Semi-Supervised Learning for Eye Image Segmentation

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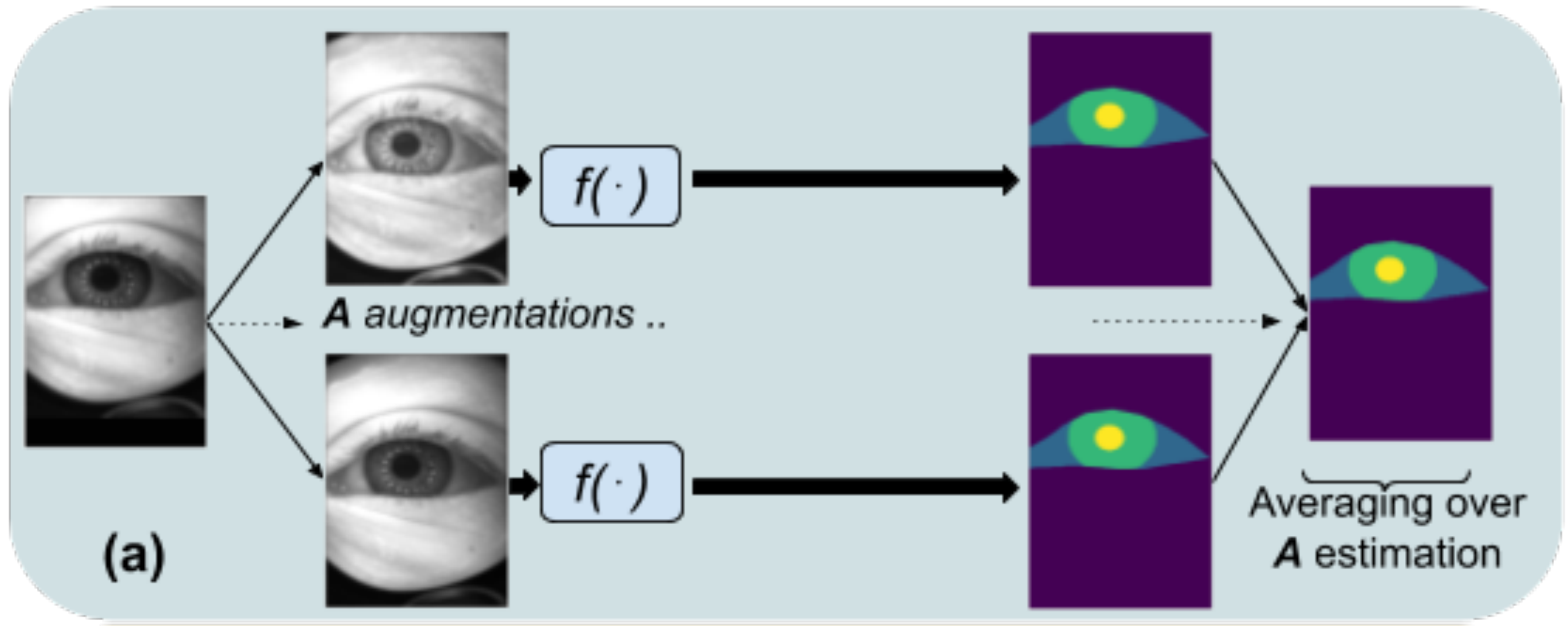
Overview

- Labeling **large** dataset is **tedious,** requires expertise [leads to] bias and inconsistency
- Semi-supervised learning (SSL) : Exploit **hidden relationships** within data to predict labels for **unlabeled** images
- Network **Consistency : Same label prediction** to image even after **perturbation** (mostly used in **classification** task)
- For **semantic segmentation** assumption of network consistency **is violated**

Proposed Method

SSL with domain-specific augmentation (SSL$_D$)

