Chapter 5 Quadro-Field Coding on H.264

In this chapter, we proposed an error control technique for H.264 video coding. This technique contains a pre-processing (error resilient) and a post-processing (error concealment).

5.1 Error Control Techniques

The goals of error control are to fix errors, limit error propagation, and to minimize visual defects. At the beginning of this chapter, we will introduce some existing error concealment tools which have been designed for H.264.

5.1.1 Error Resilience Tools in H.264

There is some error control tools applied to H.264. Here we give a brief introduction.

a. Intra placement

Intra placement is to decrease error propagation. H.264 allows macroblocks as the Intra placement unit. This makes intra placement more flexible and can suppress peak bit rate can be destroyed.

b. Flexible slice size

Allowable slice sizes in H.264 are highly flexible.

c. Data partition

As described in 2.3.3.2.

d. Parameter sets structure

The parameter set contain the header information. In previous standards, a loss of header information may cause severe deterioration of visual quality. In

H.264, the parameter set can be packetized into a packet and sent to the receiver in a more reliable way. That guarantees the arrival of vital information at the receiver.

e. **Flexible macroblock ordering (FMO)**

This scheme allows the partition of a picture into several slice groups with each slice being decodable independently. FMO can significantly enhance the robustness with respect to data loss by separating spatial relationship into in different slices.

f. **Redundant slices**

This capability allows an H.264 encoder to send redundant representations of pictures.

5.1.2 Error Concealment Tools

At the decoder, we can use some post-processing method to conceal the errors in reconstructed frames. These methods can be divided into three categories: frequency-domain methods, spatial-domain methods and temporal-domain methods. We describe these three types of methods as following.

a. Frequency-domain concealment

When one block is corrupted during data transmission, we can use the DCT coefficients of neighboring blocks to estimate the DCT coefficients of the current block. The DCT coefficients contain DC and AC values. The frequency concealment methods usually attempt to reconstruct low-frequency components.

b. Spatial-domain concealment

When one block is corrupted during data transmission, we can do interpolation directly using neighboring blocks. The accuracy of spatial interpolation depends on the distance of the reference pixels. Hence, it has been proposed to interpolate pixel values within a damaged MB from its four 1-pixel-wide boundaries. A pixel can be interpolated from two nearest boundaries, as shown in Fig 5-1, or from all boundaries, as shown in Fig 5-2.

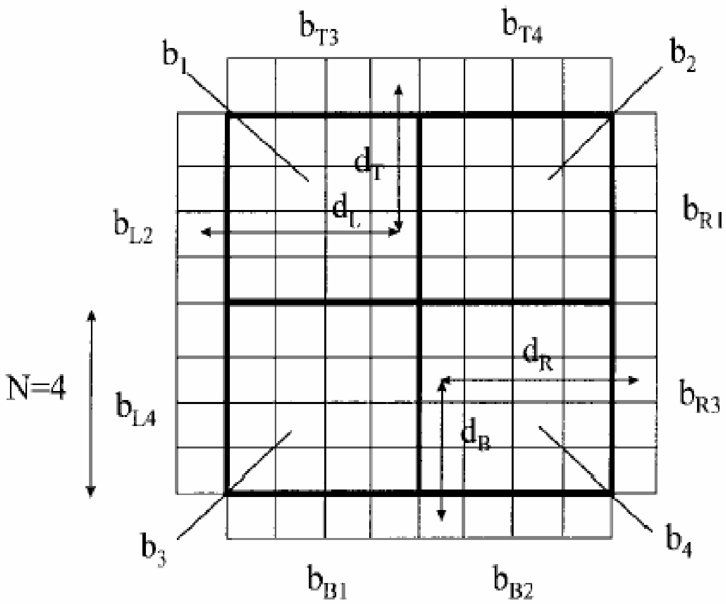

Fig 5-1

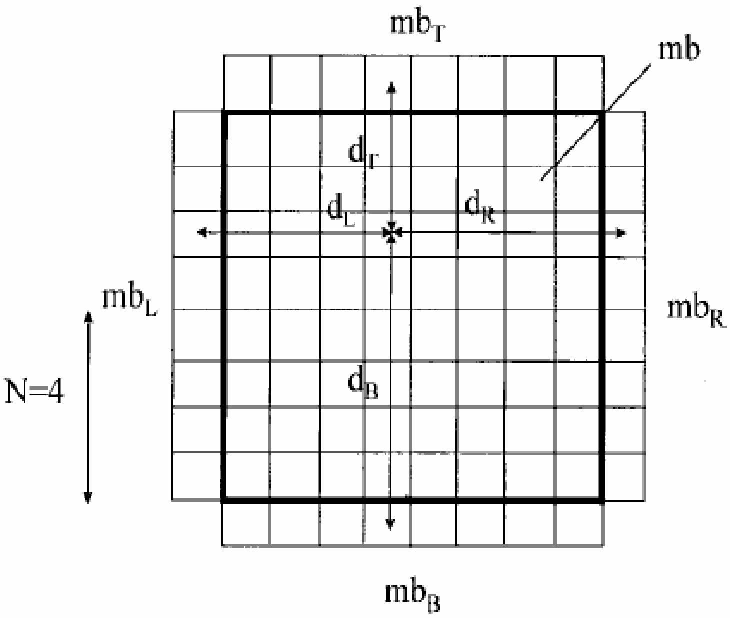

Fig 5-2

c. **Temporal-domain concealment**

When one block is corrupted during data transmission, we can replace the damaged block with the motion compensated block: i.e. with the motion vector of the corresponding block. If the estimation of the motion vector is inaccurate, the block will have artifacts at the boundaries. So far, there have been several ways to estimate motion vector, e.g. the average or median of the neighboring blocks.

