Test Zone Search Optimization Using Cuckoo Search Algorithm for VVC

Suvojit Acharjee, Jadavpur University, India*
https://orcid.org/0000-0002-7540-4777

Sheli Sinha Chaudhuri, Jadavpur University, India

ABSTRACT

Motion vector approximation is an integral part of every video coding standard to reduce temporal correlation. Estimating motion necessitates a lot of computation. Several attempts were made to reduce the computation cost in exhaustive search of motion estimation. Test zone search was accepted as benchmark algorithm for fast motion estimation by the most recent video coding standard, versatile video coding. Quality and speed of test zone search completely depends on two parameters (i.e., sub sampling frequency of search space during raster scan and dimension of the search space). Cuckoo search, one of the popular nature-inspired optimization algorithms, is used to optimize the operational parameters of test zone search. The proposed optimization enhanced the speed up to 50% while maintaining or improving the Bjontegaard rate (BD-Rate) and Bjontegaard PSNR (BDSNR).

KEYWORDS

Block Matching, Evolutionary Algorithm, Motion Compensation, Motion Estimation, Motion Factor, Nature-Inspired Algorithm, Optimization, Versatile Video Coding, Video Compression, Video Encoding

INTRODUCTION

Video is the most important medium of communication and entertainment in the present era. Video technology has witnessed a huge transformation in the last decade. The inclusion of high-resolution movie sequences, machine-generated synthetic video series, 360-degree video sequences, and other advanced video formats fundamentally transformed the video encoding and decoding process. The joint video experts team adopted the versatile video coding (VVC) standard in 2020 for such diverse video characteristics (Bross et al., 2021). VVC relied on motion estimation and motion compensation for interframe coding. As a brute force search, the full search algorithm provides the best result for motion estimation at a very slow speed (Acharjee, 2012). The geometrical pattern-based searches, such as the three-step search (Barjatya, 2004), the four-step search (Po & Ma, 1996), the diamond search (Zhu & Ma, 2000), and many more such algorithms, limit the number of search points and

DOI: 10.4018/IJMDEM.314574 *Corresponding Author

increase the speed of motion estimation. A few other approaches use the search point elimination technique to improve the pace of the process (Liu & Salari, 1995).

Hosur (Hosur, 2003) applied predictors to find the initial search point in the motion vector field adaptive search technique (MVFAST). The algorithm used the position of the present block and its neighboring blocks as an input to the predictor. Inclusion of the predictors reduced the calculation time in the motion approximation process. Tourapis et al. replaced the other predictors with the median predictor in the predictive motion vector field adaptive search technique (Tourapis et al., 2000). Tourapis further offered a few changes to the zonal search method, which included improved prediction and thresholding measures (Tourapis, 2002). These changes increased the speed of the motion approximation process considerably compared to the fixed pattern-based motion estimation.

In the high efficiency video coding standard, the zonal search-based test zone motion estimation algorithm has been accepted as a benchmark algorithm (Sullivan et al., 2012). Test zone search is a multi-staged procedure which includes both the zonal search as well as the raster search (Figure 1). In zonal search, a square or diamond pattern search is performed around the initial search point. The adaptive motion vector predictor (AMVP) is used to select the initial search point (Liu et al., 2006). The dimension of the diamond or square pattern will vary from one to the size of the search window. The search window is defined in the reference frame at a certain distance around all directions from the initial search point. The next phases in the test zone search are controlled by f_{raster}, which is the sub-sampling frequency of the search region during raster search. Following the zonal search, the test zone search follows one of the processes listed below.

First, if the best match is within one pixel of the current search center, a two-step search is performed to explore for even better results among nearby unexplored solutions.

Second, the search center moves to the position of the best match when the distance between the present best match and the search center is greater than one but smaller than the f_{raster}. A diamond or square patterned grid search is performed again with f_{raster} as the size of the search window. The search window is centered around the new search center.

Third, when the best match is identified at a distance larger than f_{raster}, the raster search of the entire search window is done with a sub-sampling frequency of f_{raster}. A refinement search was performed, centering around the position with the lowest distortion between the reference coding unit and the current coding unit during raster search.

Though the test zone search process is faster than the full search at an equivalent rate-distortion performance, it is not fully optimized. The test zone search does not consider the motion or other parameters of a coding unit during execution, leading to additional search time. Several attempts were made to increase the speed of the test zone search algorithm. In the enhanced test zone search, Parmar and Sunwoo used pentagon pattern search instead of diamond or square pattern search (Parmar & Sunwoo, 2014). The pentagon pattern reduced the number of searches by 32% in the initial zonal search. Overall, the enhanced test zone search saved 23% encoding time compared to the original test zone search. Kibeya et al. introduced search algorithms based on the small and large diamond pattern to replace the raster scan in test zone search (Kibeya et al., 2014). The modification reported an improvement of 8% to 49% in encoding speed compared to the test zone search. An octagonal-axis pattern-based raster scan in the test zone search as proposed by Goncalves et al. observed an almost 60% improvement in the search speed (Goncalves et al., 2018). Nguyen and Tropchenko combined the best of test zone search and hierarchical search (Nguyen & Tropchenko, 2017). The test zone search is not a hardwire friendly algorithm as the calculation structure in the algorithm is very complicated. Doan et al. developed a parallel computation-friendly test zone search that increased the Bjontegaard rate by 0.84 percent while cutting the code complexity in half (Doan et al., 2017).

The test zone search is not completely computationally ideal. The algorithm can achieve a higher execution speed through optimization. In this paper, the cuckoo search algorithm was used to optimize the parameters of test zone search. The cuckoo search technique is discussed in depth in the following section, as are the shortcomings in the test zone search and possible solutions employing cuckoo