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Fallon

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(54) **DATA COMPRESSION SYSTEMS AND METHODS**

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CPC ***H03M 7/3059*** (2013.01); ***G06T 9/00*** (2013.01); ***H03M 7/30*** (2013.01)

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CPC ... H03M 7/30; H03M 7/3059; H03M 7/3086; H03M 7/3088; H03M 7/48; H03M 7/3084; H03M 7/40; H03M 13/091
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See application file for complete search history.

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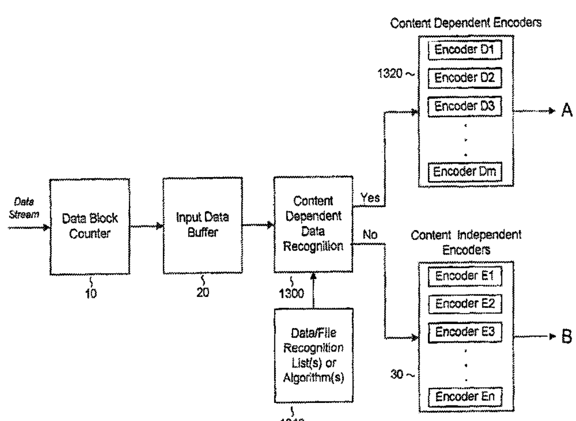
(57) **ABSTRACT**

Data compression using a combination of content independent data compression and content dependent data compression. In one aspect, a system for compressing data comprises: a processor; one or more content dependent data compression encoders; and a single data compression encoder. The processor is configured to analyze data within a data block to identify one or more parameters or attributes of the data wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based solely on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block; to perform content dependent data compression with the one or more content dependent data compression if the one or more parameters or attributes of the data are identified; and to perform data compression with the single data compression encoder, if the one or more parameters or attributes of the data are not identified.

25 Claims, 34 Drawing Sheets



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continuation of application No. 14/035,561, filed on Sep. 24, 2013, now Pat. No. 8,717,203, which is a continuation of application No. 13/154,211, filed on Jun. 6, 2011, now Pat. No. 8,643,513, which is a continuation of application No. 12/703,042, filed on Feb. 9, 2010, now Pat. No. 8,502,707, which is a continuation of application No. 11/651,366, filed on Jan. 8, 2007, now abandoned, and a continuation of application No. 11/651,365, filed on Jan. 8, 2007, now Pat. No. 7,714,747, which is a continuation of application No. 10/668,768, filed on Sep. 22, 2003, now Pat. No. 7,161,506, said application No. 11/651,366 is a continuation of application No. 10/668,768, which is a continuation of application No. 10/016,355, filed on Oct. 29, 2001, now Pat. No. 6,624,761, which is a continuation-in-part of application No. 09/705,446, filed on Nov. 3, 2000, now Pat. No. 6,309,424, which is a continuation of application No. 09/210,491, filed on Dec. 11, 1998, now Pat. No. 6,195,024.

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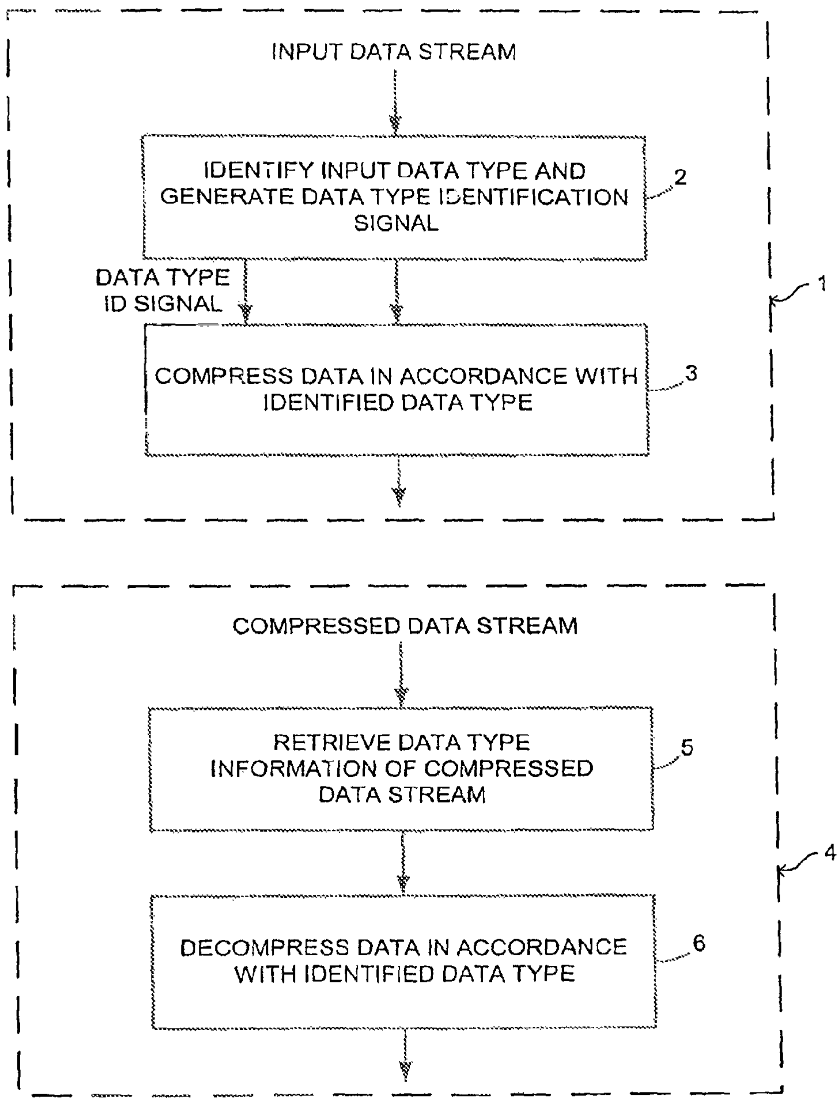
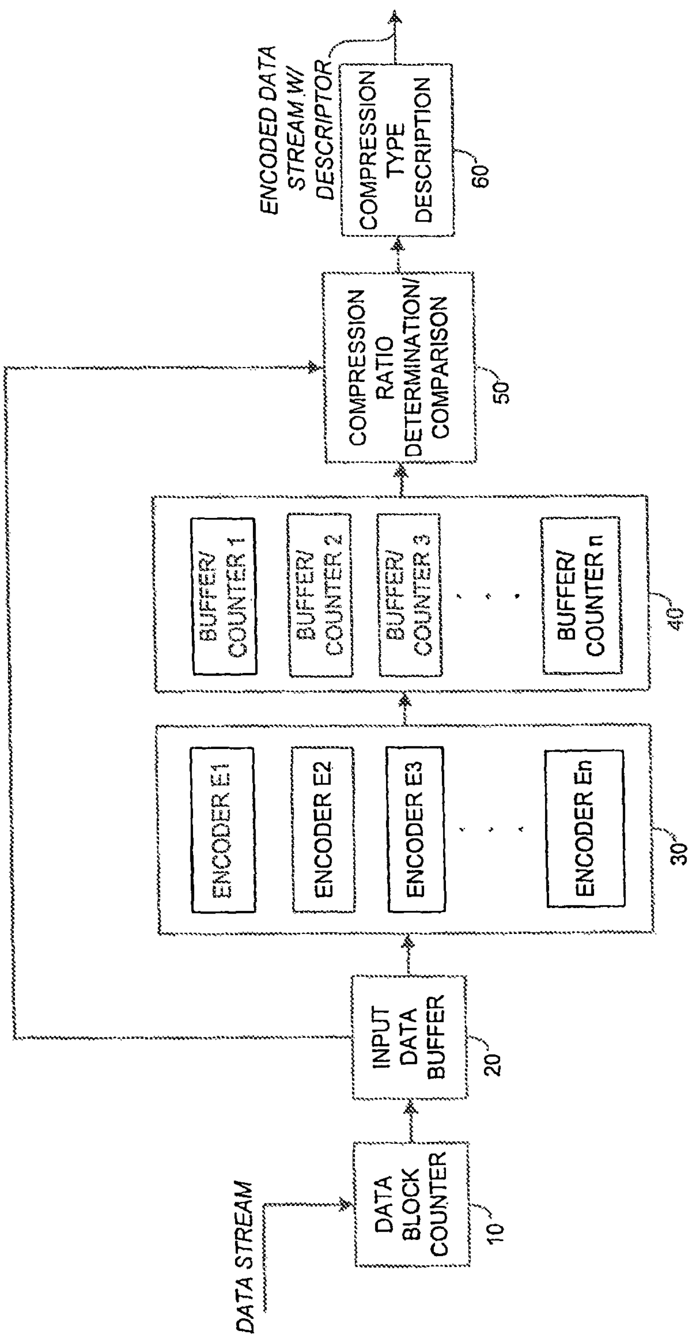


FIG. 1
PRIOR ART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DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
BUFFER/ COUNTER 1
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BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 2

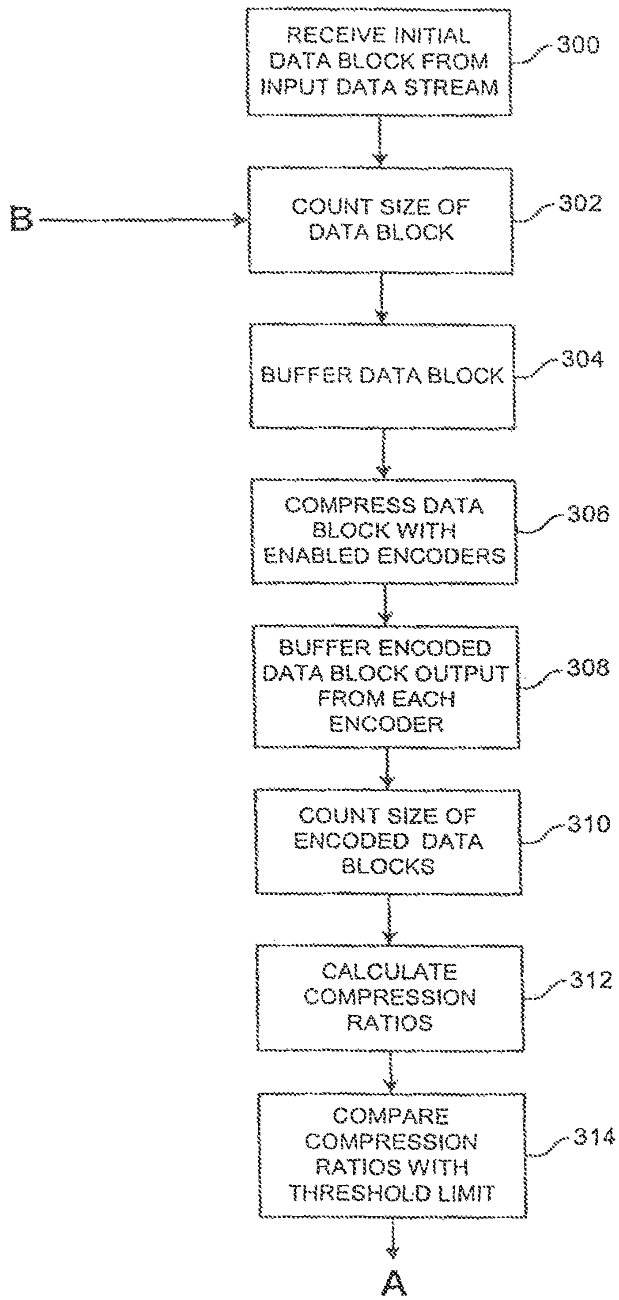

RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
300
B
COUNT SIZE OF DATA BLOCK
302
BUFFER DATA BLOCK
304
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
306
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
308
COUNT SIZE OF ENCODED DATA BLOCKS
310
CALCULATE COMPRESSION RATIOS
312
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
314
A

FIG. 3a

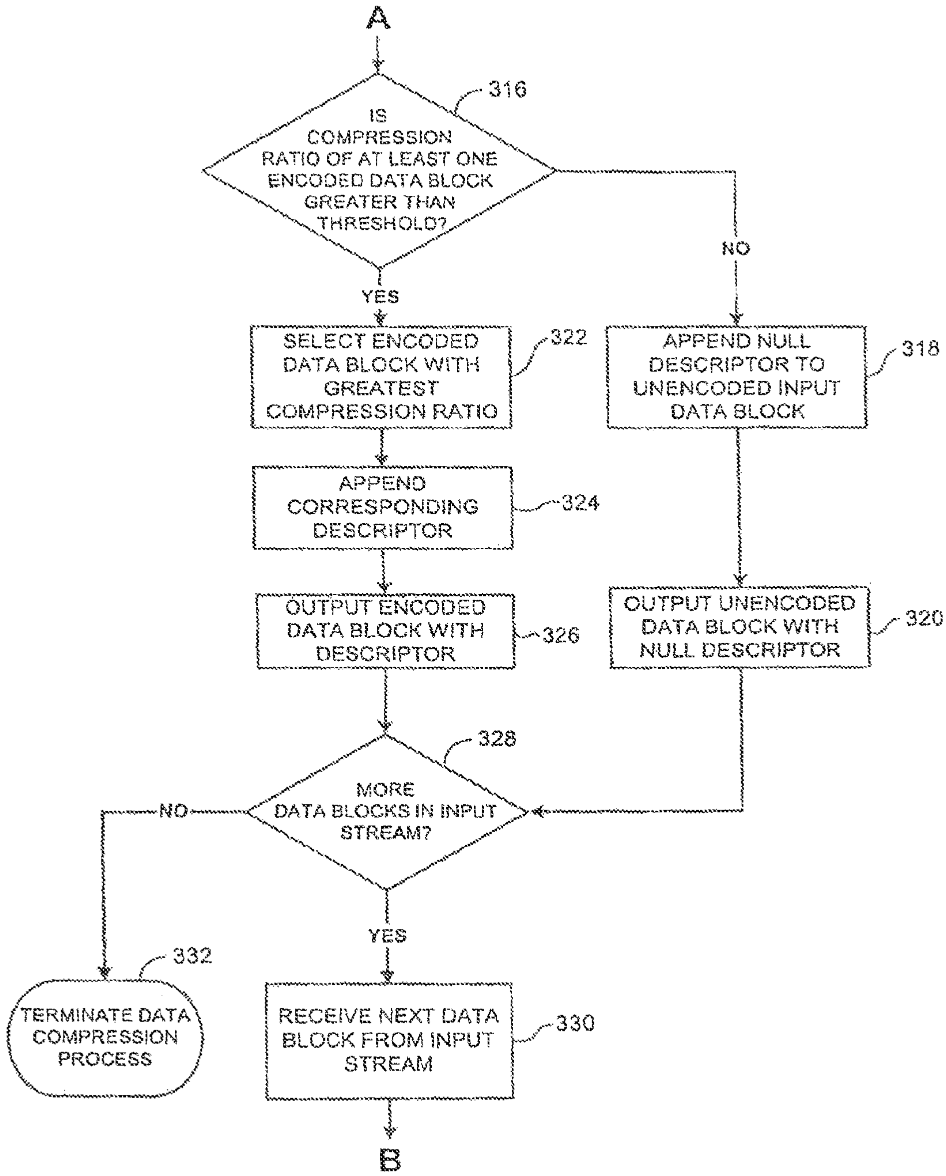

A
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
316
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
322
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
318
APPEND CORRESPONDING DESCRIPTOR
324
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
326
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
320
MORE DATA BLOCKS IN INPUT STREAM?
328
NO
YES
TERMINATE DATA COMPRESSION PROCESS
332
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
330
B

FIG. 3b

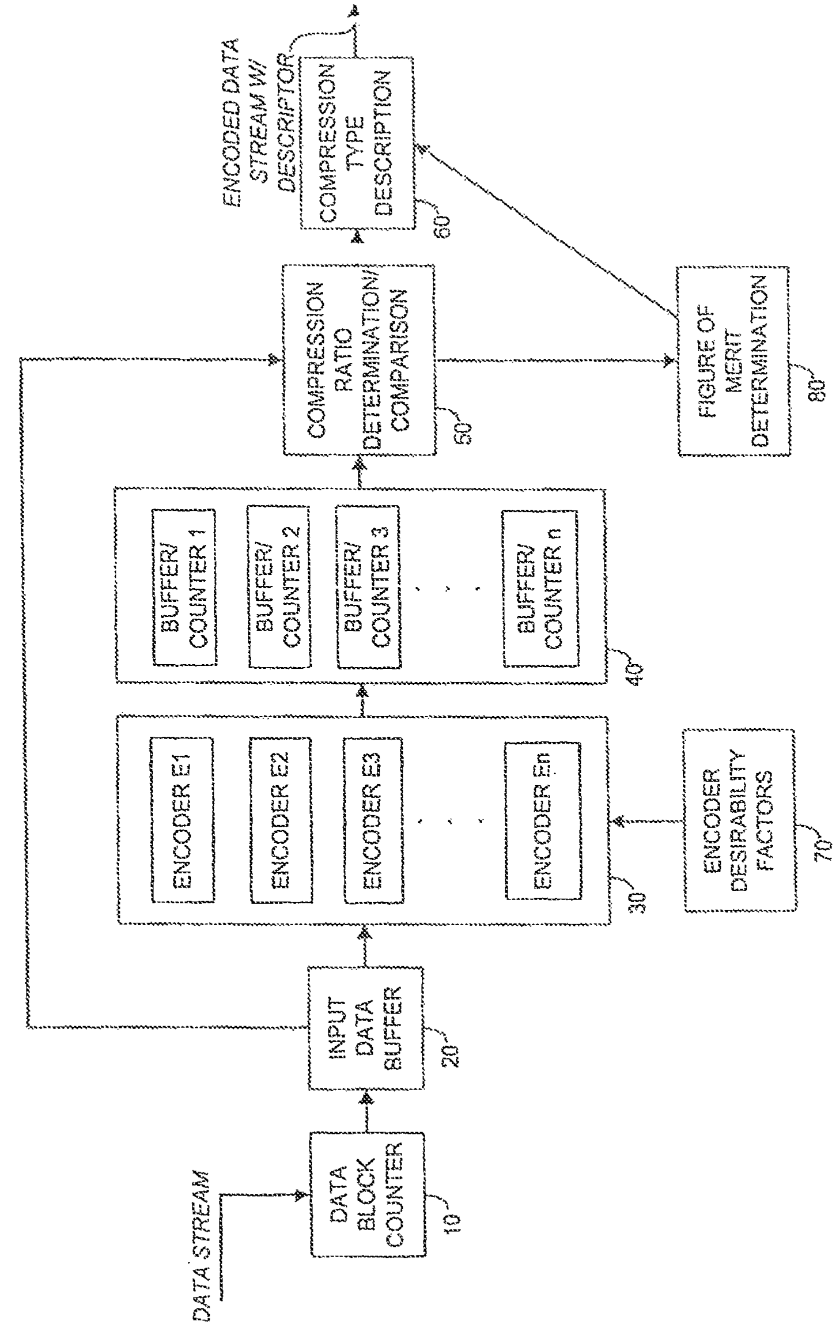

DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
ENCODER DESIRABILITY FACTORS
70
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 4

