2019 MMILAB.DIP Seminar
Week5(2/6~2/16)

Seong Su Kim

Contents

- Motion estimation and Motion vector

- Various search algorithm

  -Exhaustive search, Three step search, Logarithmic search, New three step search, Simple and efficient search, Diamond search

Motion estimation

Motion estimation

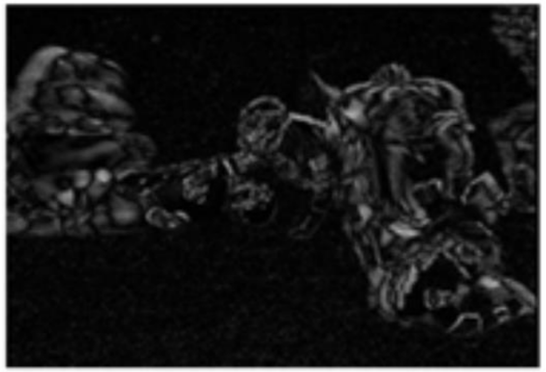
1. The process of determining motion vectors that describe the transformation from one 2D image to another

2. Helps in saving bits by sending encoded difference images which have inherently less entropy as opposed to sending a fully coded frame

Frame 9

Frame 10

Simple difference image



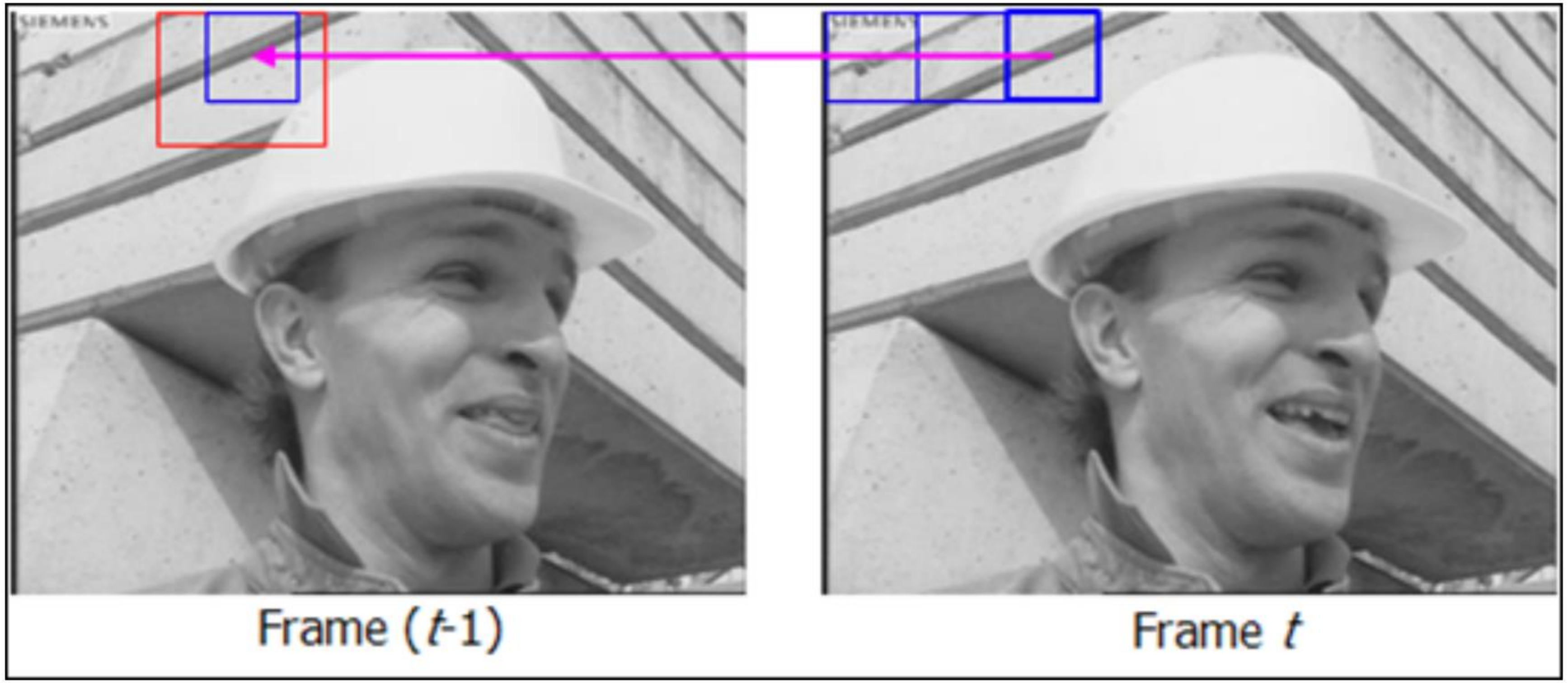
Motion estimation

Motion estimation → The most computationally expensive operation in the entire compression process

↓

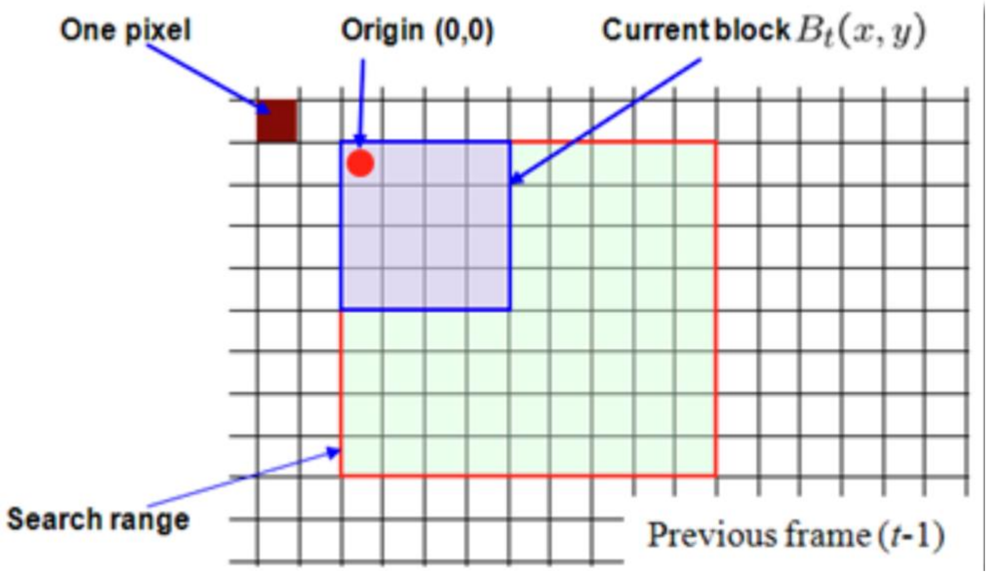
fast and computationally inexpensive algorithms needed

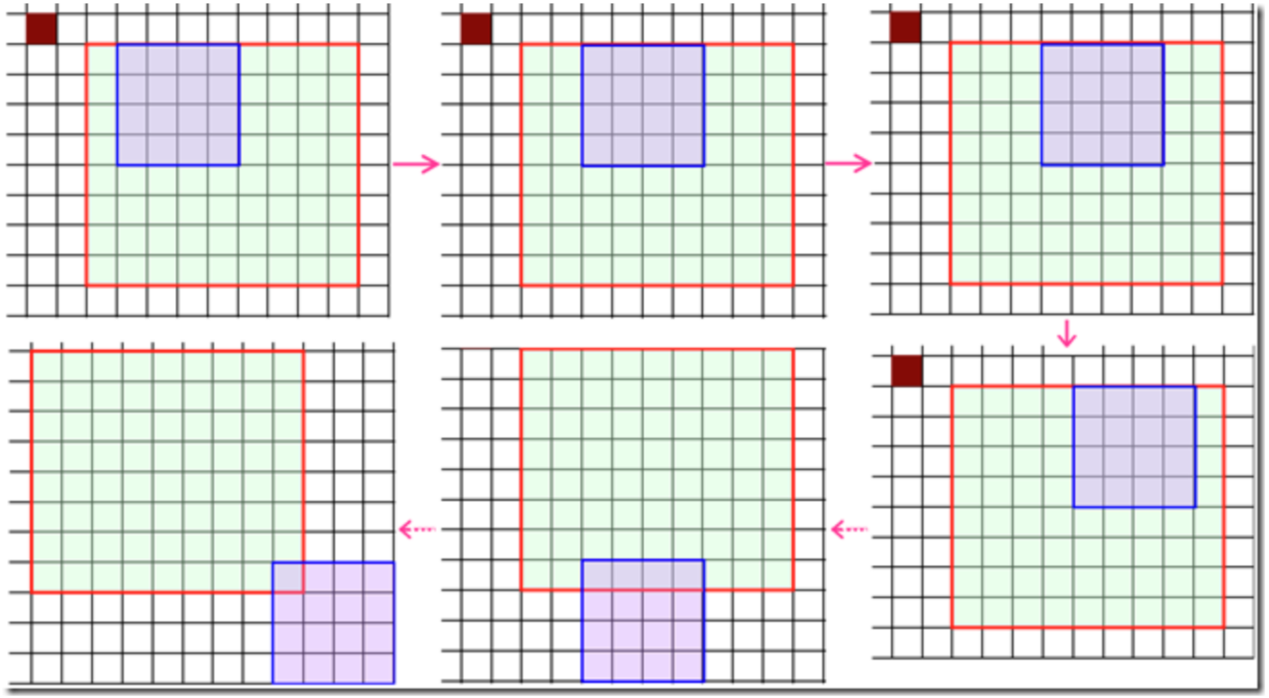
Block matching



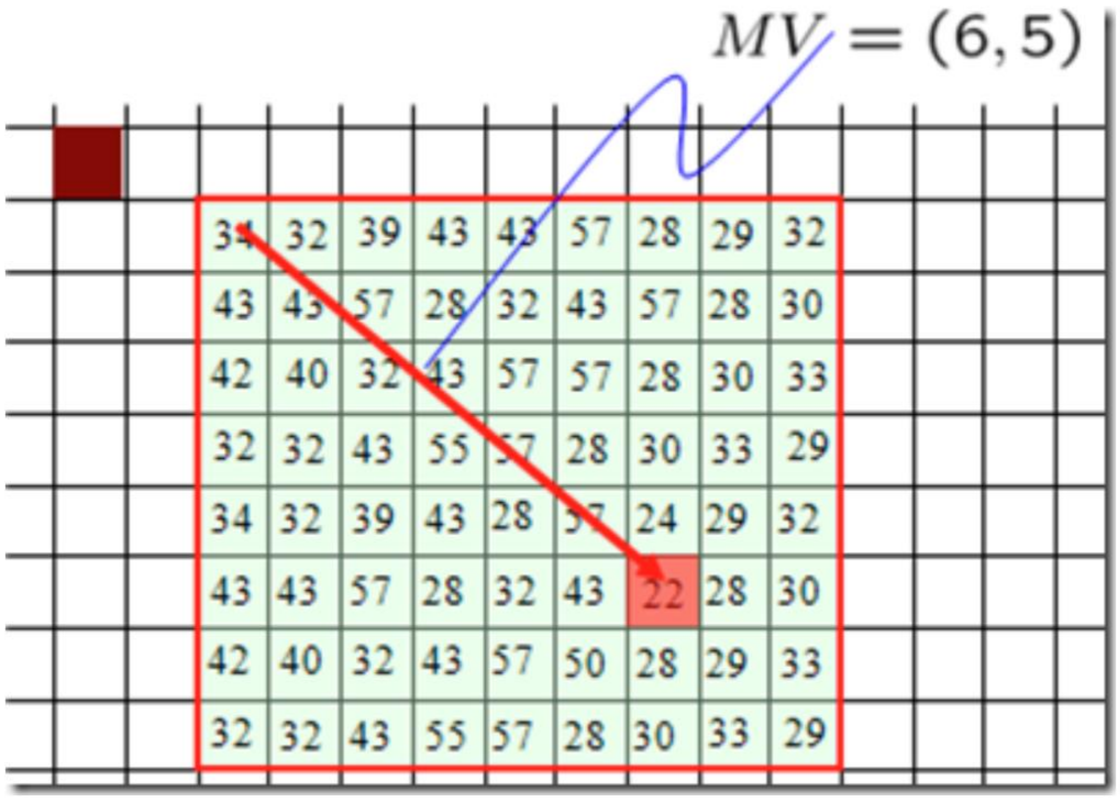
Mean Absolute Difference(MAD) = $$\frac{1}{N^2}\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}|C_{ij}-R_{ij}|$$