5.2 Quadro-Field Coding

In Quadro-field coding, frame data are partitioned into four fields and the four fields are coded individually. Fig 5-3 shows the partition method. We name each quadro-field as: Top-Left (TL), Top-Right (TR), Bottom-Left (BL), and Bottom-Right (BR) fields.

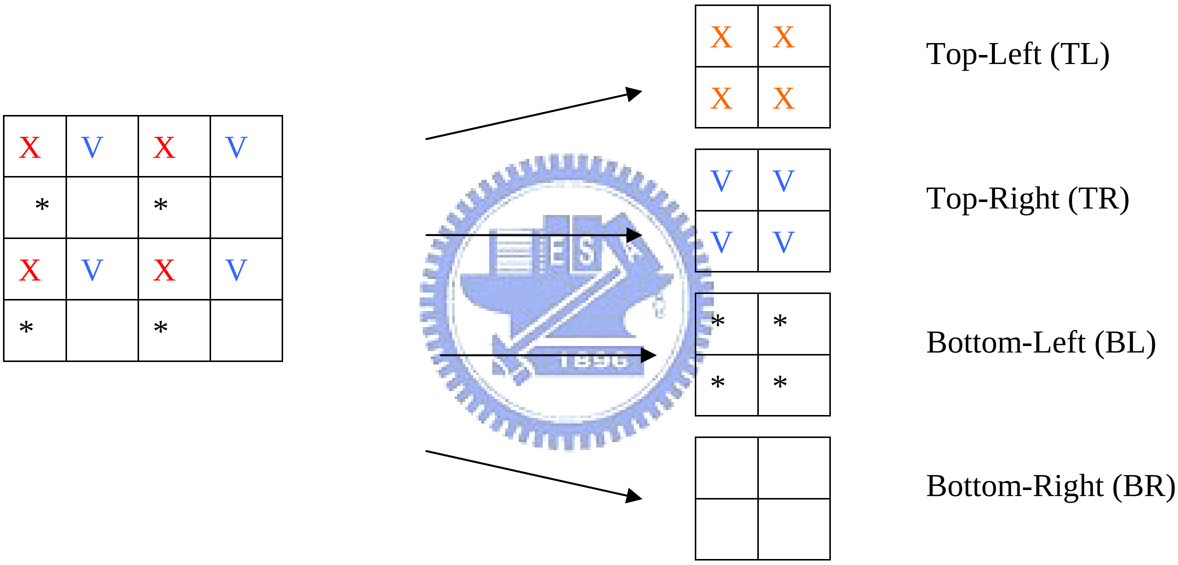

Fig 5-3 The proposedQuadro-Field Packaging

Compared with frame and field coding, quadro-field coding offers more prediction modes in inter-frame motion compensation. Fig 5-4 shows a typical prediction mode of frame coding.

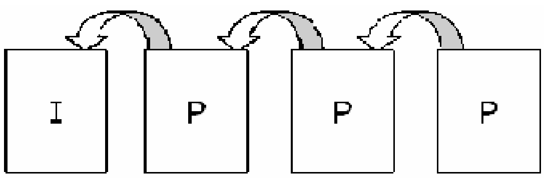

Fig 5-4 A typical prediction mode of frame coding

If the reference frame is set to 1, there are three prediction modes as shown in Fig 5-5. Fig 5.5(a) shows the parallel type of prediction coding, called Parallel Prediction Quadro-Field Coding (PPQFC). In this scheme, there is only one reference field for each field of a P frame and this reference field is restricted to the same kind of field in the previous frame. For example, a bottom-right field in a P frame can only refer to the bottom-right of the previous frame. This scheme is favorable to error resilience because the coding of these four quadro-fields become independent of each other. Fig 5.5(b) shows the Separate Prediction Quadro-Field Coding (SPQFC). In this scheme, we separate the four fields into two groups: Top Group and Bottom Group. Top Group contains TL and TR fields. Bottom Group contains BL and BR fields. In the same group, the left quadro-field can only refer to the four quadro-fields of the previous frame, while the right quadro-field can refer not only to the four quadro-fields of the previous frame but also to the left quadro-field of the same group. For example, a Top-Right quadro-field in P frame can refer to the four quadro-fields of the previous frame and the Top-Left quadro-field. Fig 5.5(c) shows the Full Search Prediction Quadro-Field Coding (FSQFC). In this scheme, the quadro-fields can refer not only to the four quadro-fields of the previous frame but also to the quadro-field in front of the current quadro-field. Consider the coding rate and the error resilience abilities, we choose SPQFC as our error reilience technique. Table 5-1 shows the coding rate of each coding scheme.

Table 5-1 The coding rate of each prediction method

QP=28	Frame	PPQFC	FSQFC	SQFC
Foreman	1	2.31	1.31	1.43
Highway	1	1.87	1.20	1.25
Table-Tennis	1	2.11	1.76	1.82
Stefan	1	2.55	1.90	1.95
Bridge-Far	1	0.86	1.32	1.28

