New frame rate up-conversion using bi-directional motion estimation

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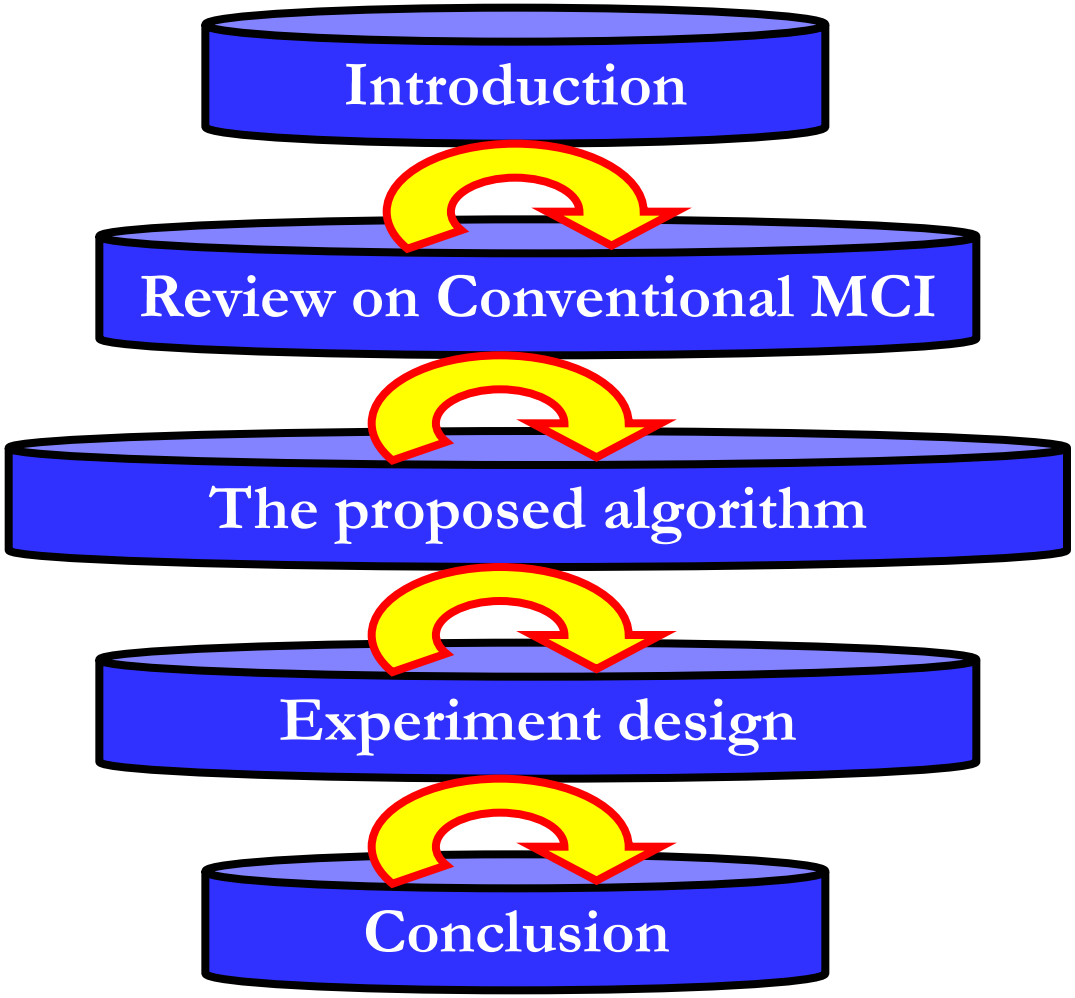