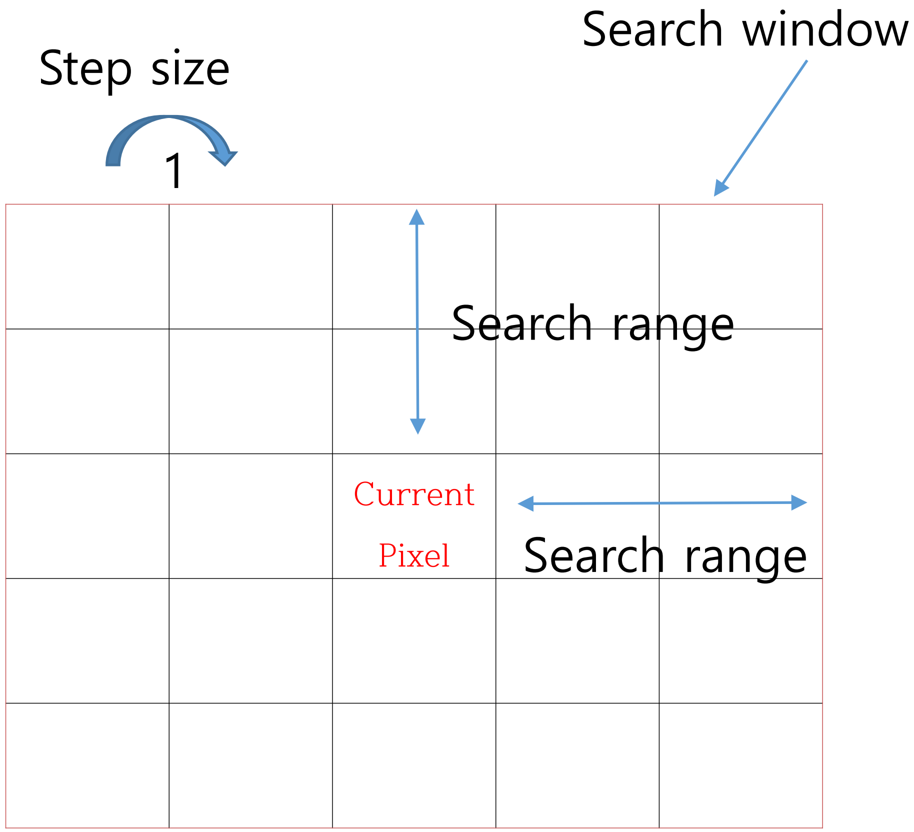
Block matching





Motion vector

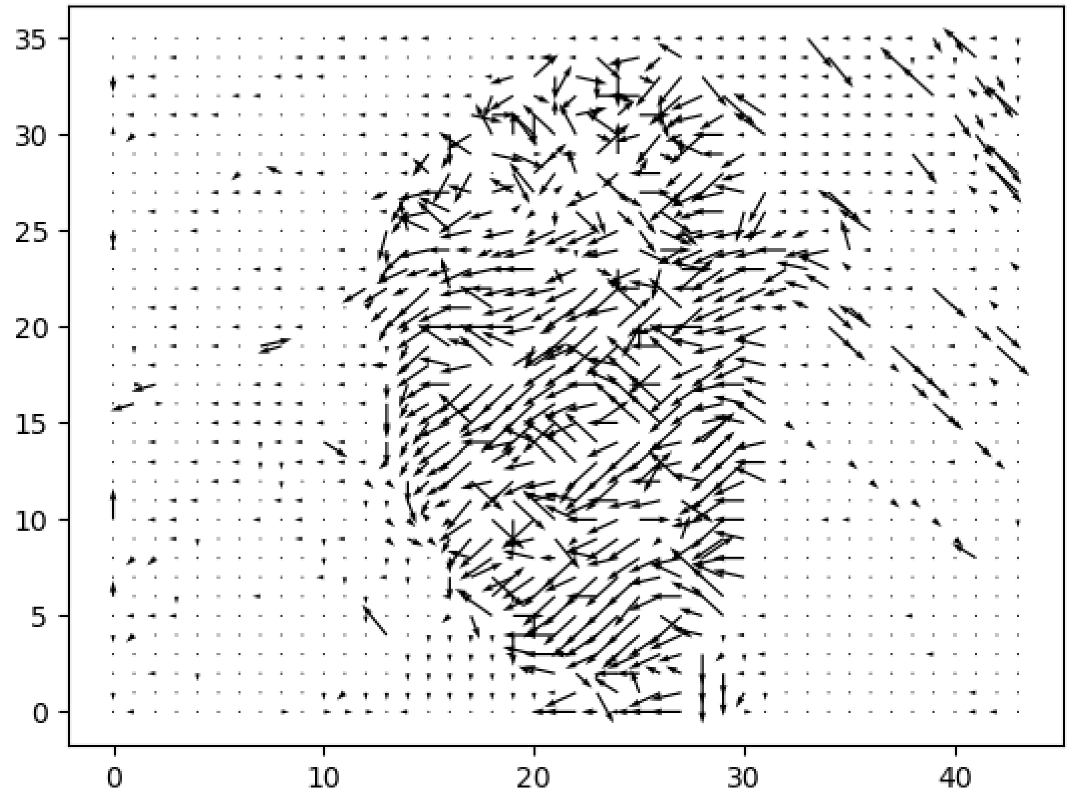




Motion vector

Frame t-1

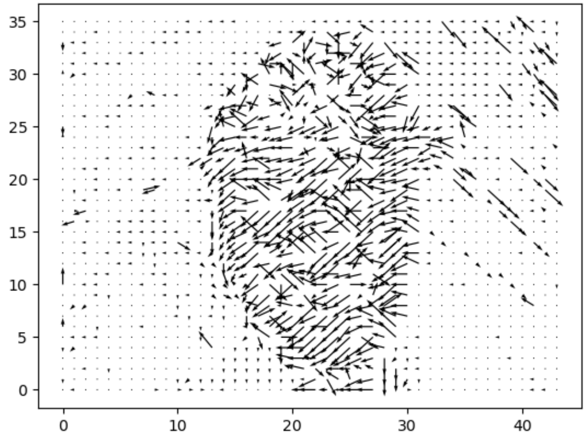
Frame t



Block_size = 8, Search range = 4 , Step_size =1

Motion vector - Reconstruction

Frame t-1



Motion vector

Frame t

Estimate Frame t

Evaluation Metrics

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

Lower, better reconstruction

$$\mathrm{PSNR} = 10\log_{10}\frac{(\text{peak to peak value of original data})^2}{\mathrm{MSE}}$$

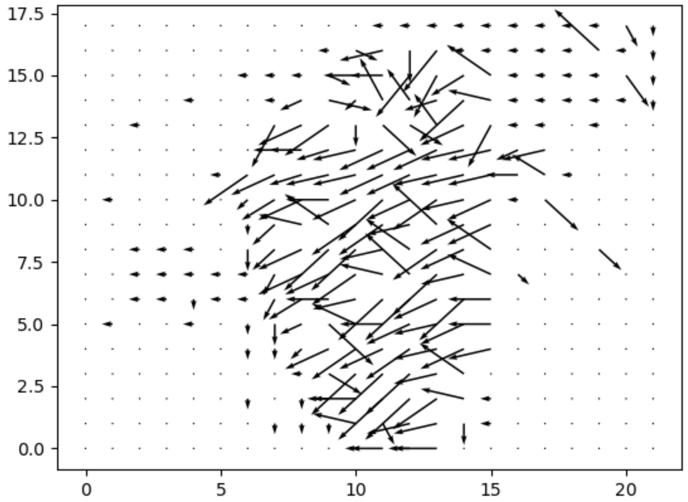
Higher, better reconstruction

Motion vector(Block size)

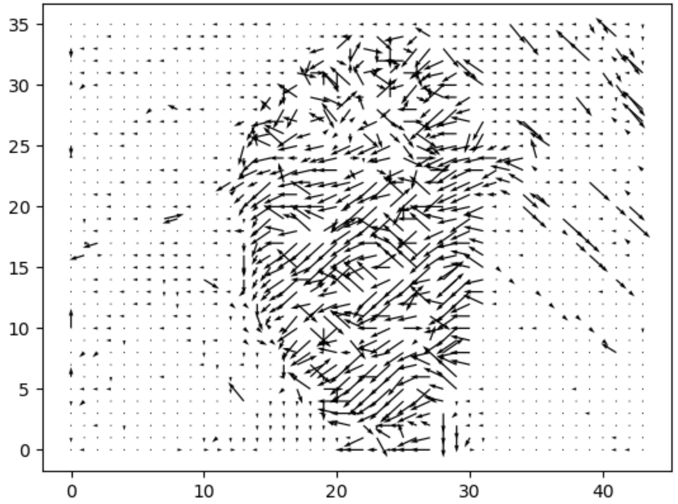
Frame t-1

Frame t

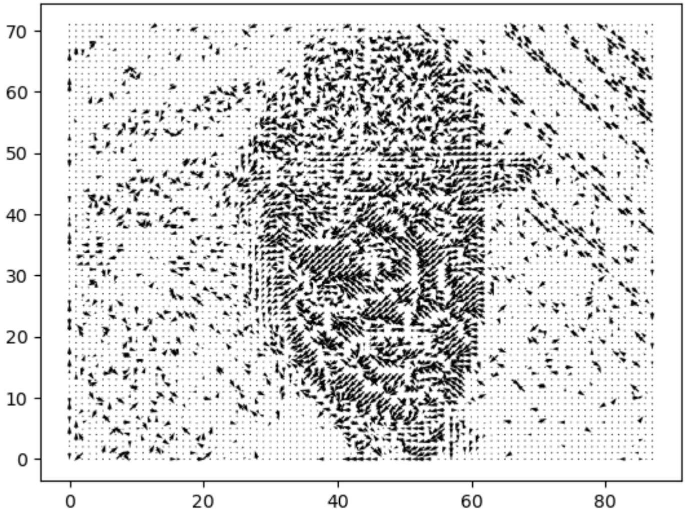
Search range = 4, Step size =1



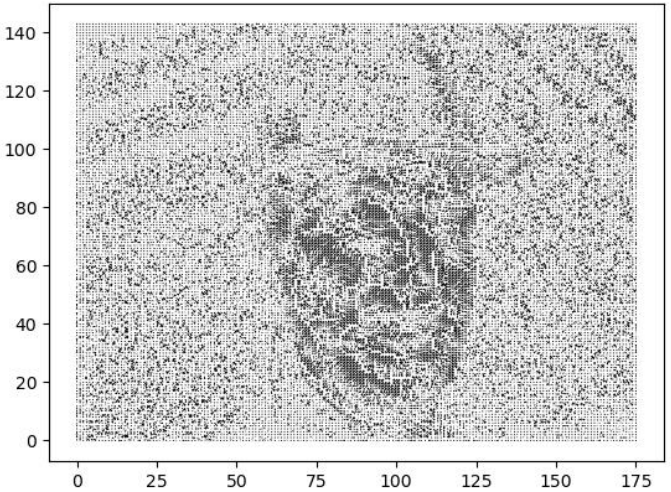
Block size :16



Block size :8



Block size :4



Block size :2

Reconstruction(Block size)

