Is it possible to create a new way of automatic, non-invasive, and robust oral cavity assessment?

Deep learning for dental spectral image analysis

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INTRO

- The goal of the research is to **help dentists** to **recognize** early-stage signs of **diseases automatically** from oral and dental spectral images to prevent severe complications.
- **Spectral imaging** provides an opportunity to reveal the **unique properties** of an object or scene invisible to the human eye.
- **Deep learning** helps us to **reduce** manual **feature engineering.**
- This DL application for dental spectral image analysis is a **pilot study**. There is **no previous research** in applying DL and hyperspectral imaging in dental domain

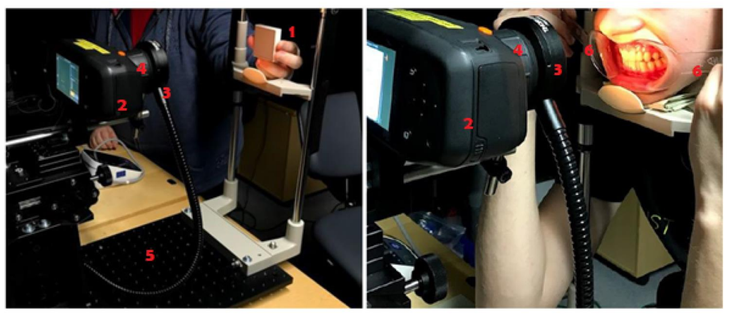

Figure 1. The process of hyperspectral imaging of oral cavity - front view. Left: neutral gray reference sample imaging. Right: imaging of oral cavity with lip retractor inserted. List of objects: 1 - neutral gray reference sample; 2 - hyperspectral camera; 3 - illumination ring; 4 - lens; 5 - construction; 6 - lip retractor

MATERIALS AND METHODS

1. **116** hyperspectral images of oral cavities acquired from **18 individual participants** (Fig. 1).
2. **Dental experts** assessed the hyperspectral images and provided ground truth annotations (Fig. 2).
3. **Annotations** include **38 classes** in **six different subgroups**: technical issues, hard tissues, soft tissues, hard tissue issues, soft tissue issues, and miscellaneous.

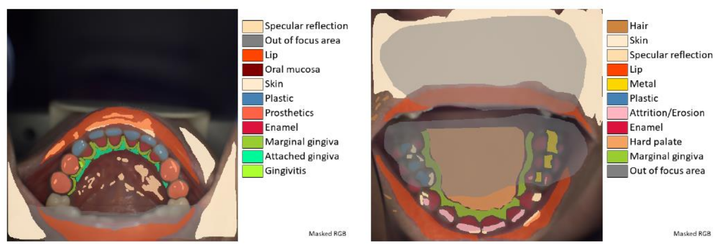

Figure 2: Examples of rendered RGB images overlayed with annotation masks.

4. Mask R-CNN was used for semantic segmentation (Fig. 3).

RESULTS

For enamel: average class prediction accuracy is 99%, and IoU is 77%. For attached gingiva: average class prediction accuracy is 96%, and IoU is 68%.

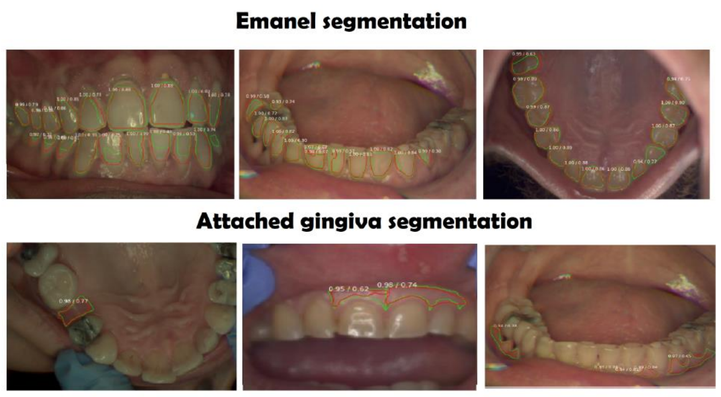

Figure 4: Enamel and attached gingiva segmentation.