Content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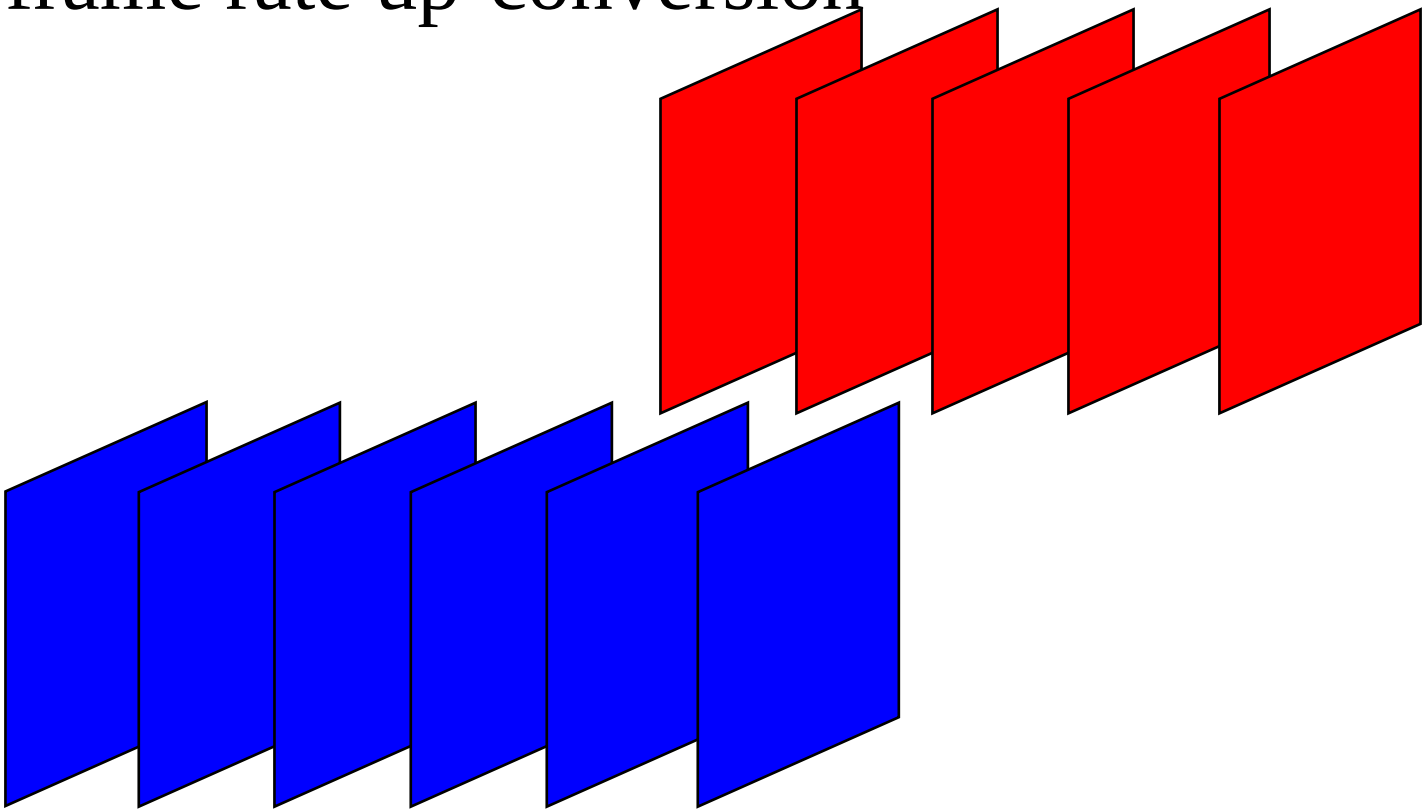
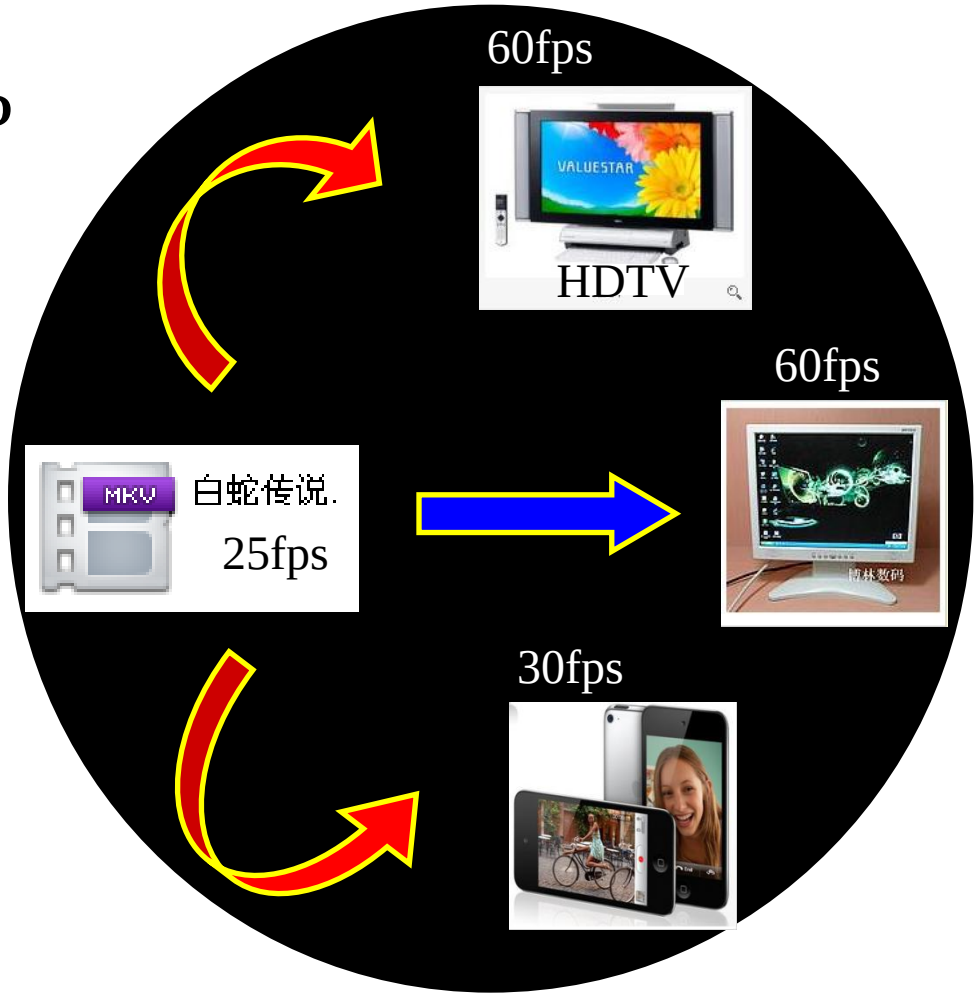
Introduction

