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Intra Prediction Algorithm for Video Frames of H.264

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Abstract

Prediction is the process of duplicating the information contained in the macro block using previously coded data.H.264 supports intra prediction. It is having two types intra prediction 16x16, 4x4.In 16x16 having 4 modes and 4x4 having 9 modes of prediction. This prediction uses previously coded data of current frame to form prediction. The frames which are intra coded using intra prediction are called I-frames. This paper will give a brief description about different modes of intra prediction and this algorithm will gives best intra prediction method by calculating the sum of absolute difference values for each mode of prediction**.**

Intoduction

H.264/AVC uses intra prediction to encode I frame macroblocks and also P and B frame's macroblocks that have poor prediction result of motion estimation. Intra prediction utilizes the space dependency to compress the video. Intra prediction of H.264/AVC is conducted in special domain. There are two types of intra prediction methods supported for H.264/AVC luminance component. One is 4×4 mode which is having nine directional intra prediction modes [4] that is well suitable for macroblocks that has lots of details. And another one is 16×16 mode which is having four directional intra prediction mores suitable for macroblocks with smooth area. For chrominance components 8×8 prediction is used. The prediction is based on referring to neighboring samples of previously coded macroblocks.

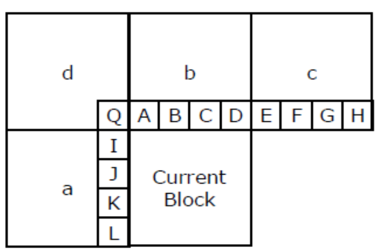

Figure 1 Reference samples of 4×4 luma prediction

4×4 Luma Prediction

When using 4×4 luma (luminance) prediction [4], each 16×16 macroblock is divided into sixteen 4×4 block. And each block a, above block B, above right block C and above left block D shows in figure 4.5[4] 13 samples that are labeled from A to L and Q in these blocks are used for prediction.

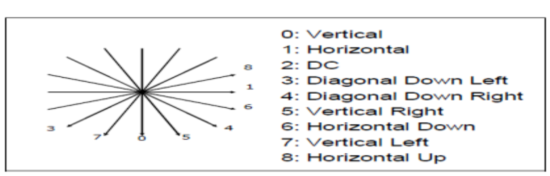

Figure 2 Predict directions of luma 4×4 prediction

There are nine prediction directions supported for 4×4 luma prediction indicated by arrows in figure 4.6. The suitable prediction angle of the following edge pattern in the block is selected. For example, vertical prediction implies that the predict block is constructed by above block b's samples A, B, C and D as illustrated in figure 4.8[4] left and is suitable to predict vertical edges in the block. So does other seven directions except the DC prediction. The only difference is that the constructional formula may be a little different for diagonal down left, diagonal down right, vertical right, vertical left, horizontal down, horizontal up but still using the samples labeled for A to L and Q. Unlike other predictions DC mode utilizes the average of all adjacency samples (A to D and I to L) to form the predict block. It is suitable for smooth area.

All prediction blocks are shown in the following figures (figure 4.8 prediction modes of 4×4 luma vertical and horizontal[4]). Each colour represents a different formula to form a predict sample. By completing computation for all the prediction directions, the encoder finds each direction's cost and outputs the one with minimum cost.