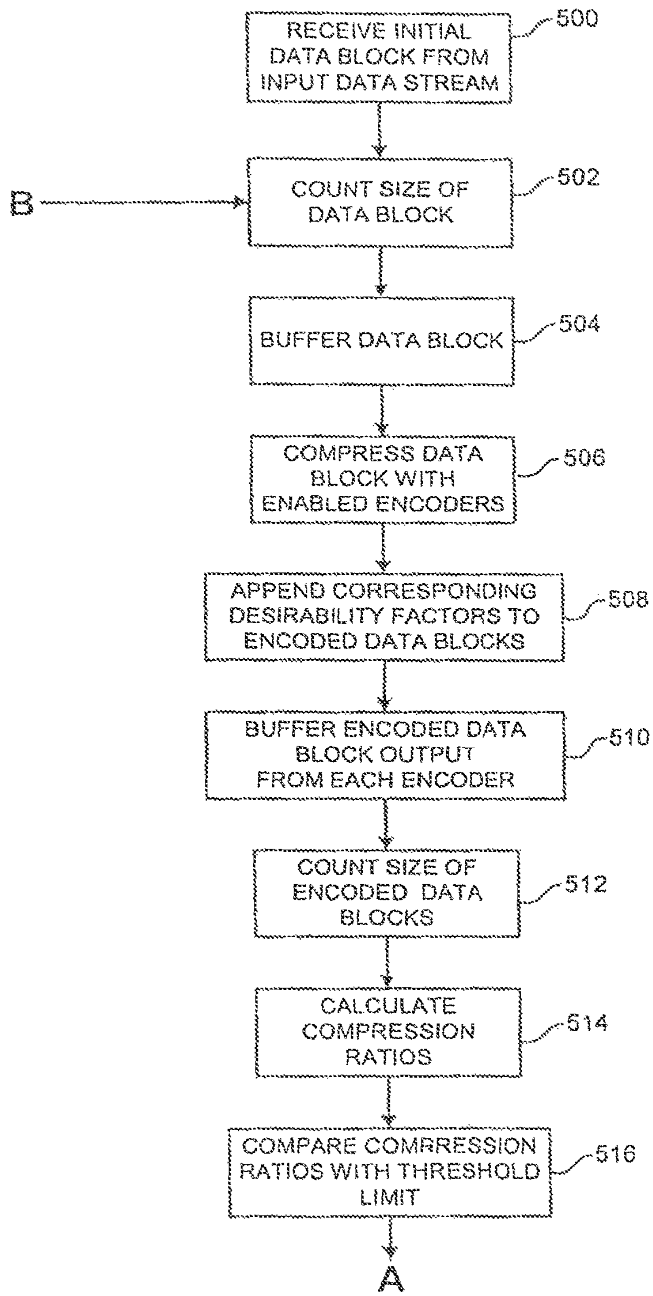

RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
500
B
COUNT SIZE OF DATA BLOCK
502
BUFFER DATA BLOCK
504
COMPRESS DATA BLOCK WITH ENABLED ENCODERS
506
APPEND CORRESPONDING DESIRABILITY FACTORS TO ENCODED DATA BLOCKS
508
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
510
COUNT SIZE OF ENCODED DATA BLOCKS
512
CALCULATE COMPRESSION RATIOS
514
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
516
A

FIG. 5a

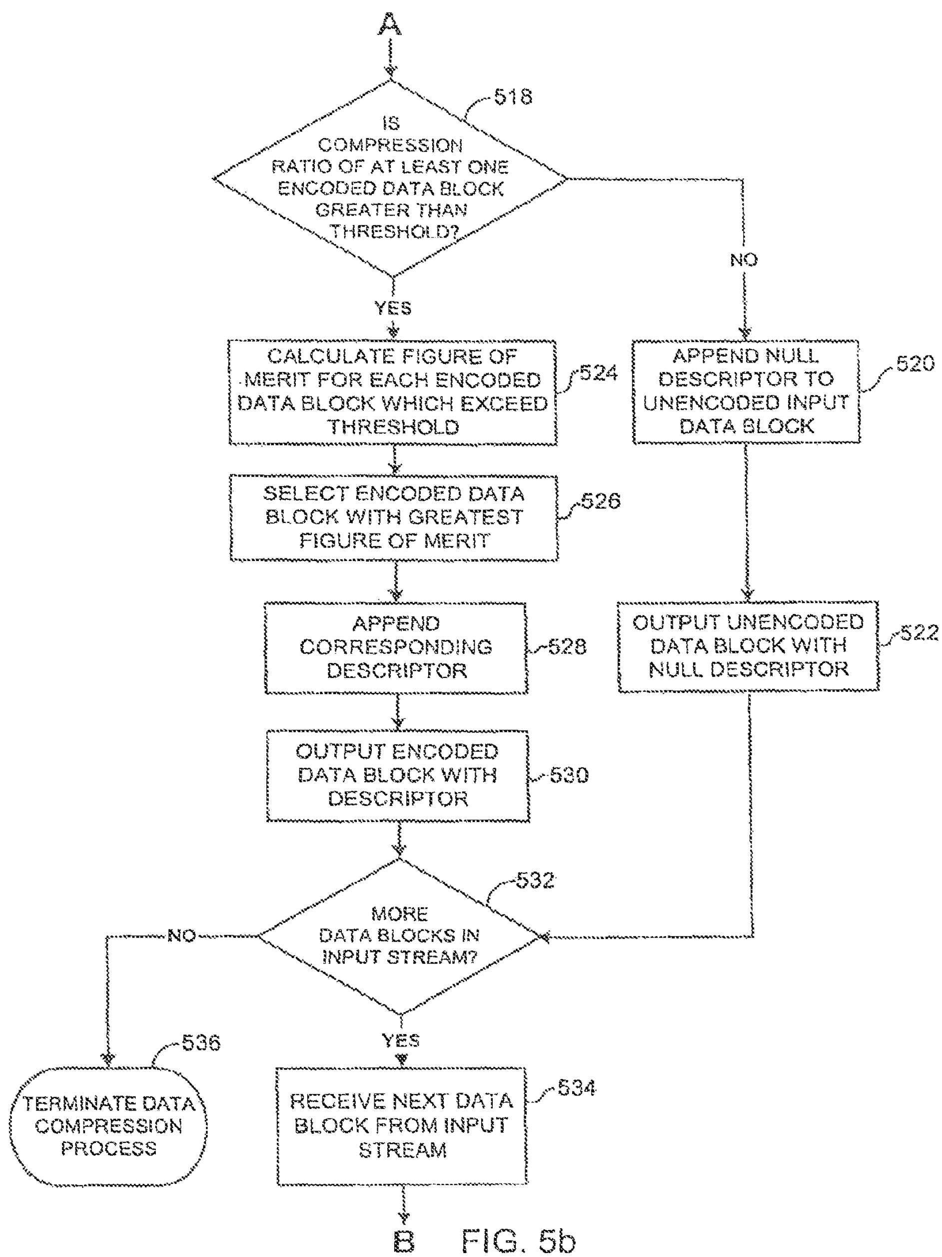

A
518
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
524
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
520
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
526
APPEND CORRESPONDING DESCRIPTOR
528
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
522
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
530
532
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
536
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
534
B

FIG. 5b

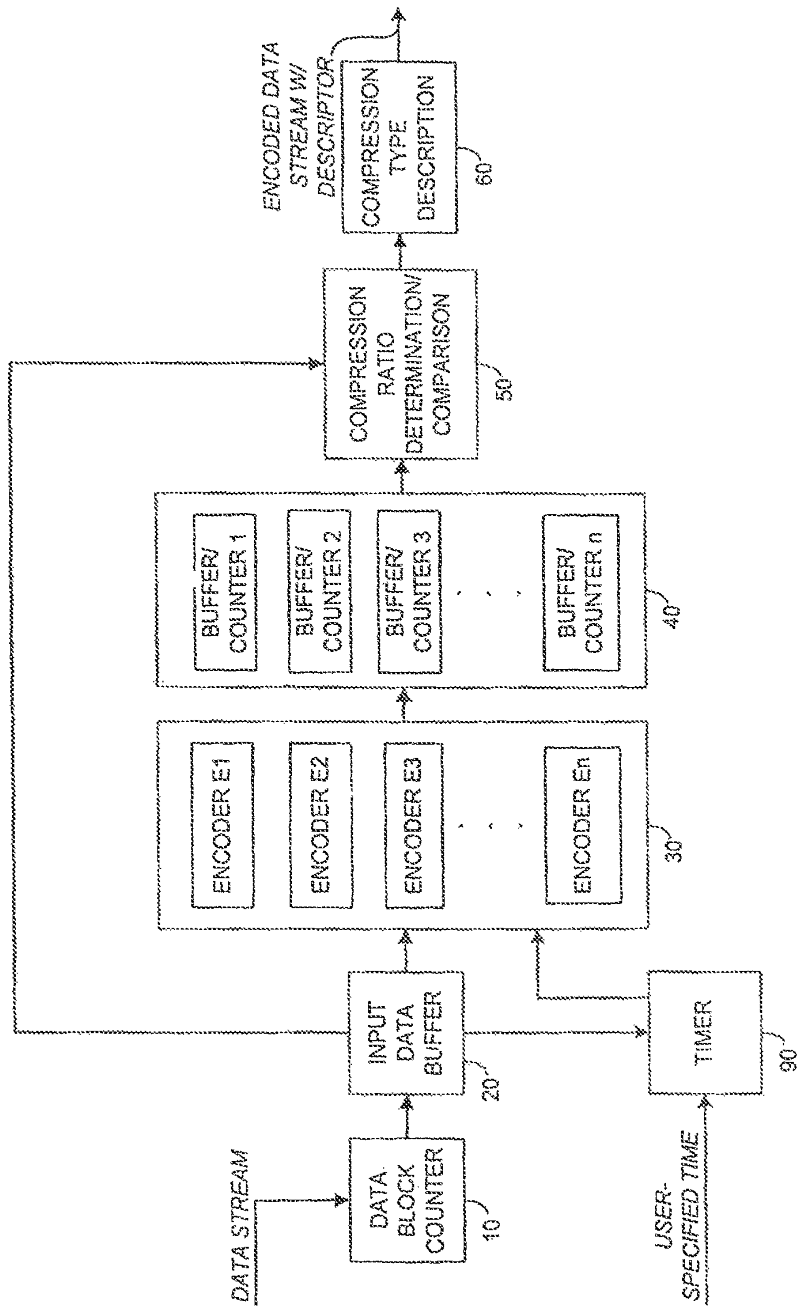

DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR
TIMER
90
USER-SPECIFIED TIME

FIG. 6

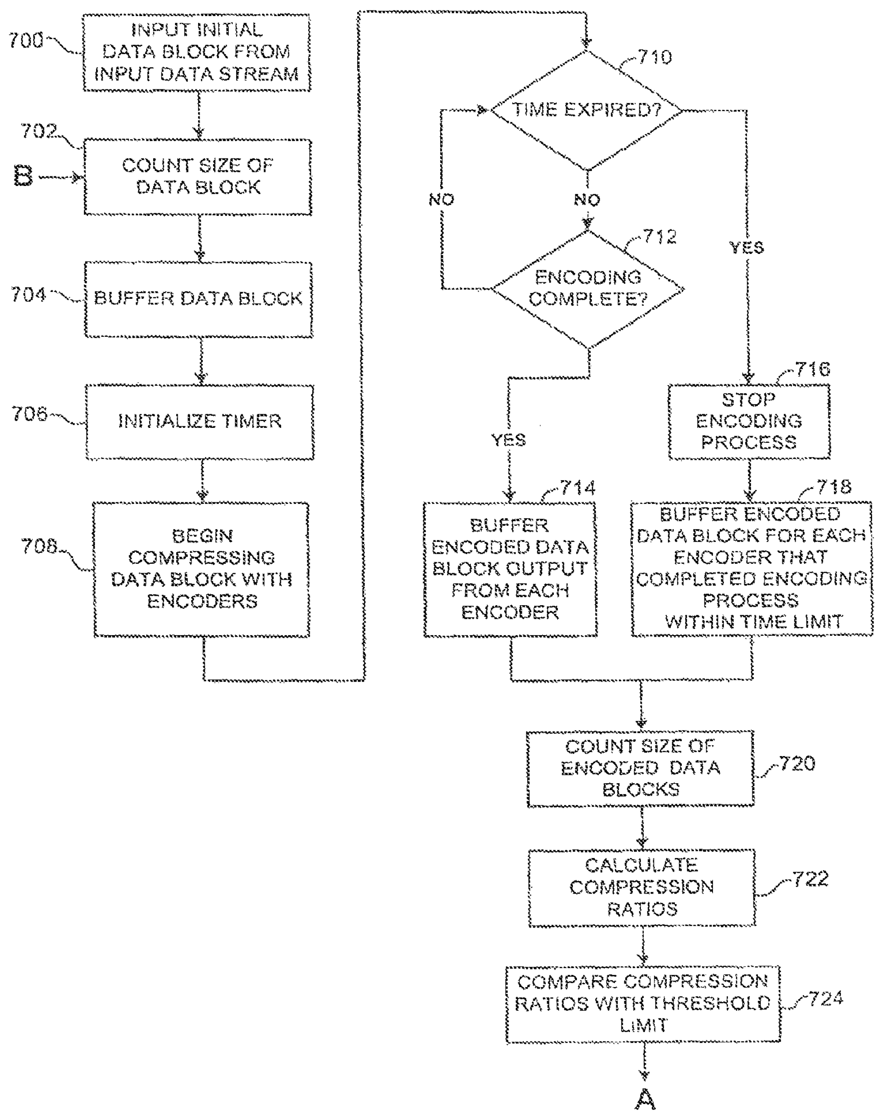

700
INPUT INITIAL DATA BLOCK FROM INPUT DATA STREAM
702
B
COUNT SIZE OF DATA BLOCK
704
BUFFER DATA BLOCK
706
INITIALIZE TIMER
708
BEGIN COMPRESSING DATA BLOCK WITH ENCODERS
710
TIME EXPIRED?
NO
NO
YES
712
ENCODING COMPLETE?
YES
716
STOP ENCODING PROCESS
714
BUFFER ENCODED DATA BLOCK OUTPUT FROM EACH ENCODER
718
BUFFER ENCODED DATA BLOCK FOR EACH ENCODER THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
COUNT SIZE OF ENCODED DATA BLOCKS
720
CALCULATE COMPRESSION RATIOS
722
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
724
A

FIG. 7a

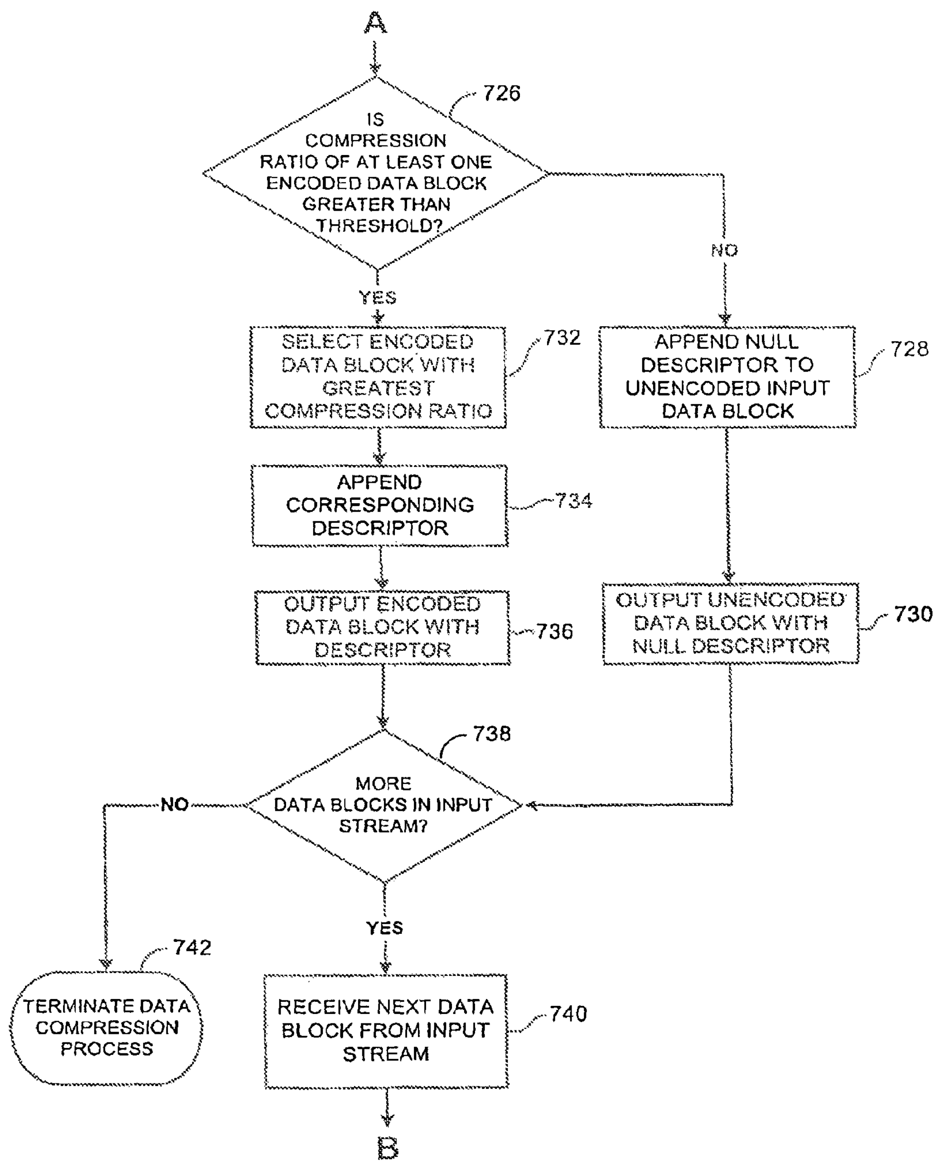

A
726
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
NO
YES
SELECT ENCODED DATA BLOCK WITH GREATEST COMPRESSION RATIO
732
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
728
APPEND CORRESPONDING DESCRIPTOR
734
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
736
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
730
738
MORE DATA BLOCKS IN INPUT STREAM?
NO
YES
742
TERMINATE DATA COMPRESSION PROCESS
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
740
B

FIG. 7b

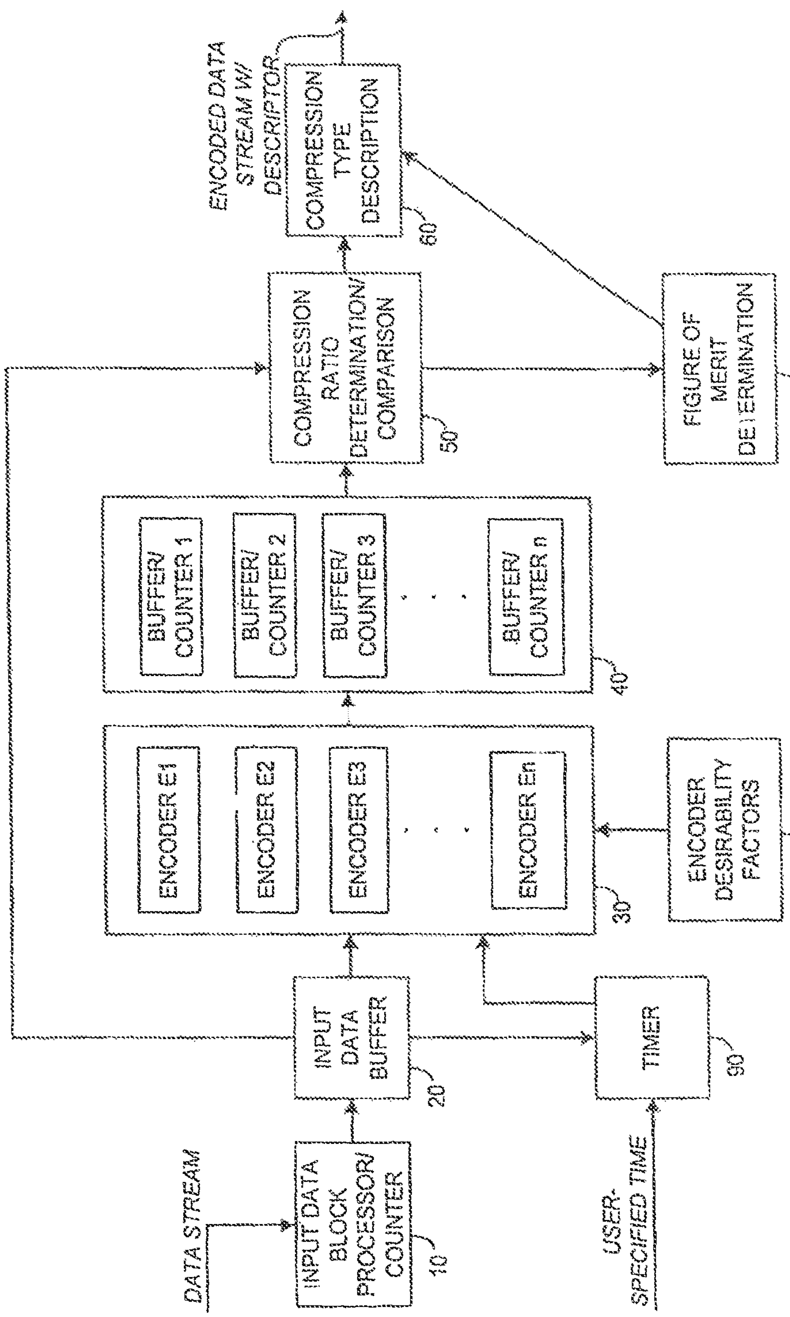

DATA STREAM
INPUT DATA BLOCK PROCESSOR/ COUNTER
10
USER-SPECIFIED TIME
INPUT DATA BUFFER
20
TIMER
90
ENCODER E1
ENCODER E2
ENCODER E3
ENCODER En
30
ENCODER DESIRABILITY FACTORS
70
BUFFER/ COUNTER 1
BUFFER/ COUNTER 2
BUFFER/ COUNTER 3
BUFFER/ COUNTER n
40
COMPRESSION RATIO DETERMINATION/ COMPARISON
50
FIGURE OF MERIT DETERMINATION
30
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 8

