ELEC S347F Multimedia Technologies,
Spring Term, 2021
Tutorial 04 Solution

Question 1: Consider the below 4x4 matrix of Chroma values.

(a) Assume the upper leftmost chroma value is used for chroma subsampling. Find the subsampling results of 4:4:4, 4:2:2, 4:1:1 and 4:2:0 schemes respectively.

(b) Repeat (a) if the matrix is of luma values.

90	100	96	42
80	18	82	78
44	62	52	38
28	23	48	22

(a) Chroma subsampling result for 4:4:4 scheme (no subsampling)

90	100	96	42
80	18	82	78
44	62	52	38
28	23	48	22

Chroma subsampling result for 4:2:2 scheme (take sample of every two horizontal pixels)

90	96
80	82
44	52
28	48

Chroma subsampling result for 4:1:1 scheme (take sample of every 4 horizontal pixels)

90
80
44
28

Chroma subsampling result for 4:2:0 scheme (take sample of every 2x2 block)

90	96
44	52

(b) No subsampling for luma values. (i.e. same 4x4 matrix)

Question 2: Motion Estimation

Consider a video with frame size of 15 x 15 and macroblock size of 2 x 2.

The luma values in the reference frame (left) and current frame (right) are given as follows:

1	4	6	7	1	2	5	4	6	3	3	2	3	1	2
2	5	3	7	4	5	1	1	5	0	1	2	6	5	4
1	2	4	8	9	1	3	5	1	6	9	3	9	4	0

#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#

ELEC S347F Multimedia Technologies,
Spring Term, 2021
Tutorial 04 Solution

0	1	7	7	6	8	2	8	8	1	0	3	6	8	2
5	5	5	1	6	2	6	3	7	5	6	0	1	0	1
7	6	0	1	2	1	4	0	0	8	7	5	2	6	6
0	8	5	8	5	4	1	4	6	7	1	7	9	7	8
8	2	1	7	8	6	2	5	3	7	4	8	9	2	4
5	0	2	9	7	5	1	2	4	8	0	6	5	2	5
8	3	7	6	7	5	2	4	4	8	5	1	5	0	8
1	2	5	8	0	6	5	8	1	3	0	3	1	2	0
3	6	9	9	4	7	6	5	7	7	6	5	9	5	3
1	5	3	1	9	5	5	5	1	1	2	9	0	1	7
7	5	7	6	7	5	4	7	0	4	5	2	8	3	0
5	2	4	4	2	1	6	2	3	9	1	4	3	5	2

#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	5	7	#	#	#	#	#
#	#	#	#	#	#	#	4	5	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#

(a) Find the motion vector of the highlight macroblock using window search with search range ± 1 pixel. List the steps to obtain the result and show the number of searches performed. Having computed the motion vector, determine the residual to be coded after motion compensation.

(b) Determine whether intra mode or inter mode coding be used for the macroblock in (a).

(c) Repeat (a)-(b) using logarithmic search with search range ± 8 pixels (i.e. initial search step size $= 4$).

(a) Window search ± 1 pixel:

(-1,-1)		(0,-1)		(+1,-1)	
1	4	4	6	6	7
2	5	5	3	3	7
(-1,0)		**(0,0)**		**(+1,0)**	
2	5	5	3	3	7
1	2	2	4	4	8
(-1,+1)		**(0,+1)**		**(+1,+1)**	
1	2	2	4	4	8
2	4	4	4	4	8

Step	Motion Vector	SAD
1	(-1,-1)	$\|5-1\|+\|7-4\|+\|4-2\|+\|5-5\| = 4+3+2+0 = 9$
2	(0,-1)	$\|5-4\|+\|7-6\|+\|4-5\|+\|5-3\| = 1+1+1+2 = 5$
3	(+1,-1)	$\|5-6\|+\|7-7\|+\|4-3\|+\|5-7\| = 1+0+1+2 = 4$
4	(-1,0)	$\|5-2\|+\|7-5\|+\|4-1\|+\|5-2\| = 3+2+3+3 = 11$

5	(0, 0)	|5-5|+|7-3|+|4-2|+|5-4|= 0+4+2+1 = 7
6	(+1,0)	|5-3|+|7-7|+|4-4|+|5-8|= 2+0+0+3 = 5
7	(-1,+1)	|5-1|+|7-2|+|4-2|+|5-4|= 4+5+2+1 = 12
8	(0,+1)	|5-2|+|7-4|+|4-4|+|5-4|= 3+3+0+1 = 7
9	(+1,+1)	|5-4|+|7-8|+|4-4|+|5-8|= 1+1+0+3 = 5

Therefore the best displacement is (1, -1) with SAD=4. (9 searches has been performed)

The residual is

5 – 6	7 – 7	=	-1	0
4 – 3	5 – 7		+1	-2

(b) MBmean = (|5| + |7| + |4| + |5|)/2^2 = 5.25

A =|5-5.25|+|7-5.25|+|4-5.25|+|5−5.25| = 0.25 + 1.75 + 1.25 + 0.25 = 3.5.