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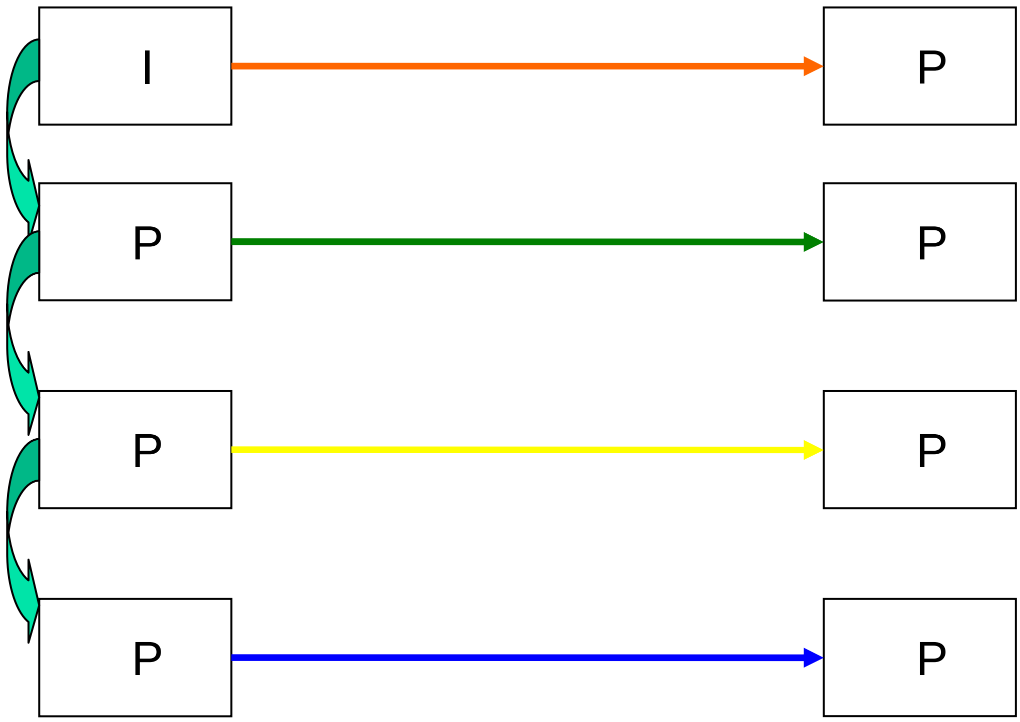
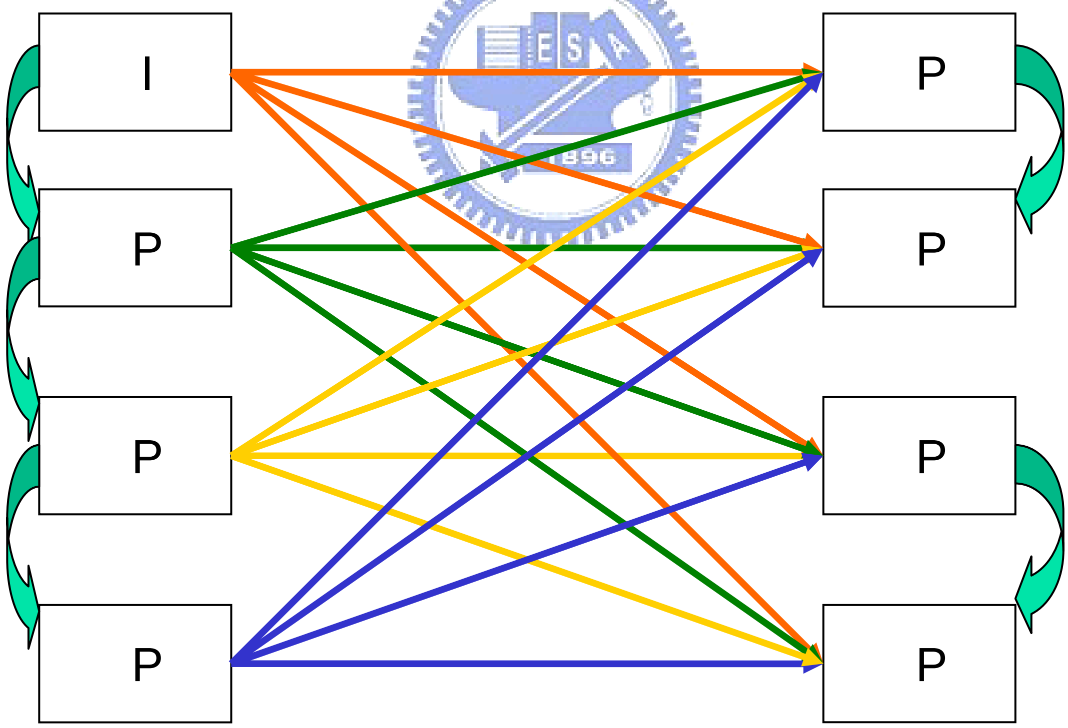
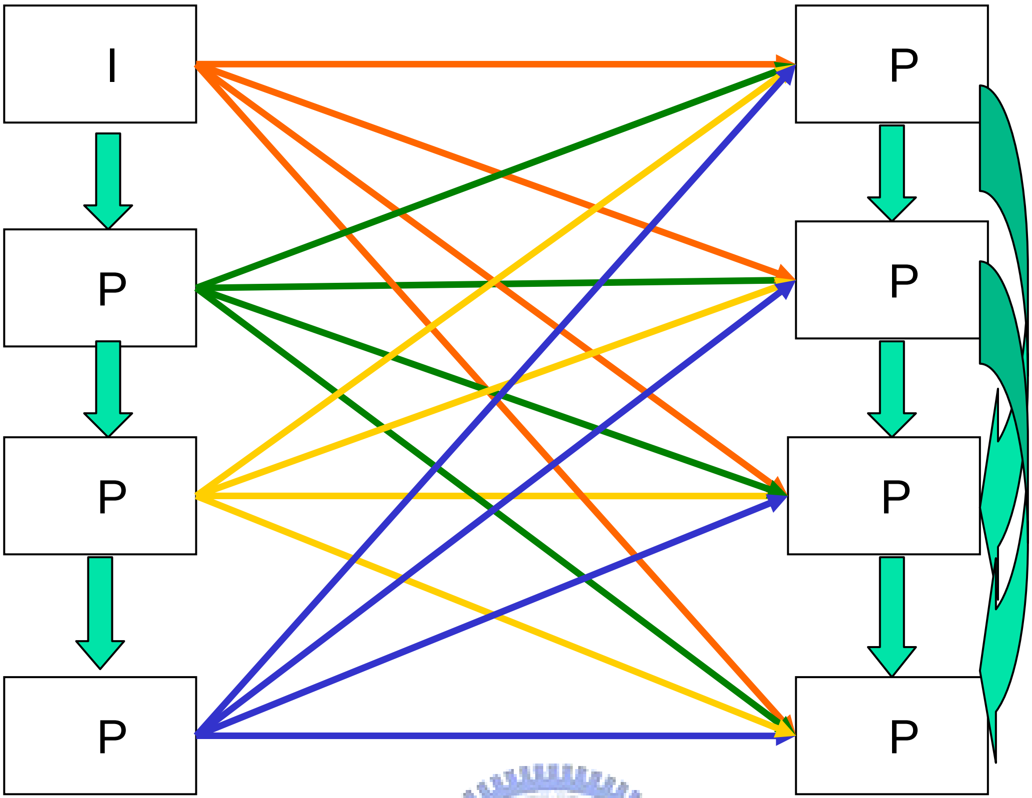


