Exercise I

Consider the following piece of two consecutive frames. Answer the following questions:

a. Consider the highlighted 2*2 macro block in frame n+1. Search in frame n the block that best matches this one using a brute force search with k=2.

Suppose now that we want to search for the highlighted block of the frame n+1 in the whole frame n.

b. For each block in frame n+1, how many MAD calculations should be done ?

c. Deduce the total number of MAD calculations to be done in order to calculate the motion vector for all the blocks in frame n+1.

d. If each 2*2 MAD calculation takes 1 ns, what is the time needed to predict all the motion vectors of all the blocks in the frame n+1?

e. Answer the parts c, d, and e if we consider a logarithmic search instead of brute search.

139	144	149	153	155	155	155	155
144	151	153	156	159	156	156	156
150	155	160	163	158	156	156	156
159	161	162	160	160	159	159	159
159	160	161	162	162	155	155	155
161	161	161	161	160	157	157	157
161	162	161	163	162	157	157	157
162	162	161	161	163	158	158	158

frame *n*

155	155	139	144	149	153	155	155
156	156	144	151	153	156	159	156
156	156	150	155	160	163	158	156
159	159	159	161	162	160	160	159
155	155	159	160	161	162	162	155
157	157	161	161	161	161	160	157
157	157	161	162	161	163	162	157
158	158	162	162	161	161	163	158

frame *n+1*

a)

139	144	149	153	155	155	155	155
144	151	153	156	159	156	156	156
150	155	160	163	158	156	156	156
159	161	162	160	160	159	159	159
159	160	161	162	162	155	155	155
161	161	161	161	160	157	157	157
161	162	161	163	162	157	157	157
162	162	161	161	163	158	158	158

search area of k=2

155	155	139	144	149	153	155	155
156	156	144	151	153	156	159	156
156	156	150	155	160	163	158	156
159	159	159	161	162	160	160	159
155	155	159	160	161	162	162	155
157	157	161	161	161	161	160	157
157	157	161	162	161	163	162	157
158	158	162	162	161	161	163	158

same position as the highlighted block

Match (MAD = 0) ⟶ Motion Vector = (-2, 0)

we should calculate MAD for each pixel. Here, we found it directly, but the number of calculation that should have been done is $(2K+1)^2 = (2 \cdot 2 + 1)^2 = 25$ (for each block).

b) If we take the block that is exactly in the middle of the matrix, to search the whole image, we need to take $\underline{K=3}$

⇒ with brute force: $(2K+1)^2 = (2 \cdot 3 + 1)^2 = \underline{49}$

c) $\frac{8 \times 8}{2 \times 2} = 16$ Macro blocks (8 × 8: image size; 2 × 2: block size)

⟹ $16 \times 49 = 784$ calculations.

d) 784 ms

e) b) 9 positions only ($(2+1)^2$) ($\frac{k}{2} = 1.5 \Rightarrow 1$, for the 2nd step, we can't do $\frac{1}{2}$!)

c) $9 \times 16 = 144$

d) $144 \times 1 = 144$ ms

Exercise II

- Consider the encoding of a 640x480 video at 30 fps using I and P frames. To encode the P frames, we consider 8x8 macroblocks and **use logarithmic search** to find the best motion vector. Assume that the search area parameter k is equal to 8.
  - Calculate the number of candidate blocks to be matched against a target macroblock.
  - Calculate the number of MAD evaluations per frame (assume that all target macroblocks, including the boundary ones, have the same number of candidates).
  - Consider now 10 minutes of video knowing that one I frame is inserted after every 4 consecutive P frames as follows:
- I PPPP I PPPP I … . Assume that 1 MAD evaluation takes 0.1 ms.
  - What is the Total number of frames? I frames? P frames?
  - Deduce the time spent on motion vector computation for these 10 minutes of video.
  - Can this be used for real-time encoding and distribution setup? Justify.

1) $\underset{\text{initial}}{9} + \underset{K/2}{8} + \underset{K/4}{8} + \underset{K/8}{8} = 33$ candidate block

2) $\frac{640 \times 480}{8 \times 8} = 4800$ macro block/frame

MAD evaluation per frame $= 4800 \times 33 = 158\,400$ MADs/frame

3) i) frame rate = 30 fps ; duration = 10 min = 600 seconds

$\Rightarrow$ total number of frames $= 30 \times 600 = 18\,000$ frames

* I PPPP I PPPP I .....

5 frames GOP

$\Rightarrow \frac{18000}{5} = 3600$ GOP

$\Rightarrow$ I frames = 3600 frames

P frames = 18000 - 3600 = 14 400 frames.

ii) $158400 \times 0.1 = 15840$ ms $= 15.84$ sec per P frame

Total time for all P frames $= 14400 \times 15.84 = 228096$ seconds

$\simeq 63.4$ hours

iii) No, 15 seconds for 1 P frame is a lot.

- Consider the encoding of a 640x480 video at 30 fps using I and P frames. To encode the P and B frames, we consider 8x8 macroblocks and a search area of k = 8. How many MADs is done to find the best motion vector for each macro-bloc in a P frame if the search method used is:
- Sequential search.
- Logarithmic search.
- Hierarchical with 4 levels.

Suppose now that the search method is the logarithmic one.

- How many macroblocks are there in each image.

Consider now 10 minutes of video knowing that one I frame is inserted after every 8 consecutive P frames and there are 4 B frames between each couple of P frames as follows:

I B B B B P B B B B P B B B B P B B B B P B B B B P B B B B I .....

- How many MADs are done for the 10 minutes of the video.

EXERCISE III

a) Sequential: $(2 \cdot 8 + 1)^2 = 289$ MADs / macro block

Logarithmic: $9 + \overbrace{8 + 8 + 8}^{8 \times \log_2(8)} = 33$ // // // //

Hierarchical :

b) $\frac{640 \times 480}{8 \times 8} = 4800$ macro block / image

c) 18 000 frames

GOP: 1 I frame
8 P frames

4 B frames between Ps → 32 B frames

=> 41 frames

Number of GOPs $= \frac{18000}{41} \approx 439$ GOPs

Total P frames $= 439 \cdot 8 = 3512$

Total B frames $= 439 \cdot 32 = 14048$

MADs per P & B frame $= 4800 \times 33 = 158400$ MADs/frame

Total MADs $= (3512 + 14048) \times 158400$

$= 2.78 \cdot 10^9$ MADs