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GPU Accelerated Nonlinear FEA of RC Beams using the ML-based Material Model

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ABSTRACT

A materially nonlinear finite element analysis (FEA) of reinforced concrete (RC) beams with the adoption of a machine learning (ML) based material model is performed in this paper. Among the ML-based material models that can compensate for the coarseness in the conventional constitutive material models induced by the limited amount of experimental data and have the flexibility for the supplementation of additional experimental data, the Gaussian process approach is considered to construct the material models of concrete and steel. Even with many benefits including accuracy and reliability, however, the ML-based material model requires a drastic increase in the computational cost and memory consumption. In addition, it is difficult to use in the nonlinear analysis of large complex RC structures composed of numerous members. To address this limitation, optimization and computing strategies with ML-integrated FEA is designed in this paper. The hardware acceleration is based upon the constitution of a parallelized computing structure, and a Python-based FEA process is developed to trace the nonlinear behavior of RC beams. Comparison with experimental data for two representative RC beams is performed to verify the efficiency and reliability of the introduced solution procedures. The load-displacement response of the beams corresponded with the experimental data, especially the load at the yielding point of the rebar showed less than a 2.28% difference, and the ultimate load showed less than a 1.55% difference. The optimized programme scaled up to 210, 000 DOFs with 24GB of GPU memory space. The speedup of acceleration over the 32-core computer was up to 6 times in terms of wall clock time and showed a linear trend of time increase along with the increase of DOFs, while the non-accelerated or non-optimized programme showed a polynomial increase.

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