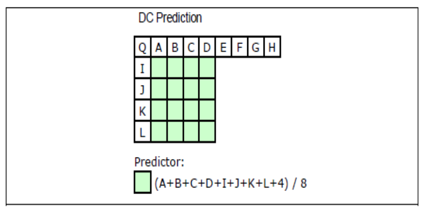

Figure 3 Prediction mode for 4×4 luma DC

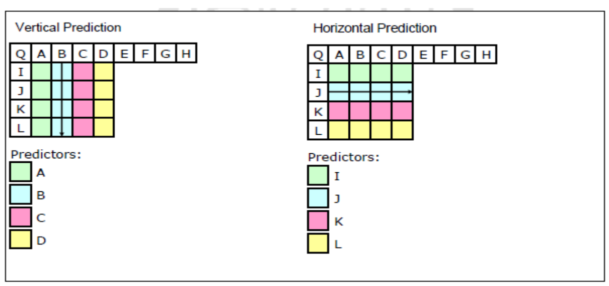

Figure 4 Prediction modes of 4×4 luma-vertical and horizontal

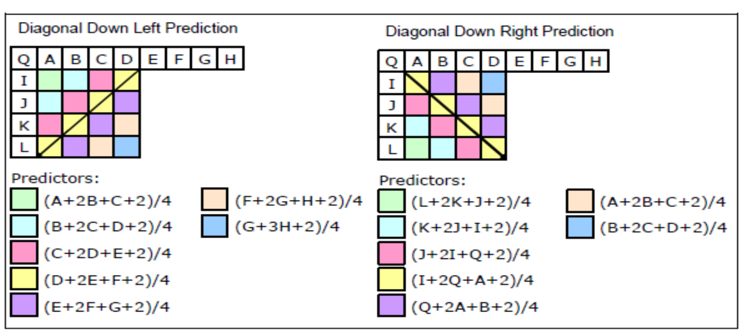

Figure 5 Prediction mode for 4×4 luma- diagonal down left/right

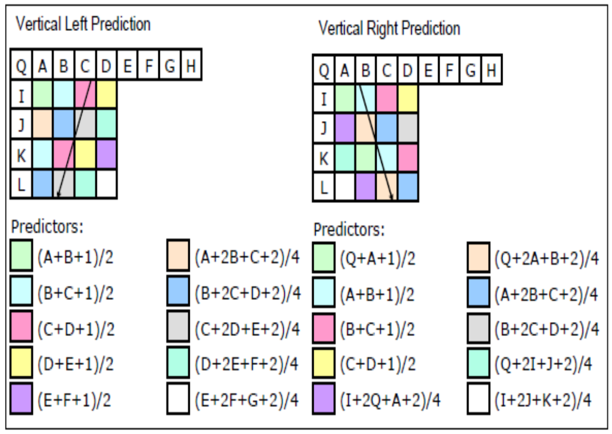

Figure 6 Prediction mode for 4×4 luma- vertical left/right

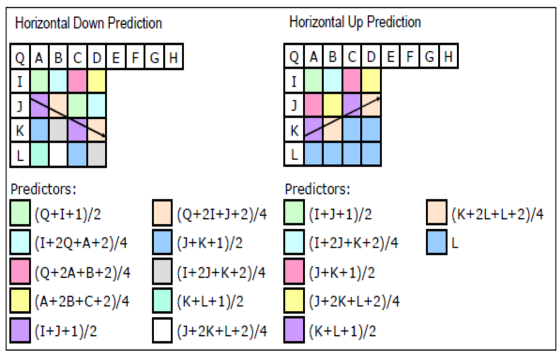

Figure 7 Prediction modes for 4×4 luma- horizontal down/up

16×16 Luma Prediction

Besides the 4×4 luma prediction [4], a 16×16 prediction mode is also used for luminance components and implemented in a similar way. 16×16 luma prediction[3] supports 4 prediction modes. They are vertical, horizontal, DC and plane predictions and it uses only above and left previously- coded macroblock to form the predict macroblock. Also the encoder calculates all the modes and chooses the one with the minimum cost. The four modes shown in the figure 4.12[3].

