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Tzou

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[54] **PROGRESSIVE IMAGE TRANSMISSION**

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[51] **Int. Cl.**[4] **H04N 1/00**; H04N 7/12

[52] **U.S. Cl.** **358/260**; 358/133; 358/135; 382/56; 364/725

[58] **Field of Search** 358/133, 260, 135, 136; 382/56; 364/723, 725, 826

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Assistant Examiner—John K. Peng
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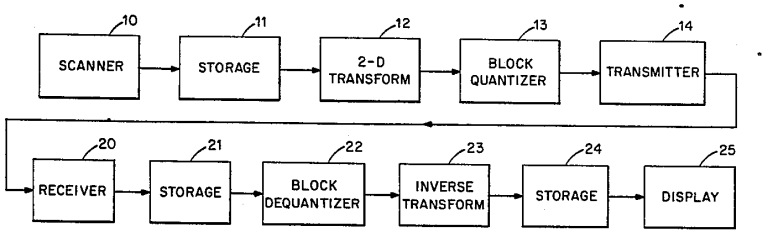
[57] **ABSTRACT**

System and method of progressively transmitting and reconstructing an image in which an approximate image is reconstructed based upon partial information and details are added as additional information becomes available. The image is divided into an array of blocks of picture elements and the data for each block is subjected to a two-dimensional transformation to provide transform coefficients thereof. The transform coefficients are quantized into a series of sets of quantized transform coefficients, each quantized transform coefficient being represented by a number of bits. Different numbers of bits are assigned to each quantized transform coefficient of each set of the series to represent the corresponding transform coefficient in increasingly finer detail. During each of a plurality of transmission sequences, signals representing the differences between each set of quantized transform coefficients and the preceding set of the series for each block are transmitted. The signals representing the differences between each set are combined as they are received to provide cumulative quantized transform coefficients for each block in increasingly finer detail after each transmission sequence. The cumulative quantized transform coefficients are dequantized to reconstituted transform coefficients which undergo an inverse of the two-dimensional transformation to provide reconstituted image data for each picture element of each block, the reconstituted image data being of increasingly finer detail after later transmission sequences.

35 Claims, 6 Drawing Figures



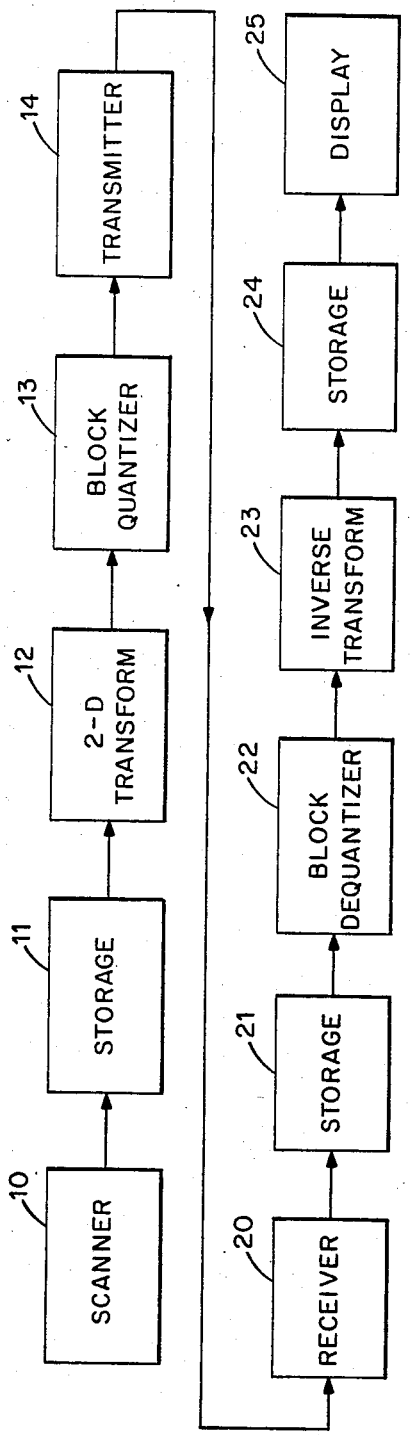


Fig. 1.

	0	1	2	3
0	102.40	18.01	7.49	3.62
1	11.70	7.86	4.76	2.74
2	4.39	4.09	3.08	2.16
3	2.32	2.20	2.03	1.74

Fig. 3.

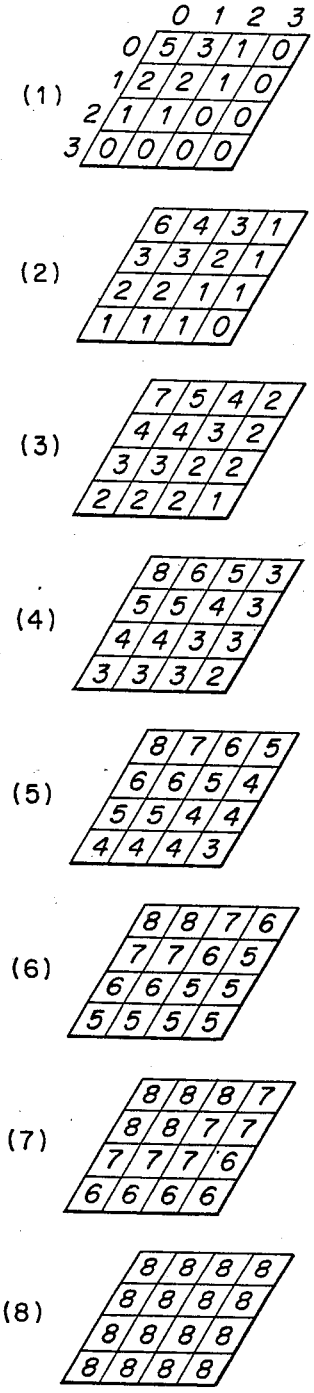


Fig. 2A.

