Under- and over-segmentation: New metrics for image segmentation accuracy measurement Author links open overlay panel

A Preprint

Authors state that metrics such as IoU e.t.c fail to comprehensively assess boundary fidelity, topological errors, and class-imbalanced scenarios while segmentation tasks progresses rapidly. To solve this problem authors propose 3 metrics: under-segmentation index (US), over-segmentation index (OS), and a combined US-OS index, which quantify segmentation errors at both regional and boundary levels.

Firstly authors describe nowadays mainly used metrics and their limitations:

- Pixel Accuracy is one of the most common and fundamental metrics for evaluating image segmentation. It provides a straightforward and intuitive method for quickly assessing the performance of segmentation algorithms. However, the primary limitation is its lack of attention to the spatial alignment between the ground truth and the predicted segmentation
- Dice similarity coefficient. Its main challenge is its variable sensitivity to segment size(for example zone segmentation and line segmentation in the same task). When dealing with large segments, the DSC exhibits reduced sensitivity to minor changes, which can lead to inaccurate assessments in certain cases
- Jaccard similarity index (JSI) or intersection over union (IoU) measures the overlap between the predicted segmentation and ground truth. On the one hand, it handles class imbalance pretty well, while on the other hand it can be sensitive to small segmentation errors as it calculates overlap which is heavily affected by small changes
- Mean IoU (mIoU) provides balanced metric across all the metrics, however due to averaging across class dim it smooths out errors on rare classes

Due to previously mentioned limitations authors propose next metrics:

Under Segmentation(US)

It refers to a situation where segmentation algorithms fail to fully identify the actual boundaries of objects or regions of interest within an image. The US index is designed to identify false negative errors and quantify them in the image segmentation process. Using this metric can help identify regions in the image that require more attention, such as fine details or complex boundaries.

$$US = \frac{Y - (X \cap Y)}{Y} = \frac{Y - TP}{Y},$$

where X is pred and Y is GT

Over Segmentation (OS)

This metric becomes relevant when the segmentation algorithm mistakenly identifies parts of the image as belonging to the ground truth, while in reality mentioned regions actually belongs to other objects. The main

advantage is that this metric enables a more precise evaluation of object boundaries, identifying unnecessary and extraneous regions.

$$OS = \frac{X - (X \cap Y)}{Y}$$

where X, Y are in previous notation. When OS ≈ 0 this means that no over segmentation has occured

Combined US and OS

Evaluating segmentation models based solely on US or OS cannot provide a comprehensive view of the algorithm's actual performance. The combined US-OS addresses this limitation by simultaneously analyzing US and OS errors, enabling a deeper and more comprehensive analysis of segmentation algorithm performance.

$$US - OS = \frac{(X \cup Y) - (X \cap Y)}{Y}$$

The choice of denominator in the proposed US, OS, and US-OS metrics has profound implications for evaluating segmentations, particularly concerning small objects and cross-class comparability