(a)



(b)



(c)

Fig 5-5 Three prediction schemes of Quadro-Field coding

(a) Parallel Prediction Quadro-Field Coding (PPQFC)

(b) Separate Prediction Quadro-Field Coding (SPQFC)

(c) Full Search Prediction Quadro-Field Coding(FSQFC)

5.3 Error Concealment

We propose three structures for Quadro-Field coding, and we adopt SPQFC in this thesis because it is more favorable to error resilience than the other two schemes. In this subsection, we will discuss the error concealment techniques. Since the decoding process is expected to be real-time, short delay time and low complexity are the two major concerns in our development.

In SPQFC, the Top Group and Bottom Group are coded independently. In each group, the right quadro-field may refer to the left quadro-field. Hence, the left quadro-field should be protected and the strategies of error concealment would be different for different types of quadro-fields. We will also discuss the error concealment methods for more than one quadro-field loss during data transmission.

5.3.1 One Quadro-Field Loss

In SPQFC, TR quadro-field may refer to TL quadro-field while BR quadro-field may refer to BL quadro-field. Hence, different quadro-field losses need the use of different error concealment methods. In this section, we will introduce the error concealment method for each quadro-field.

5.3.1.1 Bottom-Right Quadro-Field

When a macroblock is lost in a bottom-right quadro-field, we can use the rest three quadro-fields to conceal the errors in the bottom-right quadro-field. In this case, we use spatial interpolation to conceal the errors. As shown in Fig 5-6, the lost pixel X can be recovered by the neighboring 8 pixels (a~h). Before we interpolate the lost pixel, we have to decide the interpolation direction. There are four interpolation directions such as diagonal, horizontal and vertical. The decision rule of this scheme is to choose the minimum absolute difference. As shown in Fig 5-6, if min(|a-b|,|e-f|,|d-c|,|g-h|) is equal to |d-c|, then we interpolate along the horizontal direction. Fig 5-7 shows the experiment results of bottom-right quadro-field concealment. Fig 5-8 gives an example of the damaged frame and the concealed frame.

