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MODELING THE NEW THREE STEP SEARCH ALGORITHM FOR MOTION ESTIMATION IN IMAGE SEQUENCE IN MATLAB

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APRIL 2006

“I hereby declare that this thesis is the result of my own effort except certain notes that I clearly stated as references and sources.”

Signature : ....

Writer : LENG HUEY LEY..............

Date : 5 MAY 2006.................

For my dearest father and mother

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ABSTRACT

This thesis focusing on a Motion Estimation that play an important role in motion compensated image sequence coding. Due to the huge computation demand of the conventional full search method, investigation of fast motion estimation algorithms has been a focus of research. There are few types of fast motion estimation algorithms - Three Step Search (TSS), New Three Step Search (NTSS), Full Search (FS) and the Diamond Search (DS). The New Three Step Search (NTSS) Algorithm has been proposed for the study in this project. The features of this algorithm are that it employs a center-biased checking point pattern in the first step, which is derived by making the search adaptive to the motion vector distribution, and a halfway-stop technique to reduce the computation cost. Implementation and performance analysis of New Three Step Search (NTSS) is done by using MATLAB.

ABSTRAK

Tesis ini berkenaan dengan *Motion Estimation* yang memainkan peranan penting dalam kod siri imej bagi *motion compensated.* Oleh sebab permintaan yang tinggi untuk teknik pencarian penuh secara konvensyen, analisis berkenaan algoritma *fast motion estimation* (anggaran pergerakan pantas) telah difokuskan dalam kajian ini. Terdapat beberapa algoritma yang anggaran pergerakan pantas iaitu Carian Tiga Langkah (Three Step Search), Carian Tiga Langkah Baru (New Three Step Search), Carian Penuh (Full Search), dan Carian Berlian (Diamond Search). Bagi kajian projek ini, Carian Tiga Langkah Baru telah diutarakan. Ciri-ciri yang telah ditingkatkan dalam algoritma ini adalah ianya menggunakan corak *center-biased checking point* pada langkah pertama di mana ianya diperolehi dengan membuat kajian yang boleh menyesuaikan diri terhadap pembahagian vektor pergerakan dan teknik hentian-separuh jalan (halfway-stop) untuk mengurangkan kos komputasi. Implementasi dan analisis persembahan Carian Tiga Langkah Baru (NTSS) dilakukan menggunakan perisian MATLAB.

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LIST OF ACRONYMS

BMA – Block Matching Algorithm

BDM - Block Distortion Measure

CIF - Common Intermediate format

DS – Diamond Search

EBMA – Exhaustive Block Matching Algorithm

EJO – Early Jump Out

FS – Full Search

FSS – Four Step Search

FPS – Frame Per Second

ISDN – Integrated Service Digital Network

ITU – International Telecom Union

LDSP – Large Diamond Shape Pattern

LTMCP – Long Term Memory Motion Compensation Prediction

MAD – Mean Absolute Difference

MAE – Mean Absolute Error

MB – Macroblocks

MBD – Minimum Block Distortion

ME – Motion Estimation

MPEG – Moving Picture Expert Group

MSE – Mean Squared Error

NTSS – New Three Step Search

PCM – Pulse Code Modulation

PSNR – Point Signal Noise to Ratio

QCIF – Quarter Common Intermediate format

SAD – Sum of Absolute Differences

SAE – Sum of Absolute Error

SDSP – Small Diamond Shape Pattern

LIST OF ACRONYMS

TSS – Three Search Step

VLSI – Very Large Scale Integration

CHAPTER 1

OBJECTIVE AND SCOPE OF WORK

1.1 OBJECTIVE

There are few algorithms available and developed recently to maintain the accuracy and precision in achieving high compression ratio in video coding technique. But each technique has been built on advantages and disadvantages. Thus, this project is proposed:

- To gain knowledge on image processing area
  - This includes Motion Estimation (ME)
  - Block Matching Algorithm (BMA)
  - New Three Step Search (NTSS) algorithm.

- To model the algorithm using MATLAB and subsequently analyses the performance.