- What is frame rate up-conversion



Introduction

- Why frame rate up-conversion is required?
  - Different display devices,different frame rate.
  - Frame rate up-conversion technique can be used for video compression and slow motion replay.



Review on Conventional MCI's

(1) Moving objects: Bi-directional MCI

$$f_{ti}(\mathbf{p})=W_b*f_{t1}(\mathbf{p}-W_f*\mathbf{D}_{1,2}(\mathbf{p}))+W_f*f_{t2}(\mathbf{p}+W_b*\mathbf{D}_{1,2}(\mathbf{p}))$$

(2) Covered background: Forward prediction

$$f_{ti}(\mathbf{p})=f_{t1}(\mathbf{p})$$

(3) Uncovered background: Backward prediction

$$f_{ti}(\mathbf{p})=f_{t2}(\mathbf{p})$$

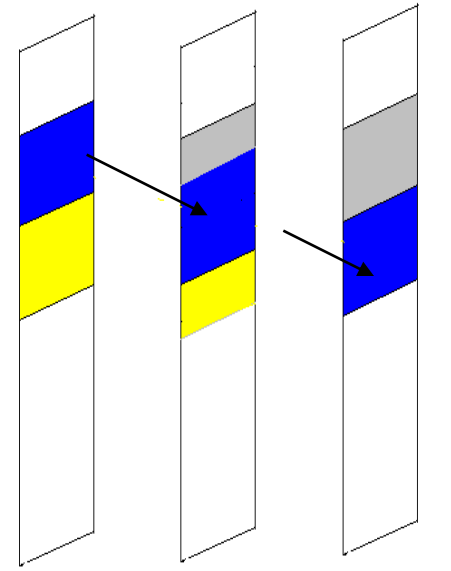
(4) Static background: Linear interpolation