Frame t-1

Block size :16

Block size :8

Frame t

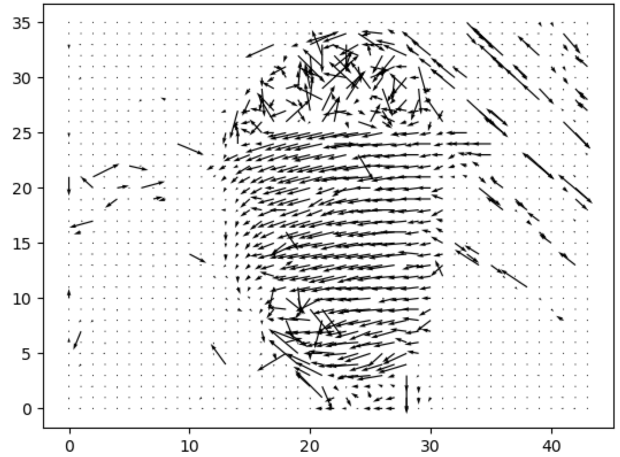
Block size :4

Block size :2

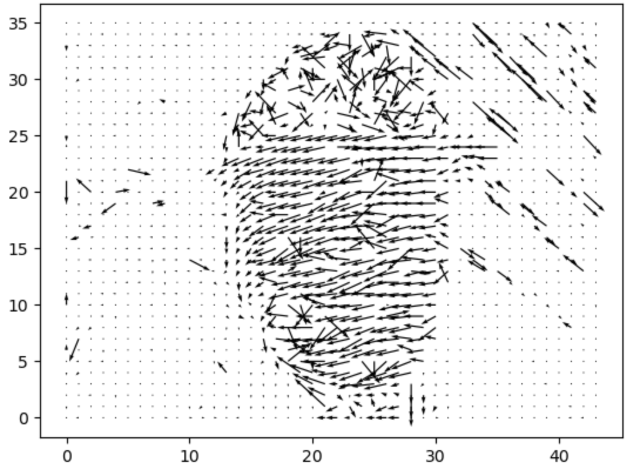
Motion vector(Search range)

Block size= 8, Step size =1

Frame t-1

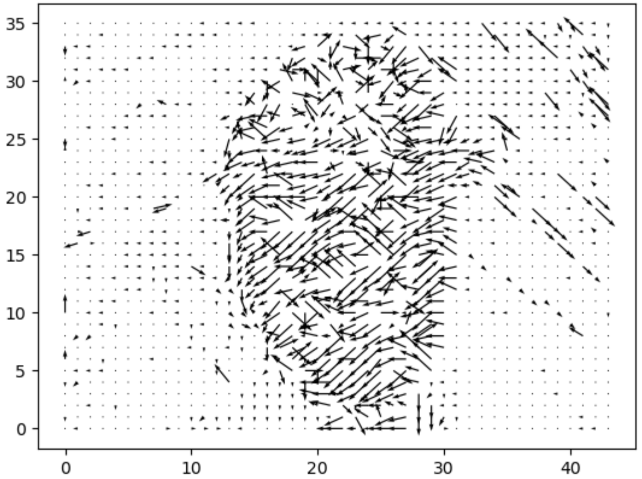


Search range :12

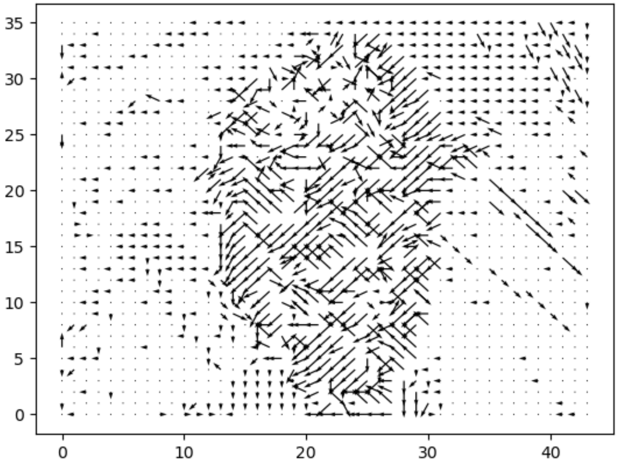


Search range :8

Frame t



Search range :4



Search range :2

Reconstruction(Search range)

Frame t

Search range :12

Search range :8

Search range :4

Search range :2

MSE and PSNR

Block size	Operations(MAD)	MSE	PSNR
16	29260	41.143	31.953
8	122608	30.163	33.302
4	501760	19.874	35.114
2	2024164	12.279	37.205

Search range :4

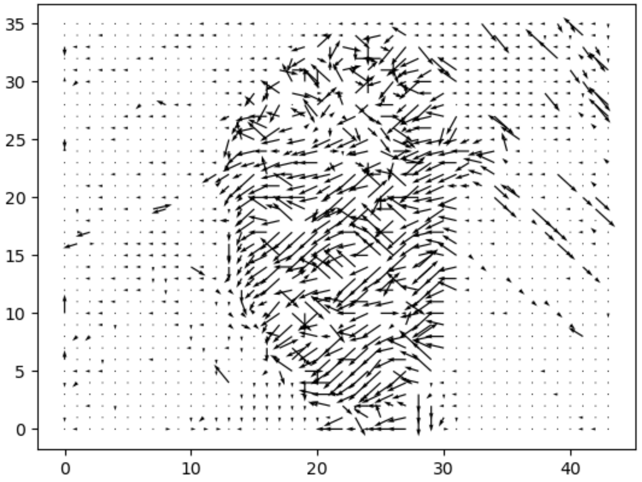
Search range	Operations(MAD)	MSE	PSNR
12	934784	16.894	35.819
8	436272	19.356	35.228
4	122608	30.163	33.302
2	38016	50.108	31.097

Block size:4

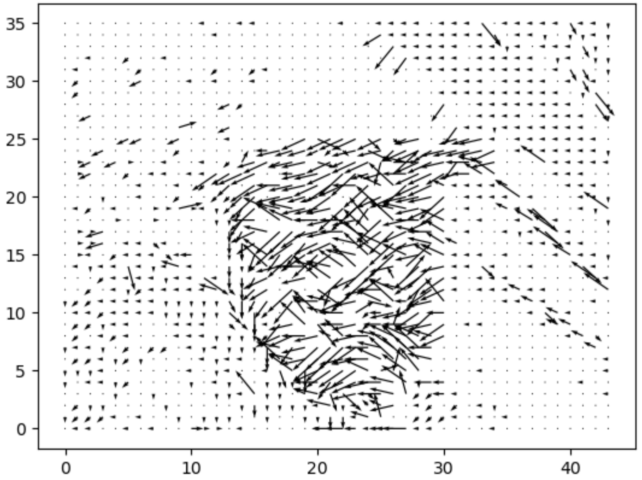
Effect of Thresholding

Block size= 8, Search range =4 ,Step size =1

Frame t-1



No Thresholding



MAD Threshold =100

Frame t

MSE : 30.163 PSNR : 33.302

MSE : 27.520 PSNR : 33.700

Various search algorithm- Basic concept

The fast motion estimation techniques based on UESA mainly constrain the number of checking points.

UESA = Unimodal Error Surface Assumption

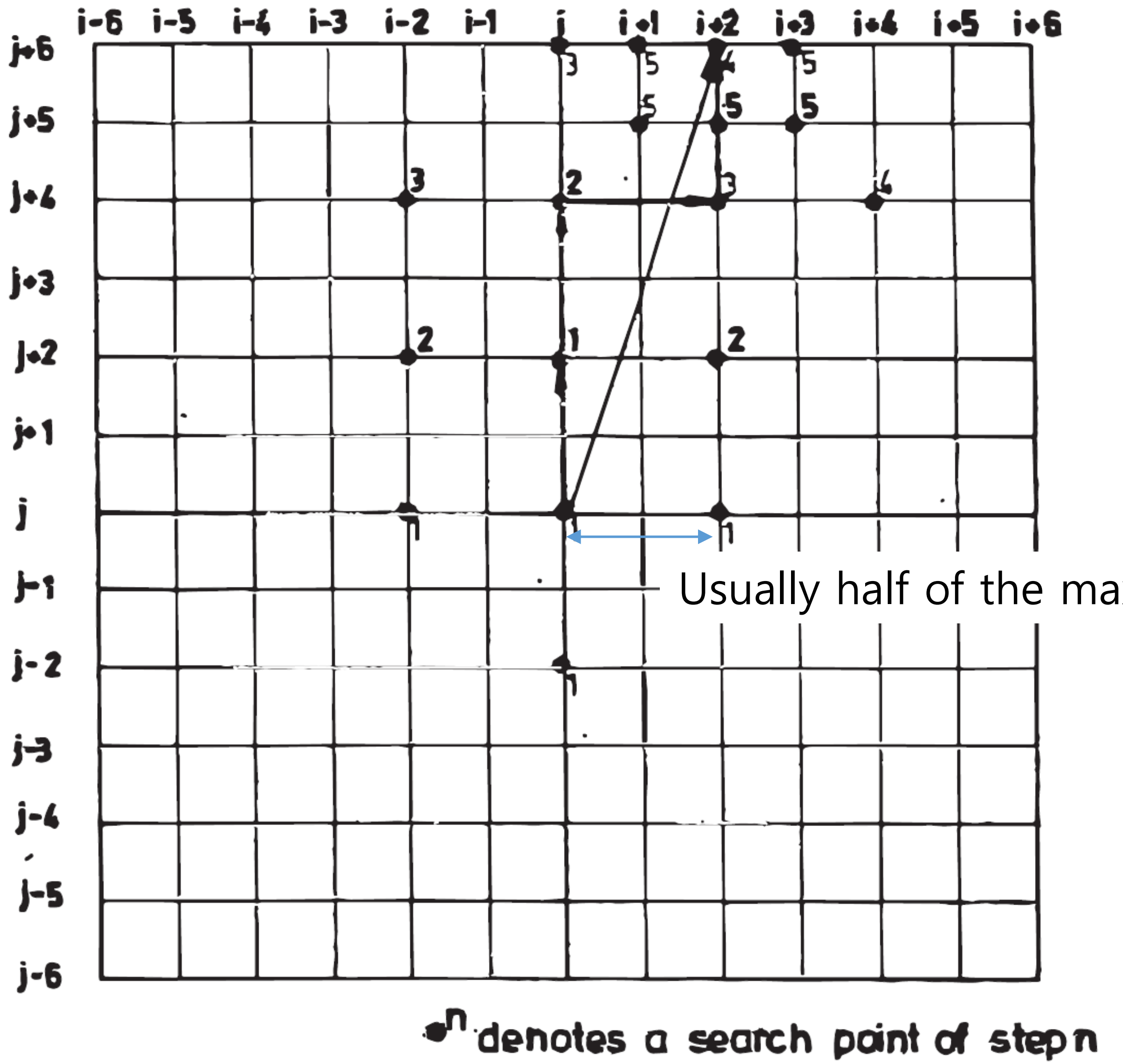
Meaning?
-Residual error of the block matching increases monotonically when the checking point moves away from the location of the global minimum error

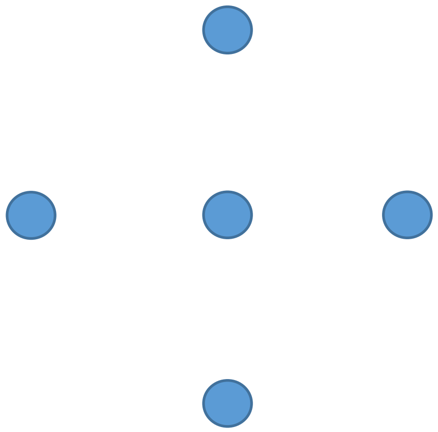
Fault?
- Search could fall into a local minimum, which is not the optimal motion vector

