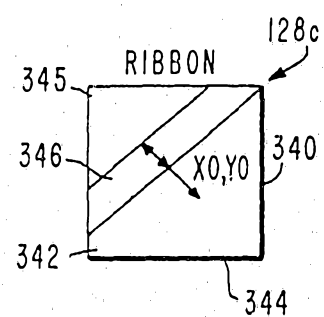


Fig. 3c.

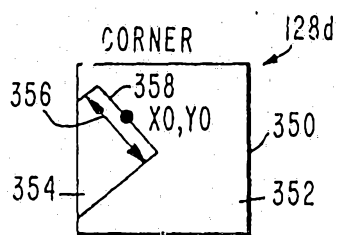


Fig. 3d.

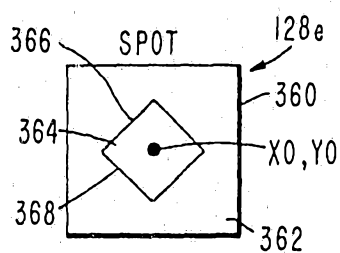


Fig. 3e.

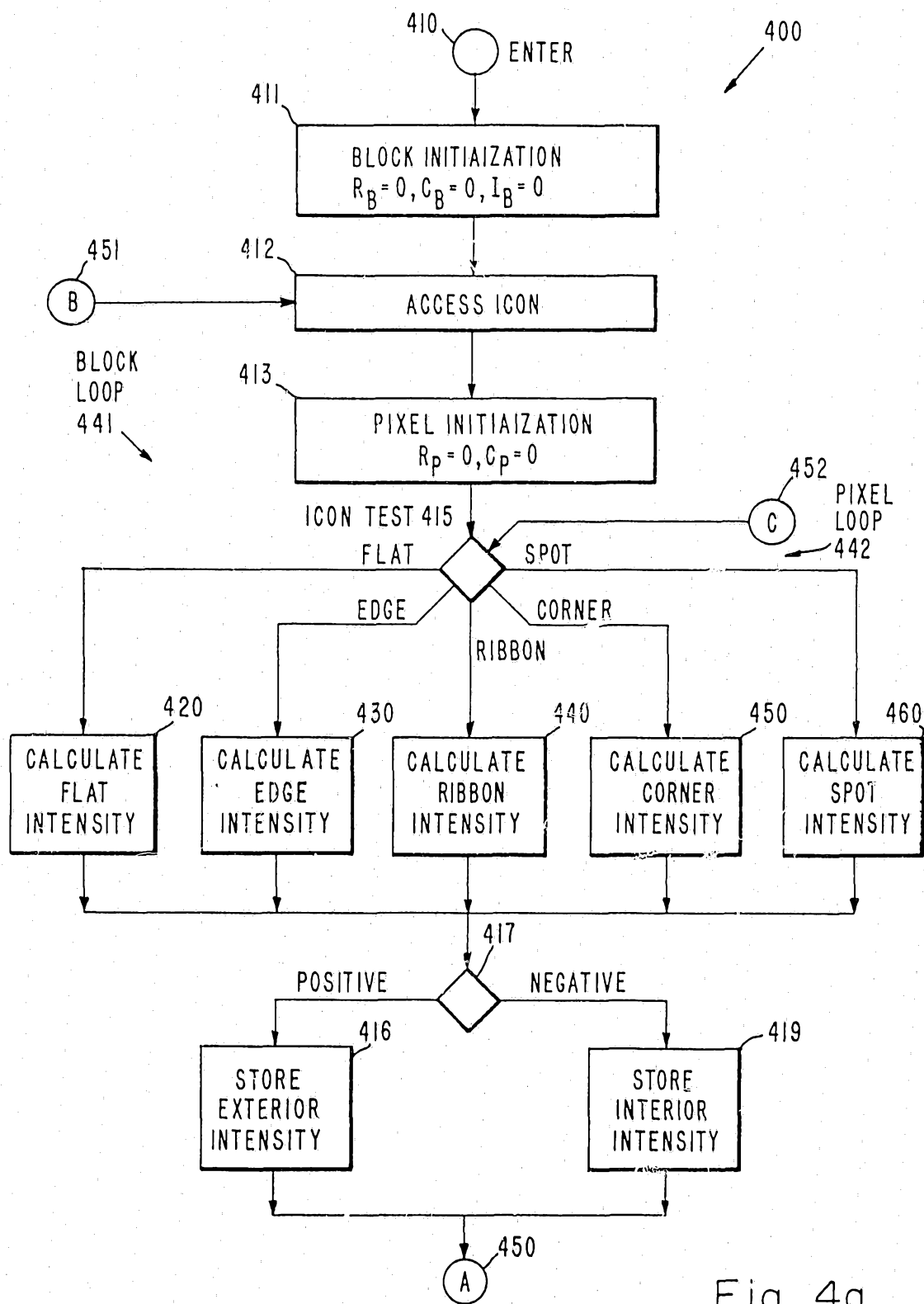


Fig. 4a.

