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An enrichment approach for enhancing the expressivity of neural operators with applications to seismology

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The Eikonal equation plays a central role in seismic wave propagation and hypocenter localization, a crucial aspect of efficient earthquake early warning systems. Despite recent progress, real-time earthquake localization remains challenging due to the need to learn a generalizable Eikonal operator. We introduce a novel deep learning architecture, Enriched-DeepONet (En-DeepONet), addressing the limitations of current operator learning models in dealing with moving-solution operators. Leveraging addition and subtraction operations and a novel `root' network, En-DeepONet is particularly suitable for learning such operators and achieves up to four orders of magnitude improved accuracy without increased training cost. We demonstrate the effectiveness of En-DeepONet in earthquake localization under variable velocity and arrival time conditions. Our results indicate that En-DeepONet paves the way for real-time hypocenter localization for velocity models of practical interest. The proposed method represents a significant advancement in the field of operator learning and uses it to solve an outstanding challenge in seismological research. The proposed method represents a significant advancement in operator learning that is applicable to a gamut of scientific problems, including those in seismology, fracture mechanics, and phase-field problems.