# Automatic detection of ulcerative colitis lesions in colonoscopy videos

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## Abstract/Objectives

Colonoscopy is a routine exam for patients suffering from inflammatory bowel diseases. It produces videos that may contain more than 10,000 images, in which the gastroenterologist looks for lesions such as bleeding and ulcers.
**We propose an automatic feature detection method to classify pixels belonging to bleeding or ulcers.**

The method is based on:

1. a modified definition of sensitivity to account for heavy mislabeling in the training data,
2. a sampling strategy for only exploring non trivial linear classifiers

## Ulcerative Colitis (UC)

**Ulcerative Colitis (UC)** is a chronic condition that damages the lining of the large intestine, causing inflammation, bleeding and ulcer lesions.

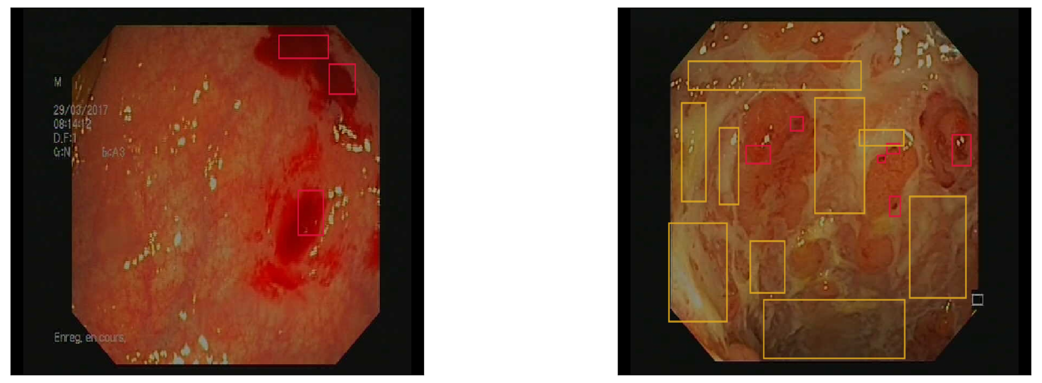

**Figure 1:** Examples of bleeding (left) and ulcers (right) lesions

**Colonoscopy** [1] is the method of reference for evaluating the disease severity, then making treatment decisions and assessing treatment response [2, 3].

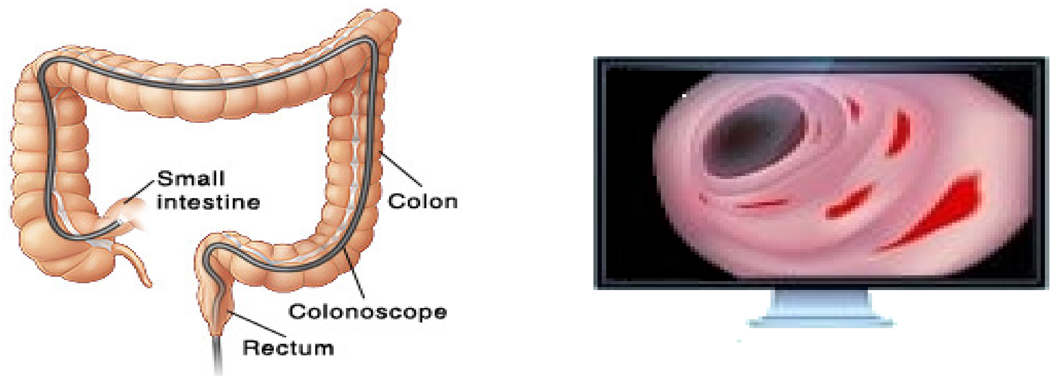


**Figure 2:** on left: colonoscopy exam procedure, at right: visualisation of endoscopic videos

## References

[1] Fay Probert, Alissa Walsh, Marta Jagielowicz, Tianrong Yeo, Timothy DW Claridge, Alison Simmons, Simon Travis, and Daniel C Anthony. Plasma nuclear magnetic resonance metabolomics discriminates between high and low endoscopic activity and predicts progression in a prospective cohort of patients with ulcerative colitis. *Journal of Crohn's and Colitis*, 12(11):1326–1337, 2018.