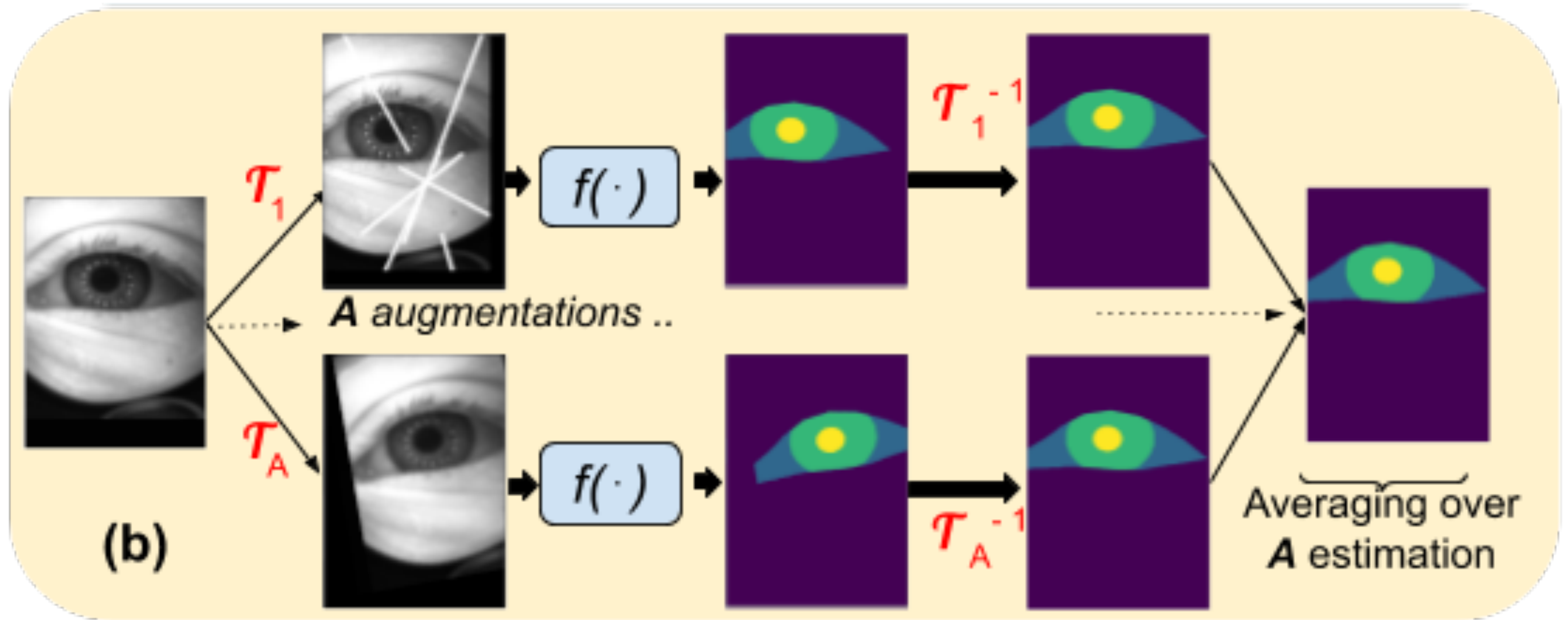
- Vary **contrast & luminance** of eye images
- **CLAHE & Gamma correction**



For each unlabeled image, labels are guessed for A separate copies generated via proposed SSL with domain-specific augmentation

SSL with self-supervised Learning (SSL$_{SS}$)

- **Pretext learning task** -> predicting image from inversion of the transformed image
- Account for **translation / rotation** of images



For each unlabeled image, labels are guessed for A separate copies generated via proposed SSL with a self-supervised approach

Objective function

Total loss = Supervised loss +
$\lambda u \times$ **unsupervised loss +**
$\lambda ss \times$ **self-supervised loss**