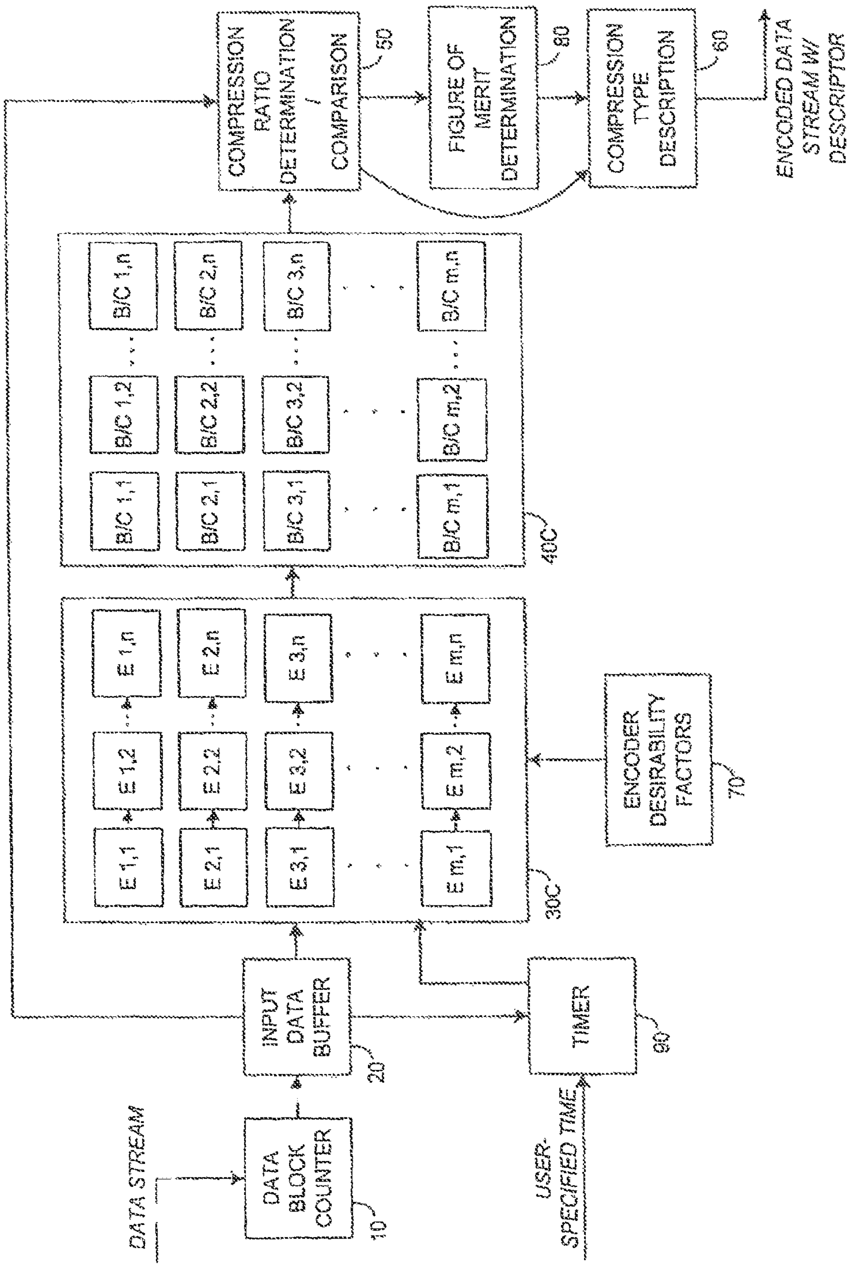
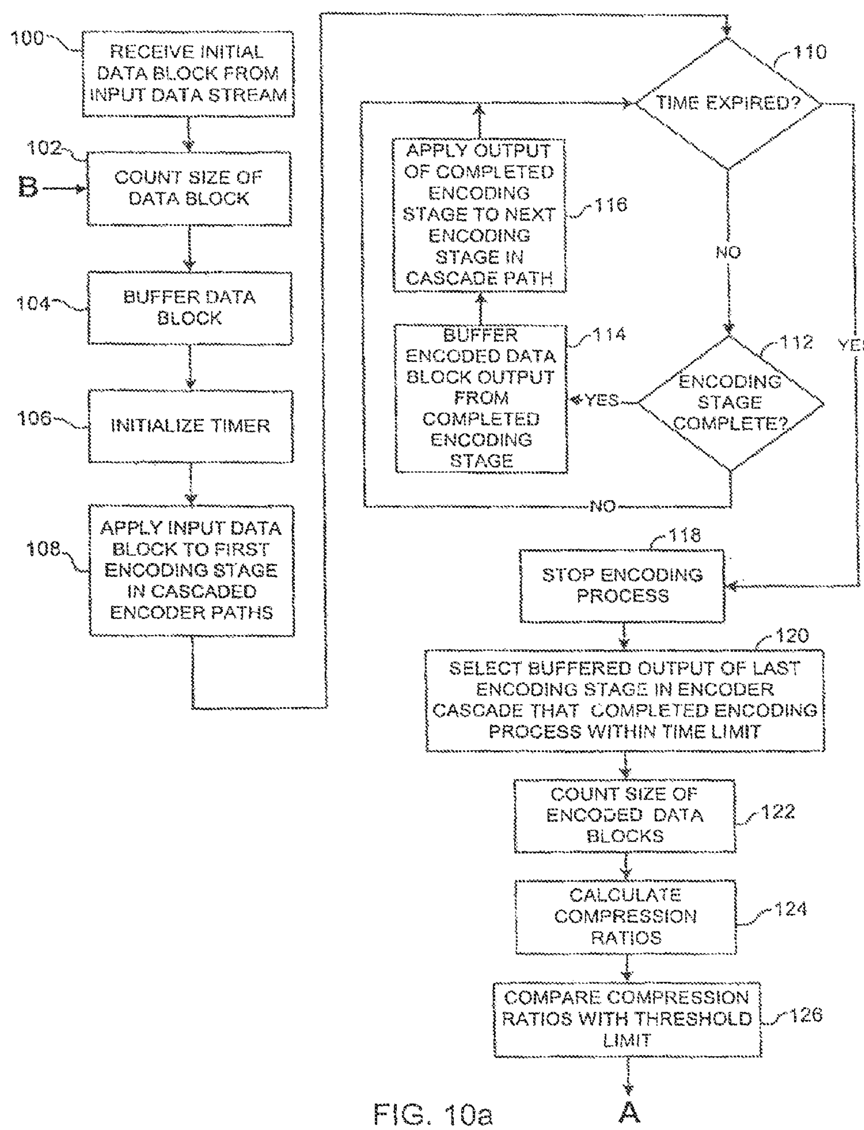

DATA STREAM
DATA BLOCK COUNTER
10
INPUT DATA BUFFER
20
USER-SPECIFIED TIME
TIMER
90
E 1,1
E 1,2
E 1,n
E 2,1
E 2,2
E 2,n
E 3,1
E 3,2
E 3,n
E m,1
E m,2
E m,n
30C
ENCODER DESIRABILITY FACTORS
70
B/C 1,1
B/C 1,2
B/C 1,n
B/C 2,1
B/C 2,2
B/C 2,n
B/C 3,1
B/C 3,2
B/C 3,n
B/C m,1
B/C m,2
B/C m,n
40C
COMPRESSION RATIO DETERMINATION / COMPARISON
50
FIGURE OF MERIT DETERMINATION
80
COMPRESSION TYPE DESCRIPTION
60
ENCODED DATA STREAM W/ DESCRIPTOR

FIG. 9



100
RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
102
B
COUNT SIZE OF DATA BLOCK
104
BUFFER DATA BLOCK
106
INITIALIZE TIMER
108
APPLY INPUT DATA BLOCK TO FIRST ENCODING STAGE IN CASCADED ENCODER PATHS
110
TIME EXPIRED?
NO
YES
APPLY OUTPUT OF COMPLETED ENCODING STAGE TO NEXT ENCODING STAGE IN CASCADE PATH
116
BUFFER ENCODED DATA BLOCK OUTPUT FROM COMPLETED ENCODING STAGE
114
YES
112
ENCODING STAGE COMPLETE?
NO
118
STOP ENCODING PROCESS
120
SELECT BUFFERED OUTPUT OF LAST ENCODING STAGE IN ENCODER CASCADE THAT COMPLETED ENCODING PROCESS WITHIN TIME LIMIT
COUNT SIZE OF ENCODED DATA BLOCKS
122
CALCULATE COMPRESSION RATIOS
124
COMPARE COMPRESSION RATIOS WITH THRESHOLD LIMIT
126
A

FIG. 10a

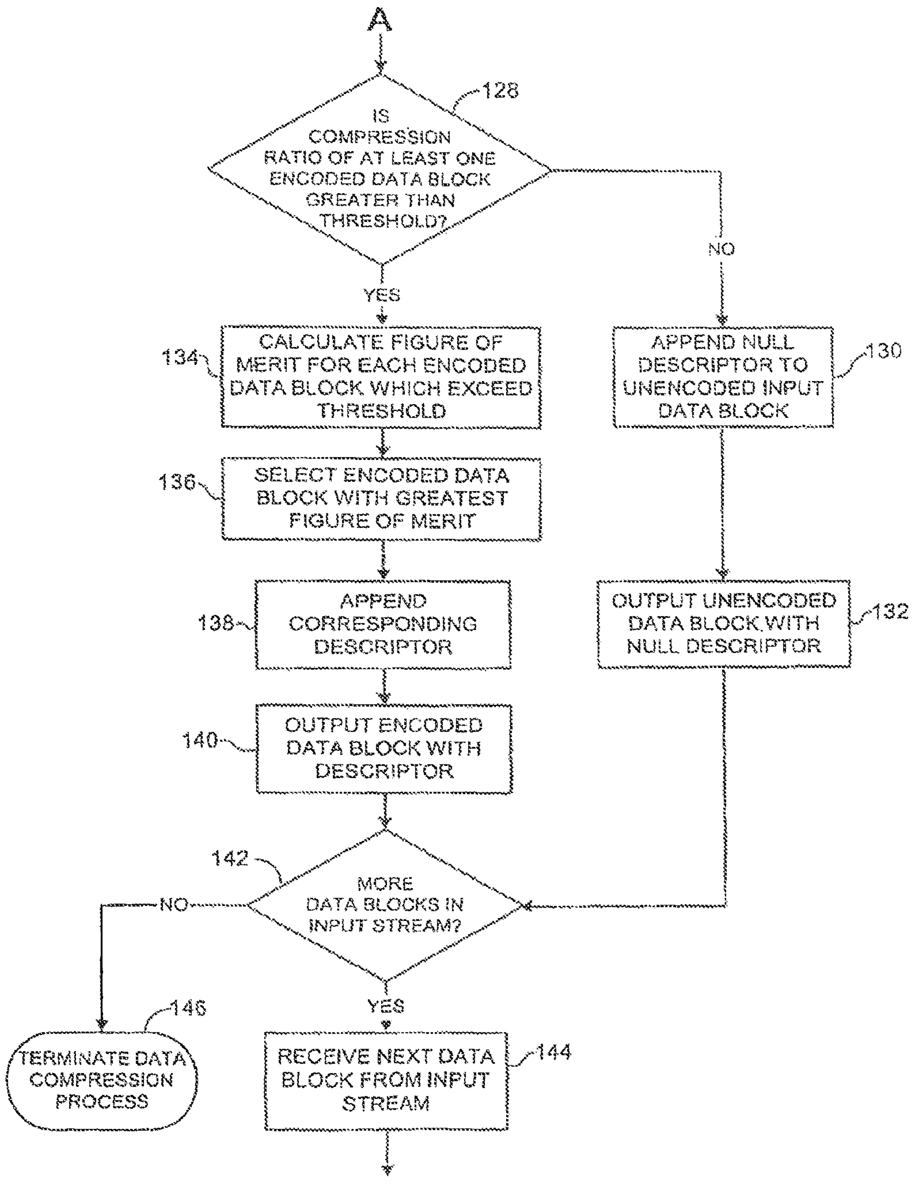

A
IS COMPRESSION RATIO OF AT LEAST ONE ENCODED DATA BLOCK GREATER THAN THRESHOLD?
128
NO
YES
CALCULATE FIGURE OF MERIT FOR EACH ENCODED DATA BLOCK WHICH EXCEED THRESHOLD
134
APPEND NULL DESCRIPTOR TO UNENCODED INPUT DATA BLOCK
130
SELECT ENCODED DATA BLOCK WITH GREATEST FIGURE OF MERIT
136
APPEND CORRESPONDING DESCRIPTOR
138
OUTPUT UNENCODED DATA BLOCK WITH NULL DESCRIPTOR
132
OUTPUT ENCODED DATA BLOCK WITH DESCRIPTOR
140
MORE DATA BLOCKS IN INPUT STREAM?
142
NO
YES
TERMINATE DATA COMPRESSION PROCESS
146
RECEIVE NEXT DATA BLOCK FROM INPUT STREAM
144
B

FIG. 10b

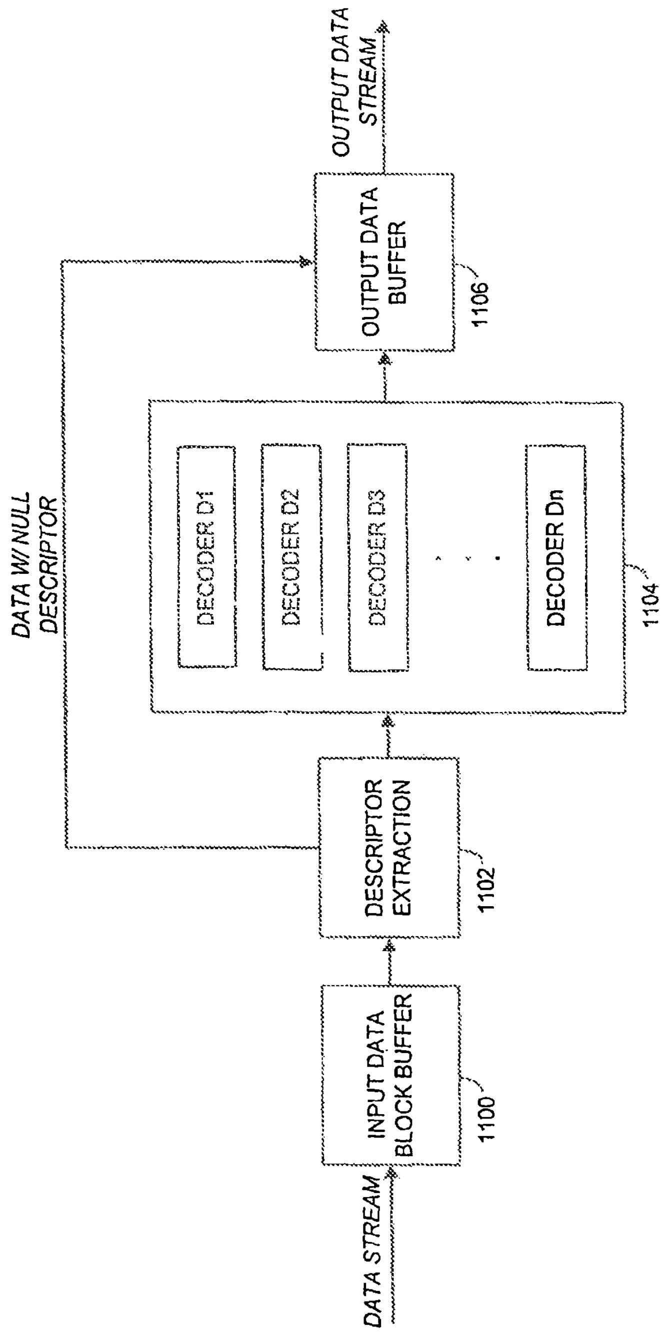

DATA STREAM
INPUT DATA BLOCK BUFFER
1100
DESCRIPTOR EXTRACTION
1102
DATA W/ NULL DESCRIPTOR
DECODER D1
DECODER D2
DECODER D3
DECODER Dn
1104
OUTPUT DATA BUFFER
1106
OUTPUT DATA STREAM

FIG. 11

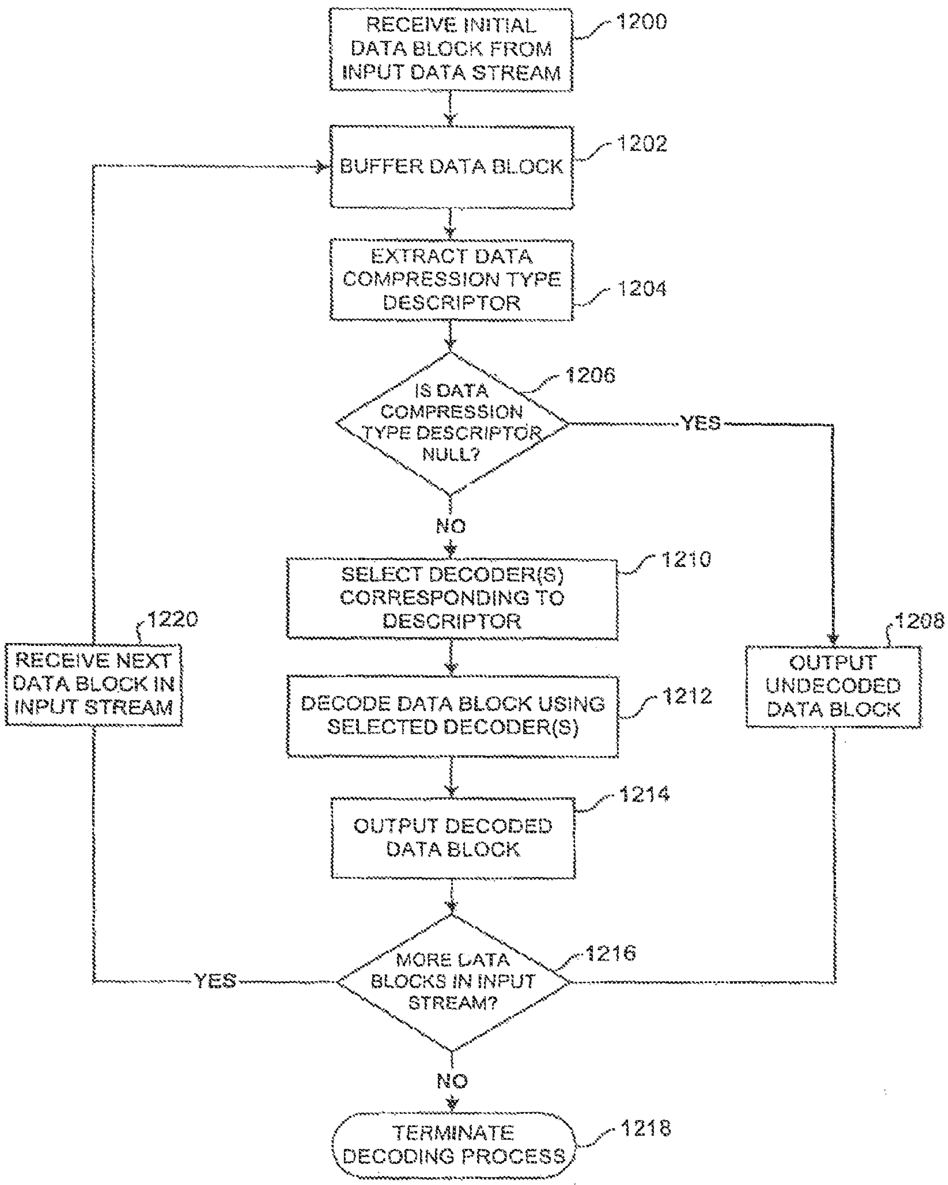

RECEIVE INITIAL DATA BLOCK FROM INPUT DATA STREAM
1200
BUFFER DATA BLOCK
1202
EXTRACT DATA COMPRESSION TYPE DESCRIPTOR
1204
IS DATA COMPRESSION TYPE DESCRIPTOR NULL?
1206
YES
NO
SELECT DECODER(S) CORRESPONDING TO DESCRIPTOR
1210
OUTPUT UNDECODED DATA BLOCK
1208
RECEIVE NEXT DATA BLOCK IN INPUT STREAM
1220
DECODE DATA BLOCK USING SELECTED DECODER(S)
1212
OUTPUT DECODED DATA BLOCK
1214
MORE DATA BLOCKS IN INPUT STREAM?
1216
YES
NO
TERMINATE DECODING PROCESS
1218