$$f_{ti}(\mathbf{p})=W_b*f_{t1}(\mathbf{p})+W_f*f_{t2}(\mathbf{p})$$

$f_{ti}(\mathbf{p})$: pixel intensity

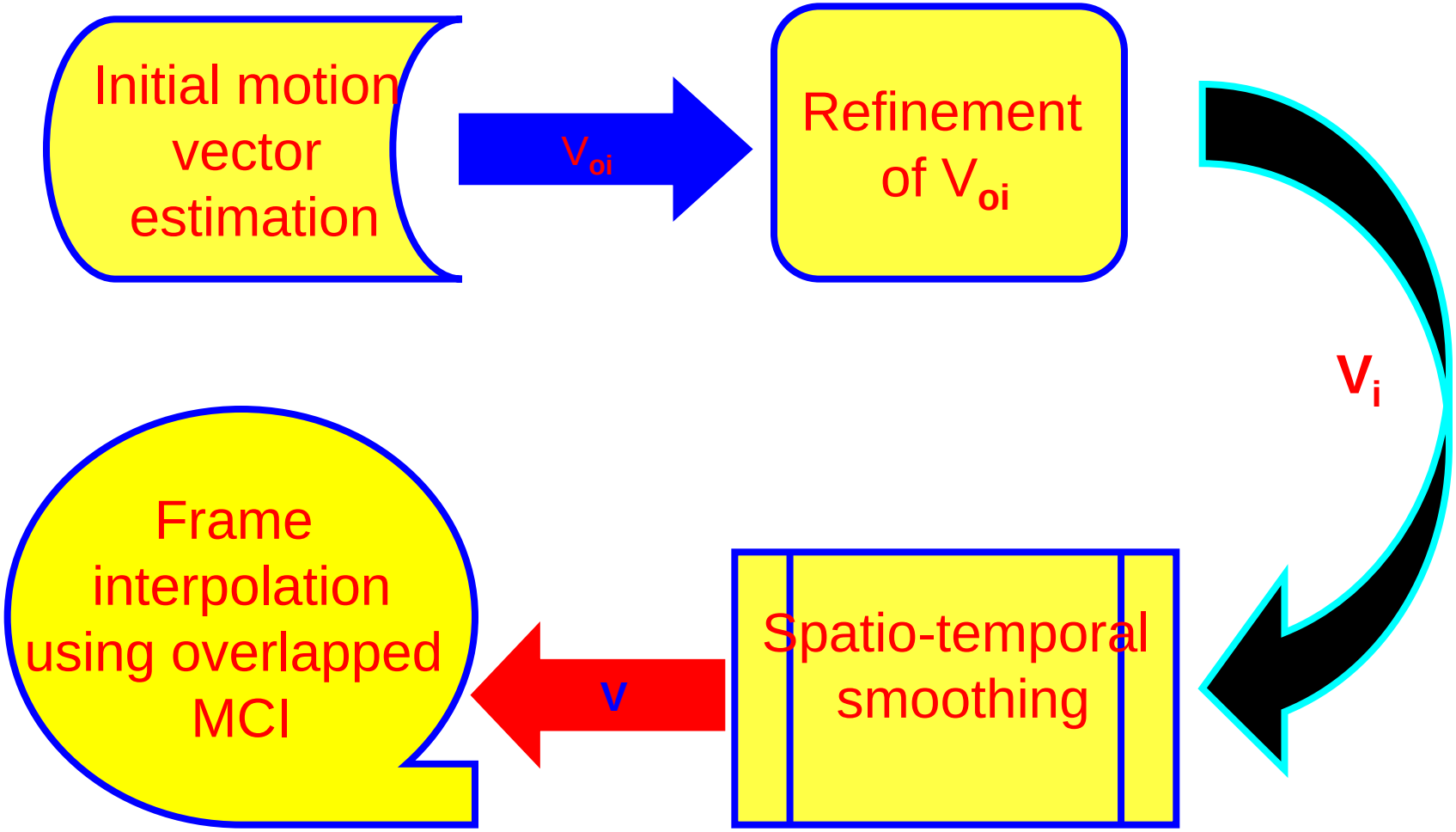
$D_{1,2}(p)$: the motion vector at pixel p from the previous frame f_{t1} to the current frame f_{t2}

Wf=(ti-t1)/(t2-t1); Wb=(t2-ti)/(t2-t1)



(Fig.1)

The proposed algorithm



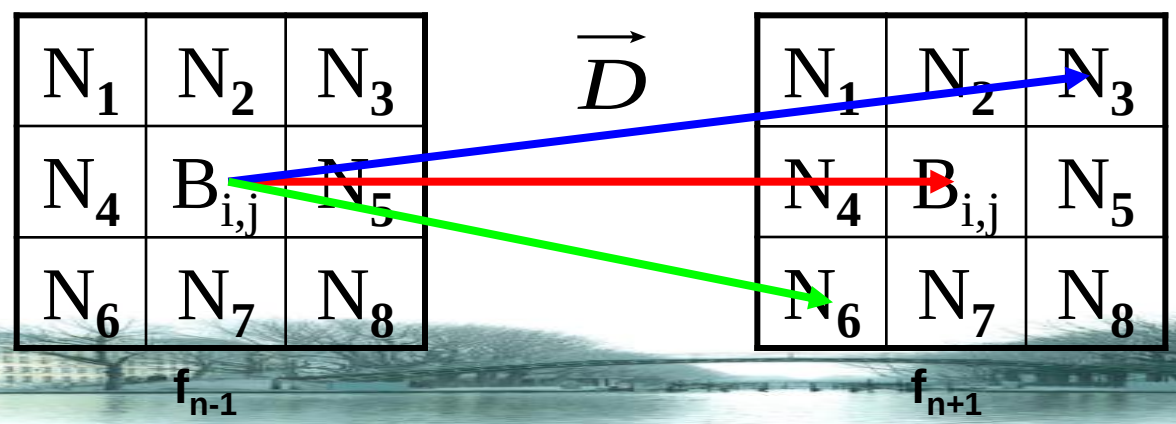
1. Initial motion vector estimation

- We get the initial motion vector with the full search block-matching algorithm. The search region is usually symmetric with respect the current block, up to Rx pixels to the left and right, and up to Ry pixels above and below.

- The initial motion vector is used to initialize the initial value of the bi-directional motion vector without any modification.