- To produce a simple, working program code for the algorithm

1.2 WORK SCOPE

There are few types of algorithm available in block matching ME when study the ME of the displacement or velocity of image structures. This is applied to one frame to another in a time sequence of 2-D images.

One of the most recent algorithms that are available for implementation is New Three Step Search (NTSS). Beside in implementing this algorithm it is essential to understand and learn about how the image processing is done using the NTSS

MATLAB system is used to execute this algorithm, and the performances of this algorithm are analyzed to verify its usefulness compared to other available algorithms.

1.3 METHODOLOGY

1. Data acquisition and literature review.
   a. Video Coding, ME
   b. BMA
   c. Algorithms available.

2. Extraction of video sequence into frame.
   a. Learn how the video sequence can be extracted into frame.
   b. How it is does in MATLAB system.

3. Block Matching Development
   a. Study how block is constructed.
   b. How the search window operates

4. NTSS development
    a. NTSS development in MATLAB.

5. Reconstruction of frames
    a. Get reconstructed image quality and average number of points
    b. Compared with other algorithms
    c. Check on the performances.

6. Final theses and Demonstration.

CHAPTER 2

BACKGROUND STUDY

2.1 MOTION ESTIMATION ALGORITHMS

ME is a process to estimate the pels or pixels of the current frame from reference frame(s). The temporal prediction technique used in video is based on ME. The basic premise of ME is that in most cases, consecutive video frames will be similar except for changes induced by objects moving within the frames.

ME can be done using the block matching technique which exploit different search patterns and search strategies for finding the optimum motion vector for particular ME which reduced the number of search points. It efficiently removes the temporal redundancy between successive frames by BMA.

Block-based ME is the most practical approach to obtain motion compensated prediction frames. It divides frames into equally sized rectangular blocks and finds out the displacement of the best-matched block from previous frame as the motion vector to the block in the current frame within a search window.

The benefits of long-term memory motion compensated prediction (LTMCP) [1] have been emphasized in recent years. Consequently, this tool has been adopted by several recent standards like H.263+ and H.264iMPEG-4 AVC [2]. As continuously dropping the costs of semiconductors, notably higher prediction gain can be achieved by estimating more reference frames in the memory buffer. Nevertheless, an obvious drawback is the complexity will increase proportionally. Extra data are also needed to describe the reference indices.

2.2 BLOCK MATCHING ALGORITHM [3]

BMA are based on the matching of macroblocks (MB) between two ME subnetwork images. For each MB, a motion vector is evaluated by matching the MB within a search area, according to the Mean Absolute Error (MAE) criterion.