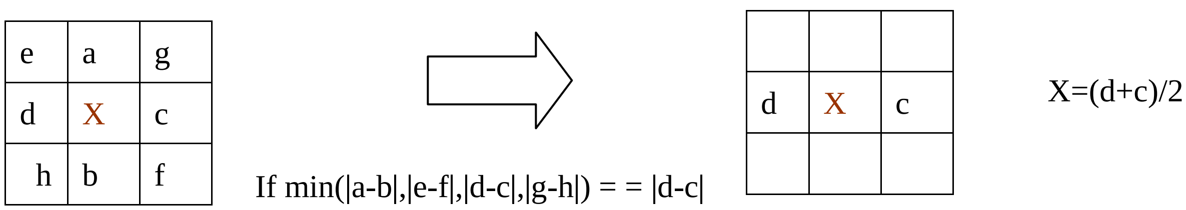


Fig 5-6 Interpolation of the lost pixel X

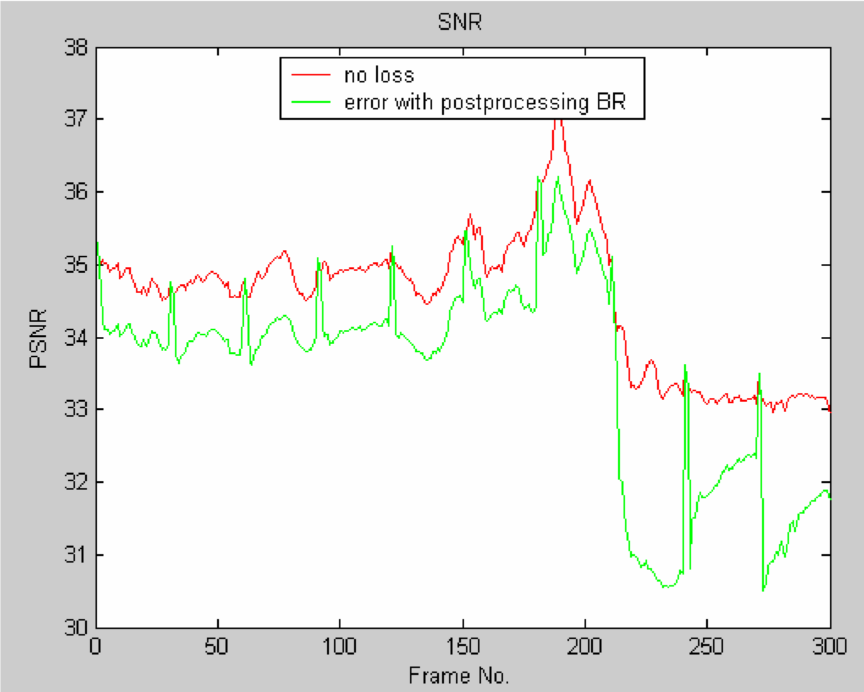
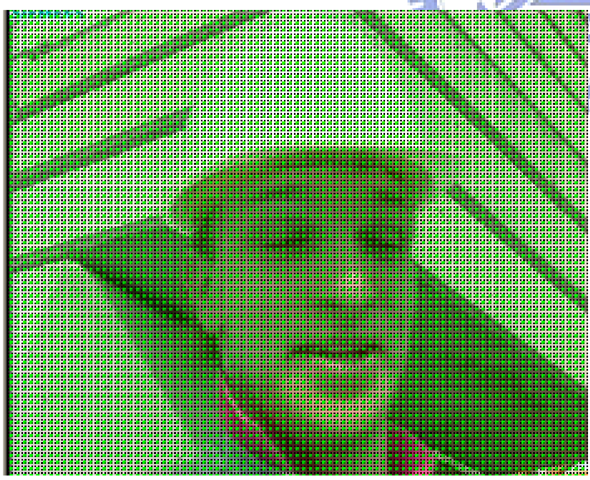


Fig 5-7 Simulation results of test sequence ‘Foreman’.

Red line: No Loss

Green line: Loss with post-processing.



(a) (b)

Fig 5-8 Experiment results of spatial interpolation

(a) Frame with the whole Bottom-Right quadro-field being lost

(b) The concealed frame

5.3.1.2Bottom-Left Quadro-Field

In this case, because of the BR quadro-field can refer to the BL quadro-field when a Bottom-Left quadro-field is lost, it may be influence the Bottom-Right quadro-field. Fig 5-9(a) shows the damaged frame. Hence, for this case, the information along the horizontal direction cannot be use. Fig 5-10 shows the interpolation method adopted in this scheme. Fig 5-11 shows the experiment results of this scheme.