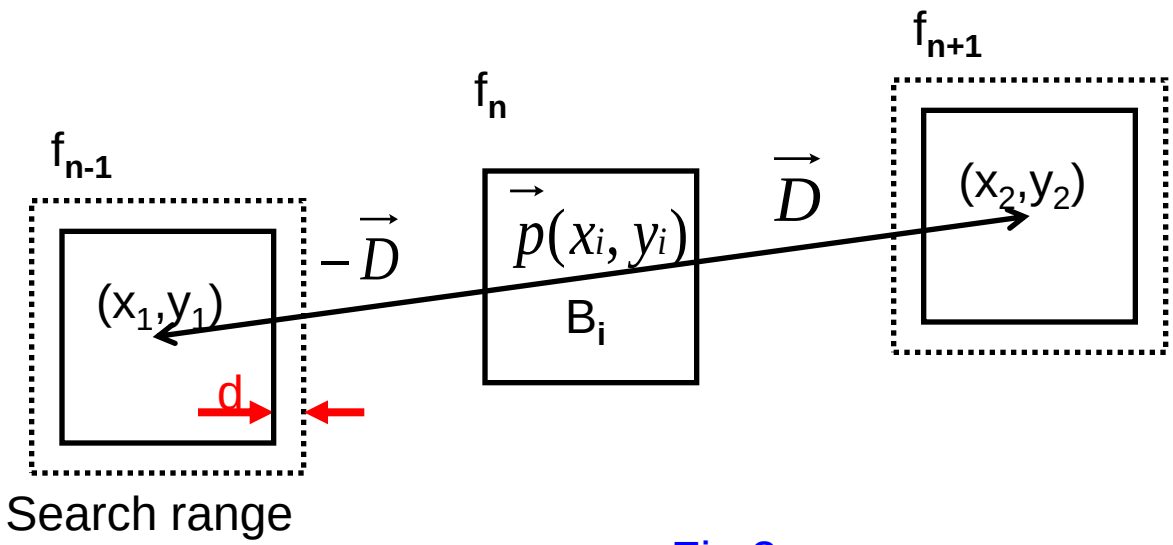
$$MAD[B_{i,j}, \vec{D}] = \sum_{p \in Bi,j} | f_{n-1}(\vec{p}) - f_{n+1}(\vec{p} + \vec{D}) |$$

$$\vec{D}s(B) = \arg\min MAD[B_{i,j}, \vec{D}](\vec{D}s(B) \in \vec{D})$$



2. Refinement of initial motion vector

- Using bi-directional motion vector estimation
- To solve the problem of overlapped pixels and the hole



$$(x1, y2) = \vec{p} - \vec{D}$$
$$(x2, y2) = \vec{p} + \vec{D}$$

Fig.2

$$MAD[B_{i,j}, \vec{D}] = \sum_{p \in Bi,j} | f_{n-1}(\vec{p} - \vec{D}) - f_{n+1}(\vec{p} + \vec{D}) |$$

$$\vec{D}s(B) = \arg\min MAD[B_{i,j}, \vec{D}](\vec{D}s(B) \in \vec{D})$$

3. Spatio-temporal smoothing

N_1	N_2	N_3
N_4	B	N_5
N_6	N_7	N_8

(Fig.3) interpolated frame

$$MAD[B_{i,j}, \vec{D}] = \sum_{p \in Bi,j} | f_{n-1}(\vec{p} - \vec{D}) - f_{n+1}(\vec{p} + \vec{D})$$

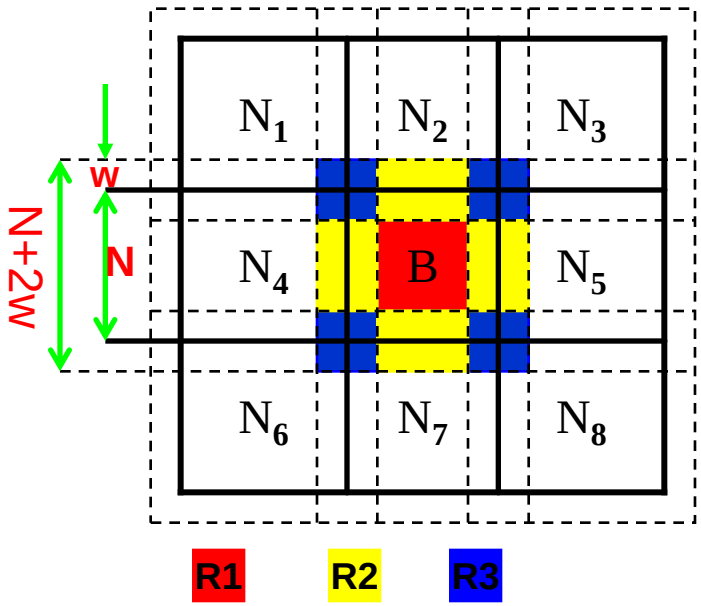
$$\vec{D}s(B) = \arg\min MAD[B_{i,j}, \vec{D}](\vec{D}s(B) \in \vec{D})$$

$\vec{D}(B) and \vec{D}(N_i)$ denote the corresponding bi-directional motion vector of B and N_i.

