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# 움직임 추정을 위한 제한된 부분 왜곡 탐색 알고리즘

# ( Regulated partial distortion search algorithm for motion estimation )

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( Won-Gi Hong, Tae-Myung Oh, and Young-Ro Kim )

요 약

본 논문은 비디오 코딩에서 조절된 부분 영상 블럭의 차이값을 이용한 빠른 움직임 추정 알고리즘을 제안한다. 제안된 방법은 적은 계산량을 통하여 매우 정확한 움직임 벡터를 구할 수 있다. 실험을 통하여 제안된 방법은 전역 검색 방법(Full Search)과 매우 유사한 정확도를 보인 반면, 전역 검색 방법 보다 6에서 28배의 속도 향상을 보여주고 있다.

Abstract

A fast motion-estimation algorithm based on regulated partial block distortions is proposed. The proposed algorithm can obtain very accurate motion vectors with a small computational load. Simulation results show that the proposed scheme provides very close performance to the full search while it is about 6 to 28 times faster than the full search.

**Keywords :** block motion estimation, regulated partial distortion search

## I. Introduction

In order to reduce the computational complexity of the full search (FS) for motion vector estimation in video coding, many popular algorithms have been proposed by limiting the number of search points[1-3]. These algorithms can reduce the computation time significantly, but they are easily trapped into local minimum points so that they may result in higher matching errors. In recent, some algorithms using partial distortions such as normalized partial distortion search [4] and sorting based partial distortion search [5] have been proposed for more accurate prediction. They greatly reduce the computation requirement while providing almost the same results as that of the FS.

In this paper, a fast motion-estimation algorithm, named regulated partial distortion search (RPDS), is proposed. Experimental results show that the proposed scheme can not only adjust the computational complexity with regulating values, but also maintain very close accuracy to the FS.

## II. Partial distortion search algorithms

In the partial distortion search algorithms, they employ partial distortions for evenly sampled pixels of a block for the block distortion comparison. For instance, the normalized partial distortion search (NPDS) compares the normalized value of the partial distortion for regularly sampled pixels with the mean absolute difference (MAD) of the current minimum

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block. Assume that the block size is $N \times N$ and $D(p)$ is the partial distortion for $p$ pixels of a candidate block. Then the normalized partial distortion ( $D_N$) in NPDS is defined as follows.

$$D_N = \frac{N^2}{p} D(p) \qquad (1)$$

When $D_N$ of a candidate is greater than the MAD of the current minimum block, NPDS rejects the candidate. Otherwise, $D_N$ is updated with more pixels, and the comparison is iterated until $p$ is equal to $N^2$. Since $D_N$ is not always the same as the MAD of the candidate, there is a slight loss in the prediction accuracy of NPDS.

Sorting based partial distortion search (SPDS) has been proposed by employing the partial distortions of sorted significant pixels to improve estimation accuracy. The positions of pixels are sorted in decreasing order of the matching errors between the reference block and the origin candidate block to utilize the center-biased distribution of motion vectors [2-4]. As the partial distortions for sorted important pixels suitably represent the MAD of the block, the scheme is able to obtain accurate motion vectors. Although SPDS shows the same estimation performance as the full search, it has the limitation of computation reduction compared to other fast algorithms.

## Ⅲ. Proposed search algorithm

In the partial distortion matching criteria, the speed performance mostly depends on the number of invalid candidates which are rejected at the early comparison steps. On the other hand, the accuracy is influenced by how to obtain the partial distortions for comparison. For example, NPDS using the partial distortions for evenly selected pixels eliminates candidates more than 95 percent at the first step for Football sequence, whereas SPDS does only about 60 percent. Due to these elimination rates, NPDS can produce higher speed than SPDS. In contrast, SPDS shows much more prediction accuracy than NPDS because SPDS exploits the partial distortions for sorted pixels that are greatly larger than those for evenly sampled pixels. Thus there exists a tradeoff between the speed and accuracy according to the magnitude of partial distortions at the initial comparison step.

