A Computer Vision Pipeline for Laryngoscopic Image Standardization through Histogram Matching and Equalization

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Abstract

Inconsistent illumination and color variation caused by endoscopic light and recording towers can lead to challenges in modern diagnosis and treatment planning during laryngoscopies. We propose a computer vision pipeline to standardize laryngoscopic images for a later improved treatment planning and unified data collection as well as comparison across examinations and visits. Two laryngoscopes were used to capture twenty videos from 14 patients with halogen and strobe lights. Stills from these videos were extracted and supplemented with publicly available laryngoscopic images. After preprocessing, images were grouped into bins based on color similarity, and two intensity thresholds were adjusted per bin to enhance dark pixels and over-illuminated areas. Using the average histogram from a selected target bin, histogram matching was used to transform the images into the target pixel intensity distribution. The correlation between each image and the target histogram was assessed before and after histogram matching to evaluate color transformation. The image enhancement and histogram matching increased the correlation for 441 images out of the 474 images transformed, representing a better correspondence with the target histogram. The pipeline standardized the correlations of our own data to fall within the range of the target bin in 96% of images. Our pipeline enhanced image quality and standardized the pixel intensity distribution across light sources and laryngoscopes. Standardizing laryngoscopic images has the potential to improve diagnosis and treatment planning in clinical routines or to create standardized datasets for artificial intelligence tasks.

Introduction

Laryngoscopic images vary in quality, illumination, and color (Fig. 1) due to varying imaging chains, hindering visualization and comparison, especially in an automated way.

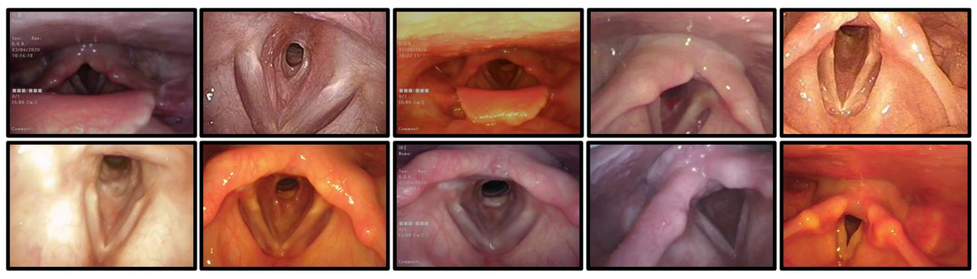

Fig. 1: Variability in laryngoscopic images

Histogram analysis, an interpretable and flexible means to standardize color, is underutilized in the laryngoscopic field.

Objective: To develop an interpretable image standardization workflow that is flexible to adapt to variables in laryngoscopic image production.

Methods

Extract frames from videos at 1-second intervals

- Publicly available data*
- Self-collected data

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Manually classify frames:

- Unusable (Discard)
- Ready (Include)
- Blurred (Sharpen and Include)

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Group frames into bins based on color tone and illumination

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Correct illumination:

- Enhance dark areas below lower intensity threshold
- Replace specular highlights above higher intensity threshold with tissue color

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Correct color using histogram matching to target histogram

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Evaluate performance by comparing histogram correlation