$\vec{D}(B), \vec{D}(N_i) \subset \vec{D}$

4. Overlapped block MCI

- To eliminate the blocking artifact



(Fig.4 Block overlappirig patlern in the overlapped block MCI.)

$$R_1 : f_0(\vec{p} \in R_1, \vec{D}(B))$$

$$R2 : \frac{1}{2}\{ f_0(\vec{p} \in R_2, \vec{D}(B)) + f_0(\vec{p} \in R_2, \vec{D}(N_i))\}$$

$$N_i \in \{N_2, N_4, N_5, N_7\}$$

$$R3 : \frac{1}{4}\{ f_0(\vec{p} \in R_3, \vec{D}(B)) + S_k\}$$

$$S_1 = f_0(\vec{p}, \vec{D}(N_1)) + f_0(\vec{p}, \vec{D}(N_2)) + f_0(\vec{p}, \vec{D}(N_4))$$

$$S_2 = f_0(\vec{p}, \vec{D}(N_2)) + f_0(\vec{p}, \vec{D}(N_3)) + f_0(\vec{p}, \vec{D}(N_5))$$

$$S_3 = f_0(\vec{p}, \vec{D}(N_4)) + f_0(\vec{p}, \vec{D}(N_6)) + f_0(\vec{p}, \vec{D}(N_7))$$

$$S_4 = f_0(\vec{p}, \vec{D}(N_5)) + f_0(\vec{p}, \vec{D}(N_7)) + f_0(\vec{p}, \vec{D}(N_8))$$

Experimental Design

- In this experiment four test sequences are used and each sequence contains frames with a specific camera motion.

Table : Four test sequences

sequence	Frame size	Typical camera motion
Foreman	176*144	complicated movement
Interview	720*576	large displacement
Inition-2d3d-Showreel	960*544	zoom in/out
InnerGate	640*384	large displacement, zoom in / out

Experimental Design

- For each sequence ,we perform1:2 frame rate up- conversion. The block size is 16*16 and the search range is ±16. The search range is from -2 to +2 in motion estimation for the refinement of the initial motion vector. In overlapped block MCI,we use the overlapping width w=2.
- Evaluative criteria

✓ **PSNR**

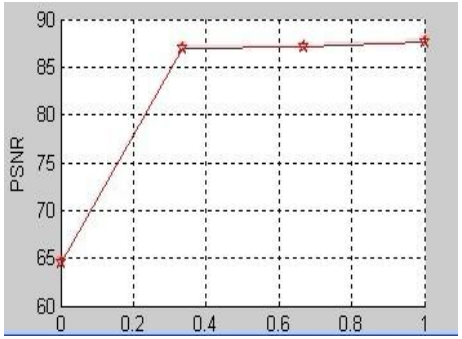
✓ **Visual performance**

Experimental Results

(a)

