Texture-aware ridgelet transform for machined surface roughness characterization

This NSF-sponsored research (GRF-1937698 and CMMI-2040288) investigates a hybrid data analytic method for quantification of machined surface roughness represented by images from optical profilometry, through the integration of ridgelet transformation with random forest. Using Radon transform, the texture angle of the machine surface is identified first for each patch of a surface image to ensure alignment of the ridgelet with the texture (see **Fig. 1**). The rotation, translation, and scaling properties of the ridgelet allow for tailored surface characterization in terms of matching the dominant surface line directions as well as the varying spatial frequencies of the surface profile. Taking the scale powers of the ridgelet transform as input, the probability density function of the surface roughness is obtained using a random forest model and kernel density estimation, enabling accurate roughness prediction and uncertainty quantification.

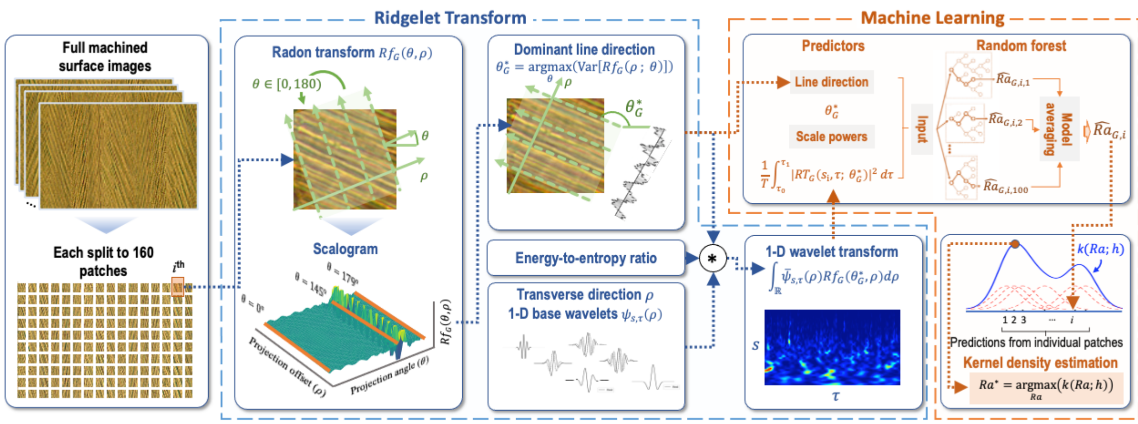

Fig. 1 Full-surface roughness prediction using ridgelet transform and machine learning

Experimental evaluation of machined H13 yielded 0.5% mean absolute percentage error (MAPE) and a coefficient of determination (R^2) of 0.99, in both the feed and stepover directions (**Fig. 2**). These results outperform the existing methods based on 2-D wavelet transform and CNNs and indicate ridgelet as an effective image processing approach for machined surface analysis.

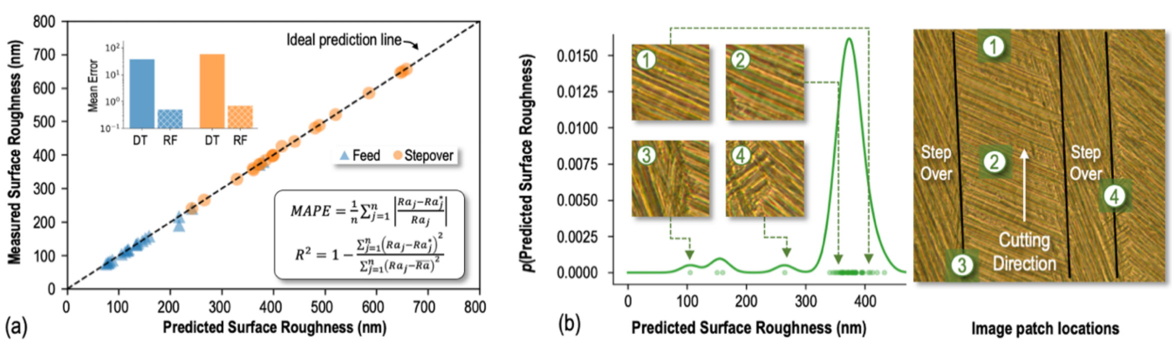

Fig. 2 (a) Roughness predictions compared to observed (DT: decision tree, RF: random forest); (b) kernel density estimate of full-surface roughness showing modal prediction of 385 nm as full-surface roughness

Related Publication

[1] C. Cooper, J. Zhang, L. Hu, Y. Guo, and R. X. Gao*, "Texture-Aware Ridgelet Transform and Machine Learning for Surface Roughness Prediction," *IEEE Trans. Instrum. Meas.*, vol. 71, pp. 1–10, 2022, doi: 10.1109/TIM.2022.3214630.