FIG. 12

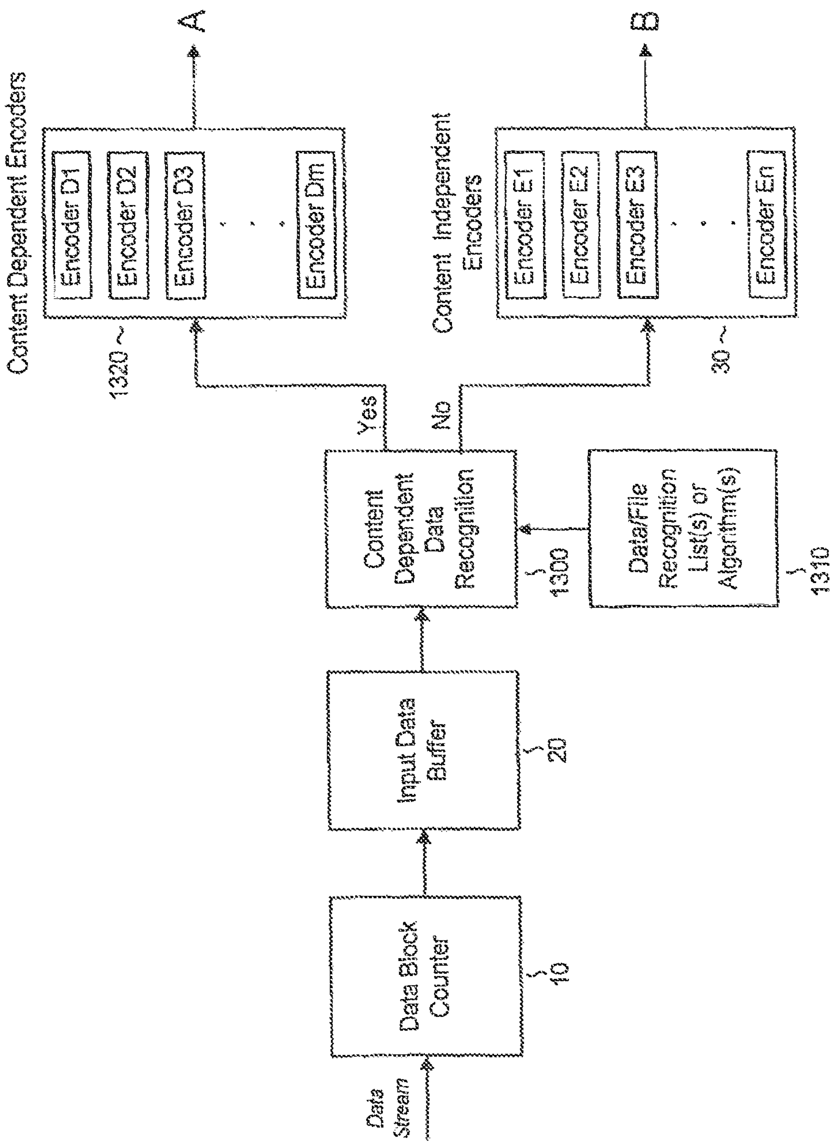

Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
Encoder Dm
A
Content Independent Encoders
30
Encoder E1
Encoder E2
Encoder E3
Encoder En
B

FIGURE 13A

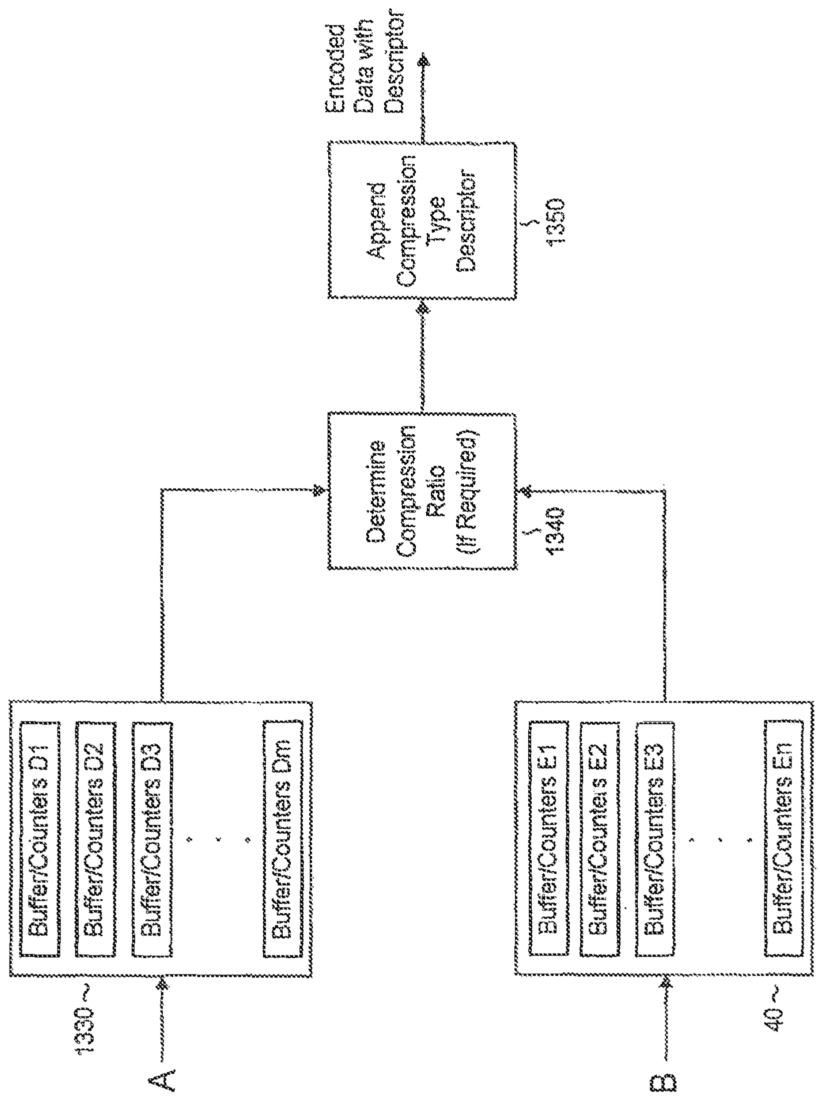

A
1330 ~
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
. . .
Buffer/Counters Dm
B
40 ~
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
. . .
Buffer/Counters En
Determine Compression Ratio (If Required)
1340
Append Compression Type Descriptor
1350
Encoded Data with Descriptor

FIGURE 13B

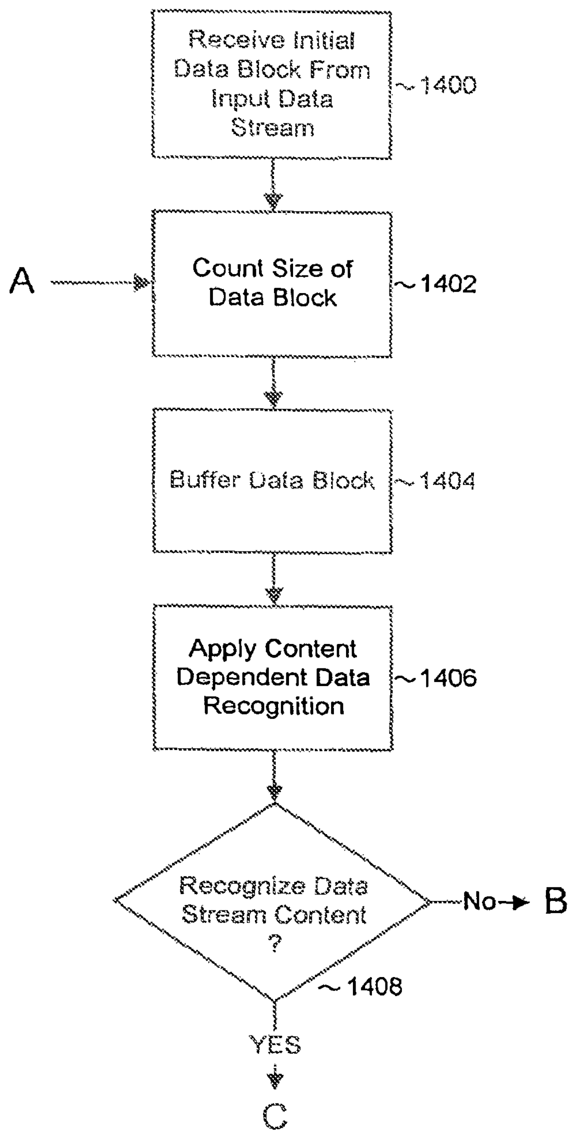

Receive Initial Data Block From Input Data Stream
1400
A
Count Size of Data Block
1402
Buffer Data Block
1404
Apply Content Dependent Data Recognition
1406
Recognize Data Stream Content ?
No
B
1408
YES
C

FIGURE 14A

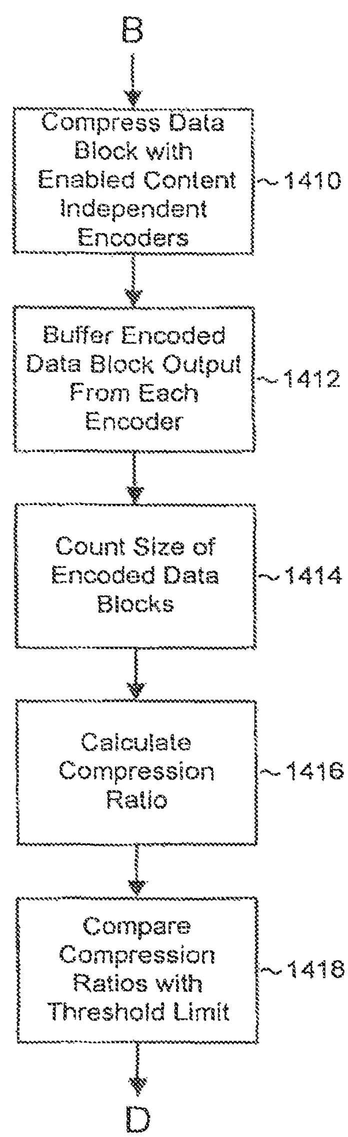

B
Compress Data Block with Enabled Content Independent Encoders
1410
Buffer Encoded Data Block Output From Each Encoder
1412
Count Size of Encoded Data Blocks
1414
Calculate Compression Ratio
1416
Compare Compression Ratios with Threshold Limit
1418
D

FIGURE 14B

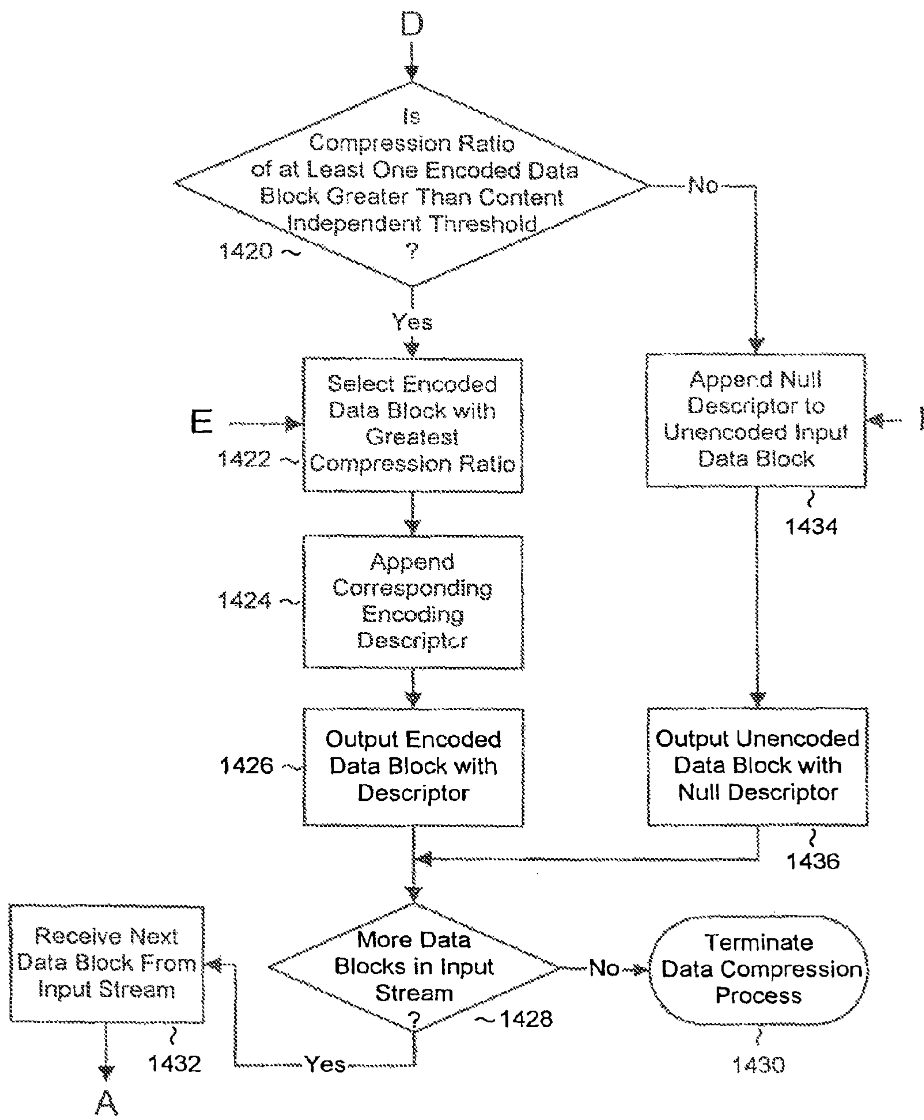

D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1420
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1422
Append Null Descriptor to Unencoded Input Data Block
F
1434
Append Corresponding Encoding Descriptor
1424
Output Encoded Data Block with Descriptor
1426
Output Unencoded Data Block with Null Descriptor
1436
Receive Next Data Block From Input Stream
1432
A
More Data Blocks in Input Stream ?
1428
No
Yes
Terminate Data Compression Process
1430

FIGURE 14C

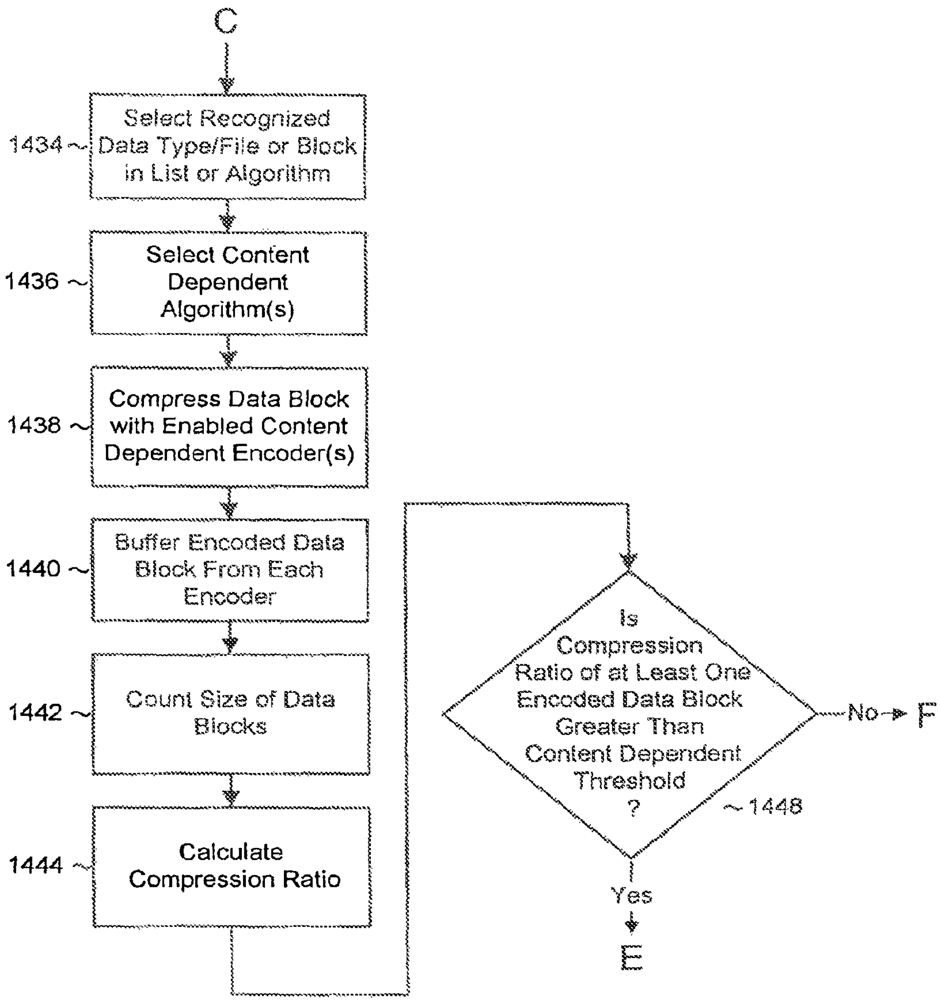

C
1434
Select Recognized Data Type/File or Block in List or Algorithm
1436
Select Content Dependent Algorithm(s)
1438
Compress Data Block with Enabled Content Dependent Encoder(s)
1440
Buffer Encoded Data Block From Each Encoder
1442
Count Size of Data Blocks
1444
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1448
No
F
Yes
E

FIGURE 14D

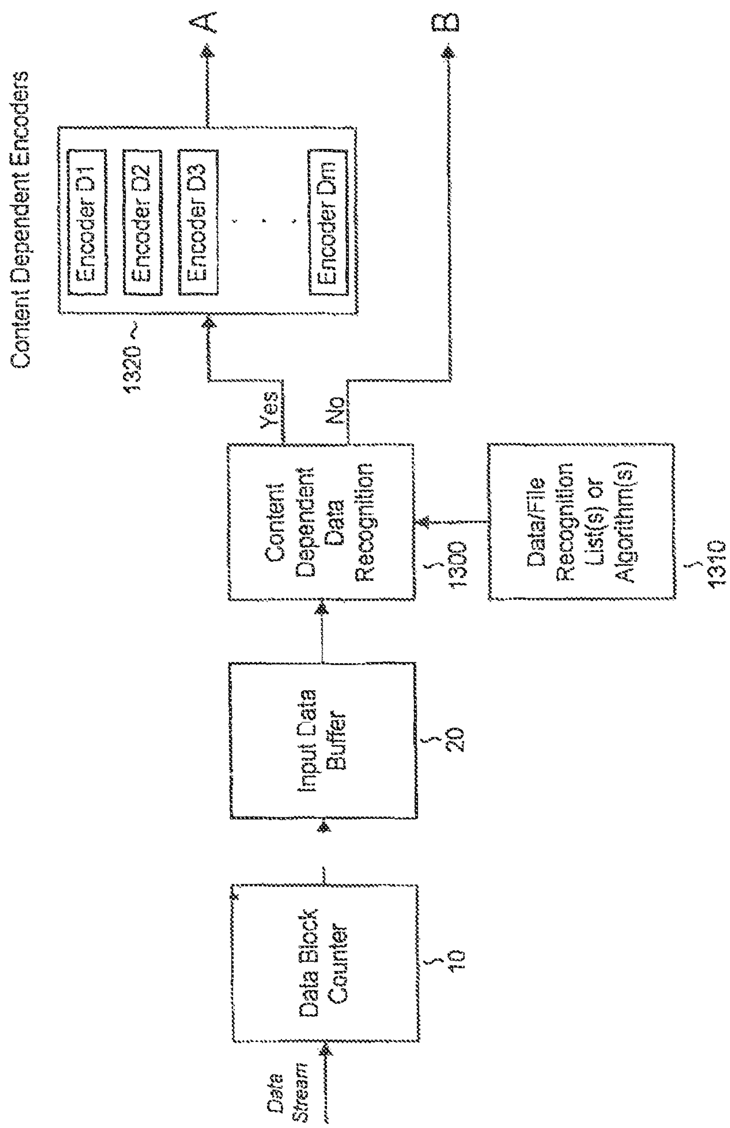

Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent Data Recognition
1300
Data/File Recognition List(s) or Algorithm(s)
1310
Yes
No
Content Dependent Encoders
1320
Encoder D1
Encoder D2
Encoder D3
Encoder Dm
A
B