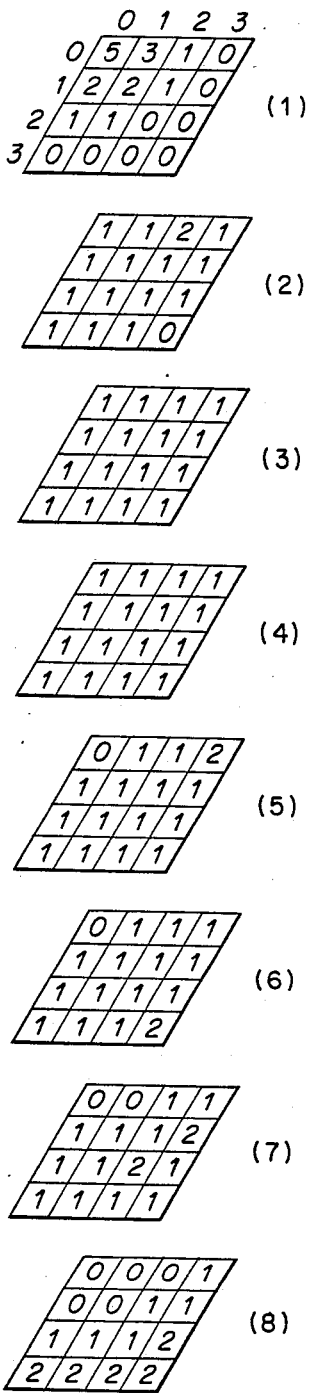


Fig. 2B.

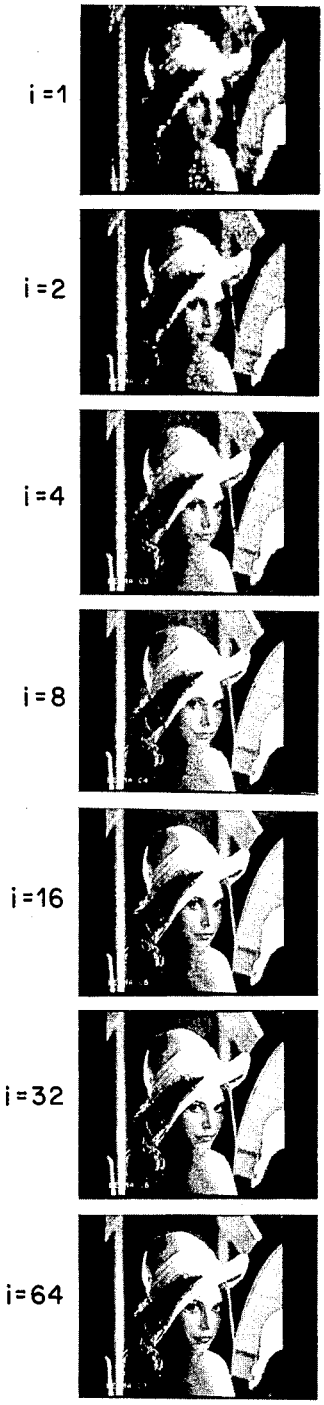


Fig. 4.

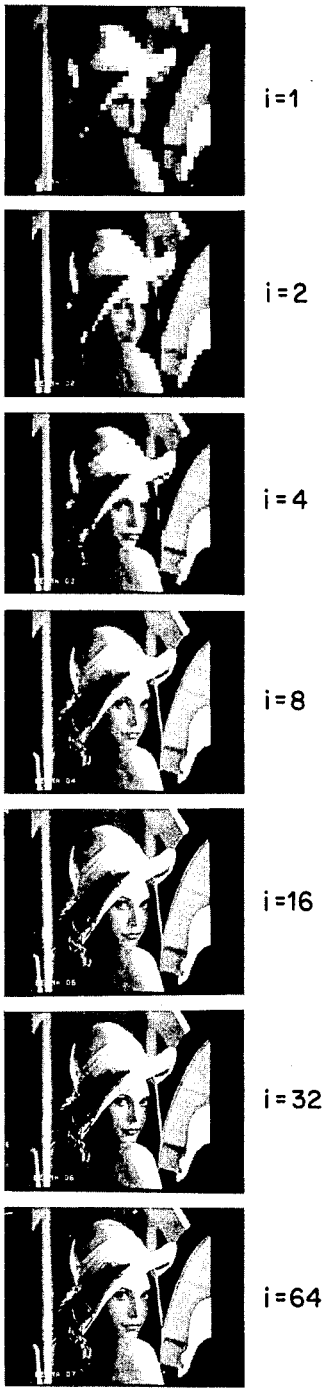


Fig. 5.