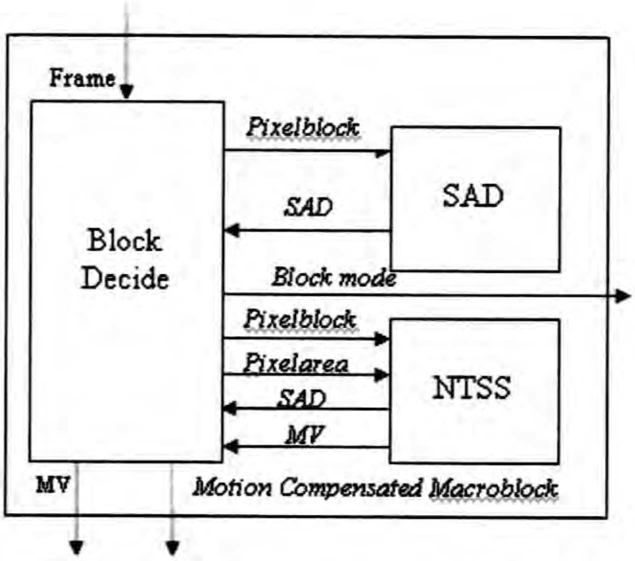

Figure 2.1: Motion Estimation subnetwork

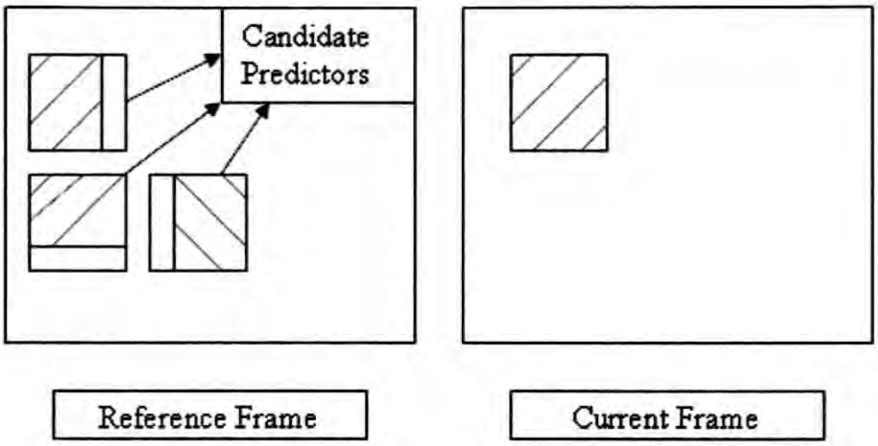

Figure 2.2 : Similarity between macroblocks of the current and reference frames

In Figure 2.2, it is clear that the dissimilar areas (represented as white patches in the reference frame) of candidate macro block predictors, can be faster identified and potentially eliminated by different scanning orders than the one used by the standard.

In the cases depicted in the figure, a scanning order from the right-most column to the left-most, from the left-most column to the right-most and from the bottom-most row to the top-most would be ideal for fast rejection of candidate predictors. The above figure also suggests that joint exploitation of horizontal and vertical sum of absolute difference (SAD) information may speed-up the rejection of candidate predictors that are not the best matches. This idea will be further exploited in the design of the scanning orders propose.

The block-matching algorithm compares two 16-byte by 16-byte blocks of memory by accumulating either a sum of absolute error (SAE), which gives similar performance of using mean square error (MSE), but with much lesser computations. Suppose the block size is *N x N*. The SAE or distortion, *D* of a block located at (x, y) in current frame, F_t matched against the block with a displacement (u, v) from (x, y) in previous frame F_{t-1} is defined as

$$D = \mathrm{SAE}_{(x,y)}(u, v) = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} |F_t(x+i, y+j) - F_{t-1}(x+i+u, y+j+v)|$$

Where Ft(. , .) and F_{t-1} (. , .) denote the pixel value in current and previous frame, respectively, while (x , y) represents the coordinates of the upper left corner pixel of the current block, and (u , v) is the displacement relative to current block located at (x, y). The basic operations of computing SAE are absolute (|.|) and addition (±) operations, and require about (3N2 – 1) operations per block distortion measure (BDM).

2.3 TYPES OF FAST MOTION ESTIMATION ALGORITHMS

- THREE STEP SEARCH ALGORITHM (TSS)
- NEW THREE STEP SEARCH ALGORITHM (NTSS)
- FOUR STEP SEARCH ALGORITHM (FSS)
- DIAMOND SEARCH (DS)

2.3.1 THREE STEP SEARCH ALGORITHM (TSS)

This algorithm was introduced by Koga et al in 1981. TSS is a popular fast algorithm. It became very popular because of its simplicity and also robust and near optimal performance. It searches for the best motion vectors in a course to fine search pattern. It is a block based search technique and uses a maximum of three steps. It is mainly used for ME in low bit rate video compression applications such as videophone and video conferencing.

The TSS algorithm is a simple and effective method used for ME. When compared with Exhaustive Block Matching Algorithm (EBMA) it has a saving factor of greater than a 100. It has a fixed number of three search steps and a maximum and minimum number of search points of 25[4] The disadvantage of this technique is that it uses a uniformly allocated checking point pattern in the first step which makes it inefficient for the estimation of small motion.

1. An initial step size is picked. Eight blocks at a distance of step size from the centre (One center point and eight points on the boundary of the search square) are compared in the first step and thereafter only 8 points are searched.
2. At the start of a new step the search point center is moved from the best matching point from the previous step. Step size is reduced by half after each step.
3. At the end of the search the step size is one pel.

2.3.1.1 Advantages

- Simplicity and also robust and near optimal performance.
- Best motion vectors in a course to fine search pattern.

2.3.1.2 Disadvantages

- Inefficient for the estimation of small motion.