Results

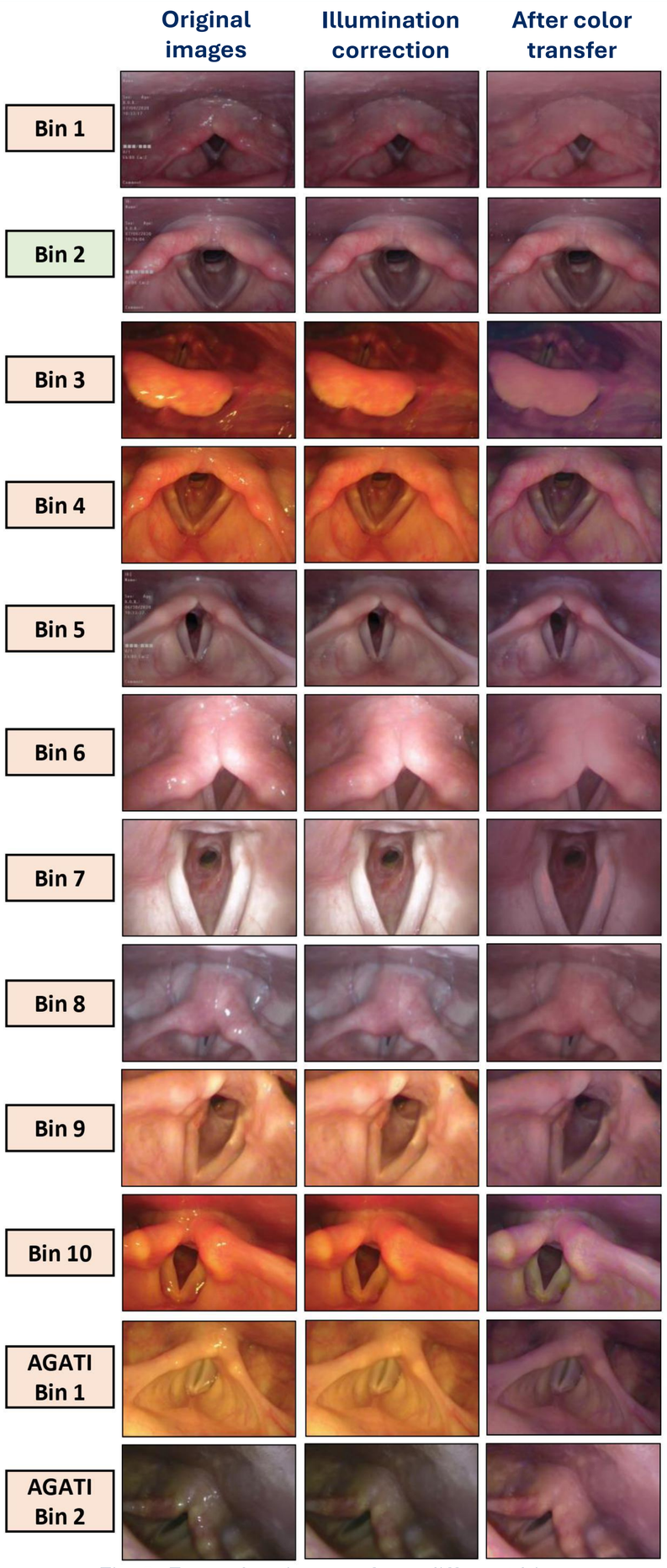

Fig. 2: Exemplary images from different bins

Qualitative results

- Illumination correction (Fig. 2 col. 2), using histogram thresholding (Fig. 3), enhanced poorly-illuminated regions and reduced visibility of specular reflections.

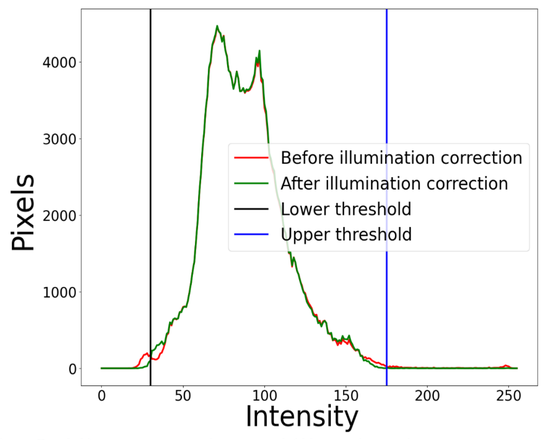

Fig. 3: Histogram-based illumination correction

- Histogram matching (Fig. 4) made images have a similar pink color tone (Fig. 2 col. 3), that aligned with the chosen target (Bin 2) (Fig. 2 row 2).

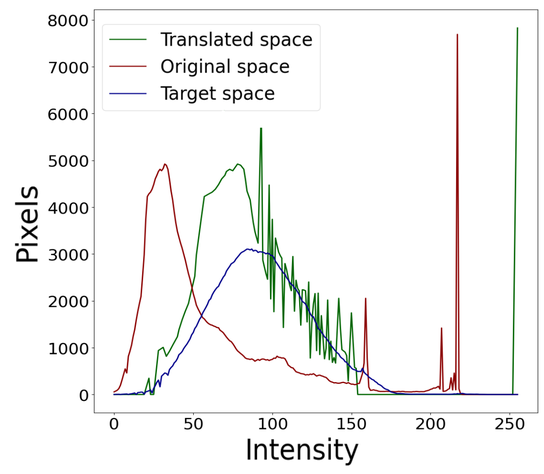

Fig. 4: Channel-wise histogram matching

Quantitative results

- On average, correlation with the *target histogram increased* by a factor of **1.74** for our own data and **1.81** for publicly available data*.
- The pipeline increased the number of images that fell within the target bin distribution range, from 58% to **96%** for our data and from 59% to **98%** for publicly available data*.

Conclusion

Our laryngoscopic image standardization pipeline achieves the following:

- Improves image quality by normalizing pixel intensity, correcting blurring, and adjusting illumination.
- Ensures consistent color tone across different laryngoscopes and light sources.
- Allows for flexible frame selection and parameter tuning based on clinician requirements.
- Has potential to reduce the workload for physicians by facilitating image comparison.
- Visual consistency aids machine learning methods by reducing performance gaps caused by varied data.

Adamian N, Naunheim MR, Jowett N. An Open-Source Computer Vision Tool for Automated Vocal Fold Tracking From Videoendoscopy. Laryngoscope. 2021;131(1):E219-E225. doi:10.1002/LARY.28669

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