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Bridging Experimental shadowgraphs and DNS in Turbulent Convection Using physically-informed U-Net

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Shadowgraph data holds significant potential, as it incorporates depth-of-field effects, enabling the extraction of richer physical information [1, 2]. The integration of physical information into it using Physics-Informed Neural Networks (PINNs) has been shown to successfully reconstruct flow fields in compressible, inviscid flows [3]. In this study, we aim to extract 3D field information from experimental shadowgraph data of turbulent convection using a trained deep learning model. Specifically, we employ a U-Net architecture to predict the temperature field over a 2D slice from shadowgraph. However, ground-truth field data is often unavailable or incomplete from experiments. Therefore, as first step, we use numerical shadowgraphs (simply modeled as Laplacian of temperature field) as input and temperature field as output from direct numerical simulation (DNS). Preliminary results, presented in Figure 1, highlight the potential of this approach. Furthermore, we investigate the feasibility of simultaneously extracting velocity fields alongside temperature fields. Finally, we apply the trained model to experimental shadowgraph images as DNS complements the experimental conditions.

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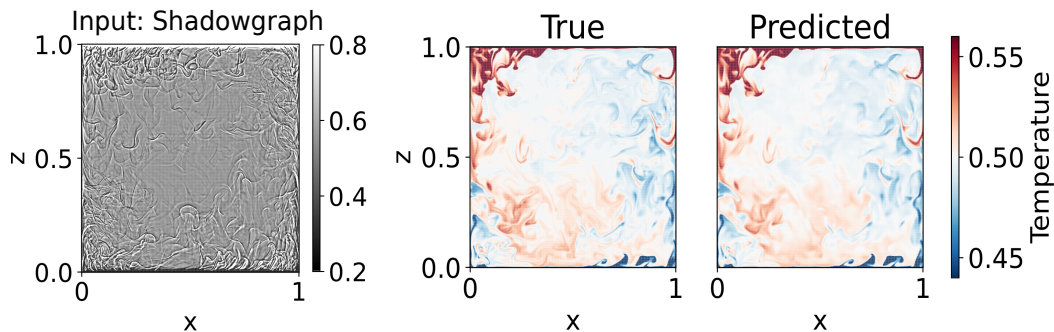


Figure 1: Results for predicting temperature field for a slice at a particular timestep in test-data from DNS simulation at Rayleigh number of 5×10^9 for the given shadowgraph image to U-Net, predicting highly accurate temperature field as output.

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