FIGURE 15A

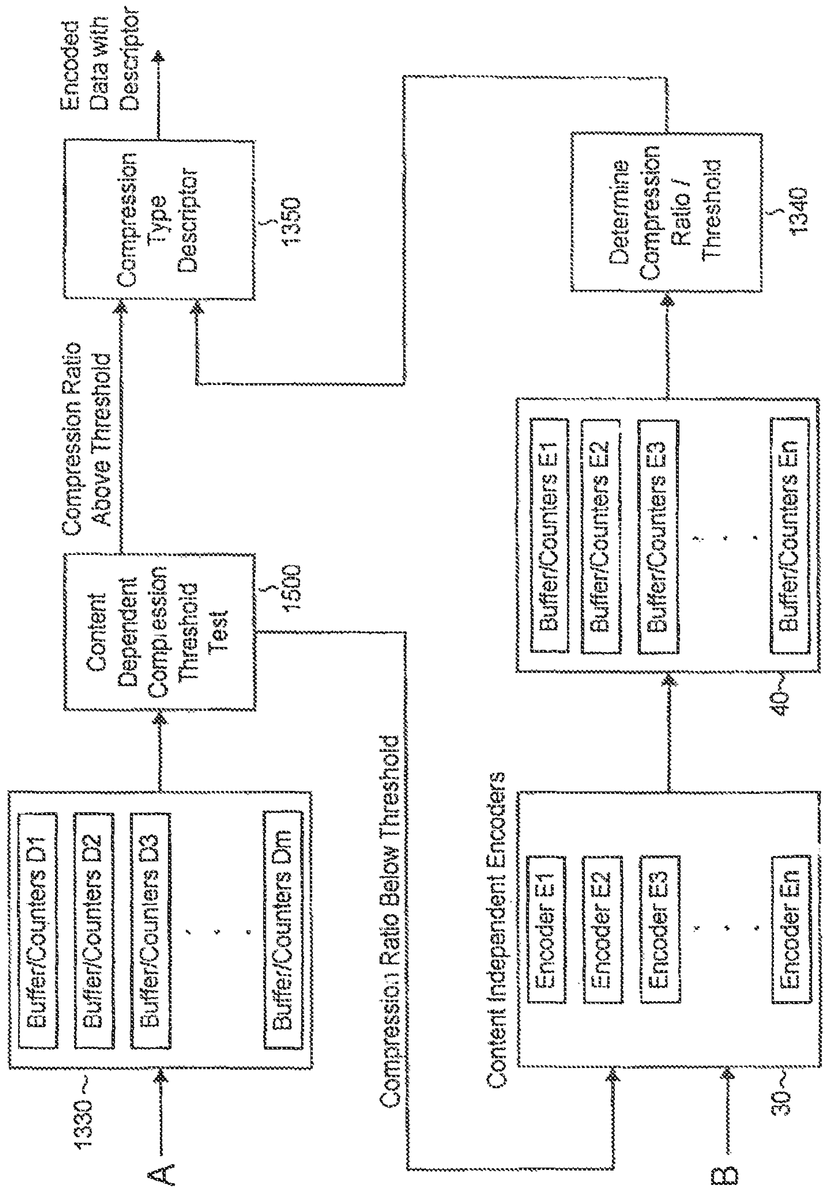

A
1330
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
Content Dependent Compression Threshold Test
1500
Compression Ratio Above Threshold
Compression Type Descriptor
1350
Encoded Data with Descriptor
Compression Ratio Below Threshold
B
30
Content Independent Encoders
Encoder E1
Encoder E2
Encoder E3
Encoder En
40
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
Determine Compression Ratio / Threshold
1340

FIGURE 15B

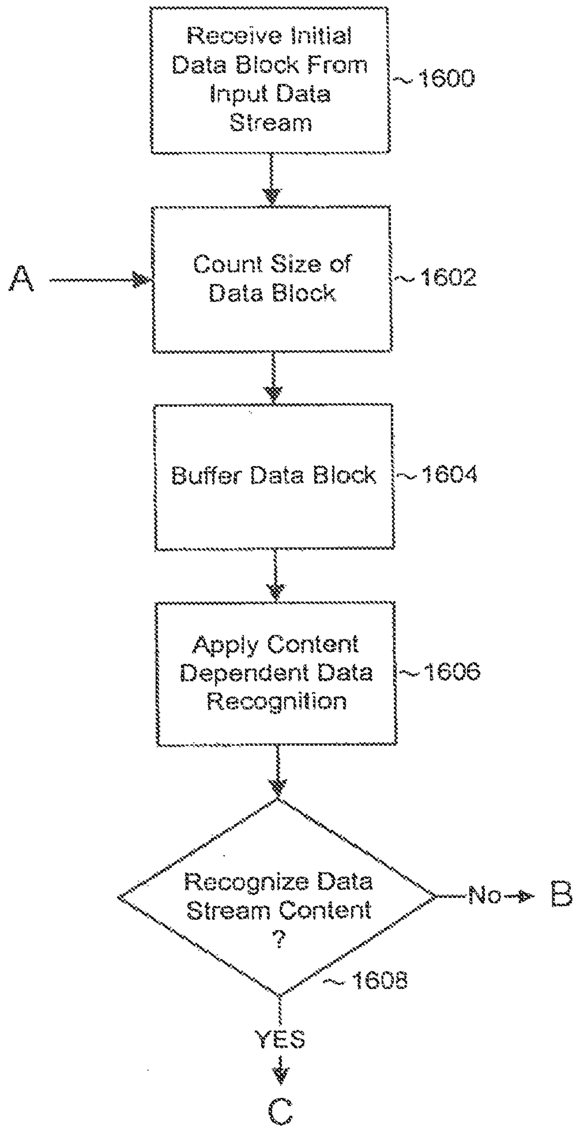

Receive Initial Data Block From Input Data Stream
1600
A
Count Size of Data Block
1602
Buffer Data Block
1604
Apply Content Dependent Data Recognition
1606
Recognize Data Stream Content ?
No
B
1608
YES
C

FIGURE 16A

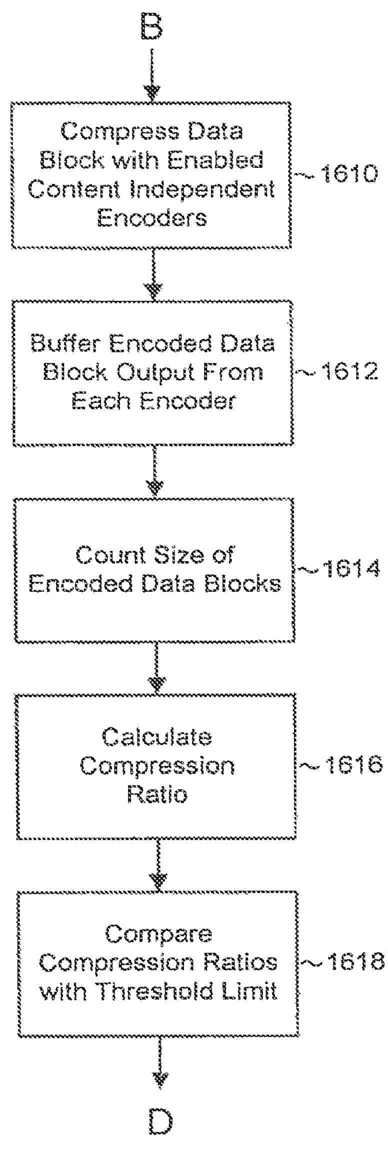

B
Compress Data Block with Enabled Content Independent Encoders
1610
Buffer Encoded Data Block Output From Each Encoder
1612
Count Size of Encoded Data Blocks
1614
Calculate Compression Ratio
1616
Compare Compression Ratios with Threshold Limit
1618
D

FIGURE 16B

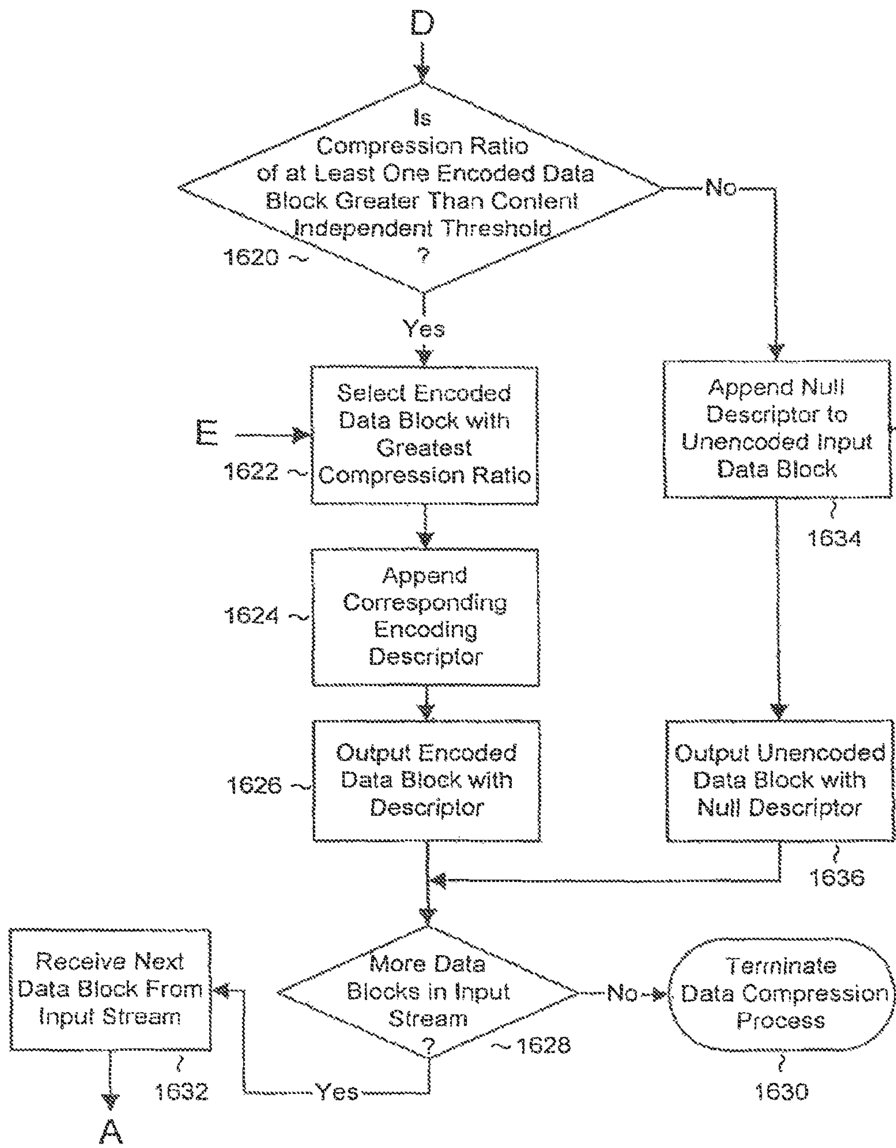

D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1620
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1622
Append Null Descriptor to Unencoded Input Data Block
F
1634
Append Corresponding Encoding Descriptor
1624
Output Encoded Data Block with Descriptor
1626
Output Unencoded Data Block with Null Descriptor
1636
Receive Next Data Block From Input Stream
1632
A
More Data Blocks in Input Stream ?
1628
Yes
No
Terminate Data Compression Process
1630

FIGURE 16C

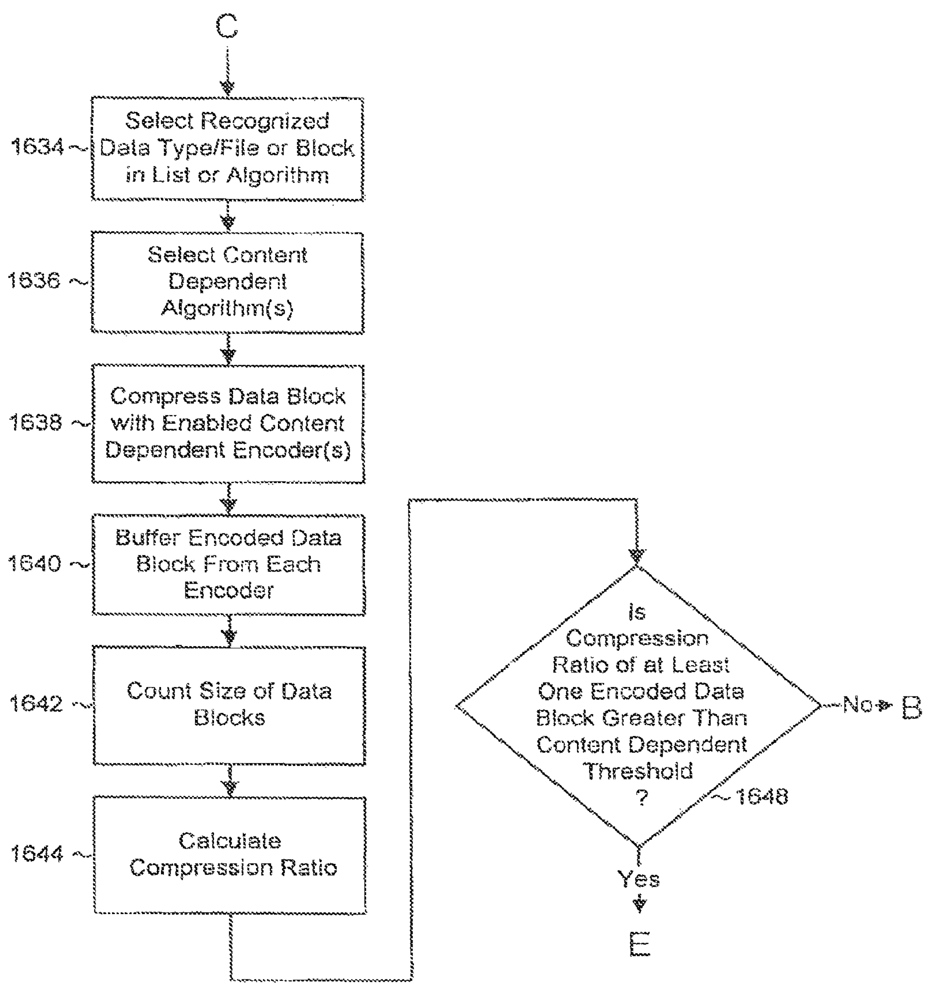

C
1634
Select Recognized Data Type/File or Block in List or Algorithm
1636
Select Content Dependent Algorithm(s)
1638
Compress Data Block with Enabled Content Dependent Encoder(s)
1640
Buffer Encoded Data Block From Each Encoder
1642
Count Size of Data Blocks
1644
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1648
No
B
Yes
E

FIGURE 16D

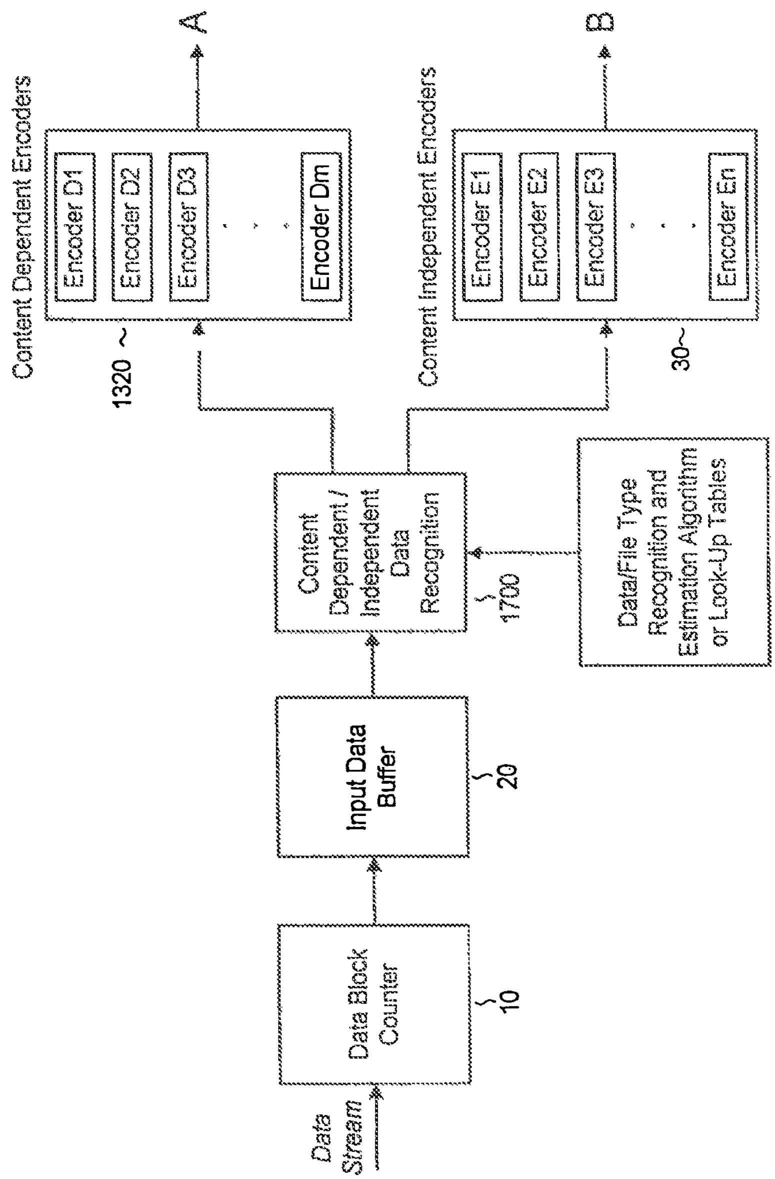

Data Stream
Data Block Counter
10
Input Data Buffer
20
Content Dependent / Independent Data Recognition
1700
Data/File Type Recognition and Estimation Algorithm or Look-Up Tables
1710
Content Dependent Encoders
Encoder D1
Encoder D2
Encoder D3
Encoder Dm
1320
A
Content Independent Encoders
Encoder E1
Encoder E2
Encoder E3
Encoder En
30
B

FIGURE 17A

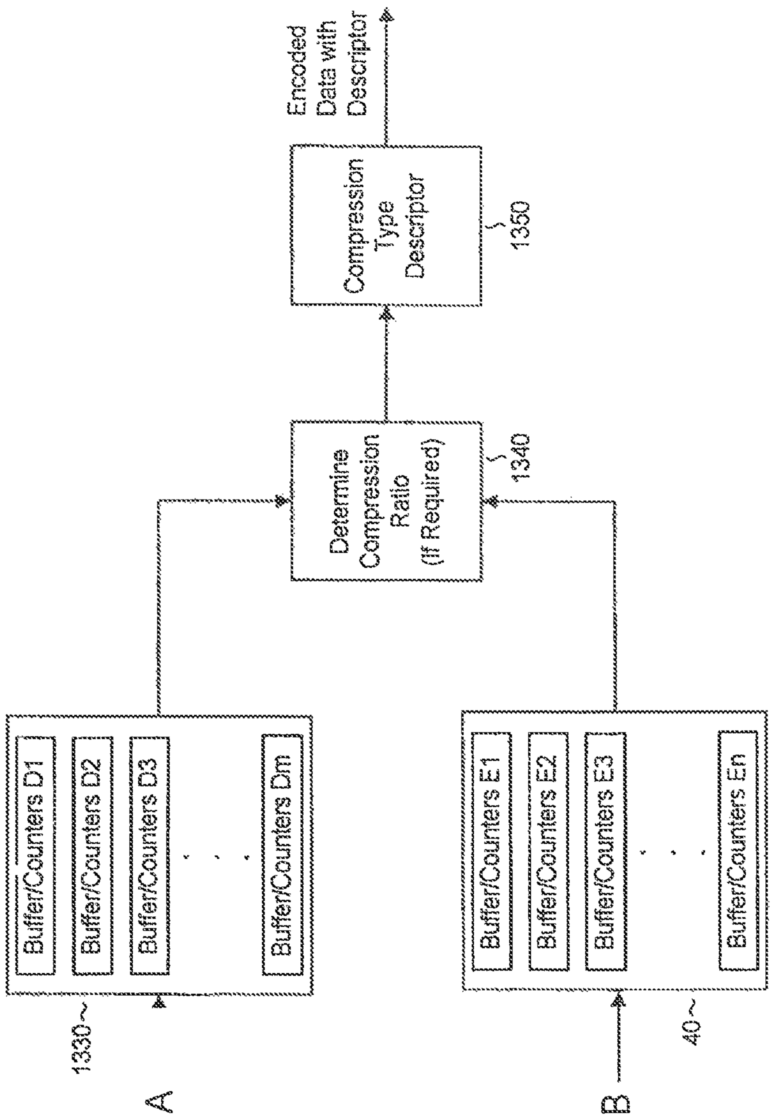

Encoded Data with Descriptor
Compression Type Descriptor
1350
Determine Compression Ratio (If Required)
1340
Buffer/Counters D1
Buffer/Counters D2
Buffer/Counters D3
Buffer/Counters Dm
1330
A
Buffer/Counters E1
Buffer/Counters E2
Buffer/Counters E3
Buffer/Counters En
40
B