[2] Ruwan Nawarathna, JungHwan Oh, Jayantha Muthukudage, Wallapak Tavanapong, Johnny Wong, Piet C De Groen, and Shou Jiang Tang. Abnormal image detection in endoscopy videos using a filter bank and local binary patterns. *Neurocomputing*, 144:70–91, 2014.

[3] Martin Goetz. Endoscopic surveillance in inflammatory bowel disease. *Visceral medicine*, 34(1):66–71, 2018.

## Performance Evaluation

In the ROC curve space, we compute the performance of a classification algorithm by two major criterias:

- **Sensitivity** measures the accuracy of detection of abnormal pixels $= \frac{\sum TP}{\sum TP + \sum FN}$
- **Specificity** is the proportion of healthy pixels classified correctly $= \frac{\sum TN}{\sum TN + \sum FP}$

Where

- true positives (TP): count of abnormal pixels correctly identified as abnormal
- true negatives (TN), count of normal pixels correctly identified as normal
- false positives (FP), count of normal pixels identified as abnormal
- false negatives (FN), count of abnormal pixels identified as normal

## Modified Sensitivity

In our database, doctors have used rectangles to delineate the lesions as in figure [1].

**Problem 1**
The learning database contains many errors, corresponding to pixels with incorrect annotation

**Solution 1**
All the pixels inside a given annotated region are counted as true positives if at least some of them were detected. As result, a modified sensitivity, **Sensitivity$^A$** as:

$$\text{Sensitivity}^A = \frac{\text{Area of detected annotations}}{\text{Total area of annotations}}$$

will be utilized to evaluate the classifier performance.

## Conclusion

We applied the new proposed sampling strategy on a data-set of 8 colonoscopy videos for patients suffering from UC disease and evaluated it by the modified sensitivity performance parameter.

**The lesion detector obtained gives interesting results in terms of Specificity which was up to 98.69% and 78.18% for bleeding and ulcer detection respectively (cf figure [6] and figure [9]).**

In terms of the new defined Sensitivity$^A$, the optimal detectors $\hat{m}_b$ and $\hat{m}_u$ present a probability of 66.94% and 62.58% to say that a given pixel is bleeding or ulcer respectively.

## Proposed model sampling strategy

**We classify pixels as bleeding or non-bleeding based on the RGB (Red,Green,Blue) color with a linear model. Ulcers are classified in the YCbCr (Luminance, blue component and red component related to the chroma component) color space with a linear model.**

- Data Bleeding: 6 videos of total 5690 images (2443 present abnormalities)
- Data Ulcer: 7 videos of total 7127 images (2791 present abnormalities)

We utilize a random sampling in the set of all linear models for color spaces to find the optimal linear model, i.e. with the highest compromise between Sensitivity$^A$ & Specificity. The lesions detectors are defined as follow:

- **Bleeding detector** $G \leq aR + b$
- **Ulcer detector** $Y \geq c\,Cr + d$ & $Y < e$

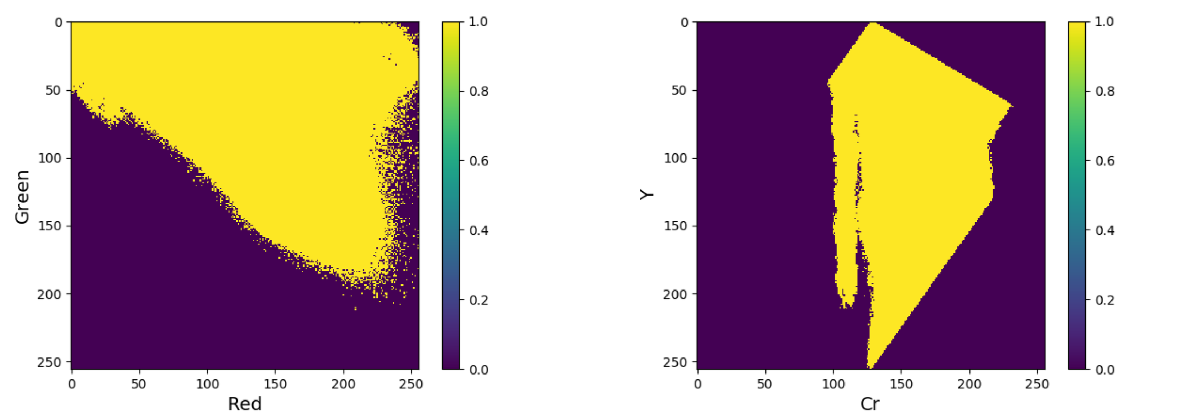


**Figure 3:** Histograms of normal pixels in (R,G) space (left) and (Cr,Y) space (right). The dark blue indicates absence of pixels in the region

