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Beam emittance and Twiss parameters from pepper-pot images using physically informed neural nets

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In the field of accelerator physics, the quality of a particle beam is a multifaceted concept, encompassing characteristics like energy, current, profile, and pulse duration. Among these, the emittance and Twiss parameters —defining the size, shape, and orientation of the beam in phase space—serve as important indicators of beam quality. Prior studies have shown that carefully calibrated statistical methods can extract emittance and Twiss parameters from pepper-pot emittance meter images. Our research aimed to retrieve these parameters with machine learning (ML) from a transverse image of the beam after its propagation through a pepper-pot grid and subsequent contact with a scintillating plate. We applied a Convolutional Neural Network (CNN) to extract the x and y emittances and Twiss parameters (α and β), producing a six-dimensional output by simply looking at the image without calibration information. The extraction of divergence-dependent parameters, such as α and emittance, from a single image presented a challenge, resulting in a large Symmetric Mean Absolute Percentage Error (SMAPE) of 30%. To mitigate this issue, our novel method that incorporated image data from two points along the particles' propagation path yielded promising results. β prediction achieved a low SMAPE of 3%, while α and emittance predictions were realized with a 15% SMAPE. Our findings suggest the potential for improvement in ML beam quality assessment through multi-point image data analysis.

Footnotes

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