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Robustness analysis of machine learning models for the task of vision-based inspection and measurement of cutting tools

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Introduction

Cutting tools used in mass production degrade rapidly, negatively impacting the quality of manufactured products. An accurate assessment of the degree of wear becomes a critical aspect for determination of regeneration parameters [1]. Authors proposed a machine vision system for inspecting the tooth rake faces of gear hobbing tools, enabling their dimensioning and unambiguous determination of the wear level. This system is based on machine learning (ML) image processing models, and it is therefore subject to all their limitations, such as a significant susceptibility to the variability of the input data character, which negatively impacts the model's accuracy [2][3]. For this reason, a number of tests are proposed to analyse the level of robustness of the developed model for the given task and to determine the extent of correct operation.

Materials and methods

For the evaluation, the authors prepared *YOLOv8l* instance segmentation models trained on (1) a set of 500 randomly selected images, (2) a full training set (1300 images), (3) a full set with additional custom augmentation (2530 images). Each model was trained with the same parameters – 60 epochs, batch size of 30 and same in-training standard YOLOv8 augmentations. Inference was assessed on a validation set subjected to a series of modifications. These modifications were intended to reproduce situations possible during industrial operation of the system resulting from changes in the acquisition conditions and included: (1) variable gaussian blur in the kernel size range from 0 to 35, (2) contrast modifications (alpha) from 0.1 to 3.0, (3) brightness modifications (beta) from -200 to +200 and (4) gamma modification from 0.15 to 3.0. As a result of the evaluation, the Mean Absolute Error (MAE) metric for the dimensioning of the tooth rake face was determined. These dimensions were determined as the length of the contour along the main axis (rake face length).

Results and discussion

The results of the conducted experiment are shown in Fig. 1. The data obtained for the three selected models allowed the determination of their areas of correct operation, which were substantially greater in all 4 cases for the model trained on the full training set with augmentations. This model also obtained the smallest MAE value for the reference point of 0.034 mm.

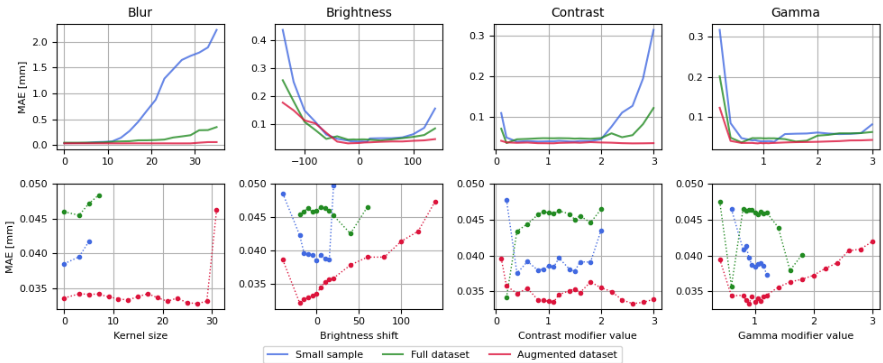

Fig. 1. Achieved MAE of tooth length after validation using different modification methods. The bottom row shows the range of correct operation (error below the accepted threshold).

Conclusions

Presented method allows the determination of a clearly interpretable dimensioning error metric under various conditions simulating changes in acquisition parameters in an industrial implementation. By analysing the obtained data, it is likewise possible to compare the robustness of the developed ML models.

References

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