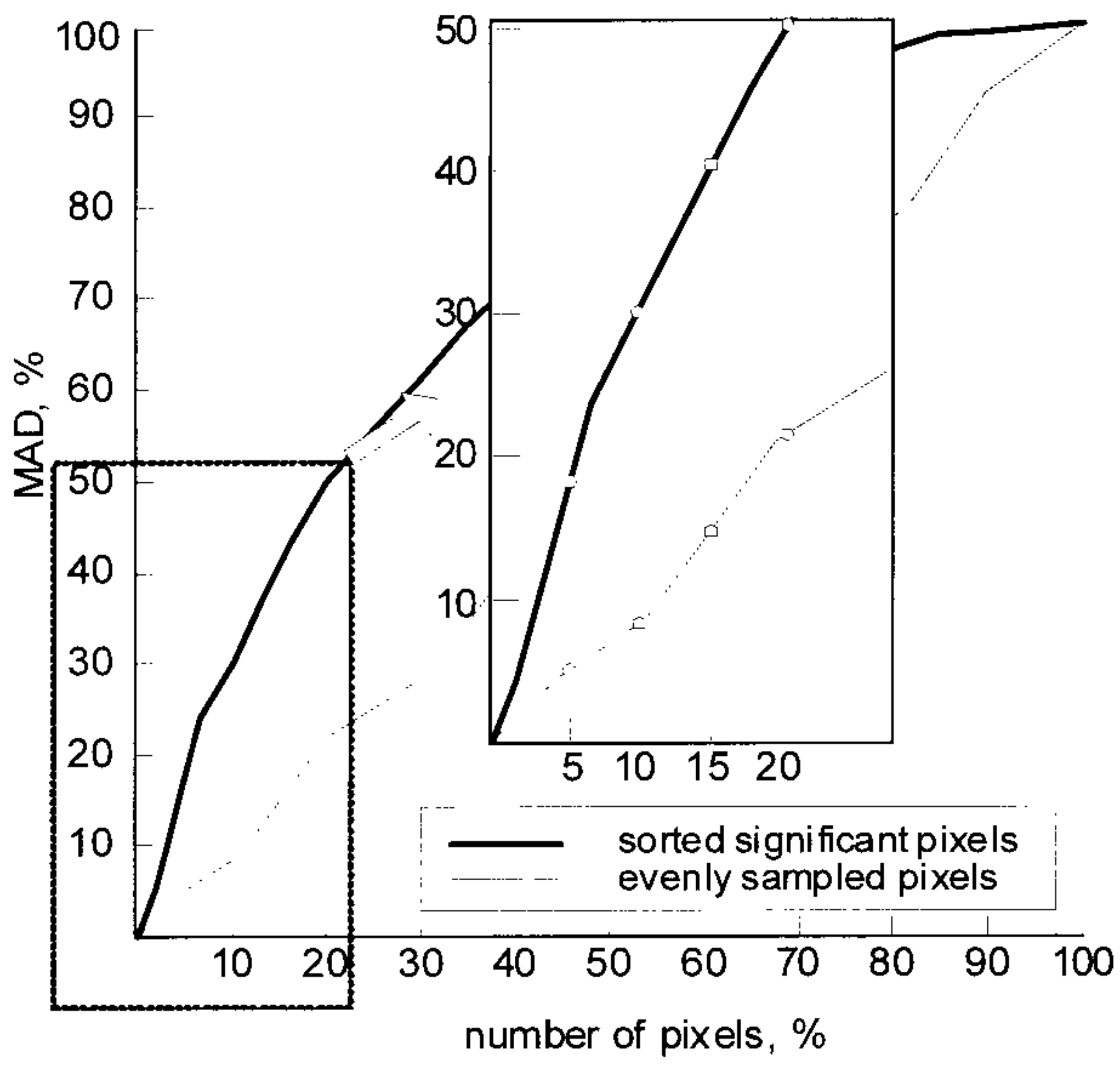


그림 1. 적은 화소일 때 Football에서 정렬된 중요 화소와 균등하게 샘플된 화소에 대한 평균 부분왜곡

Fig. 1. Average partial distortions for sorted significant pixels and evenly sampled pixels for Football when the number of pixels is small.

As shown in Fig. 1, the average partial distortion of SPDS for 10 percent significant pixels amounts to about 30 percent total matching distortion for Football sequence. In other words, it indicates that the partial distortion for 10 percent major pixels becomes approximately three times larger than that for the same percent regularly sampled pixels. The ratio between these two partial distortions grows larger as the number of pixels gets smaller. From this fact, if the partial distortions for small significant pixels are regulated appropriately, we can increase the possibility of eliminating candidate blocks enabling us to improve the computation performance with a slight loss in estimation accuracy.