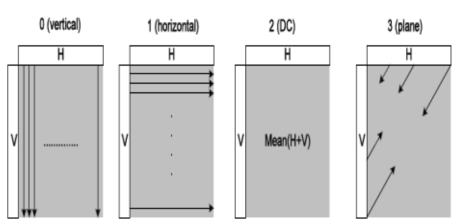

Figure 8 16×16 luma prediction modes

Modes 0,1 and 2 are computed as like 4×4 luma modes 0,1 and 2. The plane prediction is computed as follows, let us consider 16×16 plane mode as follows.

```
 LT |    T0        T1        T2     ..    T15
-----------------------------------  ..  --------
 L0 | c[ 0, 0]  c[ 1, 0]  c[ 2, 0]  ..  c[15, 0]
 L1 | c[ 0, 1]  c[ 1, 1]  c[ 2, 1]  ..  c[15, 1]
 ......
 L15 | c[0,15] c[1,15] c[2,15] ..         c[15,15]
```

Here LT to L15 and T0 to T15 are already encoded samples and c [0, 0] to c [15, 15] are to be predicted samples using plane prediction.

Computing H' and V'

```
H'  =  1* (T8  - T6) +
       2* (T9  - T5) +
       3*(T10  - T4) +
       4*(T11  - T3) +
       5*(T12  - T2) +
       6*(T13  - T1) +
       7*(T14  - T0) +
       8*(T15  - LT)
V'  =  1* (L8  - L6) +
       2* (L9  - L5) +
       3*(L10  - L4) +
       4*(L11  - L3) +
       5*(L12  - L2) +
       6*(L13  - L1) +
       7*(L14  - L0) +
       8*(L15  - LT)
```

H and V are computed as,

```
H = (5*H' + 32) / 64

V = (5*V' + 32) / 64
```

The final process for filling in the 16X16 block is,

```
a = 16 * (L15 + T15 + 1) - 7*(V+H)
for (j = 0..15)
  for (i = 0..15)
    b = a + V * j + H * i
 c[i,j] = SATURATE_U8(b / 32)
```

Saturate_U8 means the result should be within unsigned 256.

8X8 Chroma Prediction

Prediction also applies on chrominance components. It is called 8X8 chroma predictions that are almost same as 16X16 luma prediction except the size of block changed from 16X16 to 8X8 and order of mode number is different. 8X8 chroma predictions also have 4 modes that are, DC (mode 0), Horizontal (mode 1), vertical (mode 2) and plane (mode3).

Example:

Consider an image matrix of size 16X16 as shown below

92	91	89	86	85	85	87	90	94	94	94	94	93	96	97	95
91	90	89	87	86	85	88	92	94	95	95	96	95	96	99	96
89	89	89	90	87	84	85	89	93	94	96	97	98	99	99	97
88	88	89	92	91	85	85	88	91	93	95	97	99	102	99	98
88	90	93	94	100	97	89	83	81	84	93	98	104	107	102	96
96	98	98	95	96	100	97	89	79	82	89	101	105	106	104	97
95	91	96	97	94	92	95	94	89	83	89	93	91	95	99	99
90	85	83	87	85	88	87	89	93	91	82	83	84	89	91	93
87	89	90	89	88	86	84	80	85	87	87	85	84	84	84	86
86	85	87	90	90	89	91	84	85	86	87	88	86	82	81	83
86	85	85	88	87	90	89	87	87	86	87	90	90	89	91	93
86	88	87	84	83	83	87	85	88	87	87	88	89	90	90	88
88	84	85	81	83	84	87	90	91	91	92	93	90	84	81	79
85	83	83	81	79	80	83	86	87	91	95	95	96	86	82	82
85	84	84	84	85	85	87	89	90	93	96	98	97	97	87	86
87	87	87	88	87	87	89	91	91	96	100	100	100	98	94	89

