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Fast Subpixel Full Search Motion Estimation

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Abstract— *Motion estimation is one of the most important part in video coding, where only the difference between the current and reference frames will be coded by the encoder.There are many advancements happening in motion estimation techniques. The proposed algorithm provides high precision matching and even reduces the errors during compensation. The algorithm also reduces the computation time when compared to traditional Block matching techniques. It mainly aims at the motion estimation with subpixelaccuracy without interpolation, it is the combination of Block matching and the optical flow method.Fast computation may be evaluated by experimental results while even motion vectors are more accurate reducing the PSNR.*

Keywords— Motion estimation, Subpixel, Block matching algorithm, Full search.

I. INTRODUCTION

Motion estimation is the key technique used in video compression. Mainly at encoder, motion vectors obtained by motion estimation techniques can affect the coding scheme. At the encoder side the motion vectors in the current frame with respect to the previous side is measured. Later during compensation the current frame is built from the previous frame with the help of motion vectors. The encoder and decoder are used to encode the motion vectors and transmit it to the decoder side where it is decoded for compensation. The overall idea of motion estimation is the video compression resulting in the reduction of the number of bits to be encoded, thus increasing the speed[1]. Figure-1 shows the video compression process flow.

The most important part in video coding is the motion estimation. This part deals with the estimation of motion vectors from a pair of video frames which are infrequently accurate.

To increase the accuracy of compensation we go for sub-pixel estimation. Here to obtain this usually at the encoder the algorithm interpolates the images.

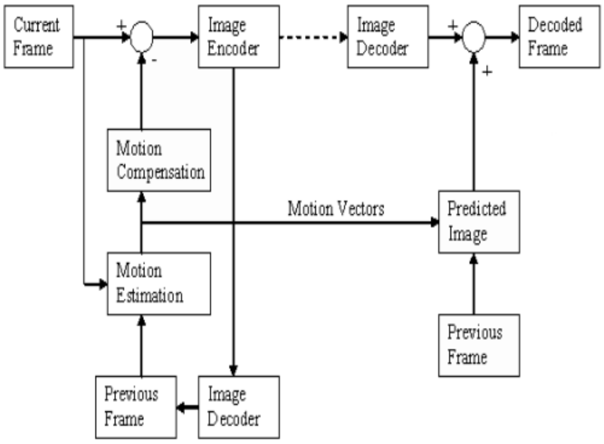

Fig.1: MPEG video compression process flow.

The algorithm proposed in this paper is a hybrid scheme, which combines both the block matching and optical flow[2]. Initially using block matching the common motion vectors are determined which is then refined using the Taylor approximation[2].

II. METHODOLOGY

2.1 BLOCK MATCHING ALGORITHMS

Block matching is a technique where the best matching block within the search space is obtained,i,ethe main idea is split the current frame into macro blocks, which is later compared with the corresponding block and its neighboring blocks in the reference frame to show the motion vector that describes the shift of macro block from its actual location to other in the previous frame. To accomplish this task many techniques are in existence such as Three Step Search, Diamond Search, Four Step Search and Adaptive Root Pattern Search. The illustration of block matching is shown in figure below.

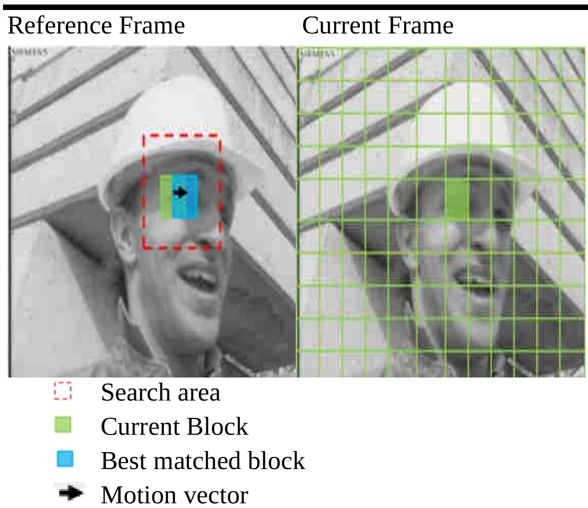

Fig.2: Block Matching

As described in figure, to obtain the best match the algorithm proceeds with straight forward method called exhaustive search which searches for all the possible positions. This is referred to full search.

2.2 Optical flow (Taylor approximation)

At the times t and t+Δt, the algorithm tries to find the motion between the two image frames at every possible position. This is based on the Taylor approximations of the image[2].