Suppose $D_S(p)$ is the partial distortions for sorted pixels of the origin candidate block and $D_C(p)$ is the partial distortions for pixels of the other candidate blocks. Since $D_S(p)$ is usually several times lager than $D_C(p)$ when $p$ is very small, we can adjust $D_S(p)$ by dividing it by a regulating factor, $k$ ($k \geq 1$) as follows.

$$\frac{1}{k} D_S(p) \tag{2}$$

The proposed algorithm, called regulated partial distortion search (RPDS), is composed of three stages as follows.

● First stage: Differences for all pixels between the reference block and the origin candidate block are computed. The positions of pixels are sorted in decreasing order of the differences and then used as the matching order for the other candidates. The partial distortions of $D_S(p)$ are also computed for the comparison at the second stage.

● Second stage: Comparisons between $D_S(p)$ and $D_C(p)$ are carried out. When $p$ is very small, RPDS employs $\frac{1}{k} D_S(p)$ as the partial distortion of the origin instead of $D_S(p)$. If $D_C(p)$ is greater than $\frac{1}{k} D_S(p)$ or $D_S(p)$, the candidate is rejected. Otherwise, the comparison is repeated with increased pixels of these two blocks according to the sorted positions until all pixels are exploited for the comparison.

● Third stage: If $D_C(p)$ is less than $D_S(p)$ with all pixels, the candidate block becomes a new minimum, and $D_S(p)$ is replaced with $D_C(p)$. After the second and third stages are iterated within the search window, the block with the minimum MAD becomes the global optimal block.

The proposed scheme is able to adjust the computation complexity by adopting several appropriate regulating values.

## Ⅳ. Simulation results

In our simulation, we used two sequences of Salesman and Football that have slow and fast motions, respectively. Each frame size is 352×240 pixels quantized to eight bits. The search range and the block size are 7 and 16×16, respectively. The sum of absolute difference is used as the block matching criterion.

표 1. 80 프레임에 대한 움직임 벡터당 평균 MSE, 연산량, 속도 개선

Table 1. Average MSE, operations and speed-up per motion vector of the first 80 frames.

| Algorithm | Salesman | | | Football | | |
|---|---|---|---|---|---|---|
| | MSE | Operations | Speed-up | MSE | Operations | Speed-up |
| FS | 21.78 | 172575 | 1.0 | 158.13 | 172575 | 1.0 |
| TSS | 22.76 | 19179 | 9.0 | 177.85 | 19179 | 9.0 |
| NTSS | 22.85 | 13850 | 12.46 | 167.20 | 14575 | 11.84 |
| 4SS | 22.48 | 13104 | 13.17 | 171.33 | 14321 | 12.05 |
| NPDS | 22.17 | 13850 | 12.46 | 166.19 | 12380 | 13.94 |
| SPDS RPDS (k=1.0) | 21.78 | 16804 | 10.27 | 158.11 | 25120 | 6.87 |
| RPDS (k=1.5) | 21.85 | 11684 | 14.77 | 158.74 | 16853 | 10.24 |
| RPDS (k=2.0) | 22.24 | 8321 | 20.74 | 161.24 | 11331 | 15.23 |
| RPDS (k=2.5) | 22.97 | 6789 | 25.42 | 165.89 | 8685 | 19.87 |
| RPDS (k=3.0) | 23.87 | 6188 | 27.89 | 171.71 | 7439 | 23.20 |

The proposed algorithm employs 32 steps to perform the comparison for a candidate block. At the first step, eight pixels are exploited to obtain the first partial distortion, and the number of pixels is added by eight pixels as the step is continued. Especially, only when the number of pixels ($p$) is less than or equal to 16, our algorithm uses $\frac{1}{k} D_S(p)$ in place of $D_S(p)$ to compare it with $D_C(p)$ as described above. The proposed algorithm regulates the computational complexity by varying the regulating factor ($k$) from 1 to 3. First 80 frames of each sequence are used for the performance comparison of the FS, three-step search (TSS) [1], new three-step search (NTSS) [2], four-step search (4SS) [3], NPDS, SPDS, and RPDS.

