

VISION-BASED EVALUATION OF POSITIONING REPEATABILITY IN PROBE-BASED MICRO-SCALE SYSTEMS

Ujjawal Malani^{1,2}, Jurate Jolanta Peateroniene¹, Andrius Dezdicis¹, Vytautas Buchinskas¹

¹Vilnius Gediminas Technical University, Mechanics faculty, Department of Mechatronics, Robotics, and Digital Manufacturing, Vilnius, Lithuania

²Center for Physical Science and Technology, Department of Functional Materials and Electronics, Vilnius, Lithuania
ujjawal.malani@stud.vilniustech.lt

Electrochemical investigation and surface engineering of living cells using ultramicroelectrodes require highly reliable probe positioning and accurate return-to-origin behavior. In probe-based systems such as Scanning Electrochemical Microscopy (SECM), SECM is a probing system used to measure chemical reactivity on the surface of the subject [1], small trajectory-dependent deviations in the positioning system can affect probe approach safety and measurement repeatability.

This study presents a vision-based approach for characterizing motion deviations in a Cartesian positioning system intended to support electrochemical probe-based experiments[2]. A CMOS camera was used to track the shadow of a platinum ultramicroelectrode at the return-to-origin position following repeated motion cycles. Image sequences were analyzed using a centroid-based intensity method to estimate positional deviations associated with different motion trajectories and feed rates.

The method was applied to representative linear and multi-axis trajectories relevant to probe positioning tasks. Experimental results show that, for most tested conditions, return-to-origin deviations remained below 2 μm , with maximum observed deviations on the order of 4 μm for certain trajectory and feed-rate combinations.

The results indicate that the vision-based deviation characterization enables reliable estimation of micrometer-scale positioning errors and provides a practical diagnostic tool for supporting ultramicroelectrode positioning in electrochemical investigations. This approach contributes to the development of stable motion platforms for living cell surface engineering and related probe-based micro-scale applications.

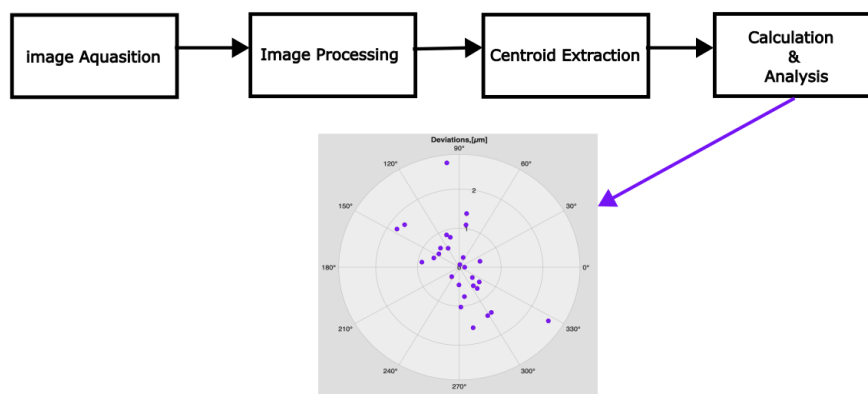


Fig. 1. Workflow diagram: Image acquisition using a CMOS sensor, image processing including grayscale conversion and filtering, centroid extraction based on intensity, calculation of positional deviations, and analysis of results. Most measured deviations were $\leq 2 \mu\text{m}$.

[1] I. Morkvenaite-Vilkonciene, A. Valiūnienė, J. Petroniene, and A. Ramanavicius, "Hybrid system based on fast Fourier transform electrochemical impedance spectroscopy combined with scanning electrochemical microscopy," *Electrochemistry Communications*, vol. 83, pp. 110–112, Sep. 2017, doi: 10.1016/j.elecom.2017.08.020.

[2] V. Ivinskij et al., "Fast detection of micro-objects using scanning electrochemical microscopy based on visual recognition and machine learning," *Ultramicroscopy*, vol. 259, p. 113937, Feb. 2024, doi: 10.1016/j.ultramic.2024.113937.