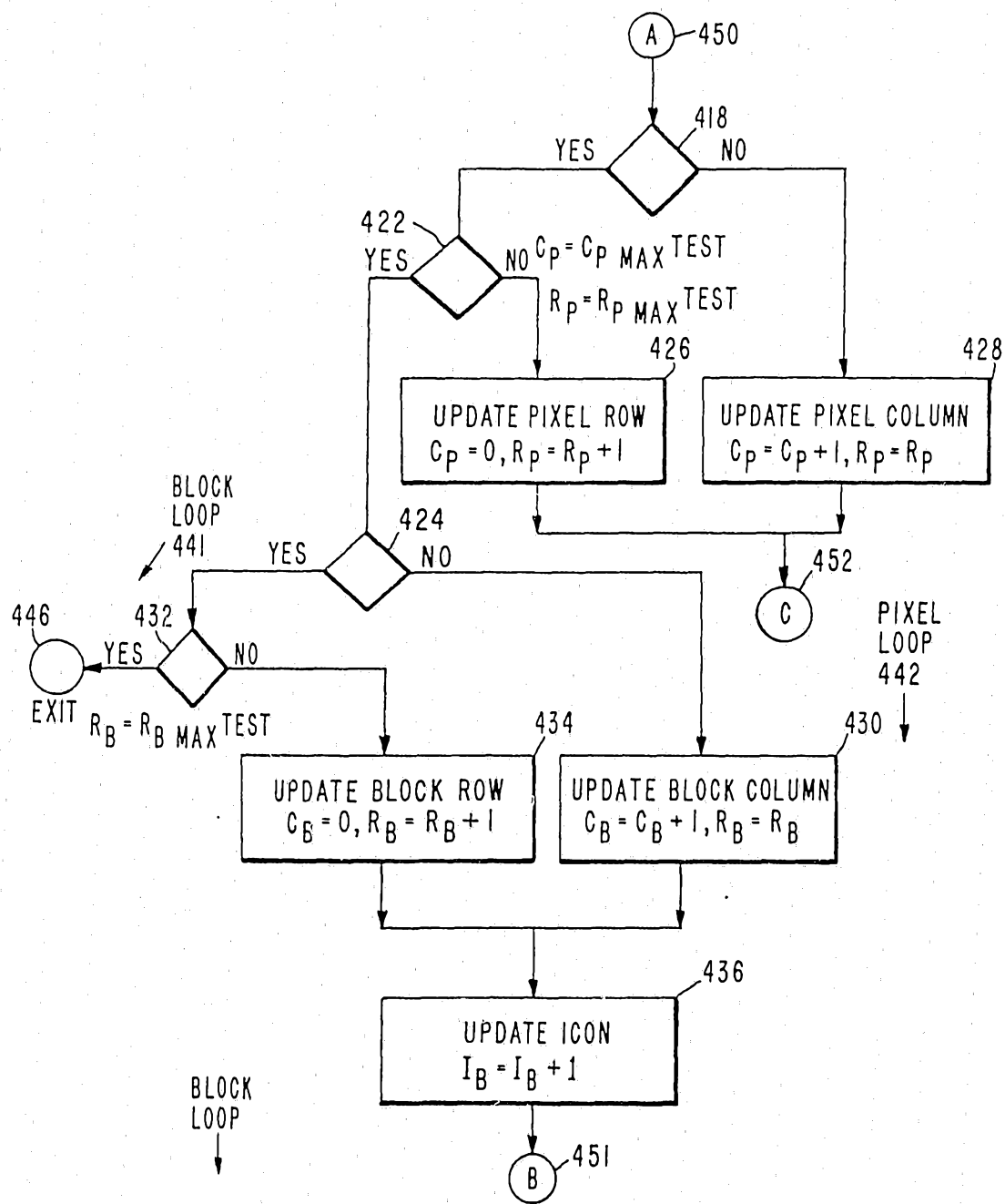


Fig. 4b.