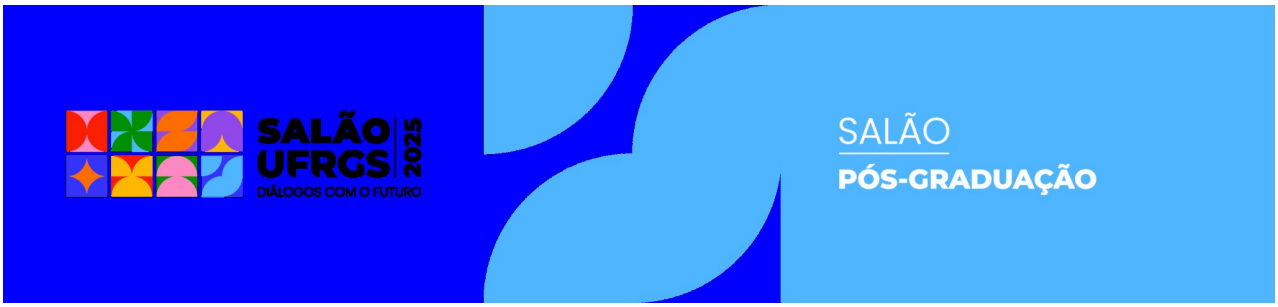


Evento	Salão UFRGS 2025: I SALÃO DA PÓS-GRADUAÇÃO
Ano	2025
Local	Campus do Vale - UFRGS
Título	Nonlinear regression in inverse problems of neutral particle transport: an approach with the MoC method and MLP networks
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ABSTRACT: Modeling neutral particle transport is fundamental to various scientific and technological fields, including heat transfer in participating media and neutron transport in nuclear reactors. Applications include radiotherapy, astrophysics, geophysics, and optical tomography, among others. In this context, inverse problems allow us to estimate internal transport parameters based on external measurements. This study applies a combination of the method of characteristics (MoC) and multilayer perceptron (MLP) neural networks to solve inverse problems described by the monoenergetic Boltzmann integro-differential equation in one-dimensional geometry. This approach considers isotropic scattering and time dependence. The goal is to estimate the absorption coefficient and source parameters. These estimations are essential for precisely understanding the physical processes involved and enable anything from controlling nuclear reactions to performing noninvasive diagnostics in biological systems. This methodology uses synthetic data generated by a direct solver based on the MoC and MLP as nonlinear regression models. These networks employ the ReLU (Rectified Linear Unit) activation function to accelerate training and favor better convergence of the parameters. Additionally, the input data were preprocessed using the standard scaler to improve training performance. We validated the MoC implementation through a manufactured solution and applied the methodology in five case studies: two for estimating the absorption coefficient in homogeneous and heterogeneous media and three for source characterization. Regarding the estimation of the absorption coefficient, the model performed remarkably well. The MLP achieved determination coefficients of $R^2_{\text{train}} = 0.9998$ for training and $R^2_{\text{valid}} = 0.9998$ for validation. In the heterogeneous case, we assessed the model's sensitivity to different noise levels in the input data. The results indicate that the MLP remains stable under low and moderate noise levels,with noise propagating to the output by a factor of approximately 3.4. Notably, the model maintained $R^2_{\text{valid}} > 0.85$ with noise up to 5%, demonstrating good generalization capacity. For parameter estimation in inverse problems of source characterization, modeling was carried out in the steady state. The MLP model demonstrated excellent training performance in all three cases, achieving an $R^2_{\text{train}} = 0.9998$. Validation with noise for the first case showed $R^2_{\text{valid}} > 0.90$, even with noise up to 10%, reaching a noise propagation factor of 1.65 to the output. However, in the last two cases, the MLP model was highly sensitive to noise in the input data, which compromised the stability of the estimates. To mitigate this sensitivity, time-dependent modeling was introduced by shifting from a steady-state formulation to a transient one. In the transient formulation, detectors were incorporated at the domain boundaries to capture scalar fluxes at different discrete time steps. This adaptation captured additional dynamic information from the system and significantly reduced noise sensitivity; the propagation factor decreased from 10.55 to 0.2. For the third problem, the propagation factor decreased from 4.0 to 0.05. These results reinforce the feasibility and potential of the method, highlighting the importance of selecting appropriate data to ensure reliable estimates and the model's good generalization capacity. Future work aims to develop and apply a hybrid approach that couples the MoC with deep learning techniques to solve inverse problems in two-dimensional optical tomography of heterogeneous media.

KEYWORDS: Inverse Transport Problems; Artificial Neural Networks; Method of Characteristics.