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# An optical colon contour tracking system for robot-aided colonoscopy

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## Background

The robotic insertion of gastrointestinal endoscopes will simplify procedures in the future. To achieve automatic performance, sensors are needed to detect the contour of the intestine. This will allow safe and pain-free insertion of the endoscope. Enhanced usability and reduced operating time are excepted.

## Material and methods

Mechanical Setup:

- Balloon prototype made of natural rubber for colon wall detection.
- Polyurethane tube $Ø_{OUT}$ = 2 mm to bring balloon prototype in position.
- Syringe to inflate balloon with 10 to 20 ml ambient air to reach a diameter of about 27 mm.
- Camera module for image acquisition.
- Matlab on a PC on which image processing is performed.

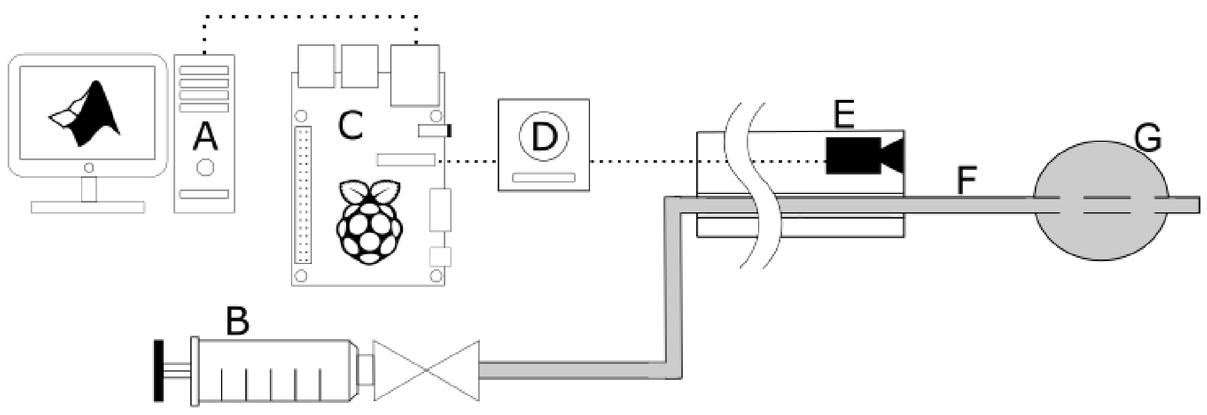



Fig. 1: Schematic of the test bench (A: PC running Matlab, B: syringe and valve, C: Raspberry Pi 3 model B, D: camera module, E: overtube with camera, F: tube, G: Balloon)

Algorithm:

The aim of the algorithm is to identify the inflated balloon as a circle and its center in an image:

Capture image

↓

Load image into Matlab

↓

Pre-processing (see Fig. 2)
*convert the original image into a grayscale image with increased contrast*

↓

Perform Hough-Transformation (see Fig. 3)
*An edge image is generated and thereon an accumulator field. [1,2]*

↓

Interpretation Hough Transformation
*Detection of the balloon and the center point. [3]*

↓

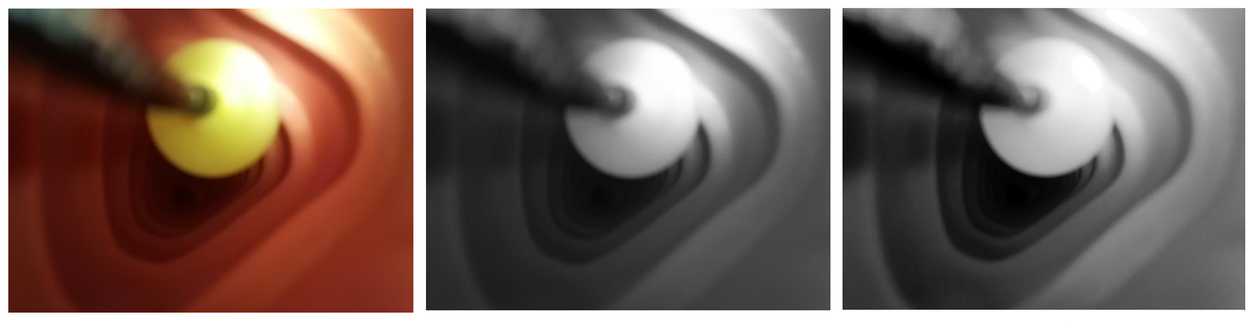
Calculate resulting vector
Indicates where the camera or overtube should move to..

↓

Show resulting image (see Fig. 4)

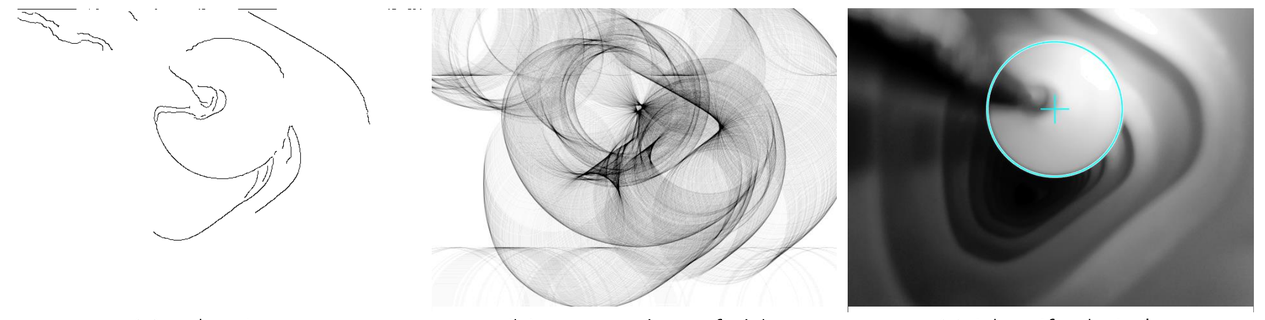
Experimental Setup:

