INTERACTIVE PROGRESSIVE IMAGE TRANSMISSION

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Abstract

In progressive image transmission (PIT) the image is transmitted progressively i.e. the low detail image is transmitted as first followed by transmission of detail signals. In our contribution we consider interactivity in the PIT. For example, the observer could specify image regions of highest interest (ROI). In this case, the image transmission should be optimised with respect to the ROI. The definition of objective criterion for interactive PIT is made in this paper as first. The spatial signal decomposition is derived with respect to this criterion. Wavelet transform of spatial components is used. At the end demonstration of proposed algorithm is made.

Keywords

Wavelets, wavelet transform, progressive image transmission,

1. Introduction

The transmission of still images could be a problem in some cases e.g. , if channel capacity is too low or time varying then the image transmission could be too slow. Typical example is the transmission of images through Internet. The progressive image transmission (PIT) [2][3] could reduce this problem in some applications. In PIT the image is transmitted progressively i.e. the low detail image is transmitted as first followed by transmission of detail signals. This mode of operation is incorporated into many up-to-date image compression standards. In our contribution we consider interactivity in the PIT. For example, the observer could specify image regions of interest (ROI). In this case, the image transmission should be optimised with respect to the ROI.

The definition of objective criterion for interactive PIT is made in this paper as first. The spatial signal decomposition is derived with respect to this criterion. Wavelet transform of spatial components is used. At the end demonstration of proposed algorithm is made.

2. Codec model

The generic interactive model of image communication system is in the fig.1. The image f is first decomposed into the set of descriptors u. Depending on the decomposition method the descriptors correspond to the transform coefficients, spectral coefficients etc. The descriptors constitute the image representation. Objective of the decomposition process is the image decorrelation and creating of the effective image representation from point of view of image transmission, reconstruction, progressive transmission etc. The descriptors are lossy coded in the next step with respect to objective and/or subjective criterion. The compressed representation s is transmitted to the receiver. On the receiver side the decoding of received descriptors is performed as first. After this the reconstruction (composition) of the image g is realized. In the case of PIT the transmission is realized in steps (phases) $k=1,2,...,K$. After the step k the partial image reconstruction g_k is achieved in the receiver. The increasing of transmission efficiency (amount of visual information to transmission rate) could be achieved by two ways:

- by using of better compression method with respect to the defined quality criterion or (and this is our case)
- by modification of the quality criterion regarding the image understanding and by adaptation of the compression method with respect to this criterion.

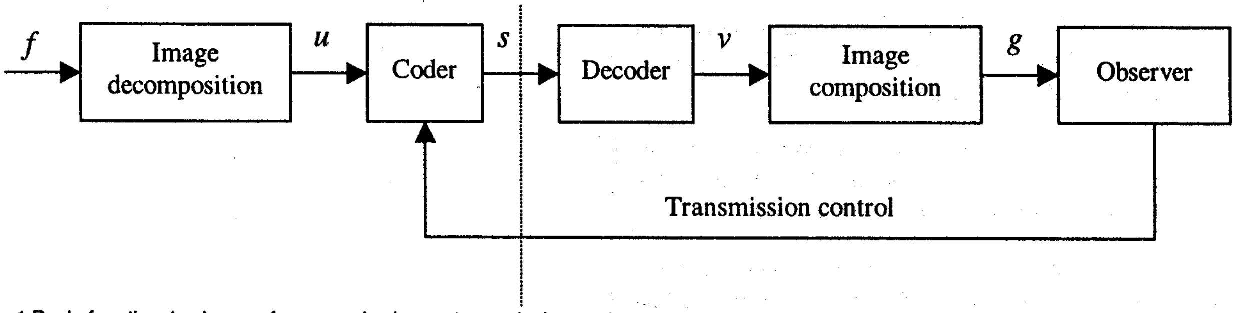


Fig.1 Basic functional scheme of progressive image transmission system

In this contribution the image transmission is adapted in the dependence to the priority of image regions. In the fig.1 the feedback channel is added to the model. The user controls the image transmission by defining of so called Region(s) Of Interest (ROI) i.e. the region which is most important for image understanding. Consequences of the unequal priority assignment to the different spatial regions with respect to the coding and transmission optimisation are:

- from point of view of PIT the reconstruction error should grow proportional to the distance form ROI centre
- with respect to the spatial priority assignment the objective criterion for the reconstructed image evaluation should be modified.

Suppose that ROI is represented by one point with co-ordinates $P=(m_0, n_0)$. For the purpose of the objective criterion modification we define the weighting function centred to the point P in form of the Gaussian function:

$$q_k(m,n) = \alpha(k)e^{\frac{(m-m_0)^2+(n-n_0)^2}{\beta(k)}} \qquad (1)$$

where $k=1,2,...,K$ represents the phase (step) of PIT. $\alpha(k)$ and $\beta(k)$ are normalization and dilation factors respectively. Note that $\beta(k)$ is positive growing function with respect to k. Due to the "nice" interpretation of weighting effect we put $\alpha(k)=1$ for all k. By putting $k=\infty$ we obtain

$$q_\infty = 1 \qquad (2)$$

From practical point of view the equation (2) should be valid also for $k=K$ i.e. the last transmission step.
With respect to the definition of weighting function we define the modified MSE objective kriterion:

$$e_k = \frac{1}{N^2}\sum_{m,n}(f(m,n)-g_k(m,n))^2 q_k(m,n) \qquad (3)$$

where N is the image dimension. We refer to the equation (3) as to the weighted mean square error (WMSE).