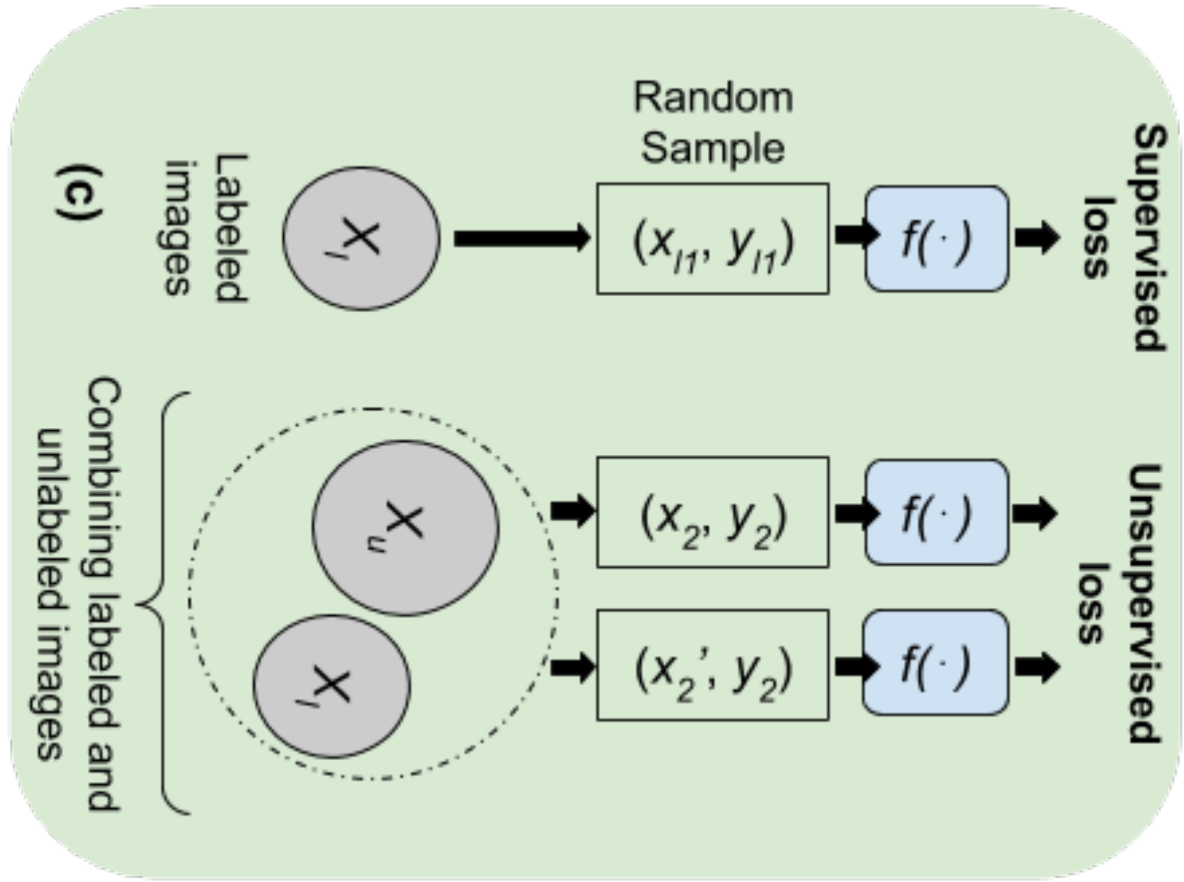


Fig: Supervised loss and unsupervised loss are computed separately for labeled and a combination of labeled and unlabeled data set in both types of SSL methods.

Results

Training with multiple subjects

- fixed unlabeled images (8916 images)
- for X_l= 8916 images, S_L achieved 94.80% whereas we obtained **94.73% with SSL$_{SS}$ for X_l = 940 images only.**