FIGURE 17B

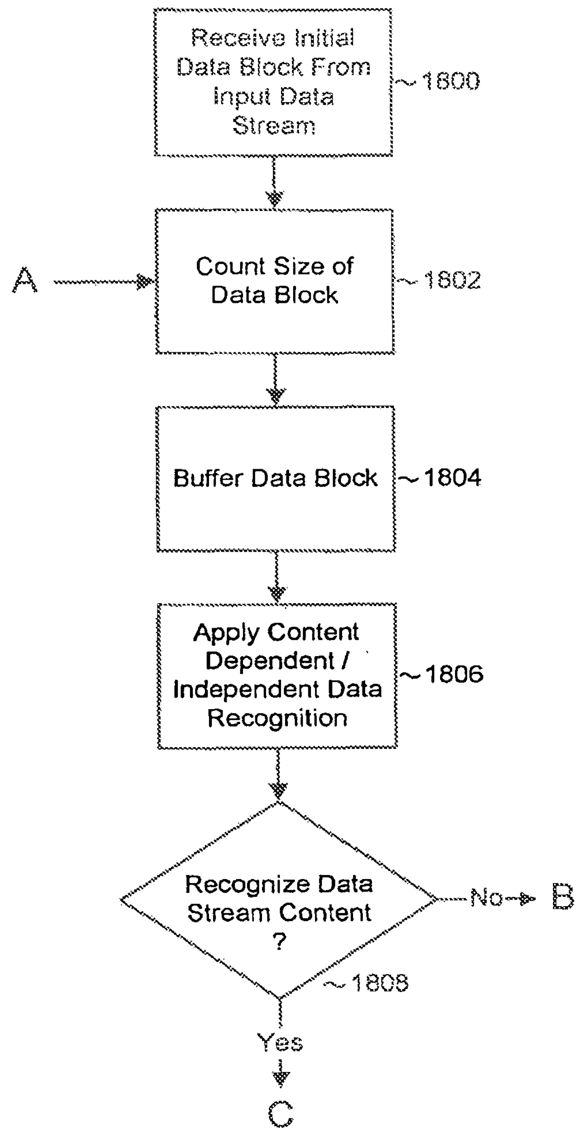

Receive Initial Data Block From Input Data Stream
1800
A
Count Size of Data Block
1802
Buffer Data Block
1804
Apply Content Dependent / Independent Data Recognition
1806
Recognize Data Stream Content ?
No
B
1808
Yes
C

FIGURE 18A

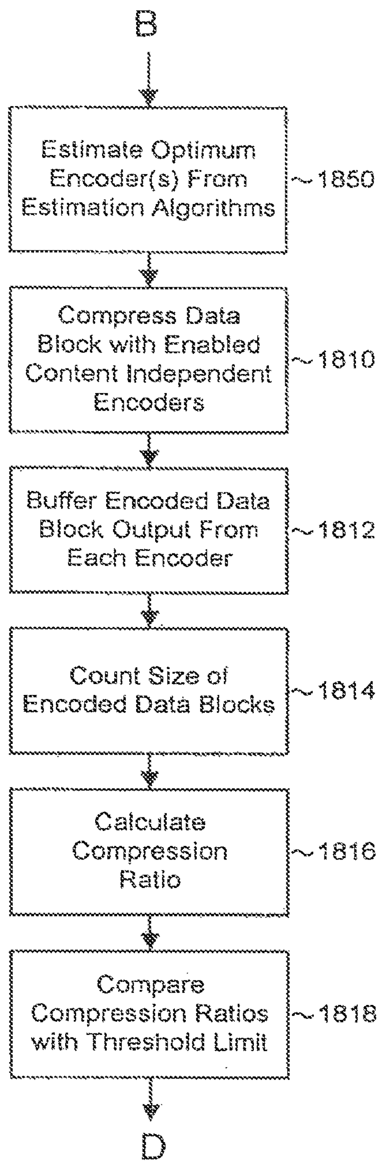

B
Estimate Optimum Encoder(s) From Estimation Algorithms
1850
Compress Data Block with Enabled Content Independent Encoders
1810
Buffer Encoded Data Block Output From Each Encoder
1812
Count Size of Encoded Data Blocks
1814
Calculate Compression Ratio
1816
Compare Compression Ratios with Threshold Limit
1818
D

FIGURE 18B

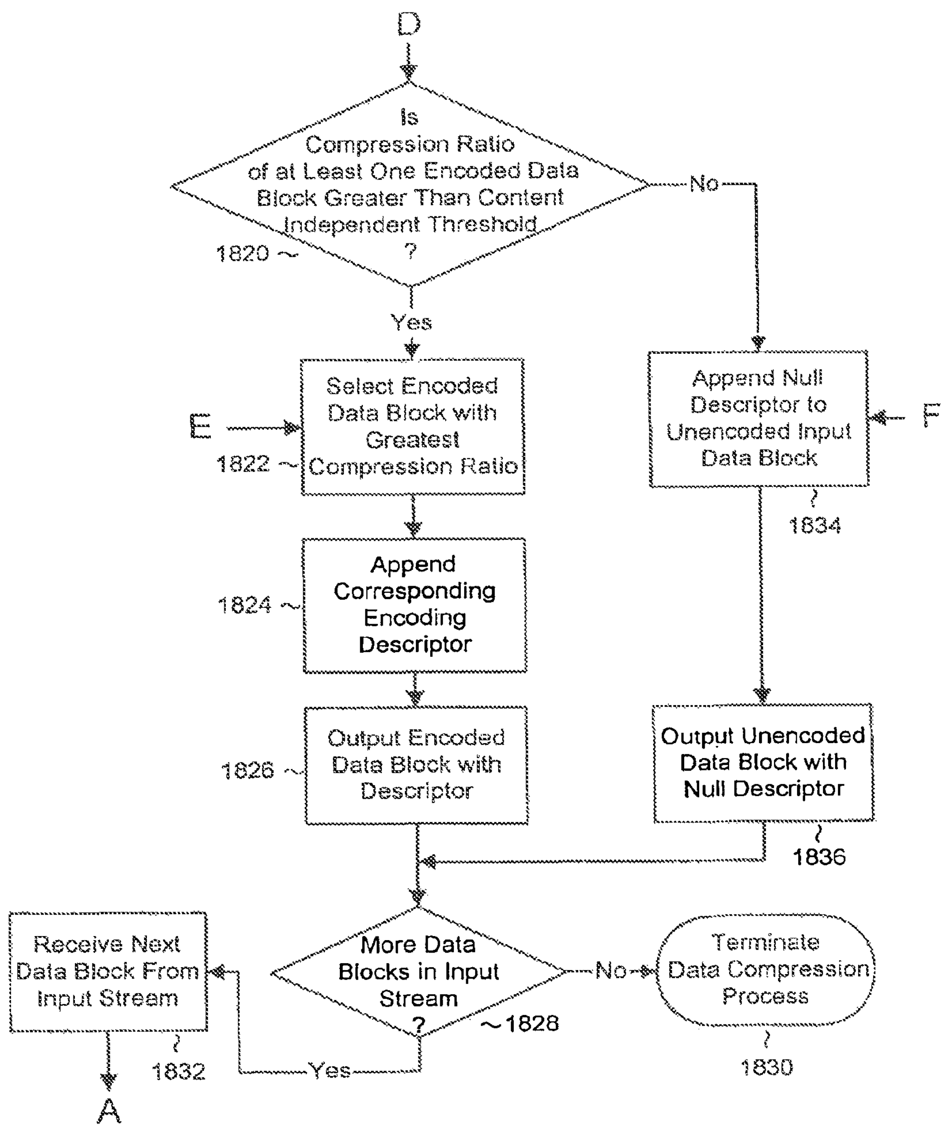

D
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Independent Threshold ?
1820
No
Yes
Select Encoded Data Block with Greatest Compression Ratio
E
1822
Append Null Descriptor to Unencoded Input Data Block
F
1834
Append Corresponding Encoding Descriptor
1824
Output Encoded Data Block with Descriptor
1826
Output Unencoded Data Block with Null Descriptor
1836
Receive Next Data Block From Input Stream
1832
More Data Blocks in Input Stream ?
1828
No
Yes
Terminate Data Compression Process
1830
A

FIGURE 18C

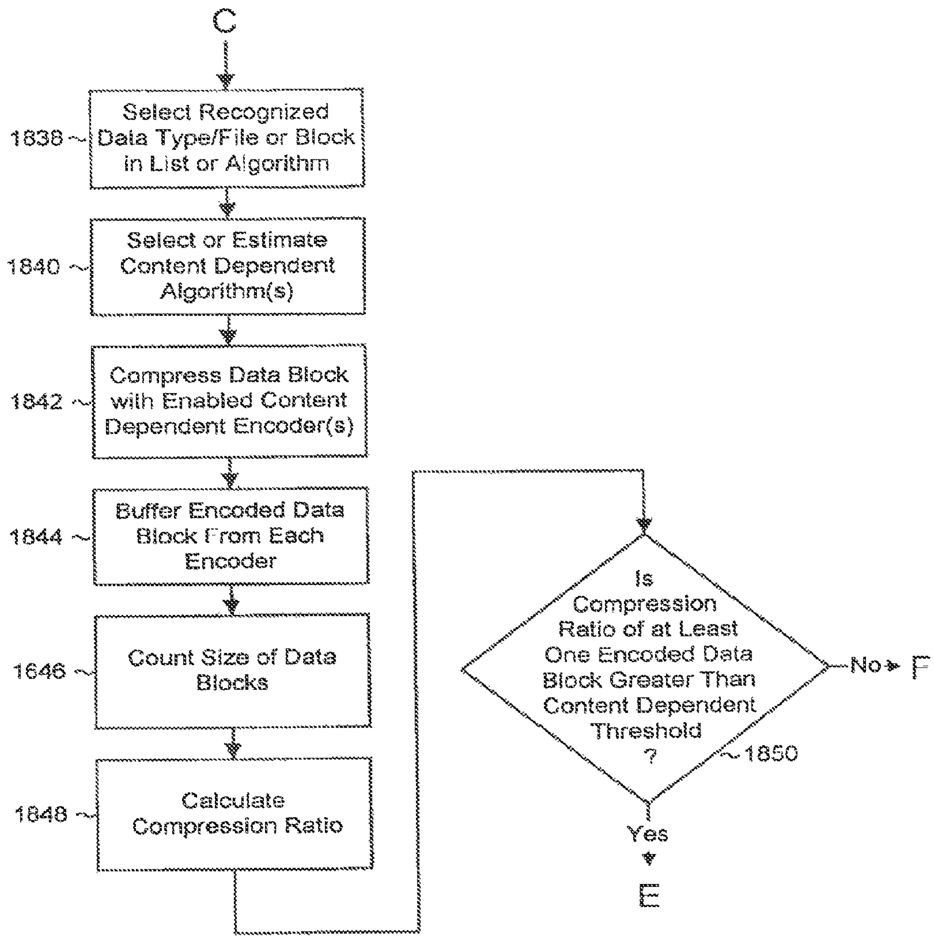

C
1838
Select Recognized Data Type/File or Block in List or Algorithm
1840
Select or Estimate Content Dependent Algorithm(s)
1842
Compress Data Block with Enabled Content Dependent Encoder(s)
1844
Buffer Encoded Data Block From Each Encoder
1646
Count Size of Data Blocks
1848
Calculate Compression Ratio
Is Compression Ratio of at Least One Encoded Data Block Greater Than Content Dependent Threshold ?
1850
No
F
Yes
E

FIGURE 18D

DATA COMPRESSION SYSTEMS AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. patent application Ser. No. 14/251,453, filed Apr. 11, 2014, which is a Continuation of U.S. patent application Ser. No. 14/035,561, filed Sep. 24, 2013, now U.S. Pat. No. 8,717,203, which is a Continuation of U.S. patent application Ser. No. 13/154,211, now U.S. Pat. No. 8,643,513, filed Jun. 6, 2011, which is a Continuation of U.S. patent application Ser. No. 12/703,042, filed Feb. 9, 2010, now U.S. Pat. No. 8,502,707, which is a Continuation of both U.S. patent application Ser. No. 11/651,366, filed Jan. 8, 2007, now abandoned, and U.S. patent application Ser. No. 11/651,365, filed Jan. 8, 2007, now U.S. Pat. No. 7,714,747. Each of application Ser. No. 11/651,366 and application Ser. No. 11/651,365 is a Continuation of U.S. patent application Ser. No. 10/668,768, filed Sep. 22, 2003, now U.S. Pat. No. 7,161,506, which is a Continuation of U.S. patent application Ser. No. 10/016,355, filed Oct. 29, 2001, now U.S. Pat. No. 6,624,761, which is a Continuation-In-Part of U.S. patent application Ser. No. 09/705,446, filed Nov. 3, 2000, now U.S. Pat. No. 6,309,424, which is a Continuation of U.S. patent application Ser. No. 09/210,491, filed Dec. 11, 1998, which is now U.S. Pat. No. 6,195,024. Each of the listed applications are incorporated herein by reference in their entireties.

BACKGROUND

1. Technical Field

The present invention relates generally to a data compression and decompression and, more particularly, to systems and methods for data compression using content independent and content dependent data compression and decompression.

2. Description of Related Art

Information may be represented in a variety of manners. Discrete information such as text and numbers are easily represented in digital data. This type of data representation is known as symbolic digital data. Symbolic digital data is thus an absolute representation of data such as a letter, figure, character, mark, machine code, or drawing.

Continuous information such as speech, music, audio, images and video, frequently exists in the natural world as analog information. As is well known to those skilled in the art, recent advances in very large scale integration (VLSI) digital computer technology have enabled both discrete and analog information to be represented with digital data. Continuous information represented as digital data is often referred to as diffuse data. Diffuse digital data is thus a representation of data that is of low information density and is typically not easily recognizable to humans in its native form.

There are many advantages associated with digital data representation. For instance, digital data is more readily processed, stored, and transmitted due to its inherently high noise immunity. In addition, the inclusion of redundancy in digital data representation enables error detection and/or correction. Error detection and/or correction capabilities are dependent upon the amount and type of data redundancy, available error detection and correction processing, and extent of data corruption.

One outcome of digital data representation is the continuing need for increased capacity in data processing, storage, and transmittal. This is especially true for diffuse data where increases in fidelity and resolution create exponentially

greater quantities of data. Data compression is widely used to reduce the amount of data required to process, transmit, or store a given quantity of information. In general, there are two types of data compression techniques that may be utilized either separately or jointly to encode/decode data: lossless and lossy data compression.

Lossy data compression techniques provide for an inexact representation of the original uncompressed data such that the decoded (or reconstructed) data differs from the original unencoded/uncompressed data. Lossy data compression is also known as irreversible or noisy compression. Entropy is defined as the quantity of information in a given set of data. Thus, one obvious advantage of lossy data compression is that the compression ratios can be larger than the entropy limit, all at the expense of information content. Many lossy data compression techniques seek to exploit various traits within the human senses to eliminate otherwise imperceptible data. For example, lossy data compression of visual imagery might seek to delete information content in excess of the display resolution or contrast ratio.

On the other hand, lossless data compression techniques provide an exact representation of the original uncompressed data. Simply stated, the decoded (or reconstructed) data is identical to the original unencoded/uncompressed data. Lossless data compression is also known as reversible or noiseless compression. Thus, lossless data compression has, as its current limit, a minimum representation defined by the entropy of a given data set.

There are various problems associated with the use of lossless compression techniques. One fundamental problem encountered with most lossless data compression techniques are their content sensitive behavior. This is often referred to as data dependency. Data dependency implies that the compression ratio achieved is highly contingent upon the content of the data being compressed. For example, database files often have large unused fields and high data redundancies, offering the opportunity to losslessly compress data at ratios of 5 to 1 or more. In contrast, concise software programs have little to no data redundancy and, typically, will not losslessly compress better than 2 to 1.

Another problem with lossless compression is that there are significant variations in the compression ratio obtained when using a single lossless data compression technique for data streams having different data content and data size. This process is known as natural variation.

A further problem is that negative compression may occur when certain data compression techniques act upon many types of highly compressed data. Highly compressed data appears random and many data compression techniques will substantially expand, not compress this type of data.

For a given application, there are many factors that govern the applicability of various data compression techniques. These factors include compression ratio, encoding and decoding processing requirements, encoding and decoding time delays, compatibility with existing standards, and implementation complexity and cost, along with the is adaptability and robustness to variations in input data. A direct relationship exists in the current art between compression ratio and the amount and complexity of processing required. One of the limiting factors in most existing prior art lossless data compression techniques is the rate at which the encoding and decoding processes are performed. Hardware and software implementation tradeoffs are often dictated by encoder and decoder complexity along with cost.

Another problem associated with lossless compression methods is determining the optimal compression technique for a given set of input data and intended application. To combat this problem, there are many conventional content dependent techniques that may be utilized. For instance, file type descriptors are typically appended to file names to describe the application programs that normally act upon the data contained within the file. In this manner data types, data structures, and formats within a given file may be ascertained. Fundamental limitations with this content dependent technique include:

(1) the extremely large number of application programs, some of which do not possess published or documented file formats, data structures, or data type descriptors;

(2) the ability for any data compression supplier or consortium to acquire, store, and access the vast amounts of data required to identify known file descriptors and associated data types, data structures, and formats; and

(3) the rate at which new application programs are developed and the need to update file format data descriptions accordingly.

An alternative technique that approaches the problem of selecting an appropriate lossless data compression technique is disclosed, for example, in U.S. Pat. No. 5,467,087 to Chu entitled "High Speed Lossless Data Compression System" ("Chu"). FIG. 1 illustrates an embodiment of this data compression and decompression technique. Data compression 1 comprises two phases, a data pre-compression phase 2 and a data compression phase 3. Data decompression 4 of a compressed input data stream is also comprised of two phases, a data type retrieval phase 5 and a data decompression phase 6. During the data compression process 1, the data pre-compressor 2 accepts an uncompressed data stream, identifies the data type of the input stream, and generates a data type identification signal. The data compressor 3 selects a data compression method from a preselected set of methods to compress the input data stream, with the intention of producing the best available compression ratio for that particular data type.

There are several limitations associated with the Chu method. One such limitation is the need to unambiguously identify various data types. While these might include such common data types as ASCII, binary, or unicode, there, in fact, exists a broad universe of data types that fall outside the three most common data types. Examples of these alternate data types include: signed and unsigned integers of various lengths, differing types and precision of floating point numbers, pointers, other forms of character text, and a multitude of user defined data types. Additionally, data types may be interspersed or partially compressed, making data type recognition difficult and/or impractical. Another limitation is that given a known data type, or mix of data types within a specific set or subset of input data, it may be difficult and/or impractical to predict which data encoding technique yields the highest compression ratio.

Accordingly, there is a need for a data compression system and method that would address limitations in conventional data compression techniques as described above.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for providing fast and efficient data compression using a combination of content independent data compression and content dependent data compression. In one aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

performing content independent data compression on the data block, if the data type of the data block is not identified.

In another aspect, the step of performing content independent data compression comprises: encoding the data block with a plurality of encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the encoders; comparing each of the determined compression ratios with a first compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression ratios do not meet the first compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the first compression threshold.

In another aspect, the step of performing content dependent compression comprises the steps of: selecting one or more encoders associated with the identified data type and encoding the data block with the selected encoders to provide a plurality of encoded data blocks; determining a compression ratio obtained for each of the selected encoders; comparing each of the determined compression ratios with a second compression threshold; selecting for output the input data block and appending a null compression descriptor to the input data block, if all of the encoder compression do not meet the second compression threshold; and selecting for output the encoded data block having the highest compression ratio and appending a corresponding compression type descriptor to the selected encoded data block, if at least one of the compression ratios meet the second compression threshold.

In yet another aspect, the step of performing content independent data compression on the data block, if the data type of the data block is not identified, comprises the steps of: estimating a desirability of using of one or more encoder types based one characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of performing content dependent data compression on the data block, if the data type of the data block is identified, comprises the steps of: estimating a desirability of using of one or more encoder types based on characteristics of the data block; and compressing the data block using one or more desirable encoders.