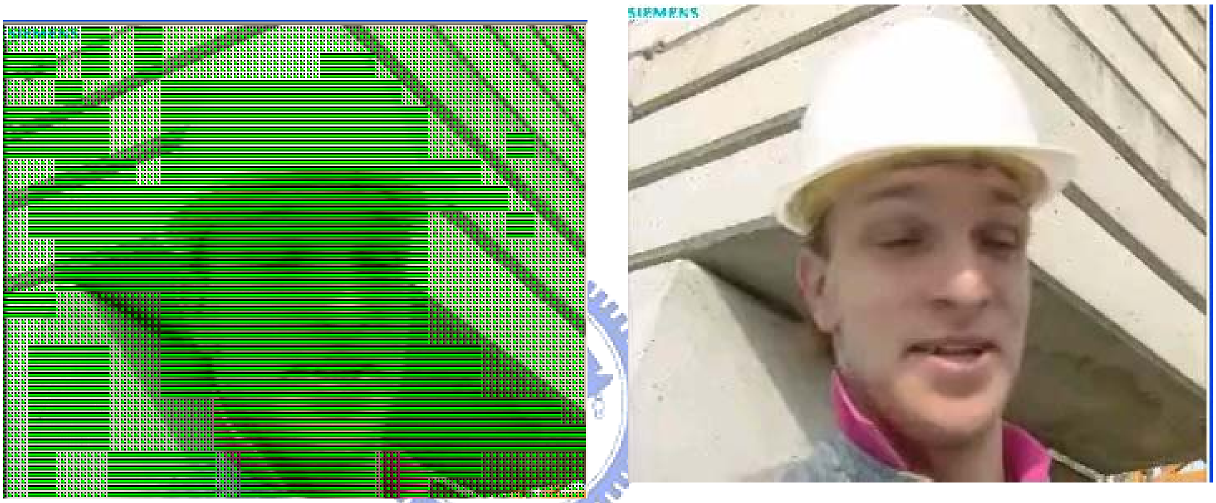


Fig 5-9 Experiment results of spatial interpolation

(a) Frame with the whole Bottom-Left quadro-field being lost

(b) The concealed frame

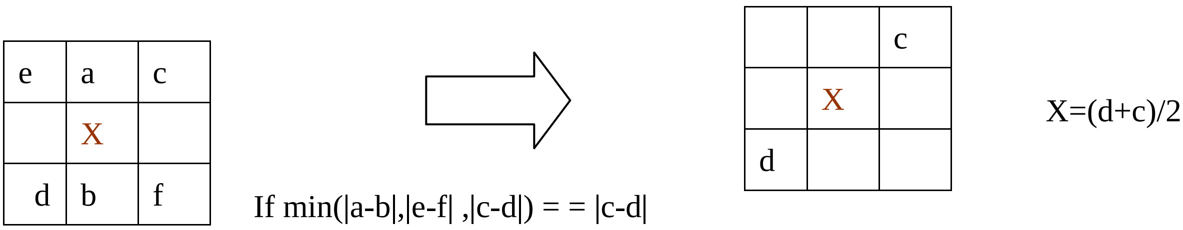


Fig 5-10 Interpolation of the lost pixel X

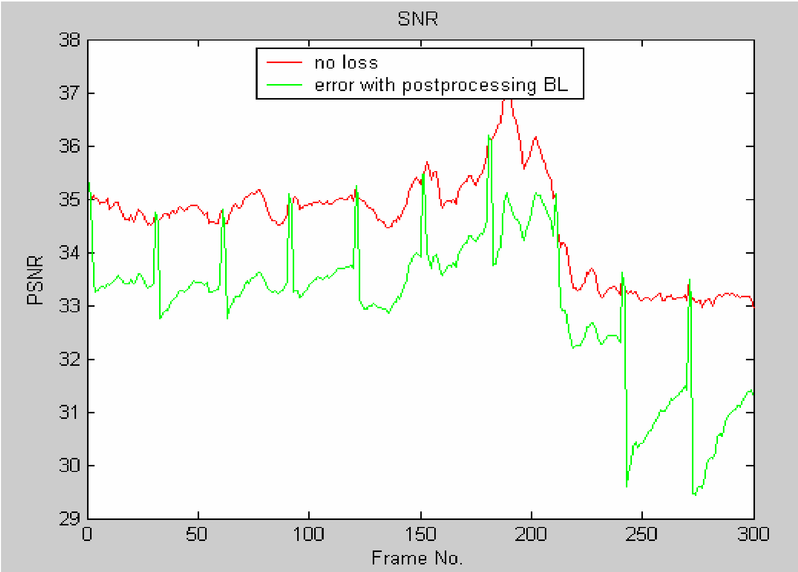


Fig 5-11 Simulation results of test sequence 'Foreman'.

Red line: No Loss

Green line: Loss with post-processing.

5.3.1.3 Top-Right Quadro-Field

In this case, the concealment method is similar to Sub-section 5.3.1.1. Fig 5-12 shows the experiment results.

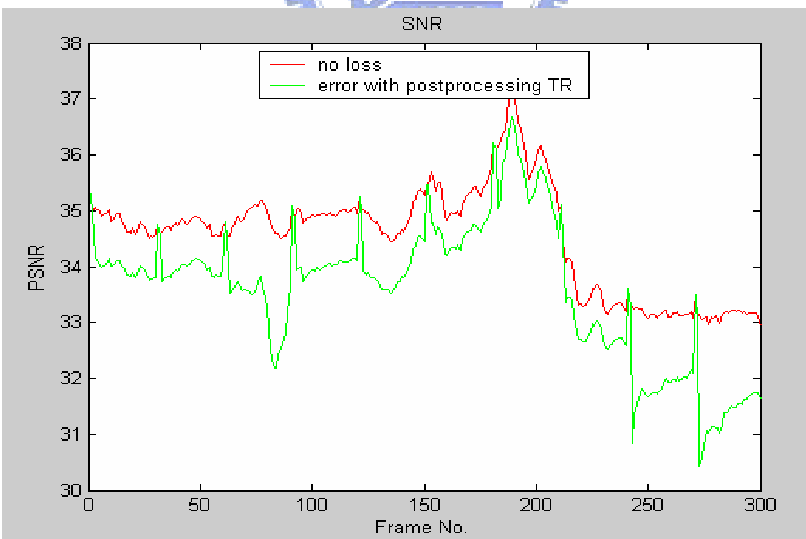


Fig 5-12 Simulation results of test sequence 'Foreman'.

Red line: No Loss

Green line: Loss with post-processing.

5.3.1.4 Top-Left Quadro-Field

When a macroblock is lost in a Top-Left quadro-field, the Top-Right quadro-field may be influenced. During the decoding processing, when the Top-Right quadro-field is received, the Bottom Group hasn't arrived yet. Based on the above reason, we can only use temporal information to conceal the Top-Right quadro-field and then we use the interpolation method as described in Subsection 5.3.1.2. For real time applications, the temporal concealment is to get the motion vector of the previous left quadro-field. We name this temporal concealment as temporal replacement. Fig 5-13 shows the experiment results of the method.

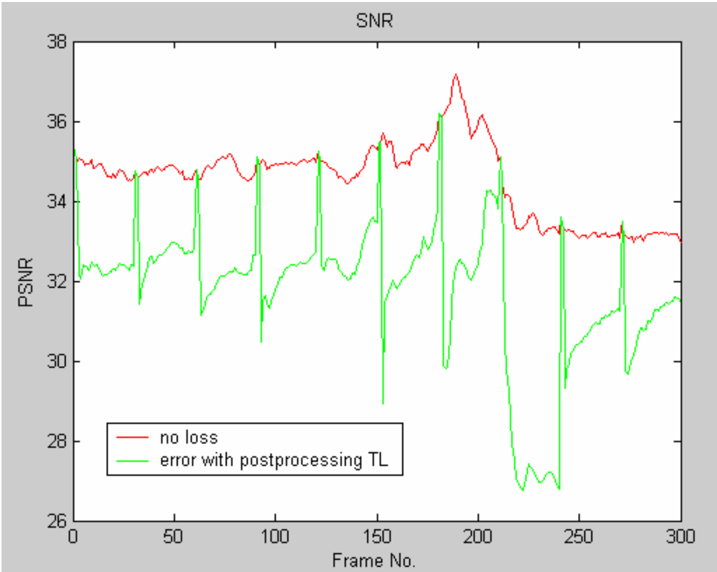


Fig 5-13 Simulation results of test sequence 'Foreman'.

