Medial axis detection of Moving Objects

1. **Background subtraction:**
   We have used OpenCV function *cv2.createBackgroundSubtractorMOG2* for background subtraction.

2. **Cleaning the image:**
   The image is cleaned using the two morphological operations:
   i) Opening
   ii) Closing
   The opening followed by closing has given better results. The kernel size of (3,3) is used in both of these operations.

3. **Identification of edges and lines**
   Edges in the image are detected first by smoothening the image with a gaussian kernel of size 3x3, and then by finding the derivative of the image in the x and y direction using the Sobel operator.

   Once the edges are obtained, Progressive Probabilistic Hough line transform (PHT) is used to obtain the straight line segments in the image, corresponding to the edges. The OpenCV implementation of PHT was used with the following parameters for appropriate line segment detection:

   ρ accuracy = 1 units
   θ accuracy = 1 degrees
   threshold = 150
   minLineLength = 30
   maxLineGap = 50

4. **Medial axis identification**
   The PHT function gives several lines corresponding to the edges in the frames. Many of these lines do not correspond to the edges of the moving instrument, but to other noises in the background subtraction and cleaning steps. Therefore, we have employed methods to separate the lines corresponding to the instrument from the other lines.
   In order to capture the line that best suites the medial axis, we used the following heuristics.
   The step by step process for the heuristics used for media axial identification is as follows:

   a) **Identifying lines originating from the top region of the image.**
      Several lines were found in most frames. But the lines which were originating from near the top region of the frames were only considered, as the other lines might have generated from the noise or movement of the base or circular object.
   b) **Histogram of angles.**

Using the coordinates of the start and end points of each line segment, the slope of each line was found. Then, a histogram of the angles of the lines, calculated from the slope values, was constructed. Then we took the most frequent bin in the histogram, as the lines belonging to this bin would be all parallel to each other, and therefore intuitively had the highest chance of belonging to the actual edges of the instrument. All the other lines whose angles (slopes) did not belong to the most frequent bin were discarded.

c) Weighting by line length.

Considering only the selected lines, we took the weighted mean of all the different lines. Each line is weighted by the length of the line. This step was done to ensure that small line segments, mostly arising due to noise, do not have a major effect on the final line. Moreover, the mean line can be thought of as an approximation of the medial axis, which is ultimately the goal.

d) Smoothing the fluctuating medial axis

The final lines that we got from the previous step was a decent representation of the medial axis but were still very fluctuating. In order to smooth out the fluctuations, the exponentially weighted smoothing of the lines is done in the consecutive frames. This is done to ensure some temporal relationship among the different medial axis found and as such the transition would be smooth. This was done by updating the current line as the weighted average of the line (detected in the current frame) with the detected line in the previous frame.

e) Dealing with undetected lines

Additionally, in some frames, no lines were detected even though the instrument was present. This may be due to the non-movement of the instrument in the frame, or some other reasons which made the subtraction and edge detection step inaccurate. Going by the temporal relationship logic, if the current frame did not contain a line and the previous few frames had a line, then it is most likely due to an error, especially if the line is not very short. If the number of consecutive blank frames is less than a specific threshold, then the medial axis line from the previous frames is shown.

f) Handling instrument less frames

There are several frames which do not contain the instrument. When the instrument reappears in the video, we need to make sure that the previous line as detected before the instrument went out of the video frame do not have any influence on the next medial axis line (i.e. they do not contribute to the exponentially weighted smoothing). Hence, if the number of frames without an instrument are above a threshold (same as the threshold used for dealing with undetected lines), i.e. the frames actually have a high chance of not having an instrument, then the old line detected in the last frame containing the instrument is discarded, thereby starting the exponentially weighted smoothing process all over again.

 # SYNTAX TO RUN THE PROGRAM

Command: *python medial_axis.py input_filename*

Output: *result + input_filename (- extension) + ".avi"*

The link of the output videos is as given below:
<video>