(b) **PSNR = 67.9614**

(c) **PSNR = 82.3975**

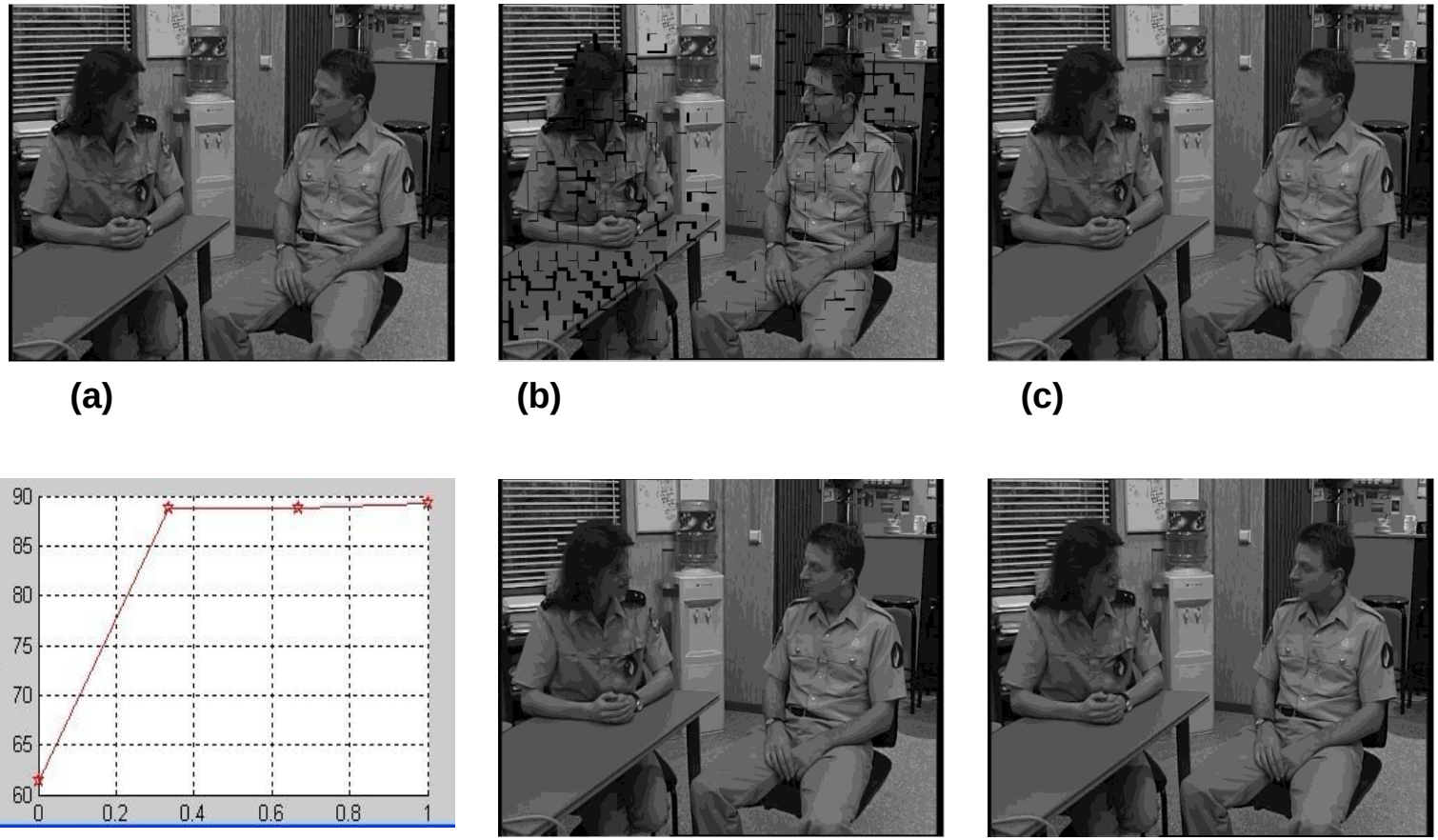


(d) **PSNR = 82.4024**

(e) **PSNR = 82.7707**

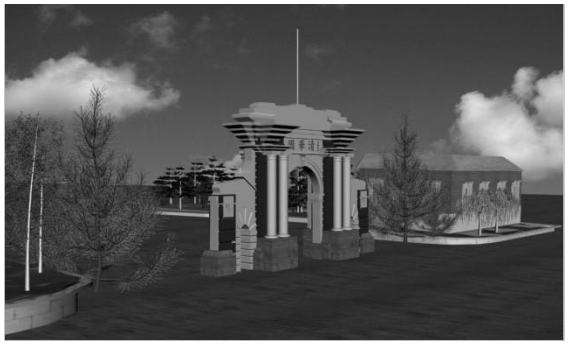
(Fig6. (a): the original image; (b): after the first step; (c): after the second step; (d): after the third step; (e): after the fourth step)

Experimental Results



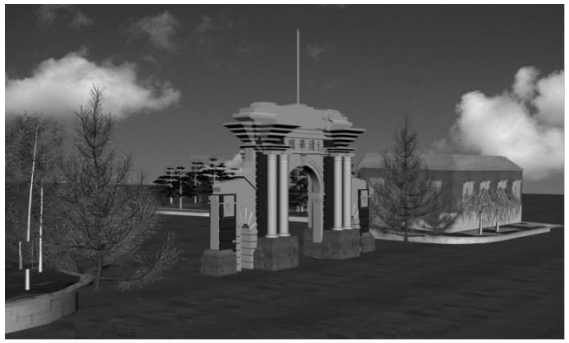
(Fig7. (a): the original image; (b): after the first step; (c): after the second step; (d): after the third step; (e): after the fourth step)

Experimental Results

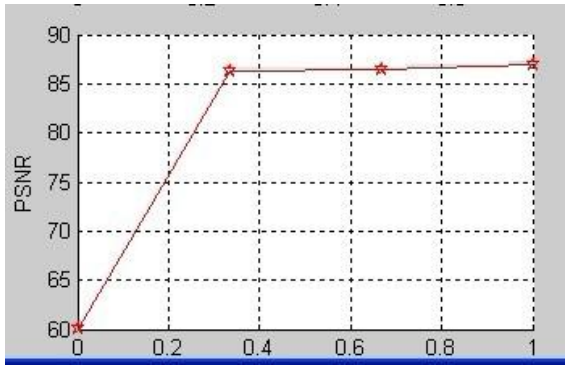


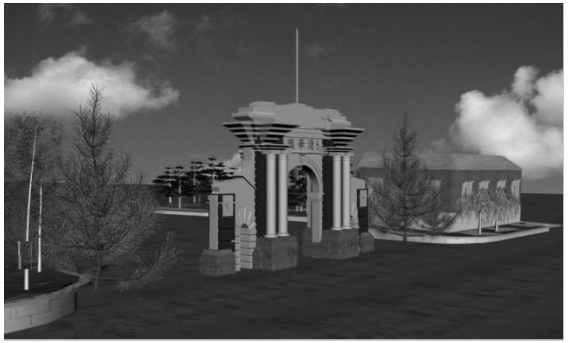
(a)