In another aspect, the step of analyzing the data block comprises analyzing the data block to recognize one of a data type, data structure, data block format, file substructure, and/or file types. A further step comprises maintaining an association between encoder types and data types, data structures, data block formats, file substructure, and/or file types.

In yet another aspect of the invention, a method for compressing data comprises the steps of:

analyzing a data block of an input data stream to identify a data type of the data block, the input data stream comprising a plurality of disparate data types;

performing content dependent data compression on the data block, if the data type of the data block is identified;

determining a compression ratio of the compressed data block obtained using the content dependent compression and comparing the compression ratio with a first compression threshold; and

performing content independent data compression on the data block, if the data type of the data block is not identified or if the compression ratio of the compressed data block obtained using the content dependent compression does not meet the first compression threshold.

Advantageously, the present invention employs a plurality of encoders applying a plurality of compression techniques on an input data stream so as to achieve maximum compression in accordance with the real-time or pseudo real-time data rate constraint. Thus, the output bit rate is not fixed and the amount, if any, of permissible data quality degradation is user or data specified.

These and other aspects, features and advantages of the present invention will become apparent from the following detailed description of preferred embodiments, which is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block/flow diagram of a content dependent high-speed lossless data compression and decompression system/method according to the prior art;

FIG. **2** is a block diagram of a content independent data compression system according to one embodiment of the present invention;

FIGS. **3***a* and **3***b* comprise a flow diagram of a data compression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **2**;

FIG. **4** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an enhanced metric for selecting an optimal encoding technique;

FIGS. **5***a* and **5***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **4**;

FIG. **6** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an a priori specified timer that provides real-time or pseudo real-time of output data;

FIGS. **7***a* and **7***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **6**;

FIG. **8** is a block diagram of a content independent data compression system according to another embodiment having an a priori specified timer that provides real-time or pseudo real-time of output data and an enhanced metric for selecting an optimal encoding technique;

FIG. **9** is a block diagram of a content independent data compression system according to another embodiment of the present invention having an encoding architecture comprising a plurality of sets of serially cascaded encoders;

FIGS. **10***a* and **10***b* comprise a flow diagram of a data compression method according to another aspect of the present invention, which illustrates the operation of the data compression system of FIG. **9**;

FIG. **11** is block diagram of a content independent data decompression system according to one embodiment of the present invention;

FIG. **12** is a flow diagram of a data decompression method according to one aspect of the present invention, which illustrates the operation of the data compression system of FIG. **11**;

FIGS. **13***a* and **13***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to an embodiment of the present invention;

FIGS. **14***a*-**14***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to one aspect of the present invention;

FIGS. **15***a* and **15***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention;

FIGS. **16***a*-**16***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention;

FIGS. **17***a* and **17***b* comprise a block diagram of a data compression system comprising content dependent and content independent data compression, according to another embodiment of the present invention; and

FIGS. **18***a*-**18***d* comprise a flow diagram of a data compression method using both content dependent and content independent data compression, according to another aspect of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to systems and methods for providing data compression and decompression using content independent and content dependent data compression and decompression. In the following description, it is to be understood that system elements having equivalent or similar functionality are designated with the same reference numerals in the Figures. It is to be further understood that the present invention may be implemented in various forms of hardware, software, firmware, or a combination thereof. In particular, the system modules described herein are preferably implemented in software as an application program that is executable by, e.g., a general purpose computer or any machine or device having any suitable and preferred microprocessor architecture. Preferably, the present invention is implemented on a computer platform including hardware such as one or more central processing units (CPU), a random access memory (RAM), and input/output (I/O) interface(s). The computer platform also includes an operating system and microinstruction code. The various processes and functions described herein may be either part of the microinstruction code or application programs which are executed via the operating system. In addition, various other peripheral devices may be connected to the computer platform such as an additional data storage device and a printing device.

It is to be further understood that, because some of the constituent system components described herein are preferably implemented as software modules, the actual system connections shown in the Figures may differ depending upon the manner in which the systems are programmed. It is to be appreciated that special purpose microprocessors may be employed to implement the present invention. Given the teachings herein, one of ordinary skill in the related art will be able to contemplate these and similar implementations or configurations of the present invention.

Referring now to FIG. **2** a block diagram illustrates a content independent data compression system according to one embodiment of the present invention. The data compression system includes a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds an a priori specified minimum compression ratio threshold. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

An encoder module **30** is operatively connected to the buffer **20** and comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder module **30** successively receives as input each of the buffered input data blocks (or unbuffered input data blocks from the counter module **10**). Data compression is performed by the encoder module **30** wherein each of the encoders E**1** . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders E**1** . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the is encoding process may be performed either in parallel or sequentially. In particular, the encoders E**1** through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders E**1** through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E**1** may comprise two parallel Huffman encoders for parallel processing of an input data block.

A buffer/counter module **40** is operatively connected to the encoding module **30** for buffering and counting the size of each of the encoded data blocks output from encoder module **30**. Specifically, the buffer/counter **30** comprises a plurality of buffer/counters BC**1**, BC**2**, BC**3** . . . BCn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **50**, operatively connected to the output buffer/counter **40**, determines the compression ratio obtained for each of the enabled encoders E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BC**1** . . . BCn. In addition, the compression ratio module **50** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders E**1** . . . En achieves a compression that exceeds an a priori-specified threshold. As is understood by those skilled in the art, the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. A description module **60**, operatively coupled to the compression ratio module **50**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

The operation of the data compression system of FIG. **2** will now be discussed in is further detail with reference to the flow diagram of FIGS. **3***a* and **3***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **300**). As stated above, data compression is performed on a per data block basis. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **302**). The data block is then stored in the buffer **20** (step **304**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **306**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **308**), and the encoded data block size is counted (step **310**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of each encoded data block output from the enabled encoders (step **312**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **314**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art.

After the compression ratios are compared with the threshold, a determination is s made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **316**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **316**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **318**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **320**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **316**), then the encoded data block having the greatest compression ratio is selected (step **322**). An appropriate data compression type descriptor is then appended (step **324**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **326**).

After the encoded data block or the unencoded data input data block is output (steps **326** and **320**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **328**). If the input data stream includes additional data blocks (affirmative result in step **328**), the next successive data block is received (step **330**), its block size is counted (return to step **302**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **328**), data compression of the input data stream is finished (step **322**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

Referring now to FIG. **4**, a block diagram illustrates a content independent data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **4** is similar to the data compression system of FIG. **2** except that the embodiment of FIG. **4** includes an enhanced metric functionality for selecting an optimal encoding technique. In particular, each of the encoders E**1** . . . En in the encoder module **30** is tagged with a corresponding one of user-selected encoder desirability factors **70**. Encoder desirability is defined as an a priori user specified factor that takes into account any number of user considerations including, but not limited to, compatibility of the encoded data with existing standards, data error robustness, or any other aggregation of factors that the user wishes to consider for a particular application. Each encoded data block output from the encoder module **30** has a corresponding desirability factor appended thereto. A figure of merit module **80**, operatively coupled to the compression ratio module **50** and the descriptor module **60**, is provided for calculating a figure of merit for each of the encoded data blocks which possess a compression ratio greater than the compression ratio threshold limit. The figure of merit for each encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor. As discussed below in further detail with reference to FIGS. **5***a* and **5***b*, the figure of merit substitutes the a priori user compression threshold limit for selecting and outputting encoded data blocks.

The operation of the data compression system of FIG. **4** will now be discussed in further detail with reference to the flow diagram of FIGS. **5***a* and **5***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **500**). The size of the first data block is then determined by the counter module **10** (step **502**). The data block is then stored in the buffer **20** (step **504**). The data block is then sent to the encoder module **30** and compressed by each (enabled) encoder in the encoder set E**1** . . . En (step **506**). Each encoded data block processed in the encoder module **30** is tagged with an encoder desirability factor that corresponds the particular encoding technique applied to the encoded data block (step **508**). Upon completion of the encoding of the input data block, an encoded data block with its corresponding desirability factor is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **510**), and the encoded data block size is counted (step **512**).

Next, a compression ratio obtained by each enabled encoder is calculated by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **514**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **516**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **518**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **518**), then the original unencoded input data block is selected for output and a null data compression type descriptor (as discussed above) is appended thereto (step **520**). Accordingly, the original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **522**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **518**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **524**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected for output (step **526**). An appropriate data compression type descriptor is then appended (step **528**) to indicate the data encoding technique applied to the encoded data block. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **530**).

After the encoded data block or the unencoded input data block is output (steps **530** and **522**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **532**). If the input data stream includes additional data blocks (affirmative result in step **532**), then the next successive data block is received (step **534**), its block size is counted (return to step **502**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **532**), data compression of the input data stream is finished (step **536**).

Referring now to FIG. **6**, a block diagram illustrates a data compression system according to another embodiment of the present invention. The data compression system depicted in FIG. **6** is similar to the data compression system discussed in detail above with reference to FIG. **2** except that the embodiment of FIG. **6** includes an a priori specified timer that provides real-time or pseudo real-time output data. In particular, an interval timer **90**, operatively coupled to the encoder module **30**, is preloaded with a user specified time value. The role of the interval timer (as will be explained in greater detail below with reference to FIGS. **7***a* and **7***b*) is to limit the processing time for each input data block processed by the encoder module **30** so as to ensure that the real-time, pseudo real-time, or other time critical nature of the data compression processes is preserved.

The operation of the data compression system of FIG. **6** will now be discussed in further detail with reference to the flow diagram of FIGS. **7***a* and **7***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **700**), and its size is determined by the counter module **10** (step **702**). The data block is then stored in buffer **20** (step **704**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **706**) and starts counting towards a user-specified time limit. The input data block is then sent to the encoder module **30** wherein data compression of the data block by each (enabled) encoder E**1** . . . En commences (step **708**). Next, a determination is made as to whether the user specified time expires before the completion of the encoding process (steps **710** and **712**). If the encoding process is completed before or at the expiration of the timer, i.e., each encoder (E**1** through En) completes its respective encoding process (negative result in step **710** and affirmative result in step **712**), then an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **714**).

On the other hand, if the timer expires (affirmative result in **710**), the encoding process is halted (step **716**). Then, encoded data blocks from only those enabled encoders E**1** . . . En that have completed the encoding process are selected and maintained in buffers (step **718**). It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency and natural variation, it is possible that certain encoders may not operate quickly enough and, therefore, do not comply with the timing constraints of the end use. Accordingly, the time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are buffered (step **714** or **718**), the size of each encoded data block is counted (step **720**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each enabled encoder (step **722**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **724**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **726**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **726**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **728**). The original unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **730**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **726**), then the encoded data block having the greatest compression ratio is selected (step **732**). An appropriate data compression type descriptor is then appended (step **734**). The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **736**).

After the encoded data block or the unencoded input data block is output (steps **730** or **736**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **738**). If the input data stream includes additional data blocks (affirmative result in step **738**), the next successive data block is received (step **740**), its block size is counted (return to step **702**) and the data compression process in repeated. This process is iterated for each data block in the input data stream, with each data block being processed within the user-specified time limit as discussed above. Once the final input data block is processed (negative result in step **738**), data compression of the input data stream is complete (step **742**).

Referring now to FIG. **8**, a block diagram illustrates a content independent data compression system according to another embodiment of the present system. The data compression system of FIG. **8** incorporates all of the features discussed above in connection with the system embodiments of FIGS. **2**, **4**, and **6**. For example, the system of FIG. **8** incorporates both the a priori specified timer for providing real-time or pseudo real-time of output data, as well as the enhanced metric for selecting an optimal encoding technique. Based on the foregoing discussion, the operation of the system of FIG. **8** is understood by those skilled in the art.

Referring now to FIG. **9**, a block diagram illustrates a data compression system according to a preferred embodiment of the present invention. The system of FIG. **9** contains many of the features of the previous embodiments discussed above. However, this embodiment advantageously includes a cascaded encoder module **30***c* having an encoding architecture comprising a plurality of sets of serially cascaded encoders Em,n, where "m" refers to the encoding path (i.e., the encoder set) and where "n" refers to the number of encoders in the respective path. It is to be understood that each set of serially cascaded encoders can include any number of disparate and/or similar encoders (i.e., n can be any value for a given path m).

The system of FIG. **9** also includes a output buffer module **40***c* which comprises a plurality of buffer/counters B/Cm,n, each associated with a corresponding one of the encoders Em,n. In this embodiment, an input data block is sequentially applied to successive encoders (encoder stages) in the encoder path so as to increase the data compression ratio. For example, the output data block from a first encoder E**1**,**1**, is buffered and counted in B/C**1**,**1**, for subsequent processing by a second encoder E**1**,**2**. Advantageously, these parallel sets of sequential encoders are applied to the input data stream to effect content free lossless data compression. This embodiment provides for multi-stage sequential encoding of data with the maximum number of encoding steps subject to the available real-time, pseudo real-time, or other timing constraints.

As with each previously discussed embodiment, the encoders Em,n may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Encoding techniques are selected based upon their ability to effectively encode different types of input data. A full complement of encoders provides for broad coverage of existing and future data types. The input data blocks may be applied simultaneously to the encoder paths (i.e., the encoder paths may operate in parallel, utilizing task multiplexing on a single central processor, or via dedicated hardware, or by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, an input data block may be sequentially applied to the encoder paths. Moreover, each serially cascaded encoder path may comprise a fixed (predetermined) sequence of encoders or a random sequence of encoders. Advantageously, by simultaneously or sequentially processing input data blocks via a plurality of sets of serially cascaded encoders, content free data compression is achieved.

The operation of the data compression system of FIG. **9** will now be discussed in further detail with reference to the flow diagram of FIGS. **10***a* and **10***b*. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the data stream is received (step **100**), and its size is determined by the counter module **10** (step **102**). The data block is then stored in buffer **20** (step **104**).

Next, concurrent with the completion of the receipt and counting of the first data block, the interval timer **90** is initialized (step **106**) and starts counting towards a user-specified time limit. The input data block is then sent to the cascade encoder module **30**C wherein the input data block is applied to the first encoder (i.e., first encoding stage) in each of the cascaded encoder paths E**1**,**1** . . . Em,**1** (step **108**). Next, a determination is made as to whether the user specified time expires before the completion of the first stage encoding process (steps **110** and **112**). If the first stage encoding process is completed before the expiration of the timer, i.e., each encoder (E**1**,**1** . . . Em,**1**) completes its respective encoding process (negative result in step **110** and affirmative result in step **112**), then an encoded data block is output from each encoder E**1**,**1** . . . Em,**1** and maintained in a corresponding buffer (step **114**). Then for each cascade encoder path, the output of the completed encoding stage is applied to the next successive encoding stage in the cascade path (step **116**). This process (steps **110**, **112**, **114**, and **116**) is repeated until the earlier of the timer expiration (affirmative result in step **110**) or the completion of encoding by each encoder stage in the serially cascaded paths, at which time the encoding process is halted (step **118**).

Then, for each cascade encoder path, the buffered encoded data block output by the last encoder stage that completes the encoding process before the expiration of the timer is selected for further processing (step **120**). Advantageously, the interim stages of the multi-stage data encoding process are preserved. For example, the results of encoder E**1**,**1** are preserved even after encoder E**1**,**2** begins encoding the output of encoder E**1**,**1**. If the interval timer expires after encoder E**1**,**1** completes its respective encoding process but before encoder E**1**,**2** completes its respective encoding process, the encoded data block from encoder E**1**,**1** is complete and is utilized for calculating the compression ratio for the corresponding encoder path. The incomplete encoded data block from encoder E**1**,**2** is either discarded or ignored.

It is to be appreciated that it is not necessary (or in some cases desirable) that some or all of the encoders in the cascade encoder paths complete the encoding process before the interval timer expires. Specifically, due to encoder data dependency, natural variation and the sequential application of the cascaded encoders, it is possible that certain encoders may not operate quickly enough and therefore do not comply with the timing constraints of the end use. Accordingly, the time limit ensures that the real-time or pseudo real-time nature of the data encoding is preserved.

After the encoded data blocks are selected (step **120**), the size of each encoded data block is counted (step **122**). Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10**) to the size of the encoded data block output from each encoder (step **124**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **126**). A determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **128**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **128**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **130**). The original unencoded data block and its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **132**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **128**), then a figure of merit is calculated for each encoded data block having a compression ratio which exceeds the compression ratio threshold limit (step **134**). Again, the figure of merit for a given encoded data block is comprised of a weighted average of the a priori user specified threshold and the corresponding encoder desirability factor associated with the encoded data block. Next, the encoded data block having the greatest figure of merit is selected (step **136**). An appropriate data compression type descriptor is then appended (step **138**) to indicate the data encoding technique applied to the encoded data block. For instance, the data type compression descriptor can indicate that the encoded data block was processed by either a single encoding type, a plurality of sequential encoding types, and a plurality of random encoding types. The encoded data block (which has the greatest figure of merit) along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **140**).

After the unencoded data block or the encoded data input data block is output (steps **132** and **140**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **142**). If the input data stream includes additional data blocks (affirmative result in step **142**), then the next successive data block is received (step **144**), its block size is counted (return to step **102**) and the data compression process is iterated for each successive data block in the input data stream. Once the final input data block is processed (negative result in step **142**), data compression of the input data stream is finished (step **146**).

Referring now to FIG. **11**, a block diagram illustrates a data decompression system according to one embodiment of the present invention. The data decompression system preferably includes an input buffer **1100** that receives as input an uncompressed or compressed data stream comprising one or more data blocks. The data blocks may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The input data buffer **1100** is preferably included (not required) to provide storage of input data for various hardware implementations. A descriptor extraction module **1102** receives the buffered (or unbuffered) input data block and then parses, lexically, syntactically, or otherwise analyzes the input data block using methods known by those skilled in the art to extract the data compression type descriptor associated with the data block. The data compression type descriptor may possess values corresponding to null (no encoding applied), a single applied encoding technique, or multiple encoding techniques applied in a specific or random order (in accordance with the data compression system embodiments and methods discussed above).

A decoder module **1104** includes a plurality of decoders D**1** . . . Dn for decoding the input data block using a decoder, set of decoders, or a sequential set of decoders corresponding to the extracted compression type descriptor. The decoders D**1** . . . Dn may include those lossless encoding techniques currently well known within the art, including: run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Decoding techniques are selected based upon their ability to effectively decode the various different types of encoded input data generated by the data compression systems described above or originating from any other desired source. As with the data compression systems discussed above, the decoder module **1104** may include multiple decoders of the same type applied in parallel so as to reduce the data decoding time.

The data decompression system also includes an output data buffer **1106** for buffering the decoded data block output from the decoder module **1104**.

The operation of the data decompression system of FIG. **11** will be discussed in further detail with reference to the flow diagram of FIG. **12**. A data stream comprising one or more data blocks of compressed or uncompressed data is input into the data decompression system and the first data block in the stream is received (step **1200**) and maintained in the buffer (step **1202**). As with the data compression systems discussed above, data decompression is performed on a per data block basis. The data compression type descriptor is then extracted from the input data block (step **1204**). A determination is then made as to whether the data compression type descriptor is null (step **1206**). If the data compression type descriptor is determined to be null (affirmative result in step **1206**), then no decoding is applied to the input data block and the original undecoded data block is output (or maintained in the output buffer) (step **1208**).

On the other hand, if the data compression type descriptor is determined to be any value other than null (negative result in step **1206**), the corresponding decoder or decoders are then selected (step **1210**) from the available set of decoders D**1** . . . Dn in the decoding module **1104**. It is to be understood that the data compression type descriptor may mandate the application of: a single specific decoder, an ordered sequence of specific decoders, a random order of specific decoders, a class or family of decoders, a mandatory or optional application of parallel decoders, or any combination or permutation thereof. The input data block is then decoded using the selected decoders (step **1212**), and output (or maintained in the output buffer **1106**) for subsequent data processing, storage, or transmittal (step **1214**). A determination is then made as to whether the input data stream contains additional data blocks to be processed (step **1216**). If the input data stream includes additional data blocks (affirmative result in step **1216**), the next successive data block is received (step **1220**), and buffered (return to step **1202**). Thereafter, the data decompression process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1216**), data decompression of the input data stream is finished (step **1218**).

In other embodiments of the present invention described below, data compression is achieved using a combination of content dependent data compression and content independent data compression. For example, FIGS. **13***a* and **13***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to one embodiment of the present invention, wherein content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The data compression system comprises a counter module **10** that receives as input an uncompressed or compressed data stream. It is to be understood that the system processes the input data stream in data blocks that may range in size from individual bits through complete files or collections of multiple files. Additionally, the data block size may be fixed or variable. The counter module **10** counts the size of each input data block (i.e., the data block size is counted in bits, bytes, words, any convenient data multiple or metric, or any combination thereof).