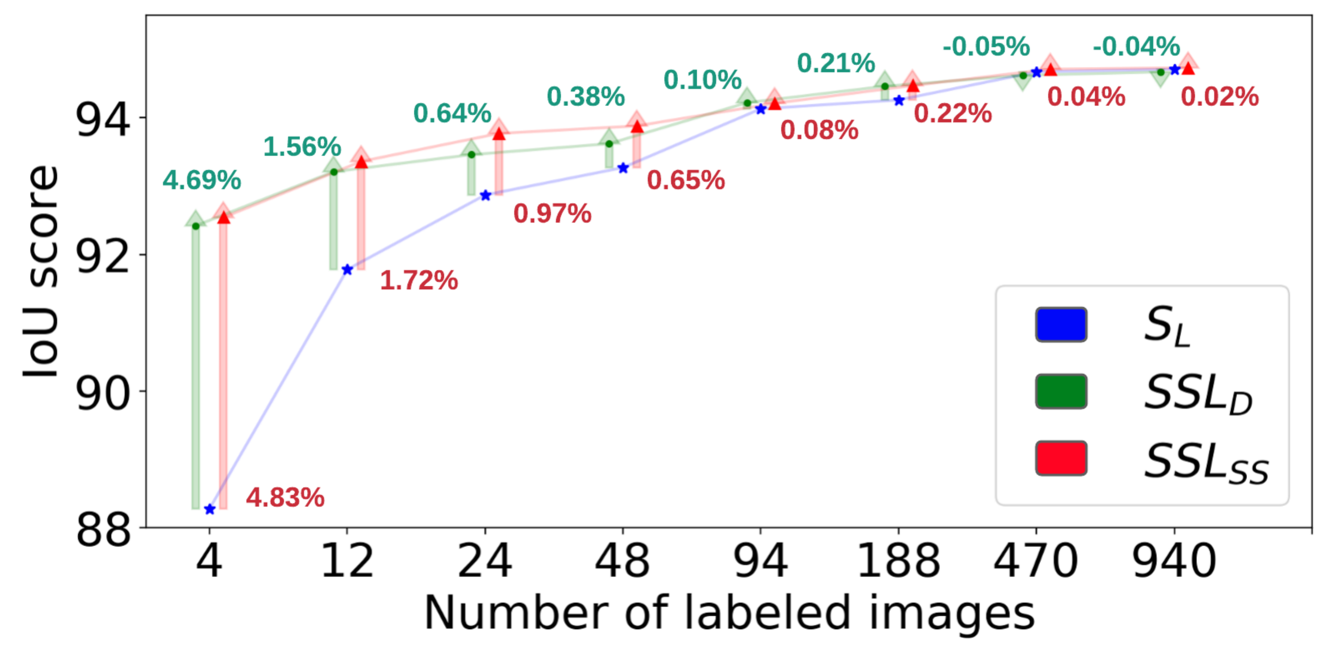


Fig: IoU score for three cases (S_L: blue, SSL_D: green, and SSL_{SS}: red) are shown with varying numbers of X_l and fixed X_u. The number alongside arrows indicate respective improvement (in %) over S_L.

Our Presence at ETRA 2021

- Enhancing the precision of remote eye-tracking using iris velocity estimation (Short Paper)
- Privacy-Preserving Eye Videos using Rubber Sheet Model (Short Paper)
- RIT-Eyes, realistically rendered eye images for eye tracking applications (Video)

Training with single subject

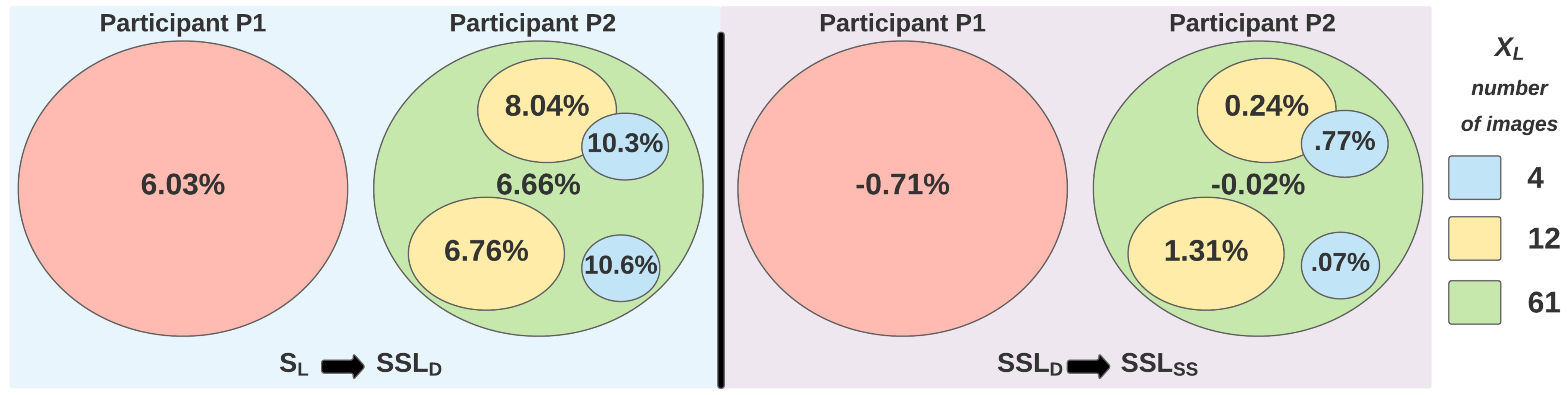


Fig: Demonstration of improvement (in %) for cases S_L to SSL_D (left) and SSL_D to SSL_{SS} (right) when models are trained on two subjects (red and green). For P2 (green), we further test the change in model performance for various subsets of X_l .