**Problem 2**
High probability of obtaining trivial models i.e. models either with TP = 0 either with TN = 0

**Solution 2**
Space reduction to the 2d color histogram of all the normal pixels

**Problem 3**
Risk of redundancy

**Solution 3**
An additive reduction space of the linear models research to the contour of the 2d color histogram

## Results

In the ROC space, the optimal model $\hat{m}$ satisfies:

$$\hat{m} = \underset{m}{\text{argmax}} \left| (1 - \text{Specificity}(m)) - \text{Sensitivity}^A(m) \right|,$$

where $m$ is in the set of the linear models crossing the contour of the 2d color histogram

**Bleeding:** $\hat{m}_b = 1_{\{G < 0.193R - 0.758\}}$

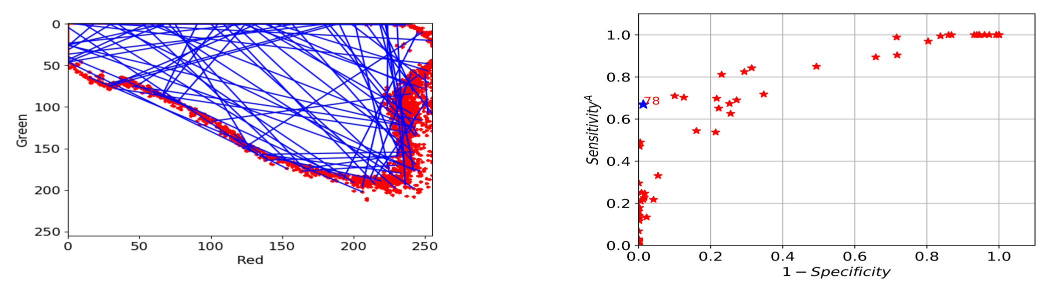


**Figure 4:** on left: Tested models (blue), contour of (R,G) histogram (red). At right: Models performance in the ROC space