An input data buffer **20**, operatively connected to the counter module **10**, may be provided for buffering the input data stream in order to output an uncompressed data stream in the event that, as discussed in further detail below, every encoder fails to achieve a level of compression that exceeds a priori specified content independent or content dependent minimum compression ratio thresholds. It is to be understood that the input data buffer **20** is not required for implementing the present invention.

A content dependent data recognition module **1300** analyzes the incoming data stream to recognize data types, data structures, data block formats, file substructures, file types, and/or any other parameters that may be indicative of either the data type/content of a given data block or the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1310** module may be employed to hold and/or determine associations between recognized data parameters and appropriate algorithms. Each data block that is recognized by the content data compression module **1300** is routed to a content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**.

A content dependent encoder module **1320** is operatively connected to the content dependent data recognition module **1300** and comprises a set of encoders D**1**, D**2**, D**3** . . . Dm. The encoder set D**1**, D**2**, D**3** . . . Dm may include any number "n" of those lossless or lossy encoding techniques currently well known within the art such as MPEG4, various voice codecs, MPEG3, AC3, AAC, as well as lossless algorithms such as run length, Huffinan, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. It is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders and or codecs are preferably selected to provide a broad coverage of existing and future data types.

The content independent encoder module **30**, which is operatively connected to the content dependent data recognition module **1300**, comprises a set of encoders E**1**, E**2**, E**3** . . . En. The encoder set E**1**, E**2**, E**3** . . . En may include any number "n" of those lossless encoding techniques currently well known within the art such as run length, Huffman, Lempel-Ziv Dictionary Compression, arithmetic coding, data compaction, and data null suppression. Again, it is to be understood that the encoding techniques are selected based upon their ability to effectively encode different types of input data. It is to be appreciated that a full complement of encoders are preferably selected to provide a broad coverage of existing and future data types.

The encoder modules (content dependent **1320** and content independent **30**) selectively receive the buffered input data blocks (or unbuffered input data blocks from the counter module **10**) from module **1300** based on the results of recognition. Data compression is performed by the respective encoder modules wherein some or all of the encoders D1 . . . Dm or E1 . . . En processes a given input data block and outputs a corresponding set of encoded data blocks. It is to be appreciated that the system affords a user the option to enable/disable any one or more of the encoders D1 . . . Dm and E1 . . . En prior to operation. As is understood by those skilled in the art, such feature allows the user to tailor the operation of the data compression system for specific applications. It is to be further appreciated that the encoding process may be performed either in parallel or sequentially. In particular, the encoder set D1 through Dm of encoder module **1320** and/or the encoder set E1 through En of encoder module **30** may operate in parallel (i.e., simultaneously processing a given input data block by utilizing task multiplexing on a single central processor, via dedicated hardware, by executing on a plurality of processor or dedicated hardware systems, or any combination thereof). In addition, encoders D1 through Dm and E1 through En may operate sequentially on a given unbuffered or buffered input data block. This process is intended to eliminate the complexity and additional processing overhead associated with multiplexing concurrent encoding techniques on a single central processor and/or dedicated hardware, set of central processors and/or dedicated hardware, or any achievable combination. It is to be further appreciated that encoders of the identical type may be applied in parallel to enhance encoding speed. For instance, encoder E1 may comprise two parallel Huffman encoders for parallel processing of an input data block. It should be further noted that one or more algorithms may be implemented in dedicated hardware such as an MPEG4 or MP3 encoding integrated circuit.

Buffer/counter modules **1330** and **40** are operatively connected to their respective encoding modules **1320** and **30**, for buffering and counting the size of each of the encoded data blocks output from the respective encoder modules. Specifically, the content dependent buffer/counter **1330** comprises a plurality of buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm, each operatively associated with a corresponding one of the encoders D**1** . . . Dm. Similarly the content independent buffer/counters BCE**1**, BCE**2**, BCE**3** . . . BCEn, each operatively associated with a corresponding one of the encoders E**1** . . . En. A compression ratio module **1340**, operatively connected to the content dependent output buffer/counters **1330** and content independent buffer/counters **40** determines the compression ratio obtained for each of the enabled encoders D**1** . . . Dm and or E**1** . . . En by taking the ratio of the size of the input data block to the size of the output data block stored in the corresponding buffer/counters BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn. In addition, the compression ratio module **1340** compares each compression ratio with an a priori-specified compression ratio threshold limit to determine if at least one of the encoded data blocks output from the enabled encoders BCD**1**, BCD**2**, BCD**3** . . . BCDm and or BCE**1**, BCE**2**, BCE**3** . . . BCEn achieves a compression that meets an a priori-specified threshold. As is. understood by those skilled in the art, the threshold limit maybe specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It should be noted that different threshold values may be applied to content dependent and content independent encoded data. Further these thresholds may be adaptively modified based upon enabled encoders in either or both the content dependent or content independent encoder sets, along with any associated parameters. A compression type description module **1350**, operatively coupled to the compression ratio module **1340**, appends a corresponding compression type descriptor to each encoded data block which is selected for output so as to indicate the type of compression format of the encoded data block.

A mode of operation of the data compression system of FIGS. **13***a* and **13***b* will now be discussed with reference to the flow diagrams of FIGS. **14***a*-**14***d*, which illustrates a method for performing data compression using a combination of content dependent and content independent data compression. In general, content independent data compression is applied to a given data block when the content of a data block cannot be identified or is not associated with a specific data compression algorithm. More specifically, referring to FIG. **14***a*, a data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1400**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1402**). The data block is then stored in the buffer **20** (step **1404**). The data block is then analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1408**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1410**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1412**), and the encoded data block size is counted (step **1414**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1416**). Each compression ratio is then compared with an apriori-specified compression ratio threshold (step **1418**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

As previously stated the data block stored in the buffer **20** (step **1404**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1406**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1434**) the appropriate content dependent algorithms are enabled and initialized (step **1436**), and the data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1438**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1440**), and the encoded data block size is counted (step **1442**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1444**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1448**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1420**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1420**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1434**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1436**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1420**), then the encoded data block having the greatest compression ratio is selected (step **1422**). An appropriate data compression type descriptor is then appended (step **1424**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1426**).

After the encoded data block or the unencoded data input data block is output (steps **1426** and **1436**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1428**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1432**), its block size is counted (return to step **1402**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1428**), data compression of the input data stream is finished (step **1430**).

Since a multitude of data types may be present within a given input data block, it is often difficult and/or impractical to predict the level of compression that will be achieved by a specific encoder. Consequently, by processing the input data blocks with a plurality of encoding techniques and comparing the compression results, content free data compression is advantageously achieved. Further the encoding may be lossy or lossless dependent upon the input data types. Further if the data type is not recognized the default content independent lossless compression is applied. It is not a requirement that this process be deterministic—in fact a certain probability may be applied if occasional data loss is permitted. It is to be appreciated that this approach is scalable through future generations of processors, dedicated hardware, and software. As processing capacity increases and costs reduce, the benefits provided by the present invention will continue to increase. It should again be noted that the present invention may employ any lossless data encoding technique.

FIGS. **15***a* and **15***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **15***a* and **15***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **15***a* and **15***b* additionally performs content independent data compression on a data block when the compression ratio obtained for the data block using the content dependent data compression does not meet a specified threshold.

A mode of operation of the data compression system of FIGS. **15***a* and **15***b* will now be discussed with reference to the flow diagram of FIGS. **16***a*-**16***d*, which illustrates a method for performing data compression using a combination of content dependent and content independent data compression. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1600**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1602**). The data block is then stored in the buffer **20** (step **1604**). The data block is then analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1608**) the data is routed to the content independent encoder module **30** and compressed by each (enabled) encoder E**1** . . . En (step **1610**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1612**), and the encoded data block size is counted (step **1614**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1616**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1618**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1620**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1634**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1636**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1620**), then the encoded data block having the greatest compression ratio is selected (step **1622**). An appropriate data compression type descriptor is then appended (step **1624**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1626**).

As previously stated the data block stored in the buffer **20** (step **1604**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1606**). If the data stream content is recognized utilizing the recognition list(s) or algorithms(s) module **1310** (step **1634**) the appropriate content dependent algorithms are enabled and initialized (step **1636**) and the data is routed to the content dependent encoder module **1620** and compressed by each (enabled) encoder D**1** . . . Dm (step **1638**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1640**), and the encoded data block size is counted (step **1642**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1644**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1648**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1648**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1620**), then the original unencoded input data block is routed to the content independent encoder module **30** and the process resumes with compression utilizing content independent encoders (step **1610**).

After the encoded data block or the unencoded data input data block is output (steps **1626** and **1636**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1628**). If the input data stream includes additional data blocks (affirmative result in step **1628**), the next successive data block is received (step **1632**), its block size is counted (return to step **1602**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1628**), data compression of the input data stream is finished (step **1630**).

FIGS. **17***a* and **17***b* are block diagrams illustrating a data compression system employing both content independent and content dependent data compression according to another embodiment of the present invention. The system in FIGS. **17***a* and **17***b* is similar in operation to the system of FIGS. **13***a* and **13***b* in that content independent data compression is applied to a data block when the content of the data block cannot be identified or is not associable with a specific data compression algorithm. The system of FIGS. **17***a* and **17***b* additionally uses a priori estimation algorithms or look-up tables to estimate the desirability of using content independent data compression encoders and/or content dependent data compression encoders and selecting appropriate algorithms or subsets thereof based on such estimation.

More specifically, a content dependent data recognition and or estimation module **1700** is utilized to analyze the incoming data stream for recognition of data types, data strictures, data block formats, file substructures, file types, or any other parameters that may be indicative of the appropriate data compression algorithm or algorithms (in serial or in parallel) to be applied. Optionally, a data file recognition list(s) or algorithm(s) **1710** module may be employed to hold associations between recognized data parameters and appropriate algorithms. If the content data compression module recognizes a portion of the data, that portion is routed to the content dependent encoder module **1320**, if not the data is routed to the content independent encoder module **30**. It is to be appreciated that process of recognition (modules **1700** and **1710**) is not limited to a deterministic recognition, but may further comprise a probabilistic estimation of which encoders to select for compression from the set of encoders of the content dependent module **1320** or the content independent module **30**. For example, a method may be employed to compute statistics of a data block whereby a determination that the locality of repetition of characters in a data stream is determined is high can suggest a text document, which may be beneficially compressed with a lossless dictionary type algorithm. Further the statistics of repeated characters and relative frequencies may suggest a specific type of dictionary algorithm. Long strings will require a wide dictionary file while a wide diversity of strings may suggest a deep dictionary. Statistics may also be utilized in algorithms such as Huffman where various character statistics will dictate the choice of different Huffinan compression tables. This technique is not limited to lossless algorithms but may be widely employed with lossy algorithms. Header information in frames for video files can imply a specific data resolution. The estimator then may select the appropriate lossy compression algorithm and compression parameters (amount of resolution desired). As shown in previous embodiments of the present invention, desirability of various algorithms and now associated resolutions with lossy type algorithms may also be applied in the estimation selection process.

A mode of operation of the data compression system of FIGS. **17***a* and **17***b* will now be discussed with reference to the flow diagrams of FIGS. **18***a*-**18***d*. The method of FIGS. **18***a*-**18***d* use a priori estimation algorithms or look-up tables to estimate the desirability or probability of using content independent data compression encoders or content dependent data compression encoders, and select appropriate or desirable algorithms or subsets thereof based on such estimates. A data stream comprising one or more data blocks is input into the data compression system and the first data block in the stream is received (step **1800**). As stated above, data compression is performed on a per data block basis. As previously stated a data block may represent any quantity of data from a single bit through a multiplicity of files or packets and may vary from block to block. Accordingly, the first input data block in the input data stream is input into the counter module **10** that counts the size of the data block (step **1802**). The data block is then stored in the buffer **20** (step **1804**). The data block is then analyzed on a per block or multi-block basis by the content dependent/content independent data recognition module **1700** (step **1806**). If the data stream content is not recognized utilizing the recognition list(s) or algorithms(s) module **1710** (step **1808**) the data is to the content independent encoder module **30**. An estimate of the best content independent encoders is performed (step **1850**) and the appropriate encoders are enabled and initialized as applicable. The data is then compressed by each (enabled) encoder E**1** . . . En (step **1810**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder E**1** . . . En and maintained in a corresponding buffer (step **1812**), and the encoded data block size is counted (step **1814**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1816**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1818**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

As previously stated the data block stored in the buffer **20** (step **1804**) is analyzed on a per block or multi-block basis by the content dependent data recognition module **1300** (step **1806**). If the data stream content is recognized or estimated utilizing the recognition list(s) or algorithms(s) module **1710** (affirmative result in step **1808**) the recognized data type/file or block is selected based on a list or algorithm (step **1838**) and an estimate of the desirability of using the associated content dependent algorithms can be determined (step **1840**). For instance, even though a recognized data type may be associated with three different encoders, an estimation of the desirability of using each encoder may result in only one or two of the encoders being actually selected for use. The data is routed to the content dependent encoder module **1320** and compressed by each (enabled) encoder D**1** . . . Dm (step **1842**). Upon completion of the encoding of the input data block, an encoded data block is output from each (enabled) encoder D**1** . . . Dm and maintained in a corresponding buffer (step **1844**), and the encoded data block size is counted (step **1846**).

Next, a compression ratio is calculated for each encoded data block by taking the ratio of the size of the input data block (as determined by the input counter **10** to the size of each encoded data block output from the enabled encoders (step **1848**). Each compression ratio is then compared with an a priori-specified compression ratio threshold (step **1850**). It is to be understood that the threshold limit may be specified as any value inclusive of data expansion, no data compression or expansion, or any arbitrarily desired compression limit. It is to be further understood that many of these algorithms may be lossy, and as such the limits may be subject to or modified by an end target storage, listening, or viewing device. Further notwithstanding that the current limit for lossless data compression is the entropy limit (the present definition of information content) for the data, the present invention does not preclude the use of future developments in lossless data compression that may increase lossless data compression ratios beyond what is currently known within the art. Additionally the content independent data compression threshold may be different from the content dependent threshold and either may be modified by the specific enabled encoders.

After the compression ratios are compared with the threshold, a determination is made as to whether the compression ratio of at least one of the encoded data blocks exceeds the threshold limit (step **1820**). If there are no encoded data blocks having a compression ratio that exceeds the compression ratio threshold limit (negative determination in step **1820**), then the original unencoded input data block is selected for output and a null data compression type descriptor is appended thereto (step **1834**). A null data compression type descriptor is defined as any recognizable data token or descriptor that indicates no data encoding has been applied to the input data block. Accordingly, the unencoded input data block with its corresponding null data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1836**).

On the other hand, if one or more of the encoded data blocks possess a compression ratio greater than the compression ratio threshold limit (affirmative result in step **1820**), then the encoded data block having the greatest compression ratio is selected (step **1822**). An appropriate data compression type descriptor is then appended (step **1824**). A data compression type descriptor is defined as any recognizable data token or descriptor that indicates which data encoding technique has been applied to the data. It is to be understood that, since encoders of the identical type may be applied in parallel to enhance encoding speed (as discussed above), the data compression type descriptor identifies the corresponding encoding technique applied to the encoded data block, not necessarily the specific encoder. The encoded data block having the greatest compression ratio along with its corresponding data compression type descriptor is then output for subsequent data processing, storage, or transmittal (step **1826**).

After the encoded data block or the unencoded data input data block is output (steps **1826** and **1836**), a determination is made as to whether the input data stream contains additional data blocks to be processed (step **1828**). If the input data stream includes additional data blocks (affirmative result in step **1428**), the next successive data block is received (step **1832**), its block size is counted (return to step **1802**) and the data compression process in repeated. This process is iterated for each data block in the input data stream. Once the final input data block is processed (negative result in step **1828**), data compression of the input data stream is finished (step **1830**).

It is to be appreciated that in the embodiments described above with reference to FIGS. **13**-**18**, an a priori specified time limit or any other real-time requirement may be employed to achieve practical and efficient real-time operation.

Although illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

What is claimed is:

1. A system for compressing data comprising;

a processor;

one or more content dependent data compression encoders; and

a single data compression encoder;

wherein the processor is configured:

to analyze data within a data block to identify one or more parameters or attributes of the data wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based solely on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block;

to perform content dependent data compression with the one or more content dependent data compression encoders if the one or more parameters or attributes of the data are identified; and

to perform data compression with the single data compression encoder, if the one or more parameters or attributes of the data are not identified.

2. The system of claim **1**, wherein the data block is received in an uncompressed form, the data block being included in one or more data blocks transmitted in sequence originating from an external source.

3. The system of claim **1**, wherein the data block is received in an uncompressed form, the data block being included in one or more data blocks transmitted in sequence originating from internal source.

4. The system of claim **1** wherein the compressing, is performed in real-time.

5. The system of claim **1**, wherein the content dependent data compression with the one or more content dependent data compression encoders is performed in real-time.

6. The system of claim **1**, wherein the data compression with the single data compression encoder is performed in real-time.

7. The system of claim **1** wherein the compressing is performed in real-time if the parameter or attribute of the data in the data block is not identified.

8. The system of claim **1** wherein the compressing is performed in real-time if the one or more parameters or attributes of the data in the data block is identified.

9. The system of claim **1**, wherein the processor is further configured to associate a data token indicative of the content dependent data compression applied to the data block to create a compressed data block.

10. The system of claim **1**, wherein the processor is further configured to associate a data token indicative of the single data compression encoder applied to the data block to create a compressed data block.

11. The system of claim **1**, wherein the content dependent data compression further comprises associating a plurality of encoders to the one or more parameters or attributes of the data, wherein at least one of the plurality of encoders provides lossy compression and at least another one of the plurality of encoders provides lossless compression.

12. The system of claim **1**, wherein the content dependent data compression is lossy or lossless depending on the one or more parameters or attributes of the data.

13. The system of claim **1**, wherein the content dependent data compression is lossy and an amount of desired resolution of the lossy compression is selected.

14. The system of claim **1**, wherein the single data compression encoder is lossy.

15. The system of claim **1**, wherein a compressed data block is stored.

16. The system of claim **1**, wherein the processor is further configured to output the data block in uncompressed form if the content dependent data compression results in a compressed data block indicative of data expansion.

17. The system of claim **1**, wherein the processor is further configured to output the data block in uncompressed form if the data compression with the single data compression encoder results in a compressed data block indicative of data expansion.

18. The system of claim **1**, wherein a compressed data block is transmitted, received, and decompressed, and wherein a time taken to compress, transmit, receive, and decompress is less than a time to transmit and receive the data block.

19. The system of claim **1**, wherein the content dependent data compression further comprises providing a compressed data block from one of a plurality of encoders, associated with the one or more of the parameters or attributes of the data;

wherein the one of the plurality of encoders has a higher desirability factor for the data block than another of the plurality of encoders.

20. The system of claim **1**, wherein the processor is further configured to output a compressed data block with a token representative of a compression technique used to compress the data block.

21. The system of claim **1**, wherein a compressed data block is the result of a lossy compression technique.

22. The system of claim **1**, wherein a compressed data block is the result of a lossy compression technique and an amount of resolution of the lossy compression technique is selectable.

23. The system of claim **1**, wherein at least one content dependent data compression technique performed by the one or more content dependent data compression encoders is lossy and a data compression technique performed by the single data compression encoder is lossless.

24. A system for compressing data comprising;

a processor;

one or more data compression encoders; and

a default data compression encoder;

wherein the processor is configured:

to analyze data within a data block to identify one or more parameters or attributes of the data wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based solely on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block; and

to compress the data block to provide a compressed data block, wherein if one or more encoders are associated with the one or more parameters or attributes of the data, compressing the data block with at least one of the one or more data compression encoders, otherwise compressing the data block with the default data compression encoder.

25. A computer implemented method comprising:

analyzing, using a processor, data within a data block to identify one or more parameters or attributes of the data within the data block;

determining, using the processor, whether to output the data block in a received form or in a compressed form; and

outputting, using the processor, the data block in the received form or the compressed form based on the determination,

wherein the outputting the data block in the compressed form comprises determining whether to compress the data block with content dependent data compression based on the one or more parameters or attributes of the data within the data block or to compress the data block with a single data compression encoder; and

wherein the analyzing of the data within the data block to identify the one or more parameters or attributes of the data excludes analyzing based only on a descriptor that is indicative of the one or more parameters or attributes of the data within the data block.

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