Red line: No Loss

Green line: Loss with post-processing.

5.3.2 Two Quadro-Field Loss

In this scheme, we classify error concealment methods into two categories. One is spatial interpolation, while the other is to use temporal replacement first and then use spatial interpolation. We will describe these two methods as below.

5.3.2.1 Spatial interpolation

When a macroblock is lost in a BL quadro-field and BR quadro-field, we can use the TL or TR quadro-field to conceal the lost two quadro-fields. The reason is when the bottom group (top group) is lost the top group (bottom group) will not be influenced. Similarly, when the BR quadro-field and TR quadro-field is lost, the TL and BL quadro-field will still exist. Hence, we can use spatial interpolation as mentioned in Subsection 5.3.1.2 to conceal the lost field. Fig 5.14~5.16 shows the experiment results about the loss of lost of the BL-BR, TL-TR, and TR-BR quadro-fields.

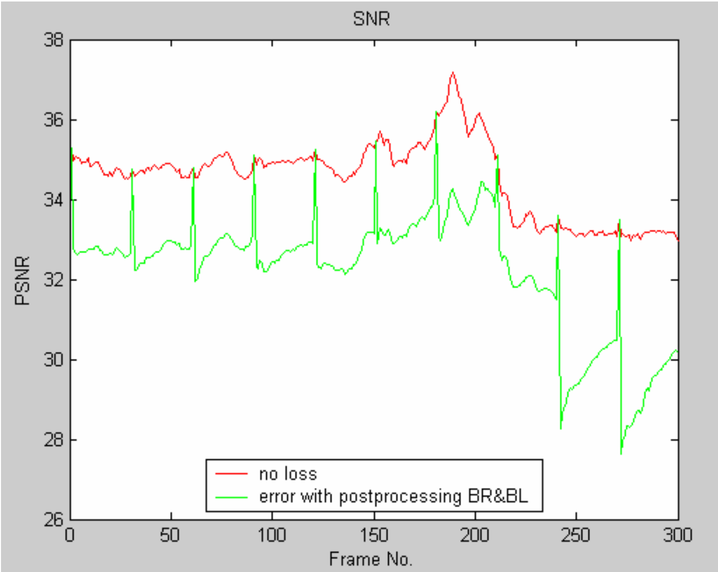


Fig 5-14 Simulation results of test sequence 'Foreman'.

Red line: No Loss

Green line: Loss with post-processing.

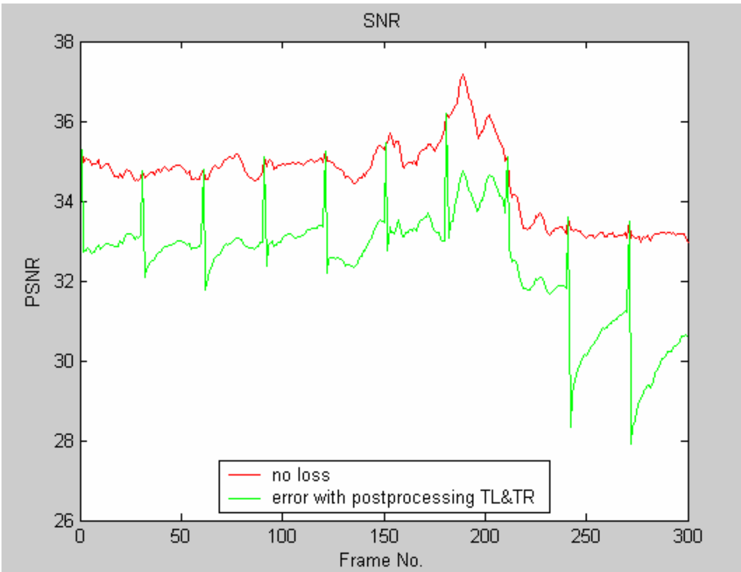


Fig 5-15 Simulation results of test sequence 'Foreman'.

Red line: No Loss

Green line: Loss with post-processing.

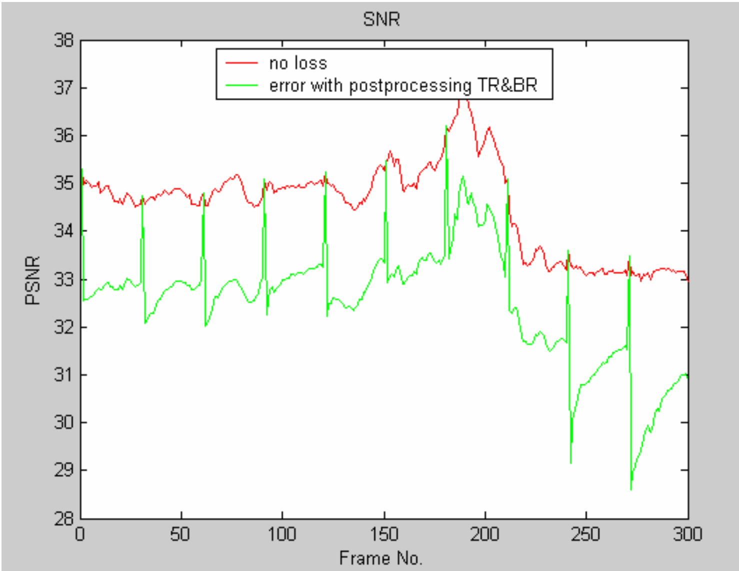


Fig 5-16 Simulation results of test sequence 'Foreman'.

Red line: No Loss

Green line: Loss with post-processing.

