Precision-driven Surface Segmentation via Neural Networks

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Abstract

With the increasing prominence of freeform structured surfaces in engineering surface metrology and manufacturing, the ability to accurately characterize these surfaces is paramount. These surfaces, featuring deterministic patterns tailored for specific functionalities, cater to diverse engineering requirements, including optical, electric contact, and bearing properties. Effective characterization optimizes performance, reduces costs, and enables precise control of these unique functional components. Segmentation, a pivotal step in characterization, divides the surface topography into distinct, non-overlapping regions. This facilitates isolated and comparative analysis, such as computing shape attributes or pertinent dimensions. Traditional computer-vision segmentation methods, like the watershed and active contour approaches, are computationally intensive, time-consuming, and often require user-tuning. Suboptimal initial conditions can also result in over- or under-segmentation. Emerging deep learning-based segmentation techniques offer superior accuracy and performance. In this context, we introduce an advanced surface segmentation approach, tailored for freeform structured surfaces. Our method harnesses the U-Net model combined with data augmentation techniques, effectively leveraging a raw dataset of twenty surface measurements. Training data comprises RGB images converted by surfaces and associated feature masks—these are ground truth pixel labels generated using computer vision techniques, including thresholding and manul fine-tuning. To amplify the accuracy of feature extraction, we've seamlessly integrated the Sobel operator into our neural network architecture. This addition acts as a pre-layer, magnifying boundary details and refining initial seeds for region-based segmentation. Post-training, our model adeptly outputs detailed feature maps with sharp boundaries. Experimental results underscore the method's exceptional performance in structured surface segmentation, fulfilling metrological prerequisites. Such advancements fortify our intelligent surface characterization framework, laying the groundwork for comprehensive feature attribute analysis and parameterization.

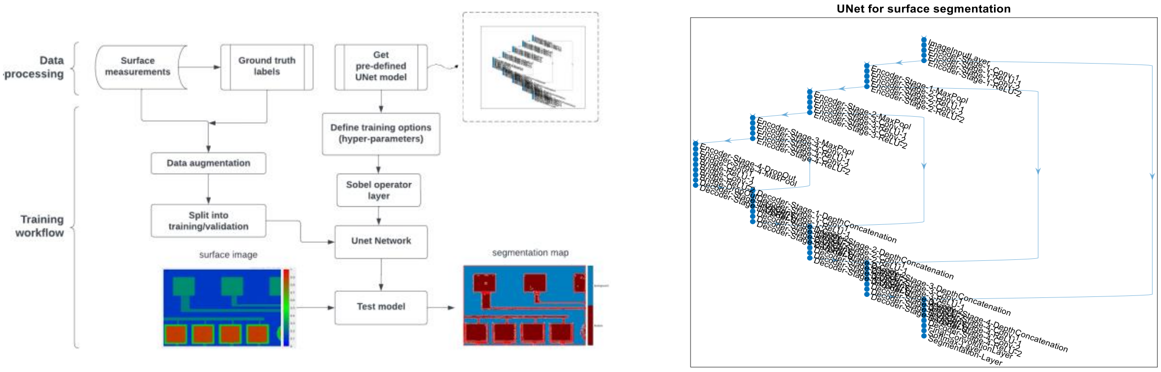

Figure 1: Framework of proposed learning-based surface segmentation