Divide the matrix in to 4X4 blocks as shown below

92	91	89	86	84	84	87	90	93	95	93	94	92	95	97	96
91	90	88	86	85	85	86	93	94	95	95	96	97	97	100	96
89	89	89	88	86	83	83	89	93	95	97	97	97	100	101	97
89	87	88	93	91	85	84	87	90	92	94	97	99	103	100	97
88	89	92	94	101	96	89	83	80	84	93	98	104	107	102	98
96	98	99	96	96	102	98	88	78	81	87	102	107	109	105	98
94	88	97	96	93	91	97	94	89	83	89	92	91	94	101	99
91	84	82	86	85	88	86	88	92	92	81	83	83	88	91	94
85	92	90	89	87	87	83	79	84	89	87	84	84	83	84	86
85	85	88	91	90	90	92	84	84	85	87	89	86	83	80	82
84	84	85	87	87	91	89	86	86	85	85	89	91	89	92	94
87	87	86	84	81	82	87	85	88	88	87	88	89	90	90	88
87	83	85	80	82	84	87	90	91	91	92	93	89	82	81	79
85	83	82	81	80	79	83	85	86	91	96	96	97	86	82	82
86	85	83	83	84	84	88	90	90	93	96	97	97	97	88	85
87	87	88	89	88	88	88	90	90	98	101	101	99	98	94	88

Now consider the first top left 4X4 block,

92 91 89 86

91 90 88 86

89 89 89 88

89 87 88 93

For the first 4X4 block, there is no previously coded data available and hence, the neighboring pixels are assumed to be 128

128 128 128 128 128 128 128 128

128 92 91 89 86

128 91 90 88 86

128 89 89 89 88

128 89 87 88 93

Therefore the predicted block will become

128 128 128 128

128 128 128 128

128 128 128 128

128 128 128 128

This is the reconstructed block of the above mentioned 4×4 block

92 90 89 **86**

91 89 88 **86**

89 89 88 **89**

89 87 88 93

The last column and last row samples which are bolded above the original block are now available for the prediction of next 4×4 block. Therefore the neighboring samples available for the second top left 4×4 block are as shown below

128 128 128 128 128 128 128 128

86 84 84 87 90

86 85 85 86 93

89 86 83 83 89

93 91 85 84 87

According to the availability of neighboring samples the modes available are selected for prediction. For the above 4×4 block only left column of samples are available. For the above block the available modes are, DC, diagonal down left, vertical left and horizontal up.

<u>DC prediction:</u>

P = (86 +86 +89 +93 +128 +128 + 128 +128 +4) / 8

P = 108

Where 4 is added as a rounding factor.

Therefore prediction block will become,

108 108 108 108

108 108 108 108

108 108 108 108

108 108 108 108

$$SAD = \sum_{for\ all\ pixels\ in\ MB} |source\ pixel - predicted\ pixel|$$

SAD for the above predicted block = 346

<u>Vertical prediction:</u>

The vertical predicted block =

128 128 128 128

128 128 128 128

128 128 128 128

128 128 128 128

SAD = 666

Horizontal prediction:

Horizontal predicted block =

86 86 86 86

86 86 86 86

89 89 89 89

93 93 93 93

SAD = 58

Diagonal down left prediction:

In this mode the pixels are calculated according to the equations mentioned earlier.

That is,

(0,0) pixel is calculated as (A+ 2B + C + 2) / 4 = (128 +2(128) + 128 +2) / 4 = 128

In the same way the pixel value is calculated according to the equations mentioned earlier.

The prediction block =

128 128 128 128

128 128 128 128

128 128 128 128

128 128 128 128

SAD = 666

Vertical left Prediction:

In this mode also the predicted pixels are calculated according to the equations mentioned earlier.

(0,0) pixel is calculated as (A + B + 1) / 2 = (128 + 128 +1) / 2 = 128

Like this all the pixel values are calculated.

Predicted block =

128 128 128 128

128 128 128 128

128 128 128 128

128 128 128 128

SAD = 666

Horizontal up prediction:

In this mode also the pixel values are predicted according to the values mentioned earlier.

The predicted block =

86 87 88 89

88 89 91 92

91 92 93 93

93 93 93 93

SAD = 71

Therefore the best prediction is the one which gives least SAD value. In this case horizontal prediction gives least SAD value compared to all other modes. The horizontal predicted block is subtracted from the source block to get residual block. The residual block is then transformed, quantized, inverse transformed and scaled to reconstruct the source block. The transform process is explained in the later section.