And some other assumptions…

1. No change in the ambient lighting.
2. Objects are rigid
3. No objects appeared or left the scene

Various search algorithm- Logarithmic search

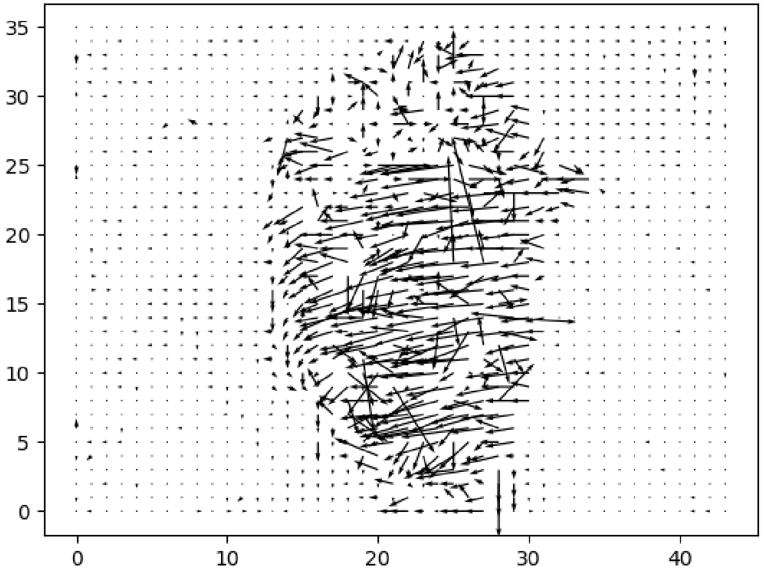




Various search algorithm- Logarithmic search

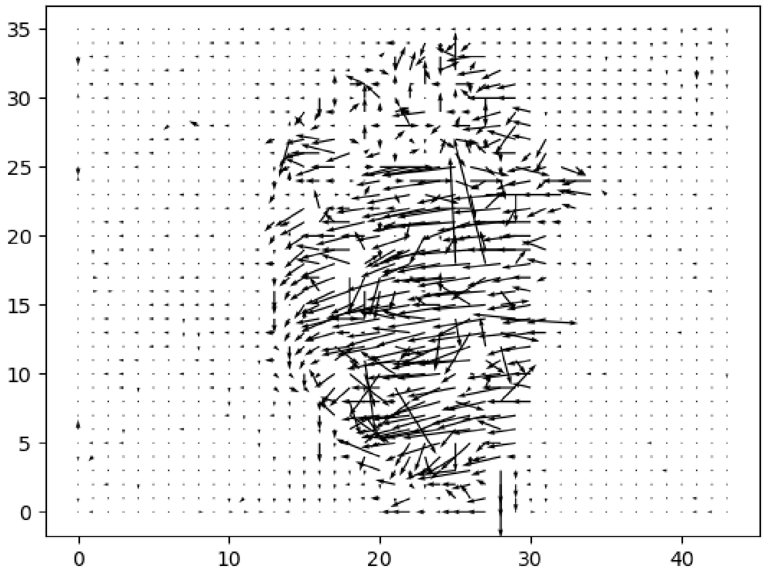
Frame t-1

Frame t

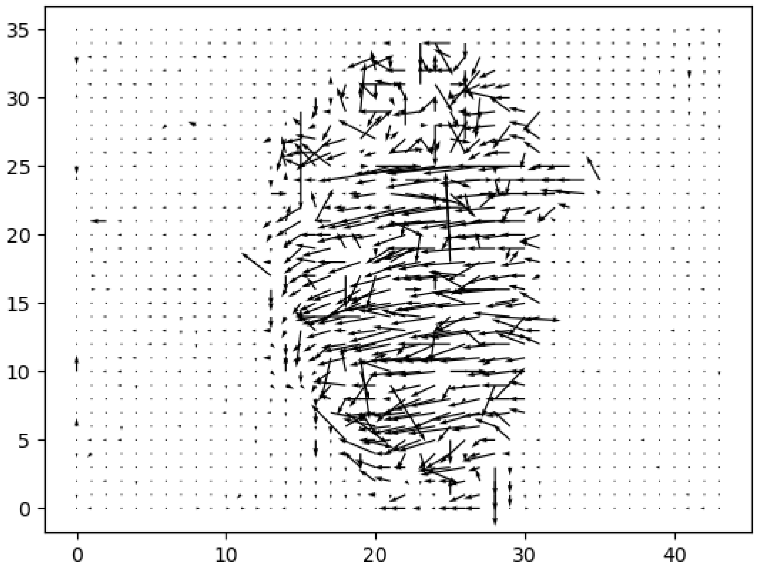


Block size : 8 , Search range :4

Various search algorithm- Logarithmic search

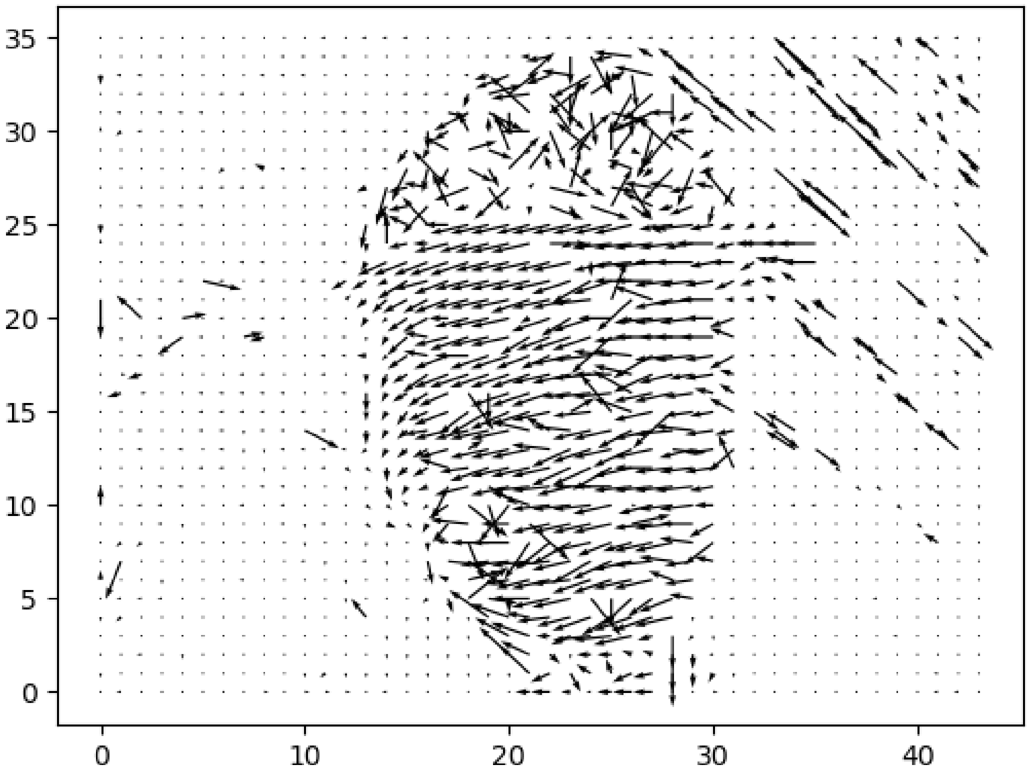


Block size : 8
Search range :4
Operations(MAD): 28355
MSE : 24.421
PSNR : 34.220

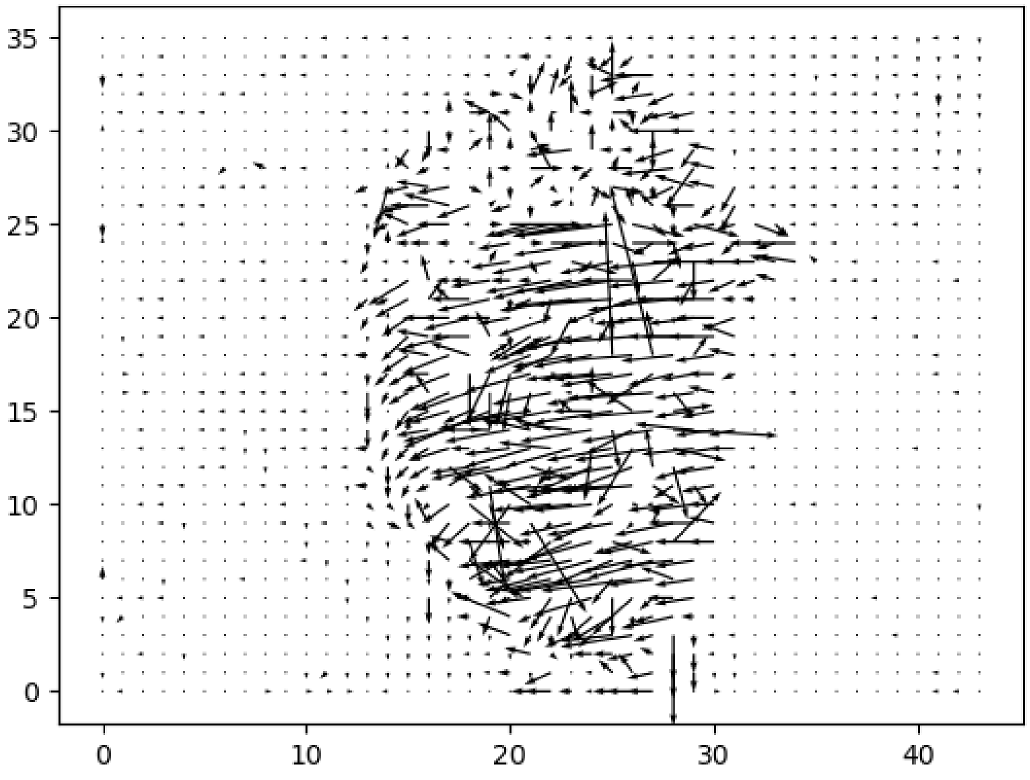


Block size : 8
Search range :8
Operations(MAD): 35167
MSE : 24.372
PSNR : 34.228

Various search algorithm- Logarithmic search

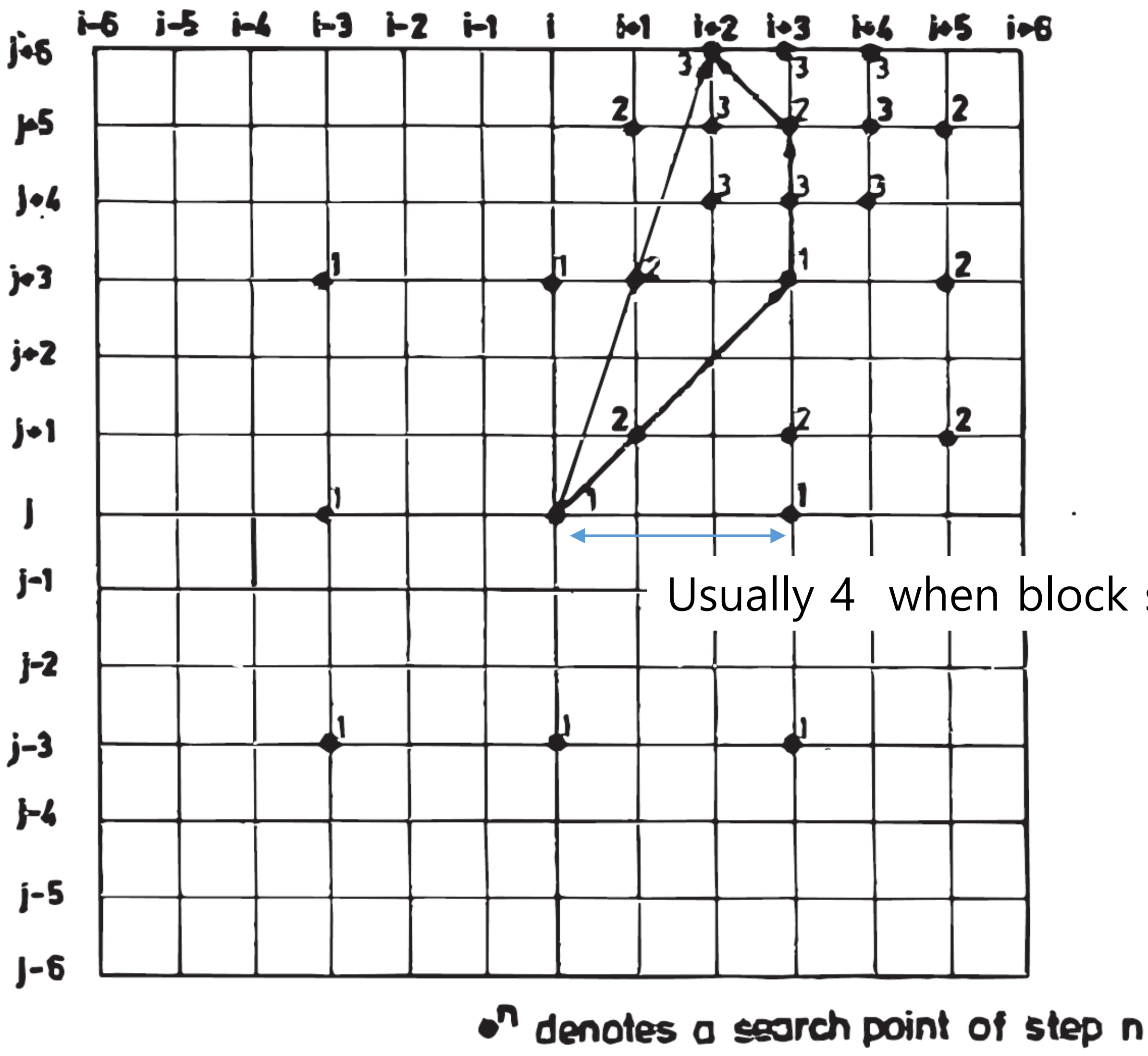


EBMA

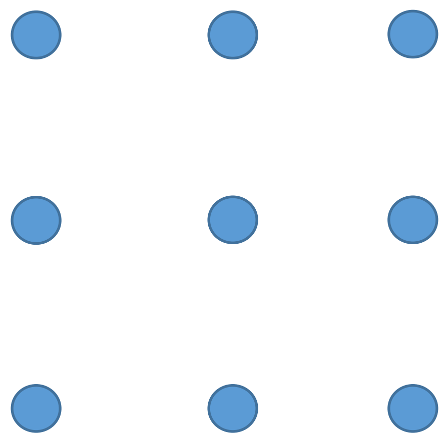


Log search

Various search algorithm- Three step search



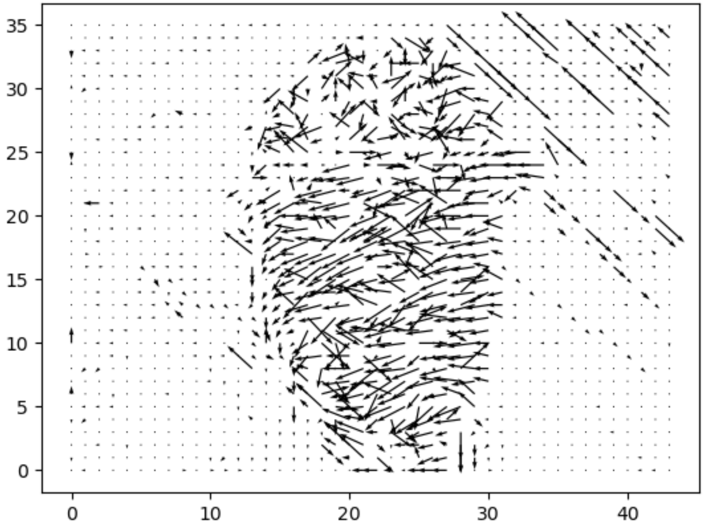
Usually 4 when block size = 8



Various search algorithm- Three step search

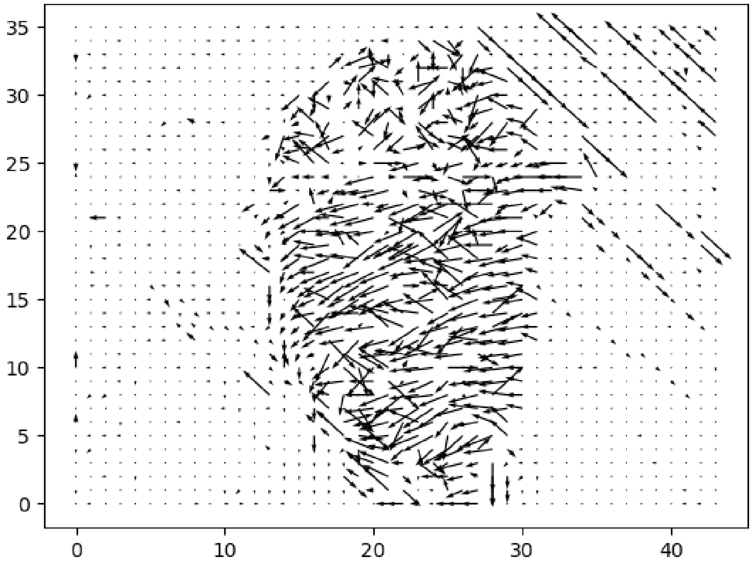
Frame t-1

Frame t

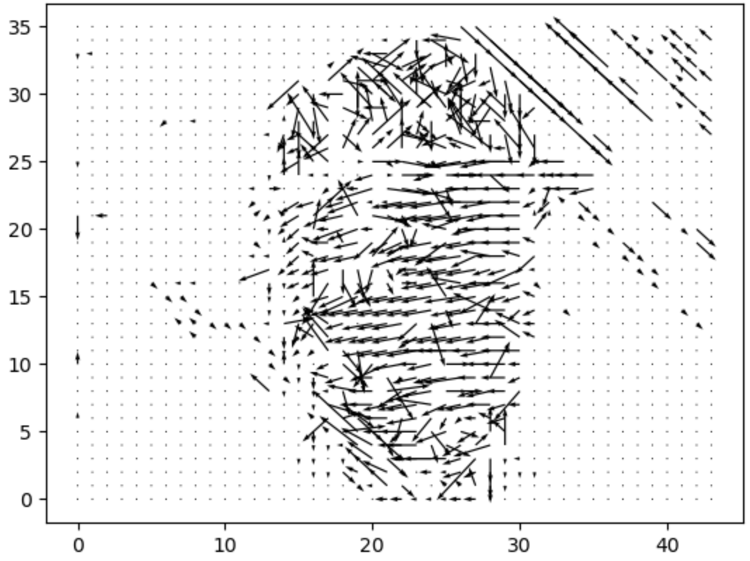


Block size : 8 , Step size : 4,2,1

Various search algorithm- Three step search