Assume the two back to back frames p(x, y) and q(x, y), we have

q(x, y) = p(x+Δx, y+Δy)

The first order Taylor equation yields

$$q(x, y)=p(x, y)+\Delta x\frac{\partial}{\partial x}p(x,y) + \Delta y\frac{\partial}{\partial y}p(x,y) \ldots (1)$$

Then the minimization is obtained by

$$min_{\Delta x,\Delta y}\ \Phi(\Delta x, \Delta y) \quad \ldots. (2)$$

Where

$$\Phi(\Delta x, \Delta y) = \sum_{x,y}(q(x,y) - (p(x,y) + \Delta x\frac{\partial}{\partial x}p(x,y) + \Delta y\frac{\partial}{\partial y}p(x,y)))^2. (3)$$

The minimization of least square error is done by making objective derivative function to zero.

$$\frac{\partial \Phi}{\partial \Delta x} = 0 \quad \text{and} \quad \frac{\partial \Phi}{\partial \Delta y} = 0$$

Resulting in linear equations

$$\begin{pmatrix} \sum_{x,y}(\frac{\partial r}{\partial x})^2 & \sum_{x,y}\frac{\partial r}{\partial x}\frac{\partial r}{\partial y} \\ \sum_{x,y}\frac{\partial r}{\partial x}\frac{\partial r}{\partial y} & \sum_{x,y}(\frac{\partial r}{\partial y})^2 \end{pmatrix}\begin{pmatrix}\Delta x \\ \Delta y\end{pmatrix} = \begin{pmatrix} \sum_{x,y}(s-r)\frac{\partial r}{\partial x} \\ \sum_{x,y}(s-r)\frac{\partial r}{\partial y}\end{pmatrix} \ldots(4)$$

Solving this provide the optimum solution.

2.3 Steps for the Proposed Algorithm

Initially here we compute the SAD[7] to verify the matching criteria. The equation is

$$SAD(i, j)=\sum_{m=1}^{M}\sum_{n=1}^{N}|f_k(m,n) - f_{k-1}(m+i, n+j)|$$

Where M and N represent search area and $f_k(m,n)$ is the starting point of searching.

The block diagram for combined operation of proposed methodology is shown in figure below.

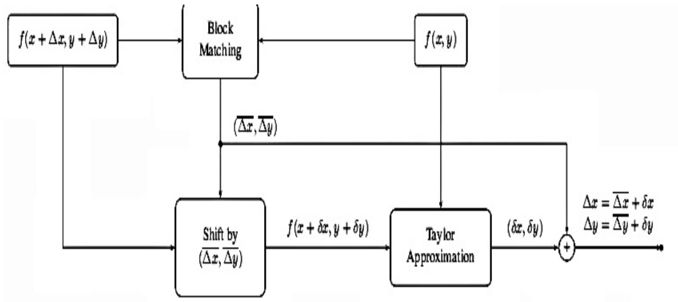

Fig.3: Block diagram of combined block matching and optical flow.

Using this the pixel displacements along x and y axis is determined. With the help of actual displacementsΔx and Δy, the estimated displacement $\overline{\Delta x}$ *and* $\overline{\Delta y}$is found.

Once $(\overline{\Delta x}, \overline{\Delta y})$ is obtained during the motion compensation the image blocks are shifted by $\overline{\Delta x}$alonx axis and $\overline{\Delta y}$ along y axis.

Next step is optical flow using Taylor series approximation. Since $(\partial x, \partial y)$ is the difference from the actual frame to the current frame, the overall displacement is determined by

$\Delta x = \overline{\Delta x} + \partial x$ and $\Delta y = \overline{\Delta y} + \partial y$

Later on we compute the PSNR (Peak Signal To Noise Ratio) given by the equation

$$PSNR=10Log_{10}\left[\frac{(Peak\ to\ peak\ value\ of\ the\ original\ data)^2}{MSE}\right]$$

Where MSE is the mean square error calculated using the equation

$$MSE = \frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(C_{ij}-R_{ij})^2$$

C_{ij} *and* $R_{ij}$are the pixels of current and reference macro blocks.

III. EXPERIMENTAL RESULTS AND ANALYSIS

To verify the proposed algorithm we choose a set of standard format frames. The results below shows the computation time for different set of frames and the calculated PSNR are depicted in a table below.

PSNR CALCULATION IN DB

Sequence	Method	PSNR (db)	Time
Foreman	Bi-predictive	**27.1435**	**37.1190**
Suzie	Bi-predictive	**36.3131**	**8.6703**
City	Bi-predictive	**30.2568**	**44.1714**
Salesman	Bi-predictive	**29.6458**	**49.4935**

By analyzing the above table it is evident that the proposed algorithm computes with minimum error and also the computation time is reduced when compared with other techniques.

The original image with the compensated image along with the motion vectors in quiver plot is shown in figure below.

Fig.4: Foreman reference frame

Fig.5: Foreman compensated frame

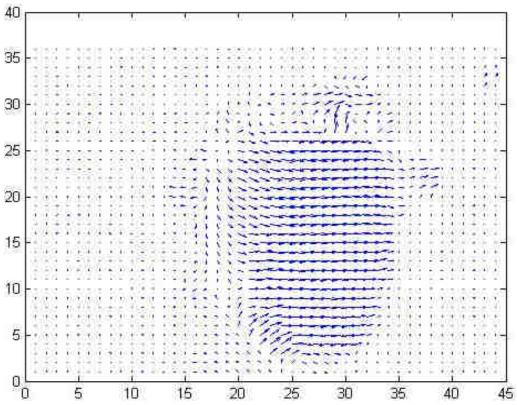

Fig.6: Motion vector field

IV. CONCLUSION

Thus, the technique provides the motion vector within vey less computation time and with minimized error ratein an effective way. The sub-pixel analysis with the combined operation of exhaustive search (Full Search) and the optimal flow using Taylors approximations thus an enhanced method for motion estimation.

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