The reconstructed block is given by.

83 84 87 **90**

85 85 86 **91**

86 82 82 **89**

91 85 84 87

The samples which are bolded are now available for prediction of next 4X4 block.

In the same way 16X16 luma and 8X8 chroma prediction are performed.

Example:

Consider a residual block of 1st top left 4X4 block in intra prediction.

Forward transformation:

$$X = \begin{bmatrix} -36 & -37 & -39 & -42 \\ -37 & -38 & -40 & -42 \\ -39 & -39 & -39 & -40 \\ -39 & -41 & -40 & -35 \end{bmatrix}$$

$$Y = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix} \cdot \begin{bmatrix} -36 & -37 & -39 & -42 \\ -37 & -38 & -40 & -42 \\ -39 & -39 & -39 & -40 \\ -39 & -41 & -40 & -35 \end{bmatrix} \cdot \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 1 & -1 \end{bmatrix}$$

$$Y = \begin{bmatrix} -623 & 19 & 3 & 2 \\ 2 & 56 & -18 & 8 \\ 5 & -9 & 7 & -2 \\ 1 & 3 & -9 & 4 \end{bmatrix} \otimes \begin{bmatrix} 13107 & 8066 & 13107 & 8066 \\ 8066 & 5243 & 8066 & 5243 \\ 13107 & 8066 & 13107 & 8066 \\ 8066 & 5243 & 8066 & 5243 \end{bmatrix} \cdot \frac{1}{2^{15+\left(\frac{QP}{6}\right)}}$$

$$Y = \begin{bmatrix} -125 & 2 & 1 & 0 \\ 0 & 4 & -2 & 1 \\ 1 & -1 & 1 & 0 \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

$\otimes$ indicates scalar multiplication.

For QP= 12

$$Y = \begin{bmatrix} -62 & 1 & 0 & 0 \\ 0 & 2 & -1 & 0 \\ 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 0 \end{bmatrix}$$

For QP= 30

$$Y = \begin{bmatrix} -8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

<u>Inverse transformation(for QP=6)</u>

$$Z = \begin{bmatrix} 1 & 1 & 1 & 0.5 \\ 1 & 0.5 & -1 & -1 \\ 1 & -0.5 & -1 & 1 \\ 1 & -1 & 1 & -0.5 \end{bmatrix} \cdot \left(\begin{bmatrix} -125 & 2 & 1 & 0 \\ 0 & 4 & -2 & 1 \\ 1 & -1 & 1 & 0 \\ 0 & 0 & -1 & 0 \end{bmatrix} \otimes \begin{bmatrix} 10 & 13 & 10 & 13 \\ 13 & 16 & 13 & 16 \\ 10 & 13 & 10 & 13 \\ 13 & 16 & 13 & 16 \end{bmatrix} \times 2^{(QP/6)} \right) \cdot \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 0.5 & -0.5 & -1 \\ 1 & -1 & -1 & 1 \\ 0.5 & -1 & 1 & -0.5 \end{bmatrix}$$

$$Z = \begin{bmatrix} -36 & -38 & -39 & -42 \\ -37 & -39 & -40 & -42 \\ -39 & -39 & -40 & -39 \\ -39 & -41 & -40 & -35 \end{bmatrix}$$

Therefore reconstructed block = predicted block + residual block

$$P = \begin{bmatrix} 128 & 128 & 128 & 128 \\ 128 & 128 & 128 & 128 \\ 128 & 128 & 128 & 128 \\ 128 & 128 & 128 & 128 \end{bmatrix}$$

$$\text{Reconstructed block} = \begin{bmatrix} 128 & 128 & 128 & 128 \\ 128 & 128 & 128 & 128 \\ 128 & 128 & 128 & 128 \\ 128 & 128 & 128 & 128 \end{bmatrix} + \begin{bmatrix} -36 & -38 & -39 & -42 \\ -37 & -39 & -40 & -42 \\ -39 & -39 & -40 & -39 \\ -39 & -41 & -40 & -35 \end{bmatrix}$$

$$= \begin{bmatrix} 92 & 90 & 89 & 86 \\ 91 & 89 & 88 & 86 \\ 89 & 89 & 88 & 89 \\ 89 & 87 & 88 & 93 \end{bmatrix}$$