Block size : 8
Step size :4,2,1
Operations(MAD): 41370
MSE : 25.691
PSNR : 33.999



Block size : 8
Search range : 8,4,2
Operations(MAD): 41349
MSE : 28..800
PSNR : 33.503

Various search algorithm- Three step search

TSS uses a uniformly allocated search pattern in its first step, which is not very efficient to catch small motions.

↓

For optimization, we should considerate some basic charcteristics of the distribution of global minima

↓

The block motion field of a real world image sequence is usually gentle, smooth, and varies slowly

↓

Global minimum distribution is **center-biased**, instead of distributed uniformly

Various search algorithm- New three step search

A New Three-Step Search Algorithm for Block Motion Estimation
Renxiang Li, Bing Zeng, and Ming L. Liou, *Senior Member,* ***IEEE***

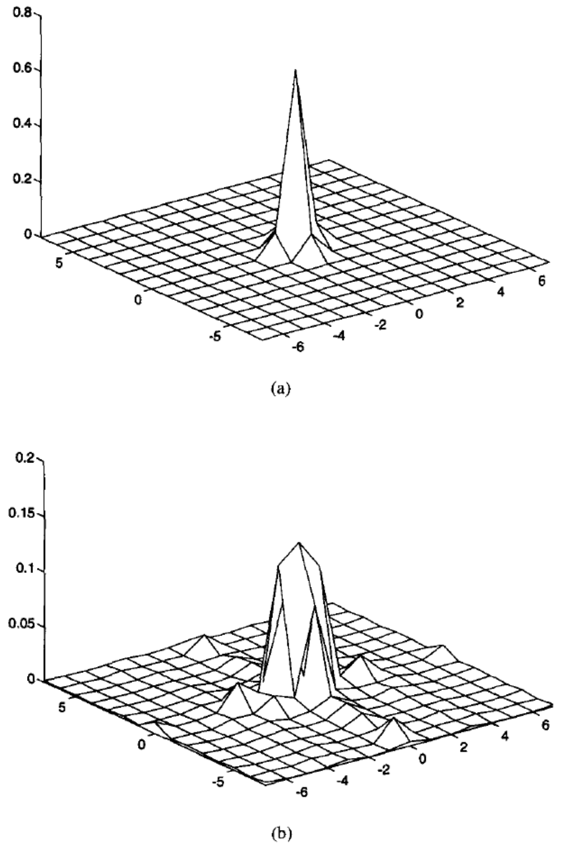
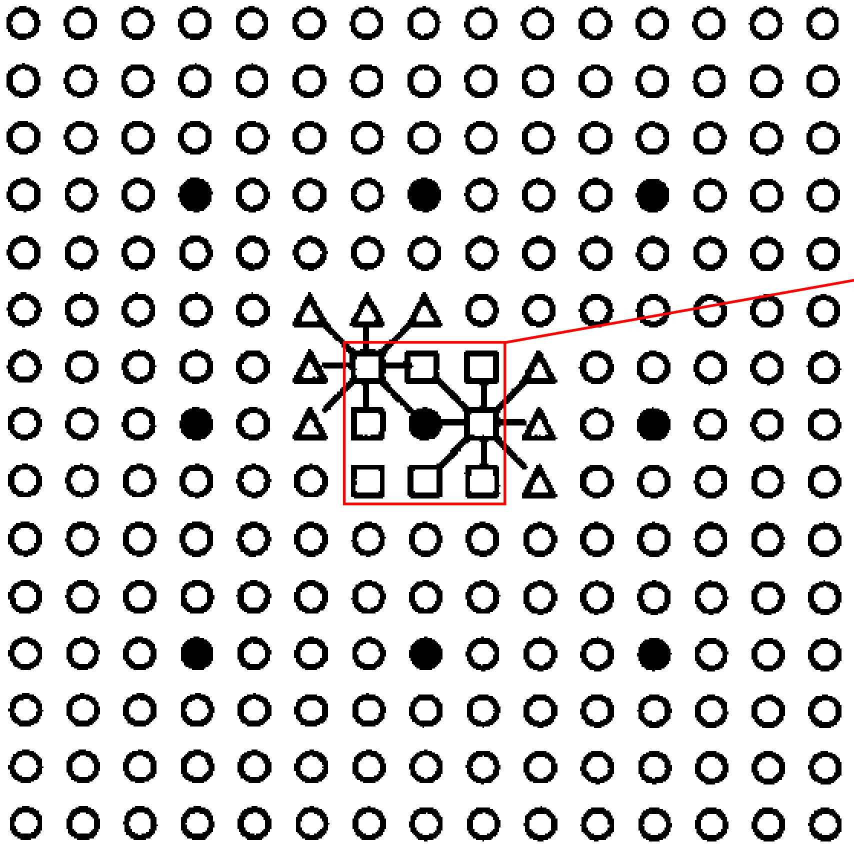


Fig. 1. The motion vector distribution derived from the full search for 100 frames of (a) Salesman sequence and (b) Miss America sequence (block size: 16 × 16).



Eight checking point added
-> 17 points in first step

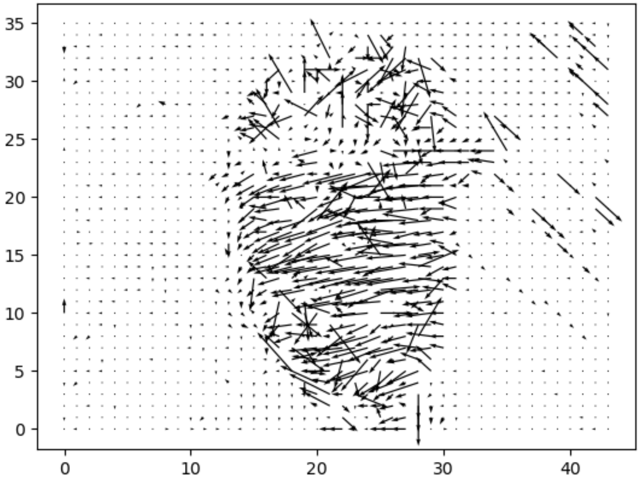
If center is global minimum
= stop searching

