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Solving the Discretised Flow Equations on Structured Grid using Machine Learning: Applications in Urban Flows Dynamics

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Recently, there has been a huge effort focused on developing highly efficient open-source libraries designed for Artificial Intelligence (AI) related computations on different computer architectures (for example, CPUs, GPUs and new AI processors). These advancements have not only made the algorithms based on these libraries highly efficient and portable between different architectures, but also has substantially simplified the entry barrier to develop methods using AI. Here, we present a novel methodology to leverage the power of both AI software and hardware into the field of numerical modelling by repurposing AI methods, such as Convolutional Neural Networks (CNNs), for the standard operations required in the field of the numerical solution of Partial Differential Equations (PDEs). CNNs are formed by the most popular AI libraires, Pytorch, in order to solve the incompressible flow equations on structured mesh through a finite element discretisation and a rapid multi-grid solution method. The proposed methodology is applied to develop a model of the airflow around many buildings and demonstrate high-fidelity simulation of urban flows using multiple GPUs, relevant to air pollution and flooding modelling. We also show how the Finite Element Method (FEM) can be modified for quadratic and higher order elements; in which case we can simplify the implementation of discrete FEM equations using CNNs filters. The results are validated with previous studies and indicate that the methodology can solve such problems using AI libraries in an efficient way, and presents a new avenue to explore in the development of numerical methods to undertake large-scale simulations.

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