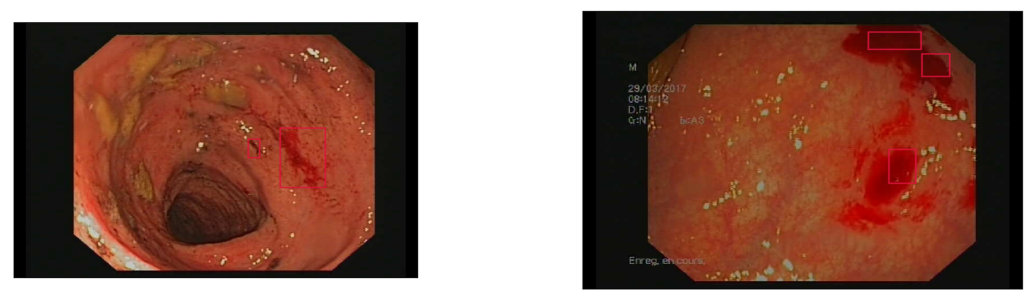

**Figure 5:** Ground truth by gastroenterologists

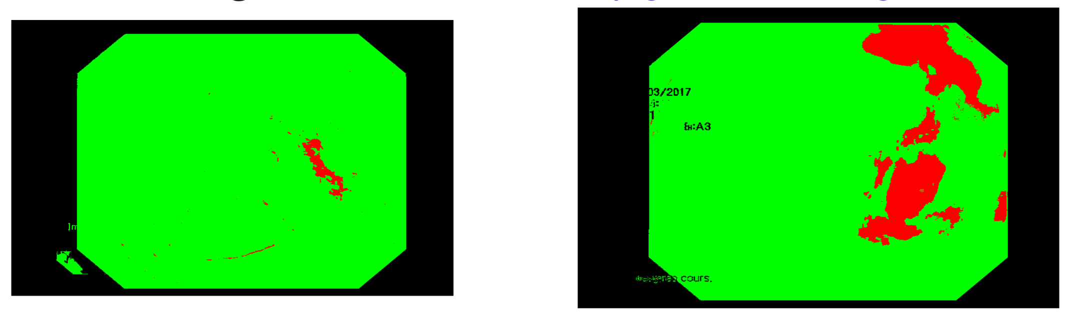

**Figure 6:** Results of bleeding detection using $\hat{m}_b$

**Ulcer:** $\hat{m}_u = 1_{\{0.611Cr - 2.947 < Y < 150\}}$

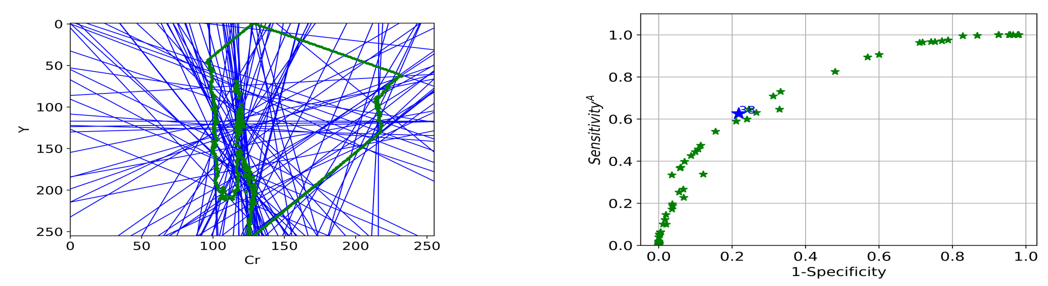


**Figure 7:** on left: Tested models (blue), contour of (Cr,Y) histogram (green). At right: Models performance in the ROC space

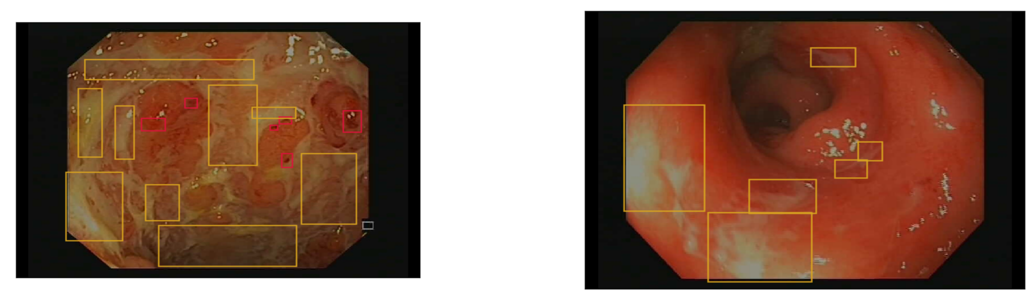

**Figure 8:** Ground truth by gastroenterologists

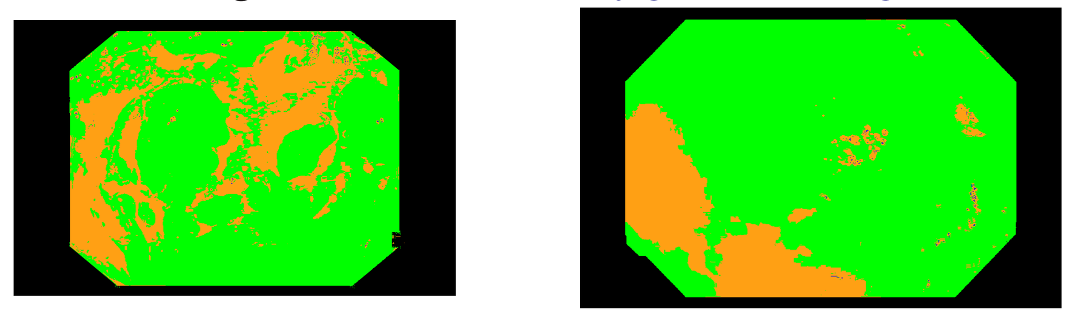

**Figure 9:** Results of ulcer detection using $\hat{m}_u$