Eye part Segmentation

X_l	4	12	24	48	4 (P1)	12 (P1)	61 (P1)
% change	4.08 (4.48)	0.85 (1.37)	0.54 (0.99)	0.44 (0.78)	4.40 (7.32)	4.50 (6.12)	2.13 (4.09)

Fig: Comparison of % change of pupil and iris (inside parenthesis) class IoU scores for cases from S_L to SSL_{SS} for varying number of X_l and fixed number of X_u. P1 indicates samples from a single subject.

Qualitative Results

- **As the number of images increases**, the confidence in prediction and unwanted spurious patches are reduced when models are trained on S_L.
- For SSL approaches, **the confidence in prediction is more even when a small number of X_l are used.**
- **No significant difference** is visible for the **two SSL approaches**, which vary mostly in **finer details.**

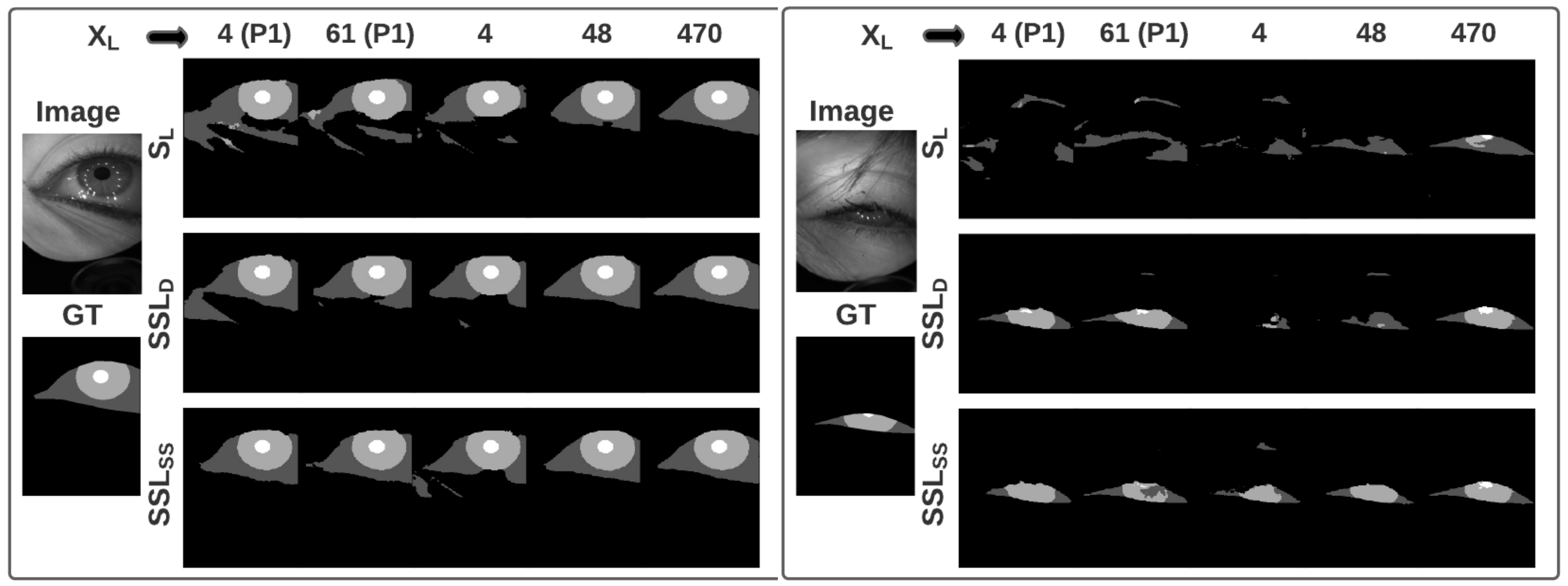


Fig: Two samples of the test set with its corresponding ground-truth and network predictions for the number of cases are shown in adjacent blocks.

Conclusion

- Frameworks to leverage **domain specific** augmentations and **novel spatially varying image transformations**
- Trained on just 4 and 48 labeled images, improvement by at least 4.7% and 0.4% respectively, in segmentation performance
- Future Work - Investigate the effect of curating labeled datasets (e.g., **considering eye position and blinks**) instead of random selection