If among the added 8 points
= Search only 8 neighboring points of the minimum

Various search algorithm- New Three step search

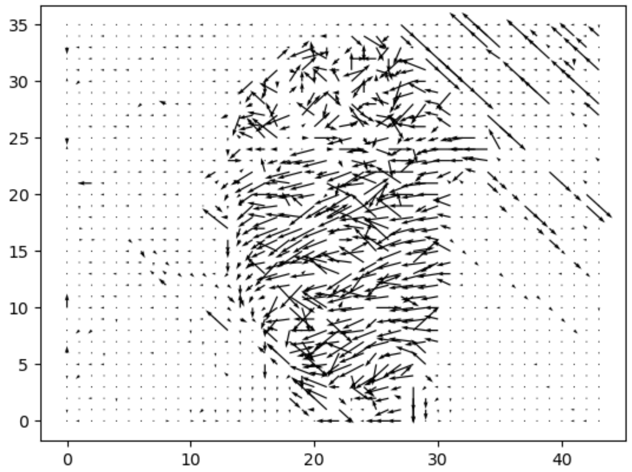
Frame t-1

Frame t



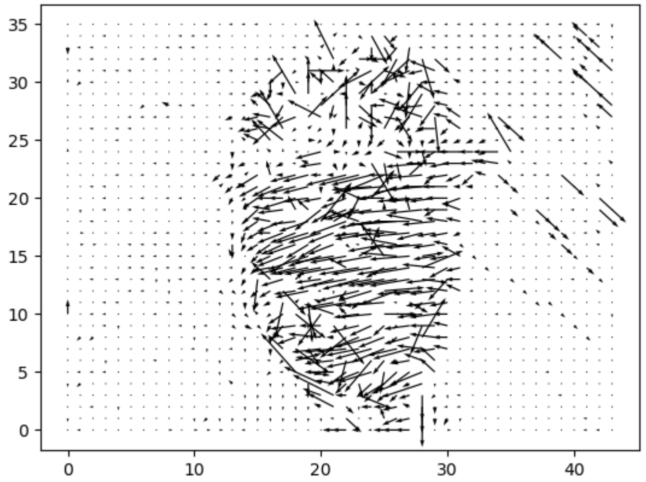
Block size : 8 , Step size : 4,2,1

Various search algorithm- New three step search



TSS

Block size : 8
Step size :4,2,1
Operations(MAD): 41370
MSE : 25.691
PSNR : 33.999



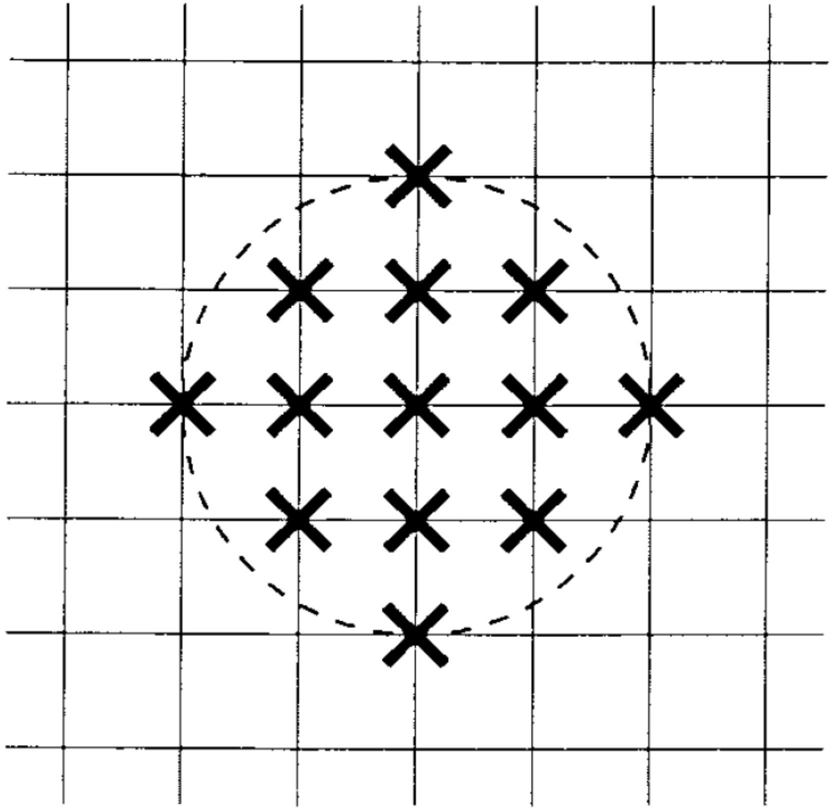
NTSS

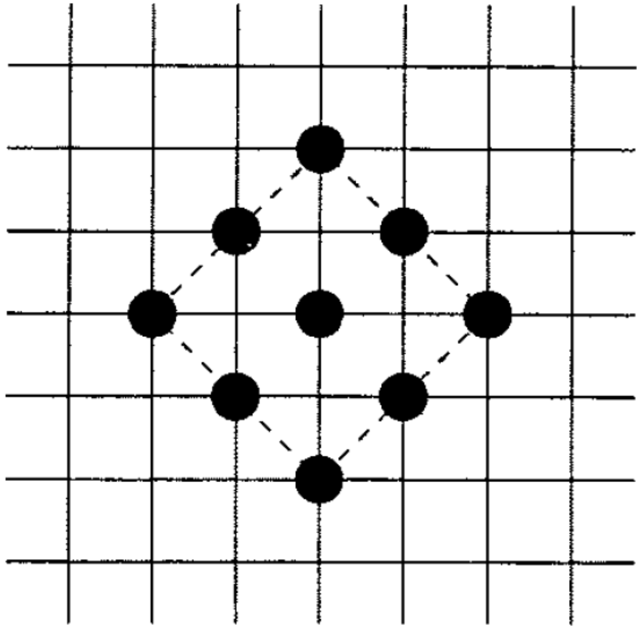
Block size : 8
Step size :4,2,1
Operations(MAD): 41549
MSE : 25.338
PSNR : 34.408

Various search algorithm- Diamond search

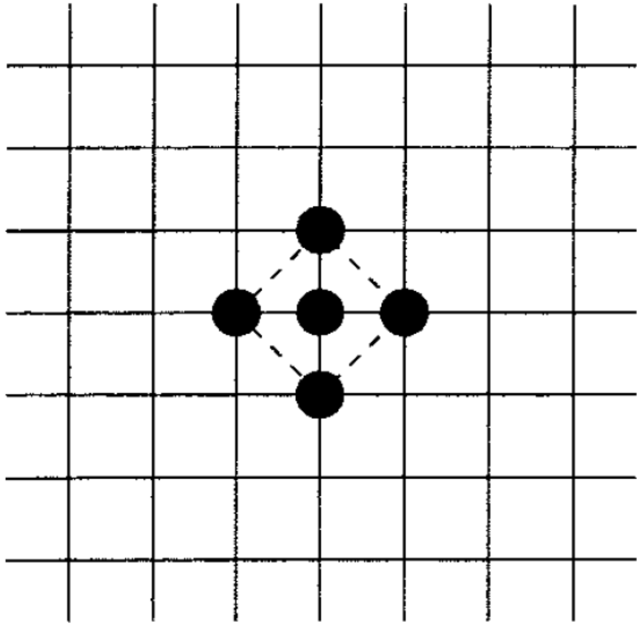
A New Diamond Search Algorithm for Fast Block-Matching Motion Estimation

Shan Zhu and Kai-Kuang Ma





(a) Large diamond search pattern (LDSP)

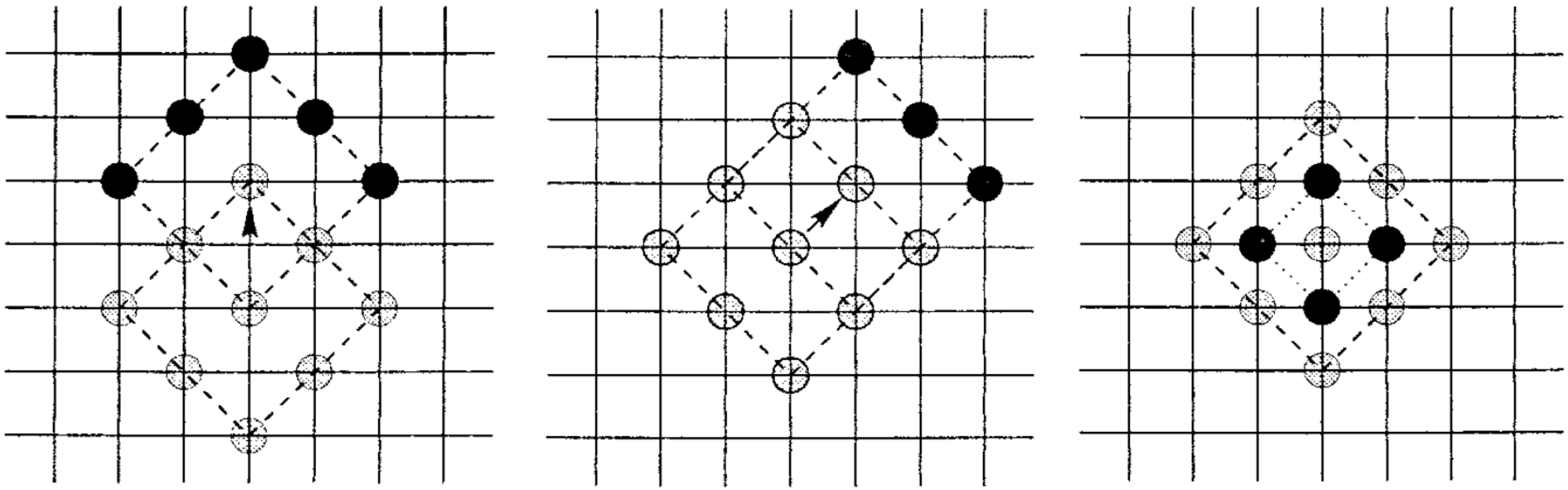


(b) Small diamond search pattern (SDSP)