DISCUSSION

- The **novelty** of the proposed method lies in the use of **non-invasive imaging method** and **automatic segmentation** of medically-relevant features
- **The question is still open**, and the project has vast potential. Thus, further investigation is needed.

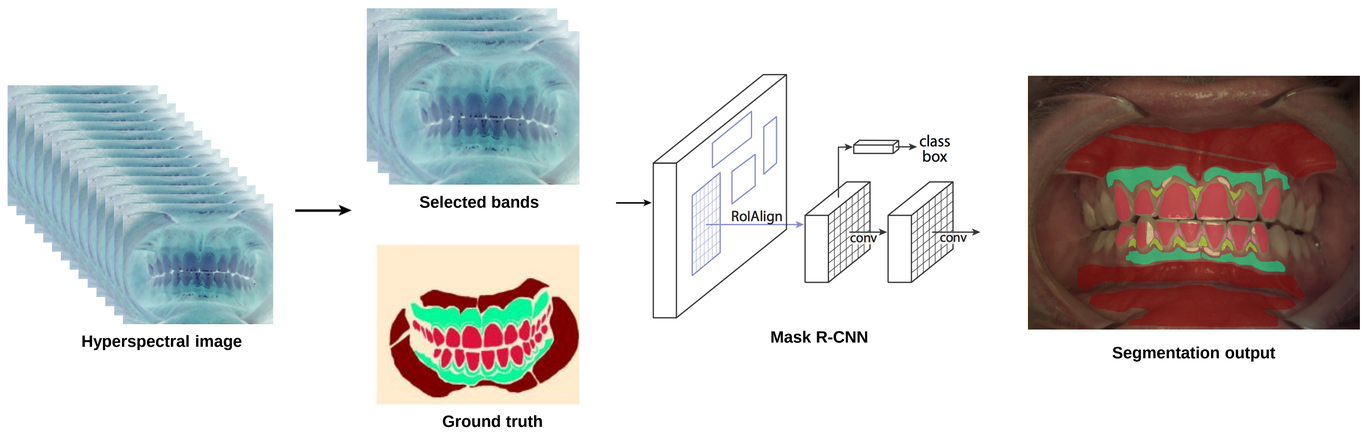

Figure 3: Experimentation pipeline.

MATERIALS AND METHODS: IMAGE PREPROCESSING

Feature scaling into range [0,1].

Flat field correction is applied to exclude the effect of illuminant and camera by using the radiance of standard gray diffuse reference panel.

Uneven illumination is eliminated by applying a Gaussian filter.

There is an issue with poor illumination at the sides of the oral cavity. However, this is a common issue for dental imaging, and it is not yet solved.

Image registration algorithm called GDB-ICP was applied to Nuance EX images to register spectral bands' misalignment to eliminate the effect of movement. Band registration was evaluated by visual assessment.

EXPERIMENTATION: MASK R-CNN

Impossible to train from scratch in our case, huge amount of data required

Transfer learning technique applied to retrain last network layers (FC)

Drawback: pre-trained network was trained on 3-channel RGB images: dimentionality reduction is required.

Dimensionality reduction methods:

Spectral band selection with relevant features.	Principal component analysis (PCA).	Rendered RGB images.

450 nm, 500 nm, and 600 nm bands were selected as they have the most relevant features for calculus, gingiva, erosion and caries detection.

PCA did not show any interesting result; average IoU score was lower than 5% for both classes.

HYPERPARAMETER'S SETUP:

- Batch size: one image (GPU limitation)
- Learning rate: 0.001.
- Training of one epoch: approx. 9-13 minutes.
- Optimizer: Adam.
- Number of channels: 3
- Pre-trained weights: MS COCO
- Backbone: ResNet101

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