Computer Vision & Pattern Recognition
Assignment 4

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Exercise 1

In order to locate the boundary of the snooker table we have started by doing some pre-processing on the given frames from the video (blurring, dilation etc.). We have started by separating the contents from the frame based on their color composition. In order to achieve this we have converted the colour space from BGR (since cv2 use this color format) to HSV and then find out the range of H, S and V values corresponding to the table cloth.
Once we have the HSV color map for the green of the table cloth, we have applied thresholding to the frame to obtain a visualization of the extracted mask as below.

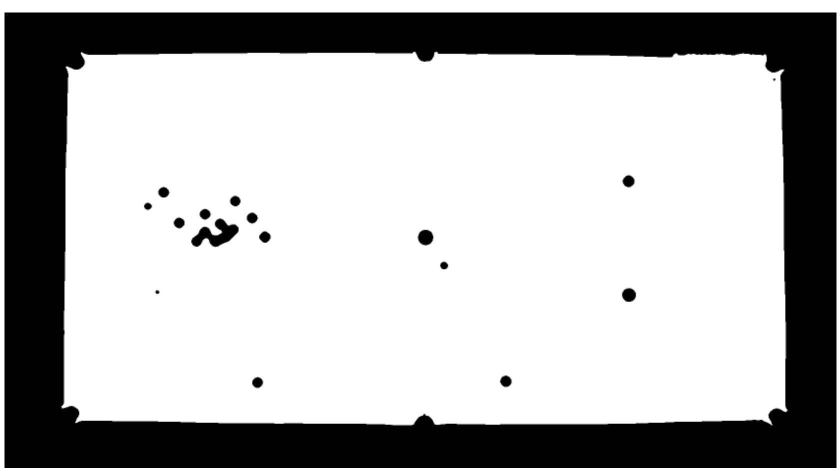

Figure 1: Frame mask for table

The table is clearly distinguishable from the image background and the balls, in black, are clearly distinguishable from the table surface.
Now, in order to extract the table contours, for each frame we applied the *Canny edge detector* followed by the *Hough Line Transform*.

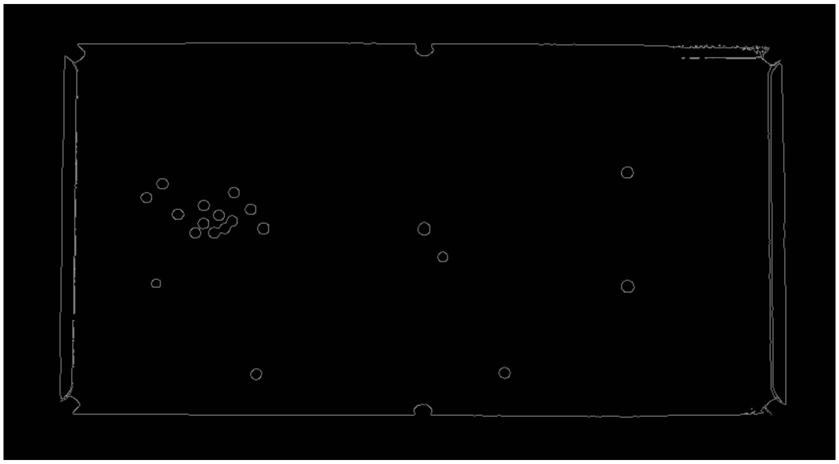

Figure 2: Frame with Canny edge detector

The results of a *Hough Transform* are a set of candidate lines for the table's boundaries, every line detected was tested and only the 4 that represent the table outline have been selected and it was calculated their intersection.

Figure 3: Frame with Hough Line Transform and line intersection

Now the remaining task is to extract the red balls, to achieve this, we had again obtain the mask using HSV based extraction method used earlier, in this particular case the *Saturation* value has been increased due to the fact that the orange ball was confused by the detector, in some frames, with red balls.

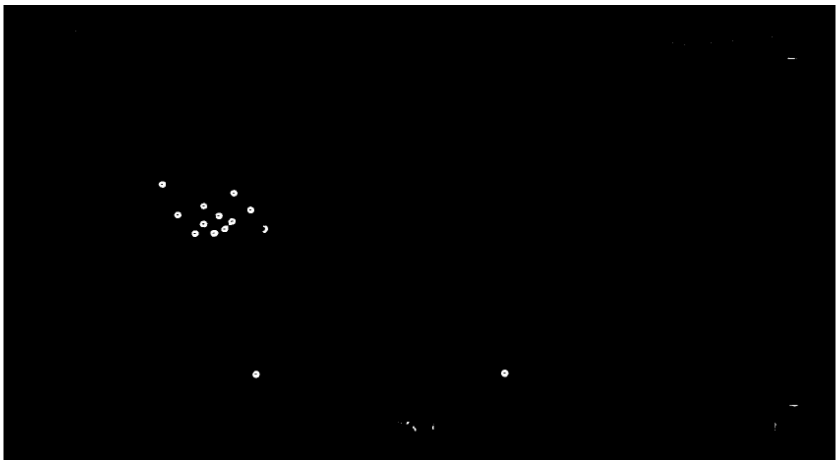

Figure 4: Frame mask for the red balls

The same approach for the table was used for the balls, so to extract the contours Canny was applied followed by the *Hough Circle Transform*.

Figure 5: Frame with Hough Circle Transform for red balls

The final result for a single frame is the one showed in Figure 6.

Figure 6: Frame with boundary locator and red balls locator

For the implementation see the attached file (`snooker_table_v1.py`)

Exercise 2

The shifted window computed in the Stephen-Harris corner detector can be approximated as:

$$A(s+\Delta x, t+\Delta y) \approx A(s,t) + \Delta x G_x(s,t) + \Delta y G_y(s,t) \tag{1}$$

This approximation is basically the *first-order Taylor series approximation* of our shifted window. From this, we can substitute the value of the shifted window in the SSD formula:

$$C(\Delta x, \Delta y) = \sum_{s=-1}^{1}\sum_{t=-1}^{1}[A(s+\Delta x, t+\Delta y) - A(s,t)]^2 \tag{2}$$

$$\approx \sum_{s=-1}^{1}\sum_{t=-1}^{1}[(\cancel{A(s,t)} + \Delta x G_x(s,t) + \Delta y G_y(s,t)) - \cancel{A(s,t)}]^2 \tag{3}$$

$$= \sum_{s=-1}^{1}\sum_{t=-1}^{1}[\Delta x G_x(s,t) + \Delta y G_y(s,t)]^2 \tag{4}$$

$$= \sum_{s=-1}^{1}\sum_{t=-1}^{1}[\Delta x^2 G_x(s,t)^2 + \Delta y^2 G_y(s,t)^2 + 2\Delta x \Delta y G_x(s,t) G_y(s,t)] \tag{5}$$

Finally, we can express this in matrix form:

$$C(\Delta x, \Delta y) \approx \begin{bmatrix}\Delta x & \Delta y\end{bmatrix} \left(\sum_{s=-1}^{1}\sum_{t=-1}^{1} \begin{bmatrix} G_x(s,t)^2 & G_x(s,t)G_y(s,t) \\ G_x(s,t)G_y(s,t) & G_y(s,t)^2 \end{bmatrix} \right) \begin{bmatrix}\Delta x \\ \Delta y\end{bmatrix} \tag{6}$$

This approximation is sufficient for the detector due to how Taylor approximation works: if Δx and Δy are small, approximation represents the sine wave sufficiently, and no higher orders are direly needed.

Exercise 3

All the code and results for this exercise are in the attached notebook (`CVPR_4_Exercise3.ipynb`)