(b)

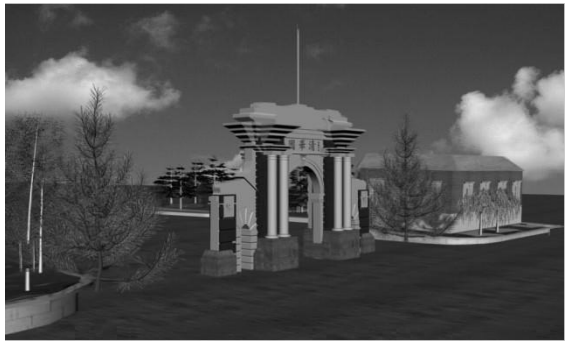


(c)





(d)

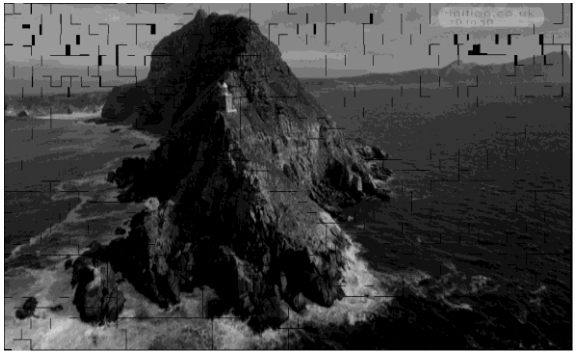


(e)

(Fig8. (a): the original image; (b): after the first step; (c): after the second step; (d): after the third step; (e): after the fourth step)

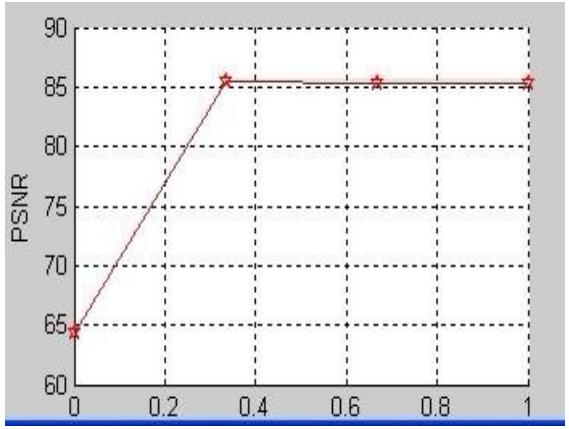
Experimental Results

(a)



(b)

(c)



(d)

(e)

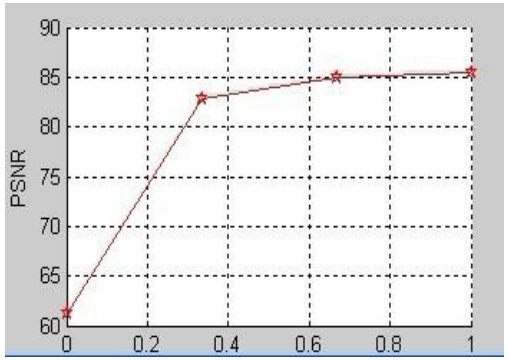
(Fig9. (a): the original image; (b): after the first step; (c): after the second step; (d): after the third step; (e): after the fourth step)

Experimental Results

(a)

(b)

(c)



(d)

(e)

(Fig10. (a): the original image; (b): after the first step; (c): after the second step; (d): after the third step; (e): after the fourth step)

NewFrameRateUpConversion

Original Frame

Experiment Results

First Step

Second Step

Third Step

Fourth Step

Function

Load P

Load N

Load Image

Clear Image

First Step

Second Step

Third Step

Fourth Step

PSNR Values

First Step

Second Step

Third Step

Fourth Step

436K/S 2.6K/S

Conclusions

The main feature of the proposed motion-compensated frame rate up-conversion scheme is that ,unlike conventional MCI algorithm , the proposed technique does not produce any overlapped pixels and hole region in the interpolated frame. It has better performance than the conventional MCI algorithm and is very robust especially in sequences with camera motions like panning and zoom.

Thank you