Image Rectifier

1. Overall Approach

The logic of my script is broadly as follows:

1) Detect Lines.
    a. Detect edges via Canny.
    b. Detect lines via Hough Transform.
2) Detect Line Intersections.
    a. Find all line intersections.
    b. Consolidate lines with similar gradients and intercepts as ‘primary lines’, and map intersections to each primary line.
3) Find Quadrilateral Corners.
    a. From the line-to-intersection mapping above, find all combinations of 4 lines that form a closed loop.
    b. Identify the corner combination that is most likely to represent a quadrilateral.
    c. Re-orient the corners to form a clockwise sequence that correctly maps the quadrilateral sides to the long and short sides of the rectangle.
4) Perform Perspective Transform on the source image using homography and warping.

2. Logical Details

Step 1: Line Detection

- To place more emphasis on strong edges and reduce noise, I have set the low and high thresholds at relatively high levels – 250 and 420 respectively.
- Similar considerations were applied to the Hough transform parameters. In addition, the HoughLinesP method was used for convenience, as it directly outputs the start and end points of the detected lines, which are useful for subsequent processing.

Step 2: Line Detection

- While I had tried using Harris corner detection, I found the results to be quite noisy and inconsistent, with the main corners entirely omitted at times. As such, I decided to compute the intersection points manually instead.
- The lines detected are consistently imprecise, often producing lines of very similar gradients and intercepts. This can make corner detection quite tricky. As such, I ‘combined’ similar lines as one for subsequent analysis, setting one line

per line group as the 'primary line' to which all intersection points in the line group are attributed.

  - The thresholds for gradient and intercept similarity are <1 (unit) and < 3% respectively. These values were set according to empirical observations.

Step 3: Quadrilateral Detection

- The first step here is to find sequences of 4 lines that form a closed loop. This is achieved by recursively finding closed loops among the unique primary lines identified in step 2.
- The main criterion for quadrilateral selection is that the lines in the closed loop have the largest sum of distances among all other closed loops. However, this is far from trivial, and multiple issues and edge cases must be accounted for:
  - In many cases, intersections outside the target quadrilateral may be derail the latter's selection (see Figure 1). As such, to qualify a quadrilateral, I have computed the percentage of the Euclidean distance between each pair of corners that has been 'covered' by a detected line (see Figure 2). The average percentage is computed for all 4 corner pairs per closed loop, and only closed loops with significant 'line coverage' are potential candidates. Several comments can be made here:

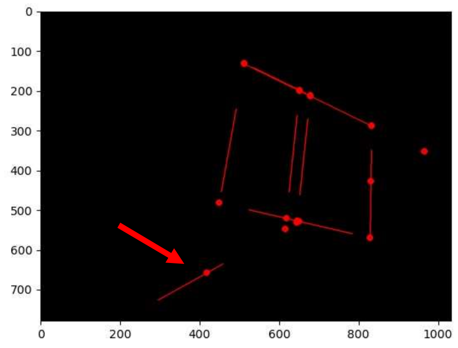


Figure 1: Edge diagram for another test image, with rogue intersection highlighted

    - The threshold value for line coverage is set as 0.74 based on empirical data.
    - *Sometimes, line detection can be quite patchy due to the nature of the image, resulting in low line coverage for all closed loops. In such cases (i.e. all closed loops have line coverage of < 0.5), I have disabled this line coverage logic here for this project, but a more nuanced logic should be considered.
    - Where there are lines that partially overlap with the corners, the following logic is used to calculate coverage. The nitty gritty of its

implementation, such as how an end point of a line is determined to be positioned between two corners, and how the correct corners are identified to calculate a and b, have been omitted from this report for brevity.

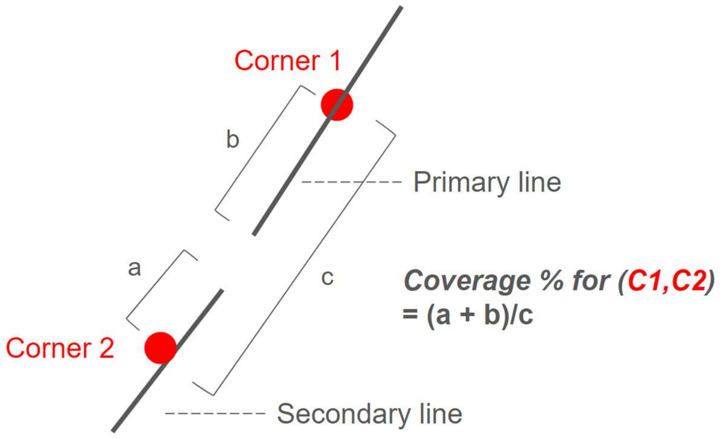


Figure 2: Logic for calculating coverage %. Notice that the two lines, while associated by the logic in step 2, may not be exactly parallel to each other.