A + $2N^2$ = 3.5 + 2(2^2) = 11.5

Since 4 = SAD_{min} <= A + $2N^2$ = 11.5, inter mode is chosen.

(c) Logarithmic search:

For vector (-4,-4), SAD=7 For vector (0,-4), SAD=7 For vector (4,-4), SAD=11

For vector (-4,0), SAD=10 For vector (0,0), SAD=7 For vector (4,0), SAD=7

For vector (-4,4), SAD=14 For vector (0,4), SAD=5 For vector (4,4), SAD=12

1	4	6	7	1	2	5	4	6	3	3	2	3	1	2
2	5	3	7	4	5	1	1	5	0	1	2	6	5	4
1	2	4	8	9	1	3	5	1	6	9	3	9	4	0
0	1	7	7	6	8	2	8	8	1	0	3	6	8	2
5	5	5	1	6	2	6	3	7	5	6	0	1	0	1
7	6	0	1	2	1	4	0	0	8	7	5	2	6	6
0	8	5	8	5	4	1	4	6	7	1	7	9	7	8
8	2	1	7	8	6	2	5	3	7	4	8	9	2	4
5	0	2	9	7	5	1	2	4	8	0	6	5	2	5
8	3	7	6	7	5	2	4	4	8	5	1	5	0	8
1	2	5	8	0	6	5	8	1	3	0	3	1	2	0
3	6	9	9	4	7	6	5	7	7	6	5	9	5	3
1	5	3	1	9	5	5	5	1	1	2	9	0	1	7
7	5	7	6	7	5	4	7	0	4	5	2	8	3	0
5	2	4	4	2	1	6	2	3	9	1	4	3	5	2

#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	5	7	#	#	#	#	#	#
#	#	#	#	#	#	#	4	5	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#

For vector (-2,2), SAD=7 For vector (0,2), SAD=12 For vector (2,2), SAD=11

For vector (-2,4), SAD=4 For vector (0,4), SAD=5 For vector (2,4), SAD=9

For vector (-2,6), SAD=7 For vector (0,6), SAD=13 For vector (2,6), SAD=12

ELEC S347F Multimedia Technologies,
Spring Term, 2021
Tutorial 04 Solution

1	4	6	7	1	2	5	4	6	3	3	2	3	1	2
2	5	3	7	4	5	1	1	5	0	1	2	6	5	4
1	2	4	8	9	1	3	5	1	6	9	3	9	4	0
0	1	7	7	6	8	2	8	8	1	0	3	6	8	2
5	5	5	1	6	2	6	3	7	5	6	0	1	0	1
7	6	0	1	2	1	4	0	0	8	7	5	2	6	6
0	8	5	8	5	4	1	4	6	7	1	7	9	7	8
8	2	1	7	8	6	2	5	3	7	4	8	9	2	4
5	0	2	9	7	5	1	2	4	8	0	6	5	2	5
8	3	7	6	7	5	2	4	4	8	5	1	5	0	8
1	2	5	8	0	6	5	8	1	3	0	3	1	2	0
3	6	9	9	4	7	6	5	7	7	6	5	9	5	3
1	5	3	1	9	5	5	5	1	1	2	9	0	1	7
7	5	7	6	7	5	4	7	0	4	5	2	8	3	0
5	2	4	4	2	1	6	2	3	9	1	4	3	5	2

#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	5	7	#	#	#	#	#
#	#	#	#	#	#	#	4	5	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#