Various search algorithm- Diamond search

A New Diamond Search Algorithm for Fast Block-Matching Motion Estimation

Shan Zhu and Kai-Kuang Ma



(a) Case 1: the corner point. LDSP → LDSP

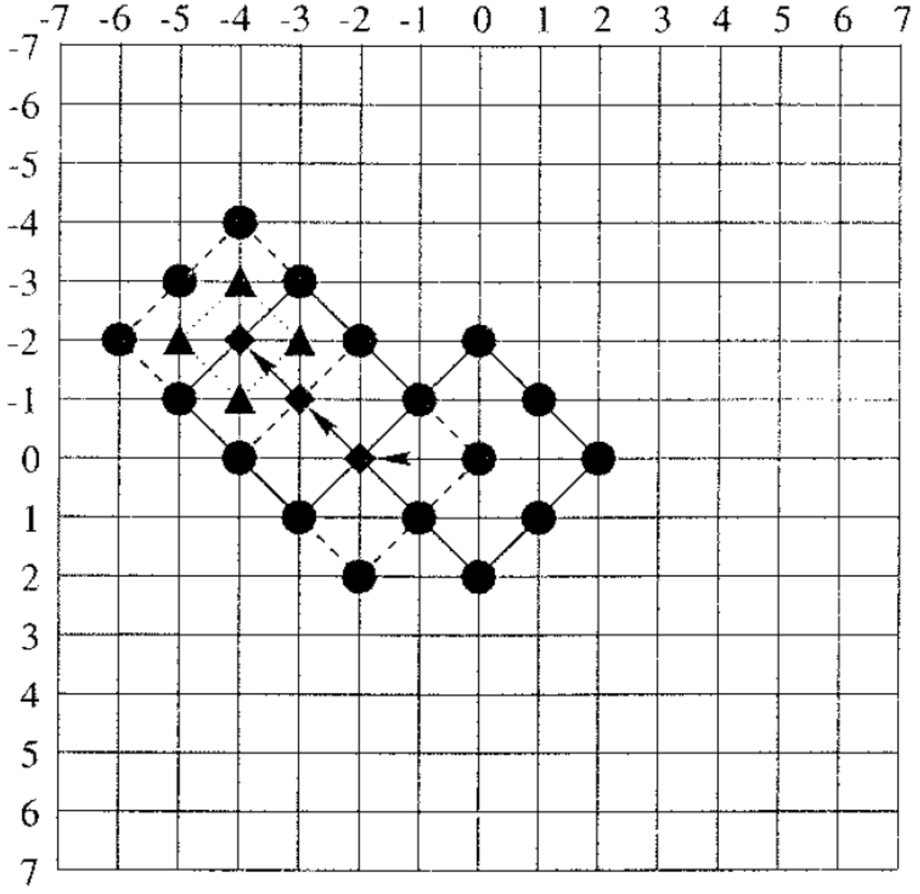
(b) Case 2: the edge point. LDSP → LDSP

(c) Case 3: the center point. LDSP → SDSP

Various search algorithm- Diamond search

A New Diamond Search Algorithm for Fast Block-Matching Motion Estimation

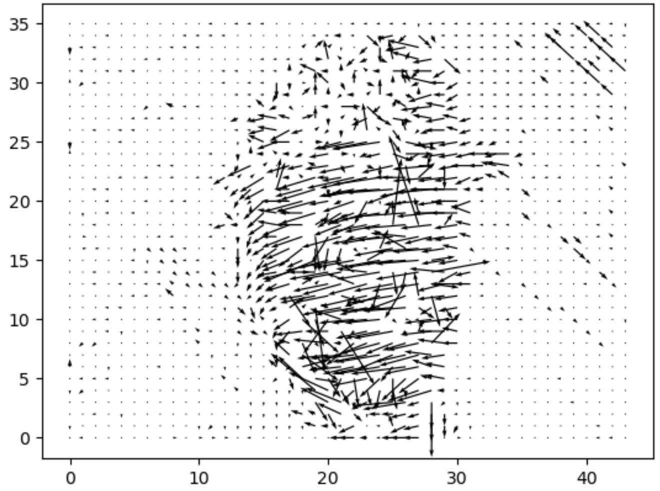
Shan Zhu and Kai-Kuang Ma



Various search algorithm- Diamond Search

Frame t-1

Frame t

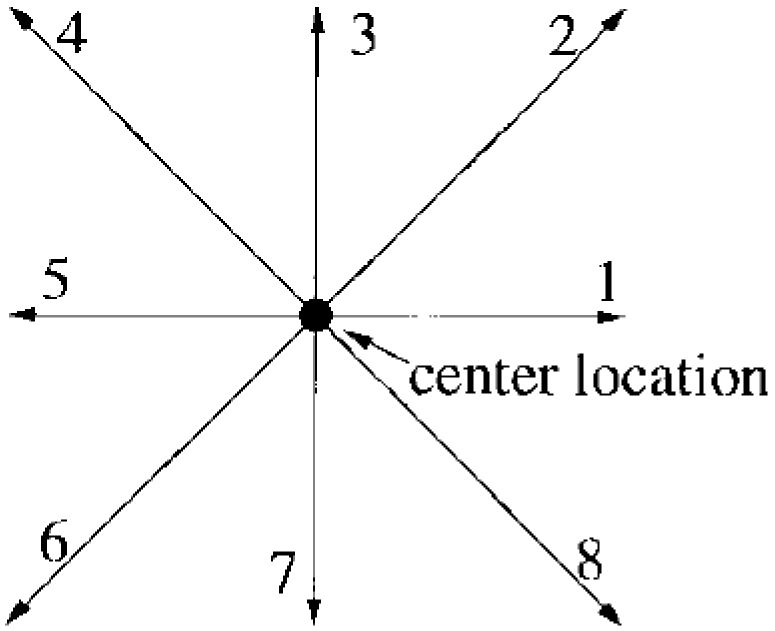


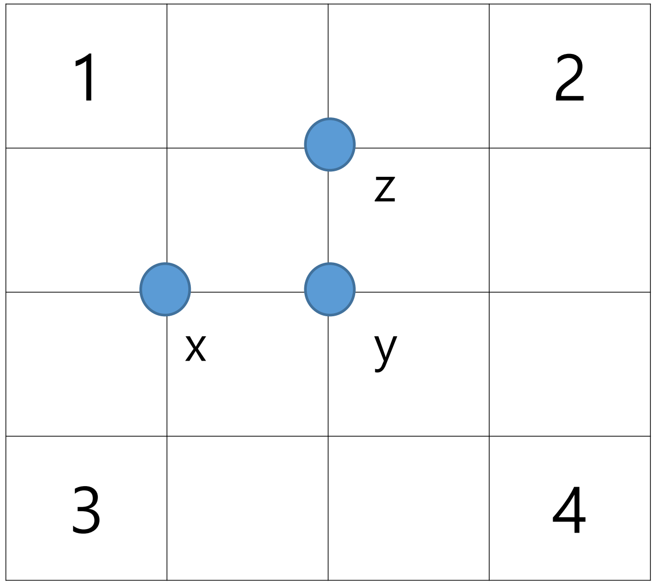
Block size : 8 ,
Operations: 35439 (39831, 11% decreased)
MSE = 23.337
PSNR = 34.408

Various search algorithm- Simple and efficient search

A Simple and Efficient Search Algorithm for Block-Matching Motion Estimation
Jianhua Lu and Ming L. Liou

UESA = Unimodal Error Surface Assumption

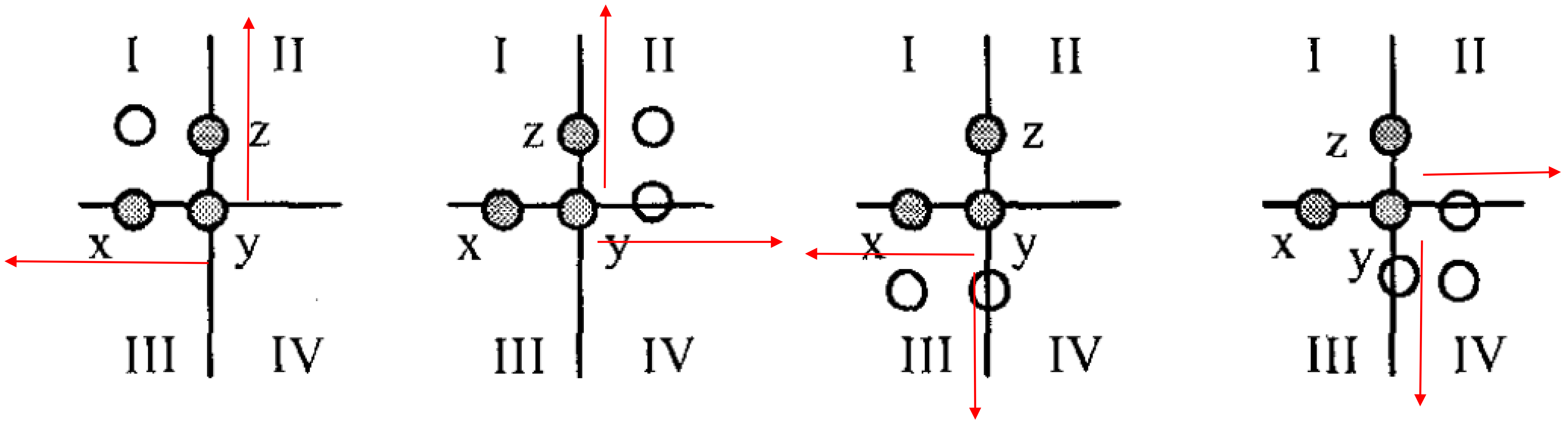




Various search algorithm- Simple and efficient search

A Simple and Efficient Search Algorithm for Block-Matching Motion Estimation

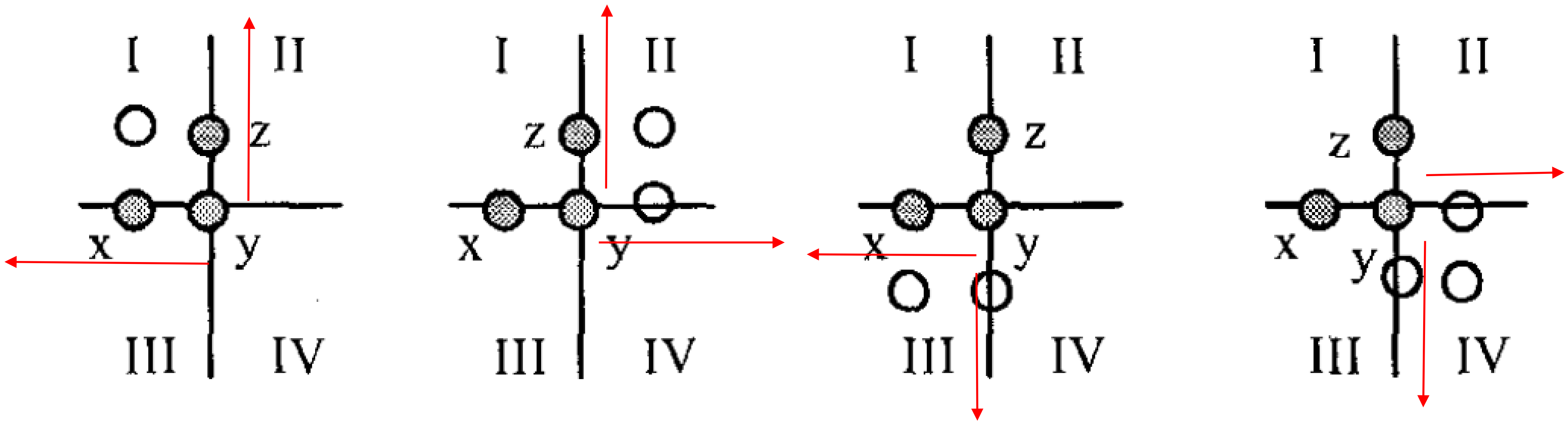
Jianhua Lu and Ming L. Liou



a) $x<y, z<y$ b) $z<y<x$ c) $x<y<z$ d) $y<x, y<z$

Various search algorithm- Simple and efficient search

A Simple and Efficient Search Algorithm for Block-Matching Motion Estimation
Jianhua Lu and Ming L. Liou



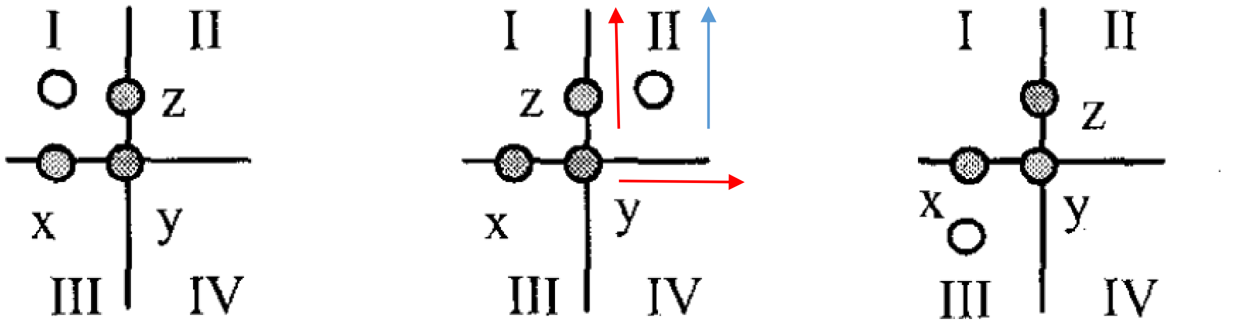
a) x<y, z<y b) z<y<x c) x<y<z d) y<x, y<z

Various search algorithm- Simple and efficient search

A fast three-step search algorithm with minimum checking points using unimodal error surface assumption