Now we investigate the influence of equation (3) to the image f. By substitution

$$w_k(m,n) = \sqrt{q_k(m,n)} \qquad (4)$$

we have

$$f_{w_k}(m,n) = f(m,n)w_k(m,n) \qquad (5)$$

where $f_{w_k}(m,n)$ is the signal extracted from image $f(m,n)$ by using the weighting function $w_k(m,n)$.
Interpretation of equation (5) is straightforward. In early stage of PIT the ROI is represented by small part of image i.e. $\beta(k)$ is small. In later stages the ROI support should grow i.e. also $\beta(k)$ grows.
Equation (5) represents spatial predecomposition of image f resulting in the set of image components

$$F = \{f_{w_k}(m,n)\}_{k=1,2,...,K} \qquad (6)$$

The representation (6) is uneffective due to the high intercomponent correlation. From point of view of coding and transmission the better way is the using of residual spatial decomposition i.e.

$$H = \{h(m,n)\}_{k=1,2,...,K} \qquad (7)$$

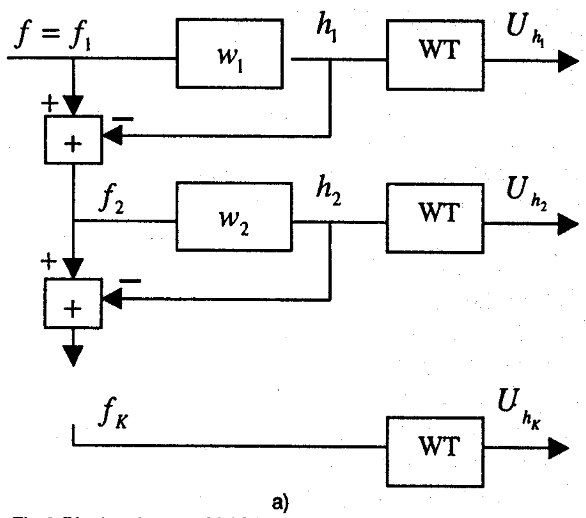
where

$$h_k = f_{w_k} - f_{w_{k-1}},\ k=2,3,...,K \qquad (8)$$

and $h_1 = f_{w_1}$. The partial image reconstruction is given by

$$g_k = \sum_{l=1}^{k} h_l \qquad (9)$$

and from (9), (8), (5) follows lossless image reconstruction at stage K



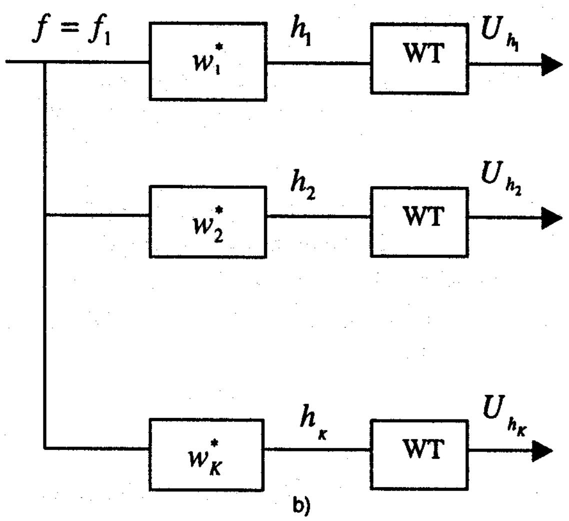


Fig.2 Block scheme of PIT by recursive (a) and modified direct (b) algorithm

$$g_K = \sum_{l=1}^{K} h_l = f \quad (10)$$

The components h_k are highly correlated so the compression method should be applied to each component prior the transmission. In our proposal the wavelet transform of components h_k was used.

3. Wavelet transform

Wavelet transform (WT) is powerfull tool for image decomposition. The motivation of using the WT in image coding is in the properties like [1][4]:

- orthogonality,
- signal decorrelation,
- multiresolution approach,
- approximation smoothness,
- compact support,
- existence of fast algorithm.

In our approach the orthogonal WT of components h_k is considered. The result of L-level, separable, orthogonal WT is the wavelet representations in the form

$$U_{h_k} = WT(h_k) = \{u_{k,L,0}, u_{k,i,j}\}_{k=1,2,\dots,K;\, j=1,2,3;\, L\le i\le 1} \quad (11)$$

where $u_{k,L,0}$ is approximation of component h_k at level L, $u_{k,i,j}$ are detail signals at level i coresponded to spatial orientation (frequency band) j.