There are two quadro-fields that can conceal the lost quadro-fields in the above three conditions. Thus spatial interpolation is a suitable choice. If one left quadro-field and a right quadro-field in different group are lost, we cannot use spatial interpolation only to conceal the lost quadro-fields. In these cases, we have to use temporal information except TR and BL loss. When the TR and BL are lost, we use TL to interpolate the BL quadro-field first, and then use TL and BR quadro-fields to interpolate the whole frame. Fig 5-17 shows the experiment results.

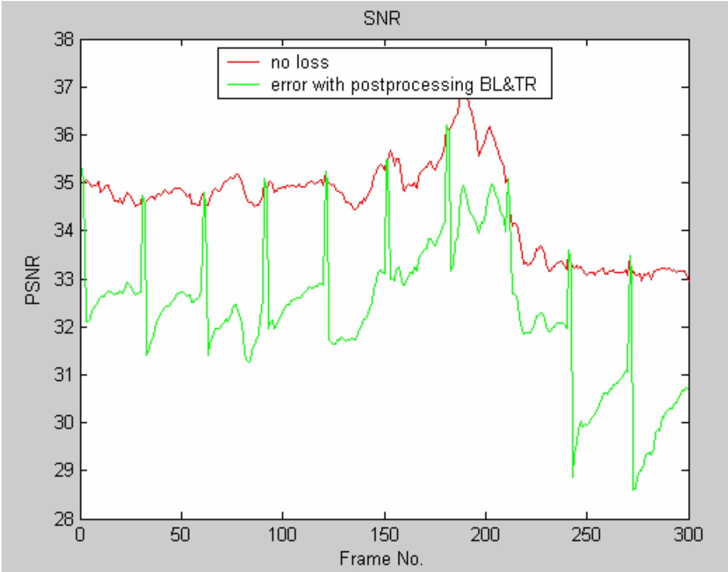


Fig 5-17 Simulation results of test sequence 'Foreman'.

Red line: No Loss

Green line: Loss with post-processing.

5.3.2.2 Spatial interpolation & temporal concealment

When a macroblock of the TL and BR is lost, the TR quadeo-field will be influenced. Hence if we want to increase our interpolation performance, we have to reconstruct the TR quadro-field first. Temporal replacement as mentioned in Subsection 5.3.1.4 is adopted. After TR is reconstructed, we use the TR and BL quadro-fields to interpolate the lost quadro-fields. Fig 5.18~Fig 5.19 shows the experiment results.

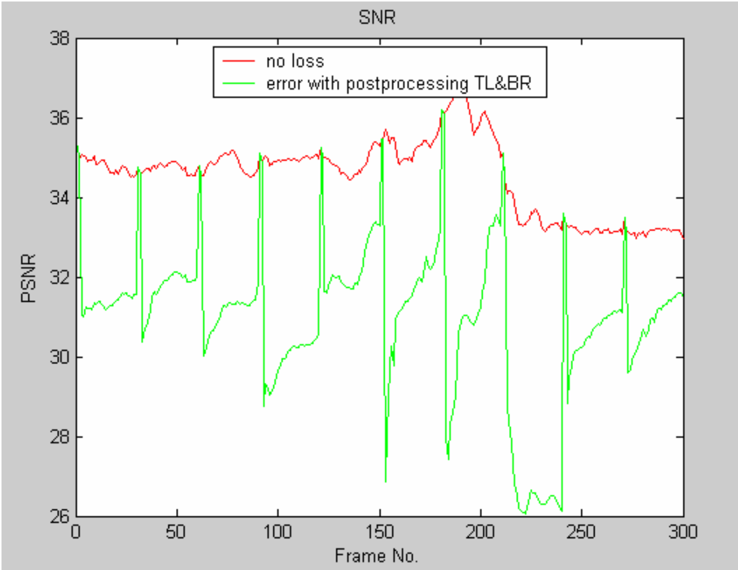


Fig 5-18 Simulation results of test sequence ‘Foreman’.

Red line: No Loss

Green line: Loss with post-processing.

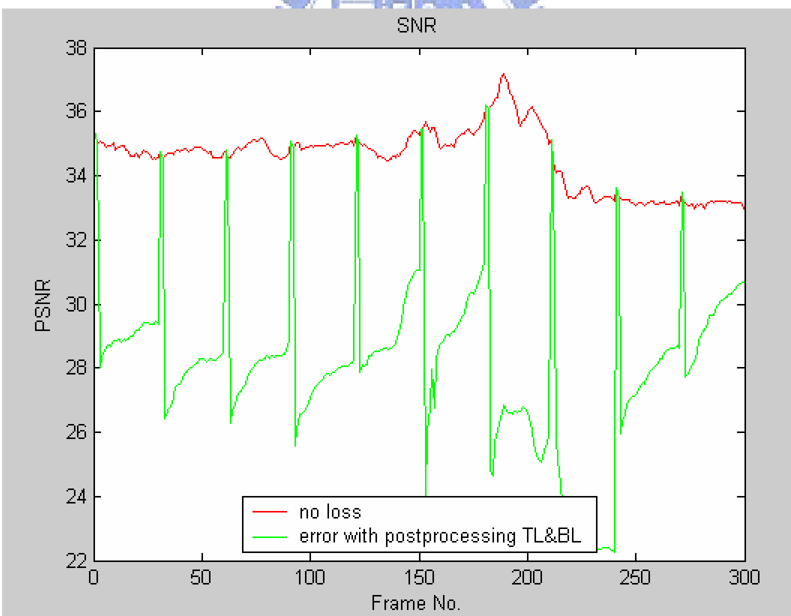


Fig 5-19 Simulation results of test sequence ‘Foreman’.

Red line: No Loss

Green line: Loss with post-processing.