1. Check all the applications where motion estimation can be employed to improve the results: **1 point**

- [x] Object tracking
- [ ] Human-computer interaction
- [x] Still image inpainting
- [x] Video compression
- [ ] Segmentation of a single image

2. We want to increase the frame rate of a video sequence by inserting a new frame between every two existing consecutive frames. Denote by y the new frame formed via linear interpolation of motion vectors between frames x_{t-1} and x_t in the original video. Assuming that a circular object is centered at pixel (i, j) in x_{t-1} and at pixel (p, q) in x_t, where will it be centered in y? **1 point**

- ○ $(p+i, q+j)$
- ◉ $((p+i)/2, (q+j)/2)$
- ○ $(p-i, q-j)$
- ○ $((p-i)/2, (q-j)/2)$

3. Calculate the Mean Square Error (MSE) between the two given image blocks (enter your answer to at least one decimal point): **1 point**

1	1	2	2
1	1	2	2
2	2	3	4
2	2	5	6

Block 1

2	2	1	1
2	2	2	2
2	2	6	4
2	2	5	3

Block 2

1.5

1.5

4. Assume that we want to perform block matching for the image block x given below. Which of the following image blocks is a better match in the Mean Absolute Error (MAE) sense? **1 point**

10	20	10	10
20	40	10	10
30	40	20	20
50	60	20	20

Block x

○

10	20	10	10
20	40	10	10
20	20	30	40
20	20	50	60

○

10	20	30	40
20	40	50	60
10	10	20	20
10	10	20	20

◉

20	30	20	20
30	50	20	20
40	50	30	30
60	70	30	30

○

1	2	1	1
2	4	1	1
3	4	2	2
5	6	2	2

5. (True or False) Sub-pixel motion estimation is used in applications where a faster and hence less accurate estimation of motion is needed. **1 point**

- ○ True
- ◉ False

6. Refer to the RGB cube shown in the video lecture for this problem. Color magenta can be obtained by 1:1 mixing red and blue; yellow can be obtained by 1:1 mixing red and green; cyan can be obtained by 1:1 mixing blue and green. If magenta, yellow, and cyan are mixed at 1:1:1 proportion, what is the resulting color? **1 point**

- ○ red
- ○ green
- ○ blue
- ○ white
- ◉ black

7. (True or False) Intensity in HSI color space is exactly the same as the Y-channel in YCbCr color space, as both represent the "brightness" of an image. **1 point**

- ○ True
- ◉ False

8. In the next two problems you will perform block matching motion estimation between two consecutive video frames. Follow the instructions below to complete this problem. **1 point**

(1) Download the two video frames from frame_1 and frame_2. The frames/images are of height 288 and width 352.

(2) Load the frame with file name "frame_1.jpg" into a 288×352 MATLAB array using function "imread", and then convert the array type from 8-bit integer to real number using function "double" or "cast" (note that the range of intensity values after conversion is between 0 and 255). Denote by I_1 the converted MATLAB array. Repeat this step for the frame with file name "frame_2.jpg" and denote the resulting MATLAB array by I_2. In this problem, I_2 corresponds to the current frame, and I_1 corresponds to the previous frame (i.e., the reference frame).

(3) Consider the 32×32 target block in I_2 that has its upper-left corner at $(65, 81)$ and lower-right corner at $(96, 112)$. Note this is MATLAB coordinate convention, i.e., the first number between the parenthesis is the row index extending from 1 to 288 and the second number is the column index extending from 1 to 352. This target block is therefore a 32×32 sub-array of I_2.

(4) Denote the target block by B_{target}. Motion estimation via block matching searches for the 32×32 sub-array of I_1 that is "most similar" to B_{target}. Recall in the video lectures we have introduced various forms of matching criteria, e.g., correlation coefficient, mean-squared-error (MSE), mean-absolute-error (MAE), etc.

In this problem, we use MAE as the matching criterion. Given two blocks B_1 and B_2 both of size $M \times N$, the MAE is defined as $MAE(B_1, B_2) = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} |B_1(i,j) - B_2(i,j)|$. To find the block in I_1 that is most similar to B_{target} in the MAE sense, you will need to scan through all the 32×32 blocks in I_1, compute the MAE between each of these blocks and B_{target}, and find the one that yields the smallest value of MAE.

Note in practice motion search is only performed over a certain region of the reference frame, but for the sake of simplicity, we perform motion search over the entire reference frame I_1 in this problem and the next. When you find the matched block in I_1, enter the sum of the x and y coordinates of the upper-left corner of the matched block in MATLAB convention. For example, if the matched block has the upper-left corner located at $(10, 20)$ then you must enter 30.

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9. In the previous question, what was the corresponding MAE value (up to two decimal points)? **1 point**

22.98