Wavelet coefficients should be lossy coded and transmitted to the receiver. In our case no image compression but interactivity in PIT was the primary motivation. Due to this fact no further coding of wavelet coefficients was used.

4. PIT algorithm

The block scheme of proposed PIT algorithm is in the fig.2a. The PIT process could be described by following way:

- PIT is performed in the steps (phases) $k=1,2,\dots,K$,
- the ROI centred in the point $P=(m_0,n_0)$ is defined,
- the parameters $\beta(k)$ for $k=1,2,\dots,K$ are specified,
- in the first transmission step $k=1$ the original image $f=f_1$ is weighted by w_1 :

$$h_1 = f_1 w_1 \quad (12)$$

- wavelet representation U_{h_1} of h_1 is obtained by the orthogonal wavelet transform

$$U_{h_1} = WT(h_1) \quad (13)$$

- U_{h_1} is transmitted to the receiver,
- for each transmission step $k=2,3,\dots,K$, the residual signal is computed

$$f_k = f_{k-1} - h_{k-1} \quad (14)$$

- residual signals f_k are weighted by functions w_k obtaining

$$h_k = f_k w_k \quad where \quad w_K = 1 \quad (15)$$

- the wavelet representations of h_k are computed by

$$U_{h_k} = WT\{h_k\} \quad (16)$$

  and are transmitted progressively to the receiver,
- image reconstruction in the receiver is realised in successive steps $k=1,2,\dots,K$ by inverse wavelet transform and accumulation of partial reconstructed signals

$$g_k = \sum_{l=1}^{k} IWT\{U_{h_l}\} \quad (17)$$

Disadvantage of this algorithm is the recursive computing. It could be shown [3] that it is possible to transform recursive algorithm from fig.2a to parallel realisation fig.2b. The modified equivalent weighting functions w_k^* are obtained by

$$w_{k+1}^* = w_{k+1} \prod_{l=1}^{k} (1 - w_l) \quad (18)$$

where $k=1,2,\dots,K-1$ and $w_1^* = w_1$.

5. Experimental results

In this part an example of interactive PIT is demonstrated. As testing image $f(m,n)$ the grayscale image Lena (256x256x8) was used. The point of interest of image Lena was the middle of the face of the girl i.e. $P=(m_0,n_0)=(140,140)$. The number of steps K of PIT was 3. At each stage of the transmission k the corespondent weighting function was used. The used weighting and equivalent weighting functions are depicted in fig.3.

In WT the orthogonal Daubechies filters of length 8 was used [4]. Three levels of the WT of each residual component f_{wk} was computed. In the fig.4 is example of PIT by proposed algorithm. It is evident that the spatial resolution increasing progressively from the centre of ROI.

6. Conclusion

A method of interactive progressive transmission of still images was presented. The observer could specify image regions of interest. The image transmission is then optimised with respect to the ROI. The spatial resolution of reconstructed image grows progressively from the centre of ROI.

The definition of objective criterion for interactive PIT was made. The spatial signal decomposition was derived with respect to this criterion. Wavelet transform of spatial components was used. As shown on the example interactivity could, in some cases, solve the problem of too small channel capacity.

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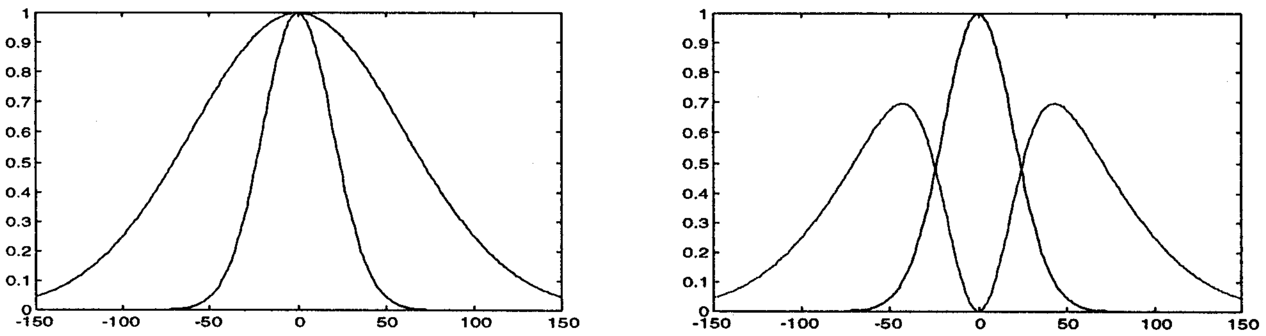

Fig.3 Example of weighting (a) and equivalent weighting functions w_k and w^*_k , k=1,2,3. beta(1)=400,beta(2)=3600, beta(3)=infinity (equations (4) and (18))

a) b) c) d)

Fig.4 Demonstration of interactive PIT. a) original image, reconstructions in the stages k=1 b), k=2 c), k=3 d). The ROI is in the middle of the face. It is evident that the spatial resolution due to the proposed algorithm decrease with distance from centre of ROI.