- Once the quadrilateral corners have been identified, they must be re-oriented before transformation. This entails the following:
    - The corners are sorted in a clockwise direction.
    - They are then sorted again based on which sides of the quadrilateral respectively correspond to the longer and shorter sides of the target rectangle. The logic I have employed here is that the pair of opposite lines in the quadrilateral with the longer combined length correspond to the longer sides of the rectangle.
        - *The assumption here is that the rectangular objects will be photographed in such a way that there is more emphasis on the long side (to allow for more accurate transformation in the first place), even if the perspective is warped. This logic is also motivated in part by the Pythagorean theorem, albeit of course to a limited extent only.

Step 4: Perspective Transform

- Finally, the homography matrix is computed for the set of source and target corners with the RanSAC algorithm, before a final perspective transform is performed on the image to produce the rectified result.

3. Areas for Improvement

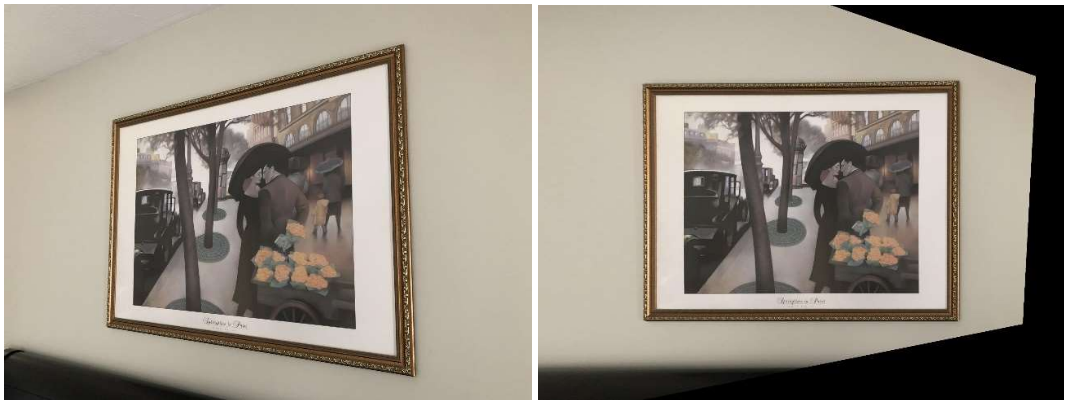
- **Efficiency**: Of the 6 test images used, 5 of them are rectified in less than 1 second, but one of them (test1: the painting) requires 30 seconds to process.

This is largely due to the recursive generation of closed loops, which I believe can be further optimized. There are also a few points of excess in the script, such as the identification of the correct order of lines and corners per closed loop, as well as the repeat computation of coverage percentages across corner pairs, which can be streamlined with further effort.

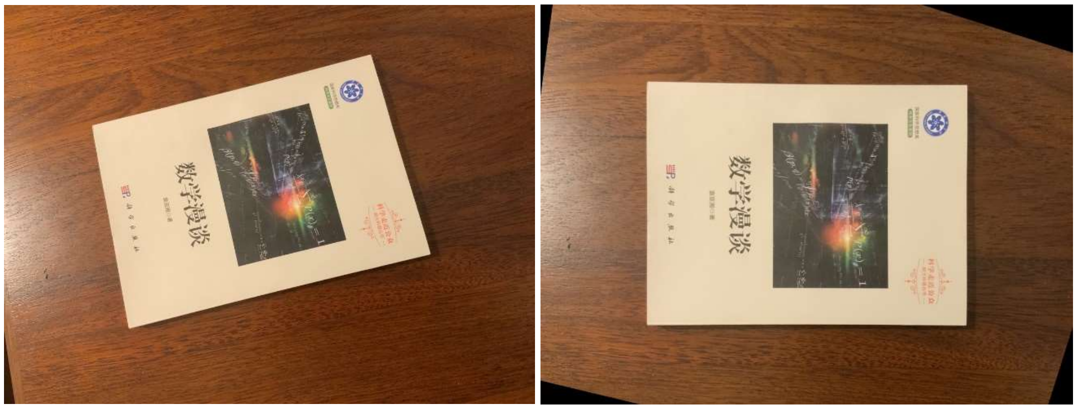
- **Logic**: There are some pieces of blunt logic that have been used here, including the asterisked points above. There is also a try-except clause used in the code for line coverage calculation to catch some edge cases in closed loop formation, which in principle should be avoided. Furthermore, the hyperparameters used, e.g. threshold values for Canny detection, can perhaps be more rigorously fine-tuned with further testing. These improvements, if made, can help enhance the script's broader applicability to edge cases.