Table 1 shows the performance comparison in

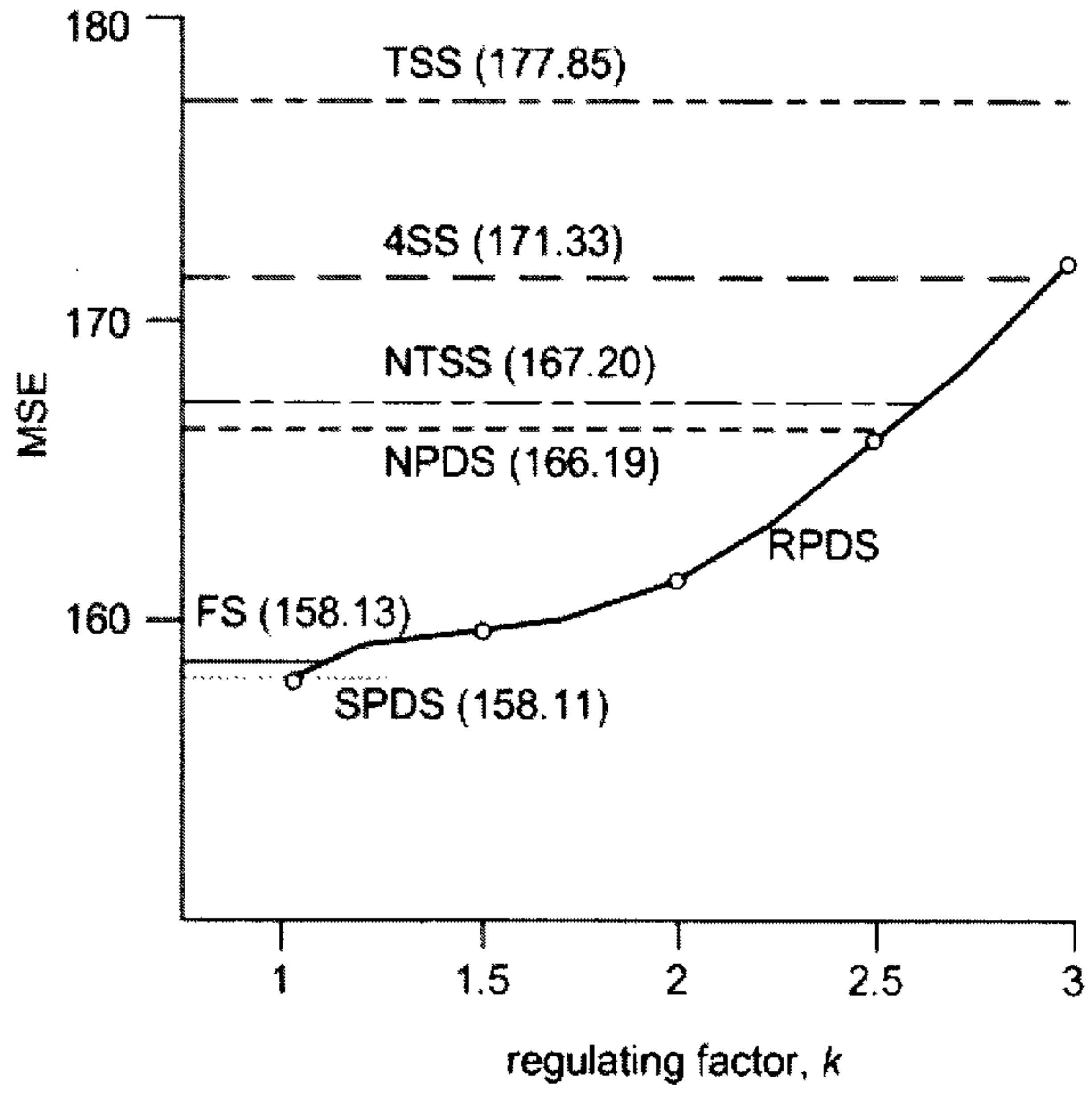


그림 2. Football 영상에 대한 평균 MSE 비교

Fig. 2. Comparison of average MSE for Football.

