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Dedication lecture

MACHINE LEARNING APPROACHES TO INVERSE RADIATIVE TRANSFER

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ABSTRACT. Modeling the transport of radiation energy through a scattering-absorbing medium is complicated due to multiple scattering encountered by the electromagnetic energy as it traverses the domain. The resulting mathematical models of radiative intensity propagation are integro-differential in nature that are difficult to solve analytically or numerically. Inverse radiative transfer is similarly impacted. Such inverse problems are ill-posed, necessitating special solution techniques. A recent example is optical tomography, where the reconstruction of property fields is desired from the radiative intensity or flux measurements at discrete locations at the boundaries.

The current state-of-the-art algorithms for inverse radiative transfer are able to qualitatively reconstruct the property distributions of absorption and scattering coefficients in the participating domain, but their accuracy is not at a stage where they can be used in any application. Interfaces within the domain where there is a sharp transition of property values cannot be accurately predicted in most cases, and property variations are shown as smooth gradients. Similarly, sharp corners are smoothed and shapes are approximated by gradually curving surfaces in the inverse problem.

In this presentation, machine learning techniques for inverse radiative transfer are discussed. A simple machine learning approach using neural networks is formulated and implemented to examine the feasibility of an alternative technique for inverse problems. It is shown that this simple formulation can predict the property fields with high fidelity, even when the data is noisy. Parameters related to the neural network configuration, and the construction of appropriate loss function to be minimized, are examined via this simple model. With a proper selection of configuration and loss function, the resulting image correlation coefficient between the actual and predicted images is almost unity for the cases considered, indicating a near-perfect image reconstruction. In comparison, traditional (non-machine learning based) methods have significantly poorer image correlation. Advanced neural networks, such as physics-informed networks are also considered that allow more complex geometries and property distributions to be accurately handled. It is seen that machine learning approaches offer a very promising path forward at present for inverse radiative transfer and image reconstruction in highly scattering media.