4. Appendix

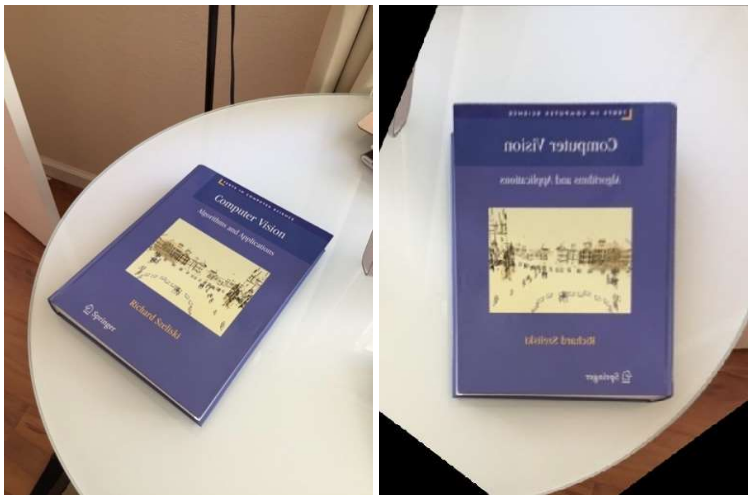
Test 1 ***(Left: Original. Right: Rectified)***



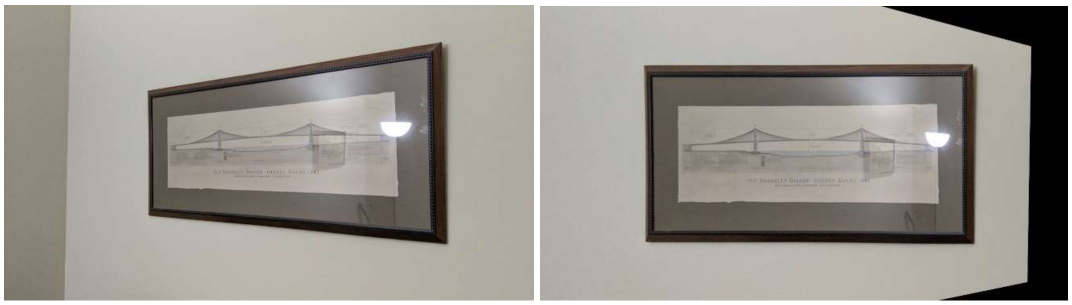
Test 2



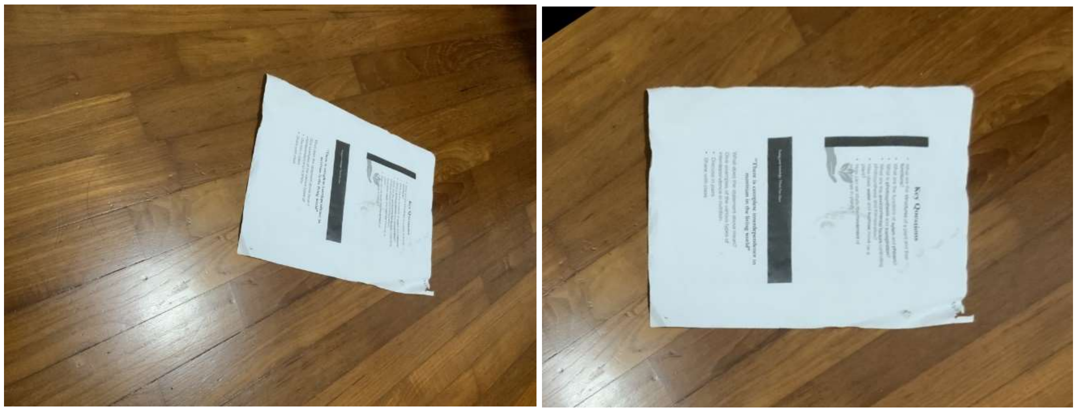
Test 3


Computer Vision
Algorithms and Applications
Richard Szeliski
Springer

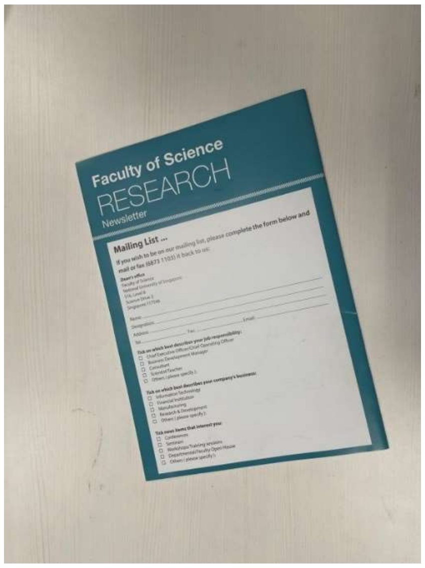
Test 4



Test 5


Key Questions

Test 6



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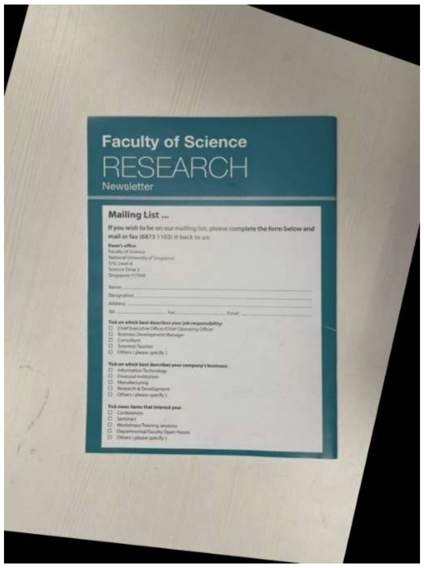

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