System implementation

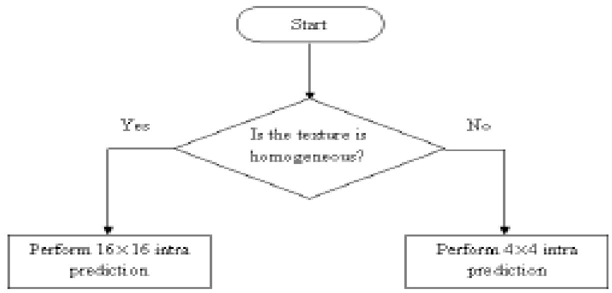

Figure 9 Flow chart for prediction of 4X4 or 16X16

the image block 16x16 checked for its texture if the texture is homogeneous 16x16 prediction method is best for prediction if the texture is variable in nature 4x4 prediction method is best to form prediction. In 4x4 intra prediction the block is first checked whether neighboring pixels are available to form prediction if they are available the prediction is formed by using all available 9 modes and the best prediction mode is selected according to the SAD value. If neighboring pixels are not available the values of neighboring pixels are assumed to be 128 and DC mode is used for prediction.

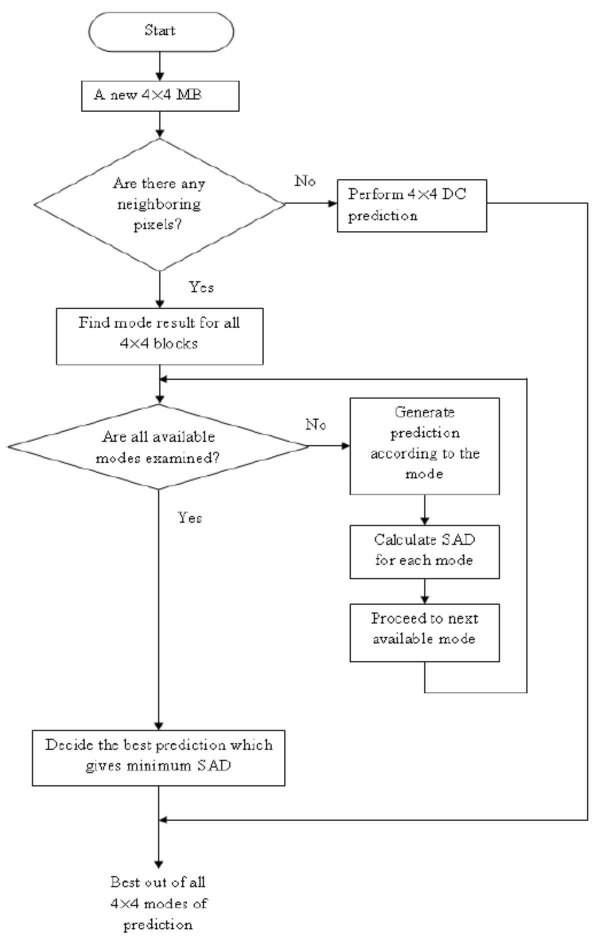

Figure 10 Flowchart for intra luma 4x4 prediction

Conclusion

In 4X4 intra prediction the prediction is found for all available modes and the best prediction is taken according to the sum of absolute difference value for different modes. The mode which gives minimum sad value is selected as a best prediction mode. using of I-frames(intra coded) improve the quality of video. In intra prediction 4x4 is used to form best prediction in variable texture.16x16 is used to form best prediction in homogeneous texture. For better quality all the available modes are used which increase code complexity. Selected modes are used to decrease the code complexity.

References

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