- 400 images
- Circles search radius 100 - 110 px
- Matlab's Stopwatch function used for process duration determination



(a) original (RGB) (b) grayscale (c) increased contrast

Fig. 2 Pre-processing of images in steps (a),(b),(c)



(a) edge image (b) accumulator field (c) identified circle

Fig. 3. Working principle Hough-Transformation (HT)

## Results

- The visualization of the image with the determined circle and values are shown live on a monitor (see Fig. 4)
- The analysis of the calculation time of the Hough-Transformation for all images was 125 ± 16 ms. Table 1 shows the quantity of correctly or false detected images and the required time of the Hough-Transformation.

Table 1: Quality and duration of balloon detection

| Identified | Quantity | Required time |
|---|---|---|
| Correctly detected | 353 images (88 %) | 122 ± 14 ms |
| More circles detected | 9 images (2 %) | 119 ± 16 ms |
| No circle detected | 38 images (10 %) | 130 ± 20 ms |

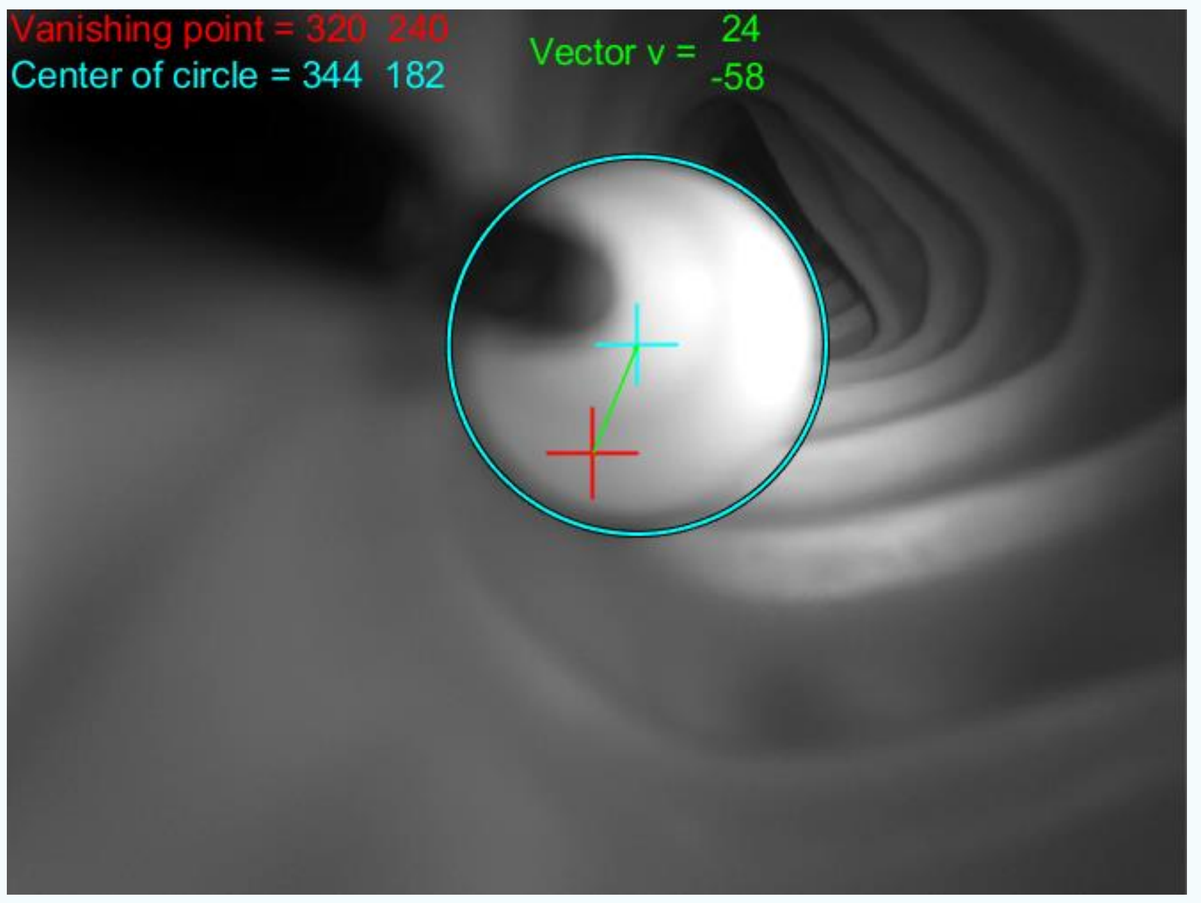



Fig. 4: Camera image taken inside the colon model with balloon detected and resulting vector (green)

## Discussion

- Construction allows a flexible placing of the balloon in front of the camera.
- It is possible to obtain information on the curved pathway of the intestine.
- With the Hough-Transformation the balloon can be recognized as a circle in an image.
- The balloon is localized in an image and thus also in the intestine and a robot-aided contour tracking can be realized.
- The balloon should be clearly distinguished in the image and no shadows should appear which are falsely detected as circles.
- High computational effort of the Hough-Transformation is accompanied by a loss of speed.

## References

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[3] Nischwitz A, Fischer M, Haberäcker P. Bildverarbeitung: Band II des Standardwerks Computergrafik und Bildverarbeitung. 4th ed. Springer Vieweg; 2020