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17 Appendix J: Fast Block-Matching Motion Estimation

17.1 Introduction

17.1.1 Originality and Contributions

At Fribourg MPEG meeting (October 1997), a public call for submitting the proposals of fast block-matching motion estimation (BMME) algorithms was initiated by the Chairmen of Encoding Optimization Ad-Hoc Group, Dr. Tihao Chiang and Dr. Huifang Sun. This appendix provides a technical description of the final adopted proposal which presents a novel fast BMME search method, called *diamond search* (DS). The earliest documentation of describing the originality of this algorithm can be found in [1]. Immediately after Fribourg MPEG meeting, Dr. Kai-Kuang Ma and Mr. Prabhudev I. Hosur have been conducting all the extensive core experiments for evaluating DS algorithm, from the very beginning until its adoption in Vancouver MPEG meeting (July 1999) [2].

Two independent verification parties, Sarnoff Co. and Mitsubishi Electric Information Technology Center America, conducted evaluation throughout the entire adoption process. For independent verification efforts, the following individuals are greatly acknowledged: Dr. Hung-Ju Lee and Dr. Tihao Chiang (from Sarnoff) and Mr. Anthony Vetro and Dr. Huifan Sun (from Mitsubishi).

17.1.2 Objectives

Block-matching motion estimation (BMME) is one of the informative cores for achieving motion-compensated video coding. If the full search (FS) method is used, BMME will occupy a major portion of total computation required by the entire encoding process. Consequently, a fast BMME algorithm that provides consistent and stable performance for any type of image sequences (thus, robust) is highly desirable and indispensable to many real-time video applications. In addition, the approach should consider not just *computational* complexity (or gain), but also *logic* complexity for hardware implementation. The adopted DS has been well proven in providing a simple and elegant solution to achieve the above-mentioned objectives.

17.2 Technical Description of Diamond Search (DS)

In BMME, the shape and size of search patterns jointly determine not only the error performance of fast block matching algorithms (BMAs) but also their search speed. It is well known that the distribution of the global minimum distortion points (MBDs) in typical real-world video sequences is centered at zero. Using several commonly used test image sequences, extensive investigations of the motion vector distribution probabilities are conducted based on the FS algorithm with the mean-square error (MSE) matching criterion. Results indicated that about 53% (in large motion case) to 99% (in small motion case) of the motion vectors are enclosed in a circular support with radium of 2 pixels and centered on the position of zero motion. Furthermore, the block displacement of real-world video sequences could be in any direction. Based on these crucial observations, the circle with radium of 2 pixels is the most appropriate search area to be considered. Accordingly, those search point positions incurred within the circle and marked by “×” in Figure 1 compose the search patterns as described in the following.

The DS algorithm employs two search patterns as illustrated in Figure 2 which are derived from the crosses “×” marked in Figure 1. The first pattern, called *large diamond search pattern* (LDSP), comprises of 9 checking points from which eight points surround the center one to compose a diamond shape. The second pattern consisting of 5 checking points forms a smaller diamond shape, called *small diamond search pattern* (SDSP). During the search, LDSP is repeatedly used until the step in which the MBD occurs at the center point. The search pattern is then switched from LDSP to SDSP as reaching to the final search stage. Among the five checking points in SDSP, the position yielding the MBD provides the motion vector of the best matching block. The DS algorithm is summarized as follows:

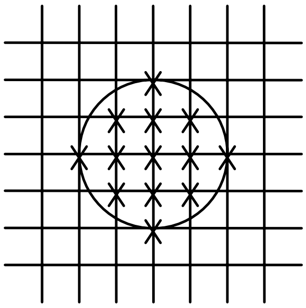
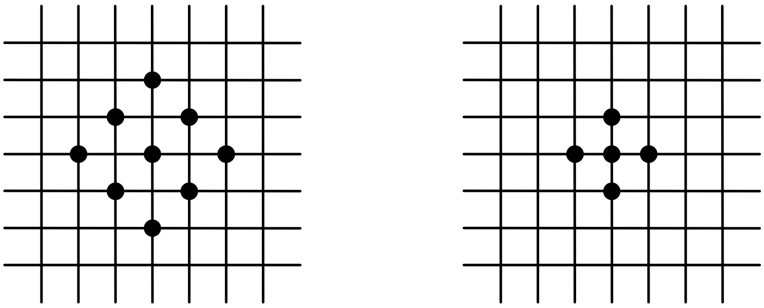


Figure 1: An appropriate search pattern support.



(a) Large diamond search pattern (LDSP) (b) Small diamond search pattern (SDSP)

Figure 2: Two search patterns derived from Figure 1.

Step 1: The initial LDSP is centered at the origin of the search window, and the 9 checking points of LDSP are tested. If the MBD point calculated is located at the center position, go to **Step 3**; otherwise, go to **Step 2**.

Step 2: The MBD point found in the previous search step is re-positioned as the center point to form a new LDSP. If the new MBD point obtained is located at the center position, go to **Step 3**; otherwise, recursively repeat this step.

Step 3: Switch the search pattern from LDSP to SDSP. The MBD point found in this step is the final solution of the motion vector which points to the best matching block.

On implementation, error measurement criterion—sum of absolute difference (SAD), is recommended as it is the most common practice due to its simple calculation. Furthermore, there are overlapping search point(s) between two consecutive search iterations. If the SAD values of the search points obtained in the previous stage were stored in the memory, those overlapped search point(s) would not needed to be re-computed in the current stage; thus, computational load is further reduced. In addition, DS algorithm doesn't restrict the number of search range (steps). However, since all the MBD values found along the search path are always in a decreasing order, the search path is impossible to form a closed search loop. Therefore, the convergence of DS algorithm is guaranteed.

17.3 References

[1]. Shan Zhu and Kai-Kuang Ma, "A New Diamond Search Algorithm for Fast Block Matching Motion Estimation," *International Conf*erence *on Information, Communication and Signal Processing* (ICICS'97), Singapore, pp. 292-296, 9-12 Sept. 1997.

[2]. Kai-Kuang Ma and Prabhudev I. Housr, "Core Experiment Results of Fast Motion Estimation Based on New Test Conditions (Q4a)," ISO/IEC JTC1/SC29/WG11 MPEG99/M4934, July 1999, Vancouver, Canada.

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