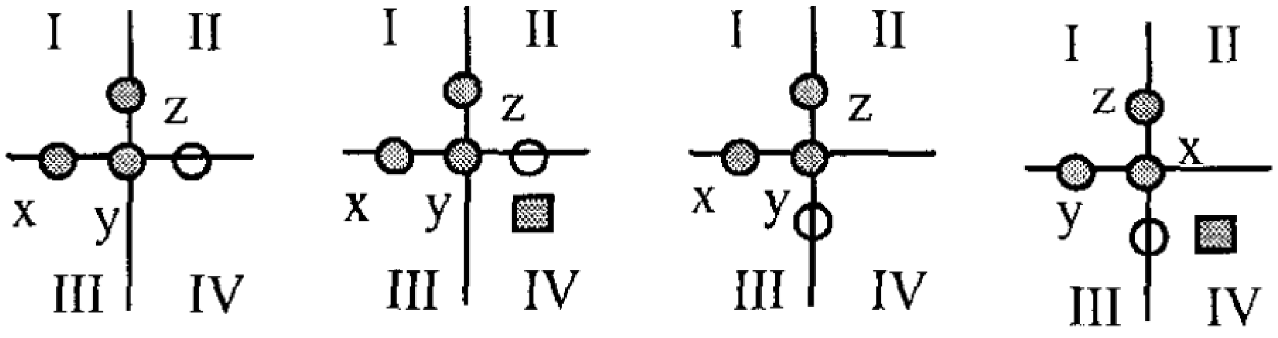
Jong-Nam Kim and Tae-Sun Choi

1or 2 additional
Checking point



a) $x<y$, $z<y$ b) $z<y<x$ c) $x<y<z$

3 additional
Checking point

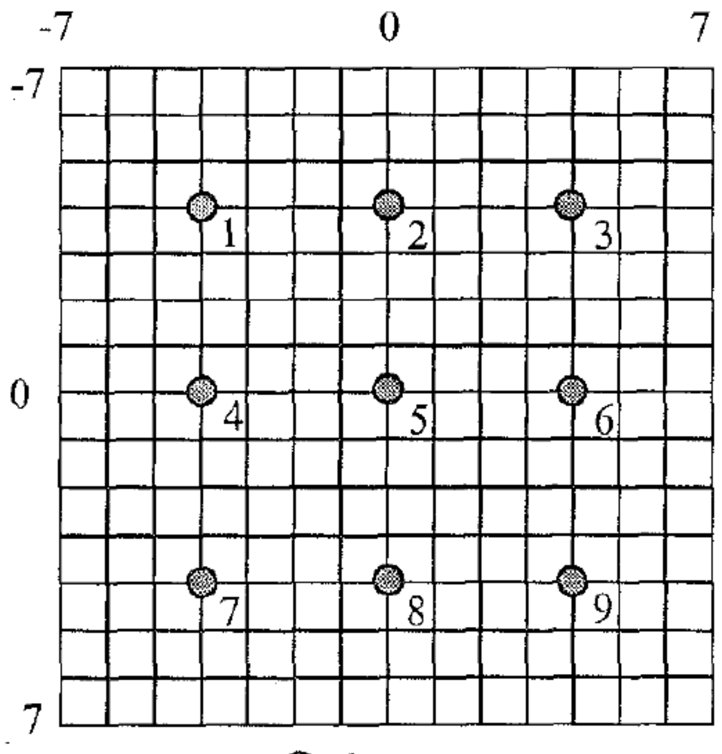


d) $y<z<x$ e) $y<z<x$ f) $y<x<z$ g) $y<x<z$

Various search algorithm- Simple and efficient search

A fast three-step search algorithm with minimum checking points using unimodal error surface assumption

Jong-Nam Kim and Tae-Sun Choi



- **If MAD(6) < MAD(5) & MAD(8) < MAD(5)**
  check 9 & select min{MAD(x)} *(4 pts)*

  End
- **If MAD(6) < MAD(5) < MAD(8)**
  then check 3 & select min{MAD(x)} *(4 pts)*

  End
- **If MAD(8)< MAD(5)< MAD(6)**
  then check 7 & select min{MAD(x)} *(4 pts)*

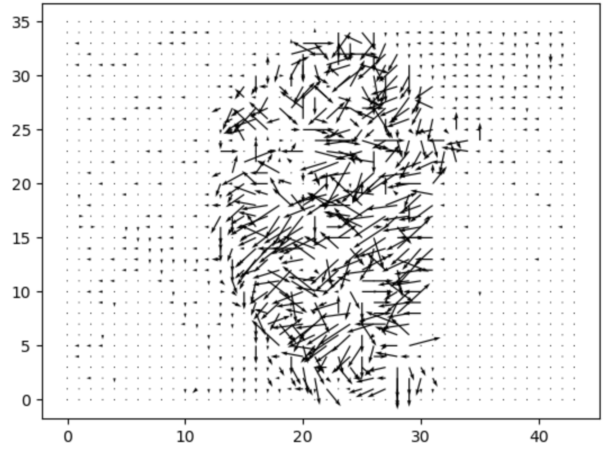
  End
- **If MAD(5) < MAD(6) & MAD(5) < MAD(8)**

```
  If MAD(5)< MAD(6)< MAD(8)
    If MAD(2)< MAD(5)
      then check 1 & select min{MAD(x)}      (5 pts)
    else   min{MAD(x)}= MAD(5)               (4 pts)
    end
  end
  If MAD(5)< MAD(8)< MAD(6)
    If MAD(4)< MAD(5)
      then check 1 & select min{MAD(x)}      (5 pts)
    else   min{MAD(x)}= MAD(5)               (4 pts)
    end
  end
```

Various search algorithm- Simple and efficient search

Frame t-1

Frame t



Block size : 8
Operations: 5480
MSE = 32.511
PSNR = 32.593

Various search algorithm- Consequence

Frame t

Exhaustive Search

Log Search

New Three step Search

Diamond Search

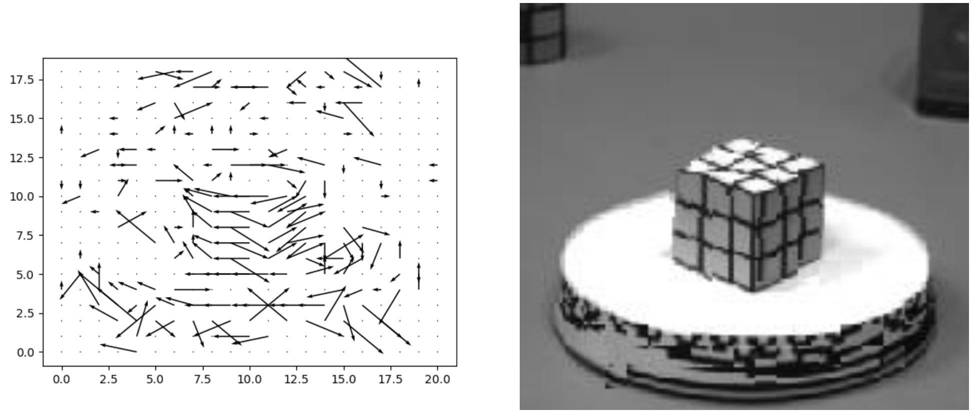
Simple and Efficient Search

Various search algorithm- Consequence

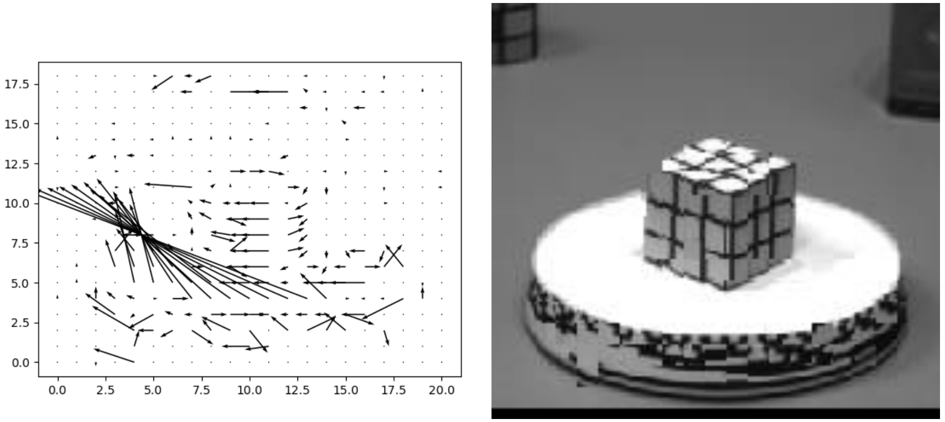
Block size = 8 Search range =4	MAD Operations	MSE	PSNR
Exhaustive search	122608	30.164	33.302
Log search	28355	24.421	34.220
Three step search	41370	25.691	33.999
New Three step search	41549	23.381	34.408
Diamond search	35439	23.337	34.408
Simple and efficient search	5480	32.511	32.593

Various search algorithm- Other image

Frame t-1

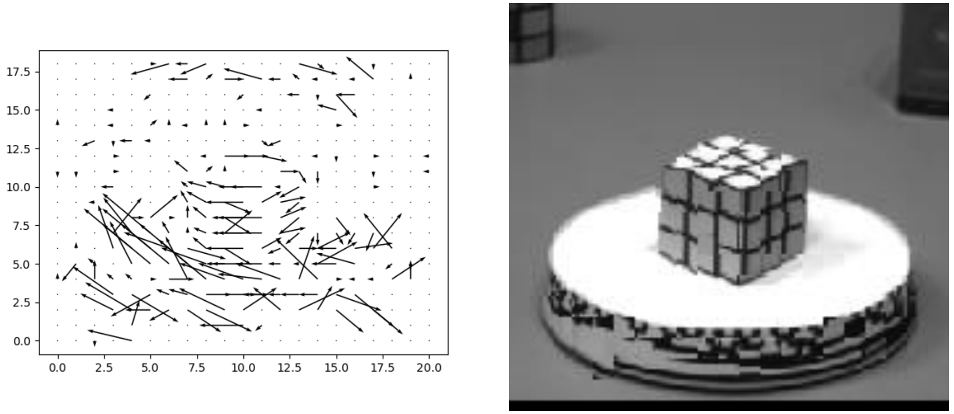


Exhaustive Search

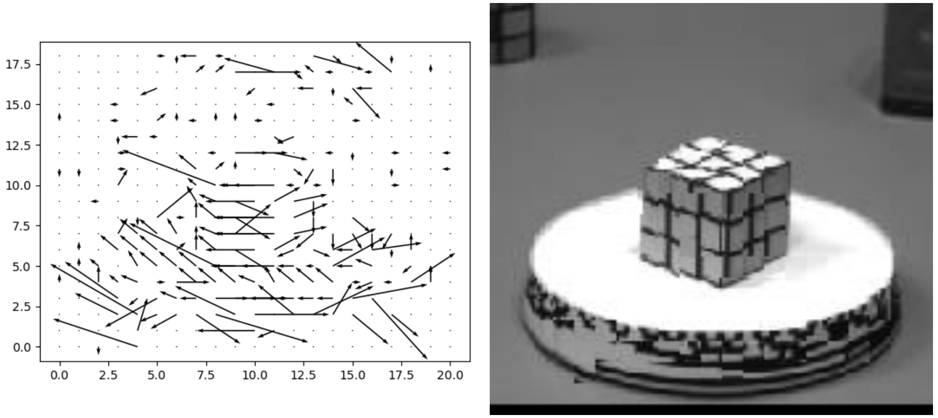


Log Search

Frame t



Three step Search

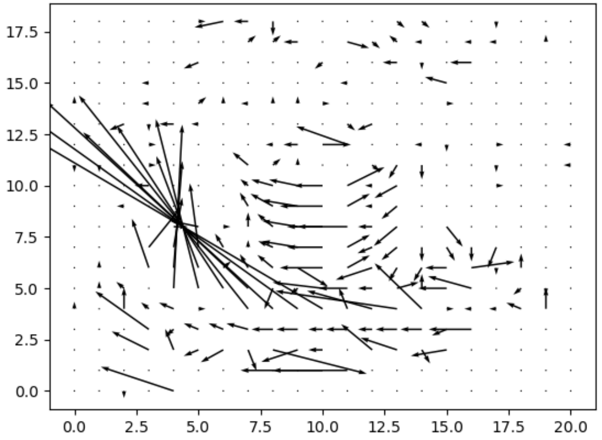


New Three step Search

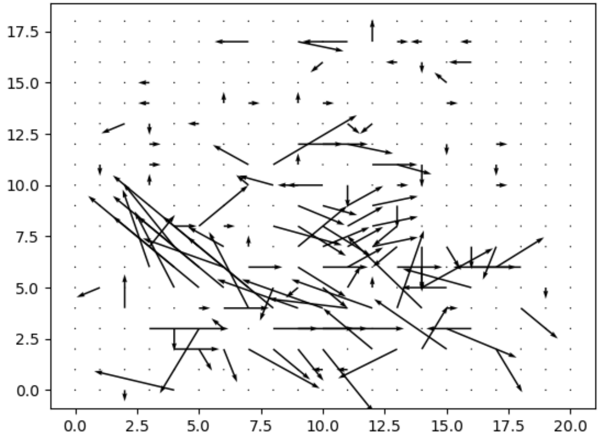
Various search algorithm- Other image

Frame t-1

Frame t



Diamond Search



Simple and efficient Search

Various search algorithm- Other image

Block size = 8 Search range =4	MAD Operations	MSE	PSNR
Exhaustive search	29503	300.545	22.933
Log search	8742	682.012	19.374
Three step search	10263	674.925	19.420
New Three step search	9169	666.357	19.475
Diamond search	9620	703.826	19.237
Simple and efficient search	1902	847.619	18.430

THANK YOU
for your attention