PROGRESSIVE IMAGE TRANSMISSION

BACKGROUND OF THE INVENTION

This invention relates to the transmission of pictorial image data. More particularly, it is concerned with the progressive transmission and reconstruction of coded images in which an approximate image is reconstructed based upon partial information and details are added as additional information becomes available.

The progressive transmission and reconstruction of coded images allows an approximate image based upon partially received information to be constructed to which additional details are added as additional information becomes available. This procedure has various applications in the field of image communications, such as for interactive picture retrieving, variable-rate video conferencing, and the quick display of freeze-frame image transmission. One relatively simple scheme proposed by Knowlton U.S. Pat. No. 4,222,076 issued Sept. 9, 1980, deals with spatial domain data for the progressive transmission of gray-scale pictures. This approach has the advantages of simplicity in implementation and no coding distortion in the final reconstructed image. However, due to the nature of successive picture subdivision introduced by this method, the number of accumulated bits of information increases exponentially with each interation.

Other schemes that deal with transform domain data have been described in articles by Takikawa "Fast Progressive Reconstruction of A Transformed Image," IEEE Trans. Inform. Theory, vol. IT-30, pp. 111–117, January 1984 and Ngan "Image Display Techniques Using the Cosine Transform," IEEE Trans. Acoust., Speech, Signal Processing, vol. ASSP-32, No. 1, pp. 173–177, February 1984. Transform image coding is well known for its compression efficiency. Its nature renders it also suitable for efficient progressive transmission and reconstruction since low frequency transform coefficients contain most of the energy of image signals. Thus, a small subset of the transform coefficients is good enough for reconstructing a rough version of the whole image, while the remainder of the transform coefficients allow the receiver to add details to the initially reconstructed picture as they are received. In one such scheme the transform coefficients of each block of image data are considered as arranged in a square lattice and are sent and received in a zig-zag pattern in order from the large through the small variance values. This scheme is described in an article of Tescher and Cox "An Adaptive Transform Coding Algorithm," ICC Conference Records, pp. 47.20–24, 1976. Although the zig-zag technique provides better compression efficiency than other proposed transform domain schemes, it is desirable to further improve the efficiency with which image data can be transmitted, particularly during the first few iterations.

SUMMARY OF THE INVENTION

The improved method of progressively transmitting an image in accordance with the present invention comprises dividing an image into a predetermined array of zones of picture elements. A predetermined spatial domain-to-transform domain transformation is performed on the picture elements of each zone to provide transform coefficients thereof. Signals containing data representing transform coefficients in different degrees of detail are produced and transmitted for each zone during the first of a plurality of transmission sequences. Signals containing data on transform coefficients which when combined with the data transmitted during preceding sequences provide cumulative data representing the transform coefficients of the zone in increasingly finer detail are produced and transmitted for each zone during subsequent sequences of the plurality of sequences.

In reconstructing the image, the signals containing data representing transform coefficients in different degrees of detail transmitted during the first transmission sequence and the signals containing data on transform coefficients transmitted during subsequent sequences are received. The signals containing data on transform coefficients transmitted during each transmission sequence subsequent to the first are combined with corresponding signals transmitted during preceding transmission sequences including the first to provide cumulative signals containing data on transform coefficients for each zone. The inverse of the predetermined spatial domain-to-transform domain transformation is performed on the cumulative signals containing data on transform coefficients for each zone after selected transmission sequences to provide reconstituted image data for each picture element of each zone. The reconstituted image data is of finer detail after later transmission sequences in the plurality.

A system in accordance with the present invention for progressively transmitting an image comprises means for dividing an image into a predetermined array of zones of picture elements and transform means for performing a predetermined spatial domain-to-transform domain transformation of the picture elements of each zone to provide transform coefficients thereof. The system includes means for producing and transmitting for each zone during the first of a plurality of transmission sequences signals containing data representing transform coefficients in different degrees of detail, and means for producing and transmitting for each zone during each subsequent sequence of said plurality of sequences signals containing data on transform coefficients which when combined with data transmitted during preceding sequences provide cumulative data representing the transform coefficients of the zone in increasingly finer detail.

For reconstructing the image the system comprises receiver means for receiving for each zone said signals containing data representing transform coefficients in different degrees of detail transmitted during said first of said plurality of transmission sequences and said signals containing data on transform coefficients transmitted during each subsequent sequence of said plurality of transmission sequences. Means are included for combining signals containing data on transform coefficients transmitted during each transmission sequence subsequent to the first with corresponding signals transmitted during preceding transmission sequences including the first to provide cumulative signals containing data on transform coefficients for each zone. Inverse transform means are also included for performing the inverse of said predetermined spatial domain-to-transform domain transformation of cumulative signals containing data on transform coefficients for each zone after selected transmission sequences to provide reconstituted image data for each picture element of each zone, the reconstituted image data being of finer detail after later transmission sequences in the plurality

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