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Physics-constrained 3D convolutional neural networks for electrodynamics of relativistic charged particle beams

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We present a physics-constrained neural network (PCNN) approach to calculating the electromagnetic fields of intense relativistic charged particle beams via 3D convolutional neural networks. Unlike the popular physics-informed neural networks (PINNs) approach, in which soft physics constraints are added as part of the network training cost function, our PCNNs respect hard physics constraints, such as $\nabla \cdot B=0$, by construction. Our 3D convolutional PCNNs map entire large (256×256×256 pixel) 3D volumes of time-varying current and charge densities to their associated electromagnetic fields. We demonstrate the method on space charge dominated, relativistic (5 MeV), short (hundreds of fs), high charge (2 nC) electron beams, such as those in the injector sections of modern free electron laser and plasma wakefield accelerators. We show that the method is accurate, respects physics constraints, and that the trained 3D convolutional PCNNs perform electromagnetic calculations orders of magnitude faster than traditional solvers which require a O(N2) process for calculating the space charge fields of intense charged particle beams.

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Footnotes

I have read and accept the Privacy Policy Statement

Yes

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