For vector (-3,3), SAD=8
For vector (-3,4), SAD=6
For vector (-3,5), SAD=9

For vector (-2,3), SAD=7
For vector (-2,4), SAD=4
For vector (-2,5), SAD=4

For vector (-1,3), SAD=3
For vector (-1,4), SAD=4
For vector (-1,5), SAD=4

1	4	6	7	1	2	5	4	6	3	3	2	3	1	2
2	5	3	7	4	5	1	1	5	0	1	2	6	5	4
1	2	4	8	9	1	3	5	1	6	9	3	9	4	0
0	1	7	7	6	8	2	8	8	1	0	3	6	8	2
5	5	5	1	6	2	6	3	7	5	6	0	1	0	1
7	6	0	1	2	1	4	0	0	8	7	5	2	6	6
0	8	5	8	5	4	1	4	6	7	1	7	9	7	8
8	2	1	7	8	6	2	5	3	7	4	8	9	2	4
5	0	2	9	7	5	1	2	4	8	0	6	5	2	5
8	3	7	6	7	5	2	4	4	8	5	1	5	0	8
1	2	5	8	0	6	5	8	1	3	0	3	1	2	0
3	6	9	9	4	7	6	5	7	7	6	5	9	5	3
1	5	3	1	9	5	5	5	1	1	2	9	0	1	7
7	5	7	6	7	5	4	7	0	4	5	2	8	3	0
5	2	4	4	2	1	6	2	3	9	1	4	3	5	2

#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	5	7	#	#	#	#	#
#	#	#	#	#	#	#	4	5	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#
#	#	#	#	#	#	#	#	#	#	#	#	#	#

Iteration	Step	Motion Vector	SAD
1	1	(-4, -4)	|5-7|+|7-6|+|4-1|+|5-6|=2+1+3+1=7
	2	(0, -4)	|5-8|+|7-8|+|4-3|+|5-7|=3+1+1+2=7
	3	(+4, -4)	|5-3|+|7-6|+|4-0|+|5-1|=2+1+4+4=11
	4	(-4, 0)	|5-7|+|7-8|+|4-9|+|5-7|=2+1+5+2=10

	5	(0, 0)	|5-5|+|7-3|+|4-2|+|5-4|=0+4+2+1=7
	6	(+4, 0)	|5-8|+|7-9|+|4-6|+|5-5|=3+2+2+0=7
	7	(-4, +4)	|5-9|+|7-4|+|4-1|+|5-9|=4+3+3+4=14
	8	(0, +4)	|5-5|+|7-7|+|4-5|+|5-1|=0+0+1+4=5
	9	(+4,+4)	|5-5|+|7-9|+|4-9|+|5-0|=0+2+5+5=12
2	10	(-2,+2)	|5-5|+|7-2|+|4-6|+|5-5|=0+5+2+0=7
	11	(0,+2)	|5-4|+|7-4|+|4-8|+|5-1|=1+3+4+4=12
	12	(+2,+2)	|5-8|+|7-5|+|4-3|+|5-0|=3+2+1+5=11
	13	(-2,+4)	|5-7|+|7-6|+|4-5|+|5-5|=2+1+1+0=4
	14	(+2,+4)	|5-7|+|7-6|+|4-1|+|5-2|=2+1+3+3=9
	15	(-2,+6)	|5-5|+|7-4|+|4-1|+|5-6|=0+3+3+1=7
	16	(0,+6)	|5-7|+|7-0|+|4-2|+|5-3|=2+7+2+2=13
	17	(+2,+6)	|5-4|+|7-5|+|4-9|+|5-1|=1+2+5+4=12
3	18	(-3,+3)	|5-0|+|7-6|+|4-4|+|5-7|=5+1+0+2=8
	19	(-2,+3)	|5-6|+|7-5|+|4-7|+|5-6|=1+2+3+1=7
	20	(-1,+3)	|5-5|+|7-8|+|4-6|+|5-5|=0+1+2+0=3
	21	(-3,+4)	|5-4|+|7-7|+|4-9|+|5-5|=1+0+5+0=6
	22	(-1,+4)	|5-6|+|7-5|+|4-5|+|5-5|=1+2+1+0=4
	23	(-3,+5)	|5-9|+|7-5|+|4-7|+|5-5|=4+2+3+0=9
	24	(-2,+5)	|5-5|+|7-5|+|4-5|+|5-4|=0+2+1+1=4
	25	(-1,+5)	|5-5|+|7-5|+|4-4|+|5-7|=0+2+0+2=4

Therefore, the best motion vector is (-1, 3) with SAD = 3. (25 searches performed)

The residual is

5 – 5	7 – 8	=	0	-1
4 – 6	5 – 5		-2	0

Since SAD <= A + $2N^2$, inter mode is chosen.