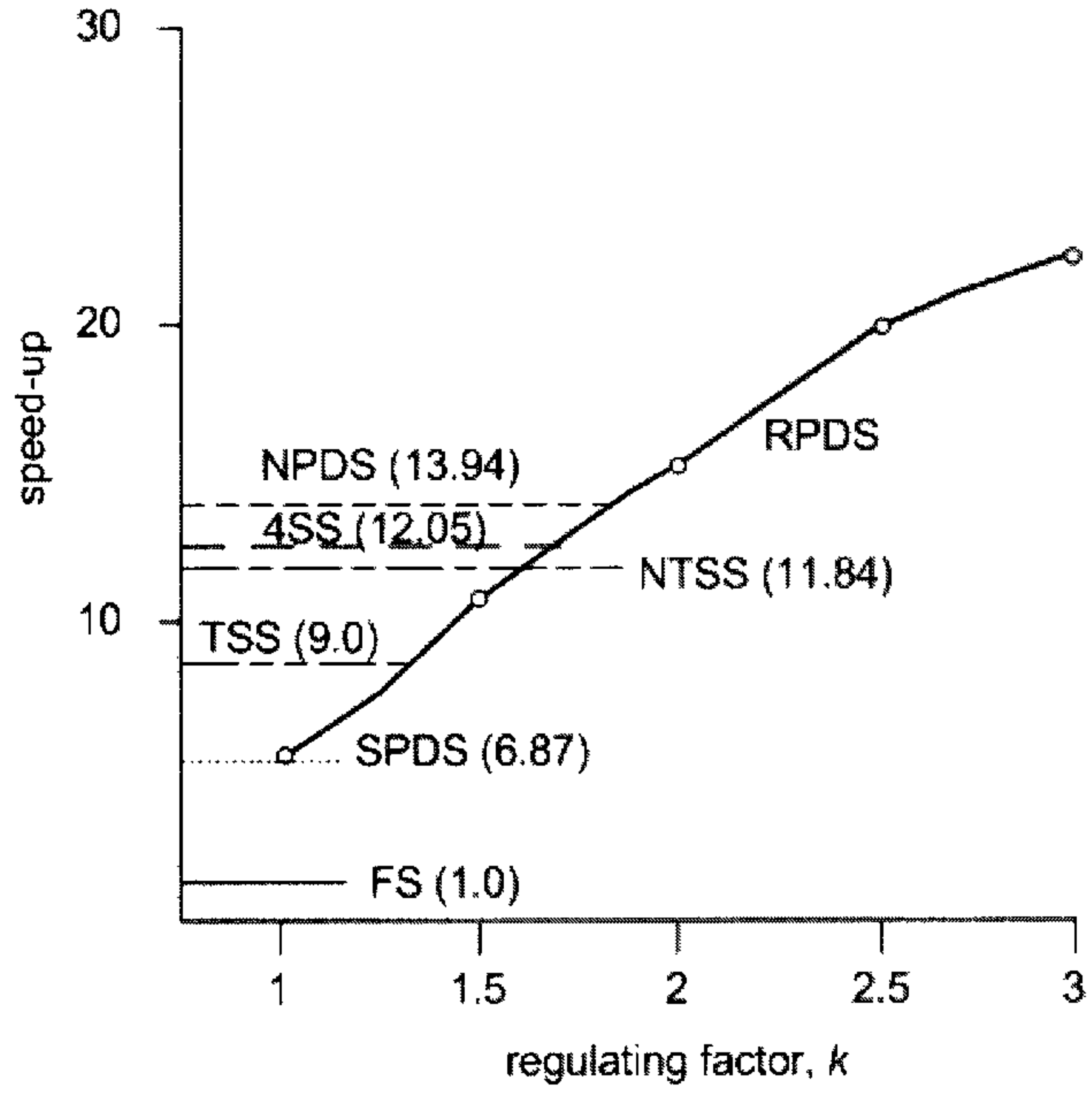


그림 3. Football 영상에 대한 평균 속도 개선 비교

Fig. 3. Comparison of average speed-up for Football.

terms of average mean square error (MSE) between the original frame and the estimated frame. It shows that RPDS provides almost the same results as the FS and SPDS when $k$ is adjusted from 1 to 1.5. In addition, the comparison of the computational complexity in terms of average total operations (addition, subtraction and absolution) and speed-up per motion vector estimation is presented. It indicates that the proposed algorithm shows superior performance than other fast algorithms, and achieves about 6 to 28 times computation reduction with a slight loss in the prediction accuracy compared with the FS.

The overall comparisons of average MSE and speed-up from $k$=1 to 3 for Football sequence are shown in Fig. 2 and 3. They demonstrate that the performance of RPDS for both visual quality and the computational complexity is better than that of other fast algorithms when $k$ is placed between about 2 and 2.5.

## V. Conclusion

In this paper, a fast block motion-estimation algorithm using regulated partial block distortions was proposed. Experimental results indicated that the proposed method yields very close MSE performance to FS, and about 6 to 28 times computation reduction compared with the FS.

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