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Physics-Informed Learning of Return-Mapping Operators for Anisotropic Elastoplastic Constitutive Integration

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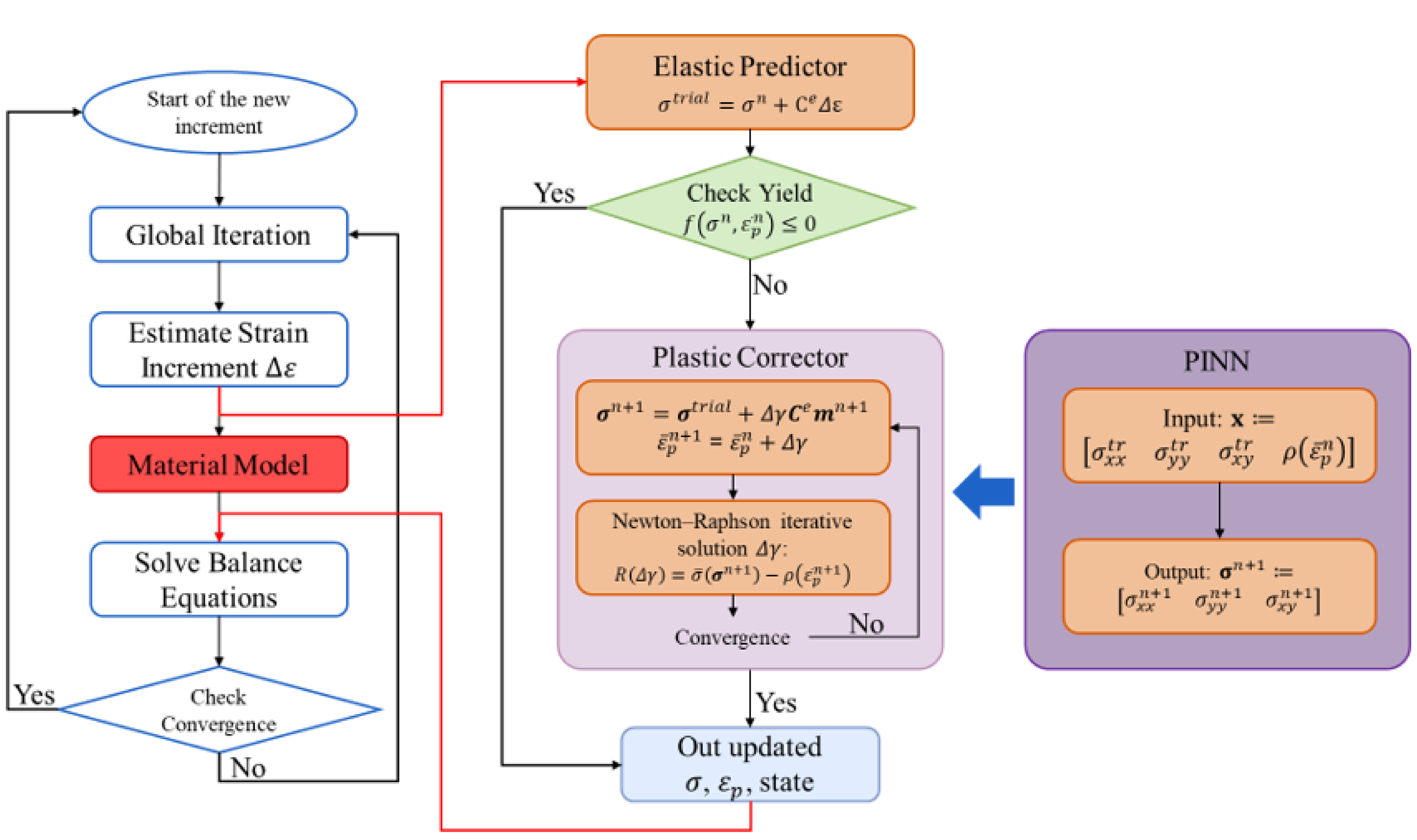
Introduction

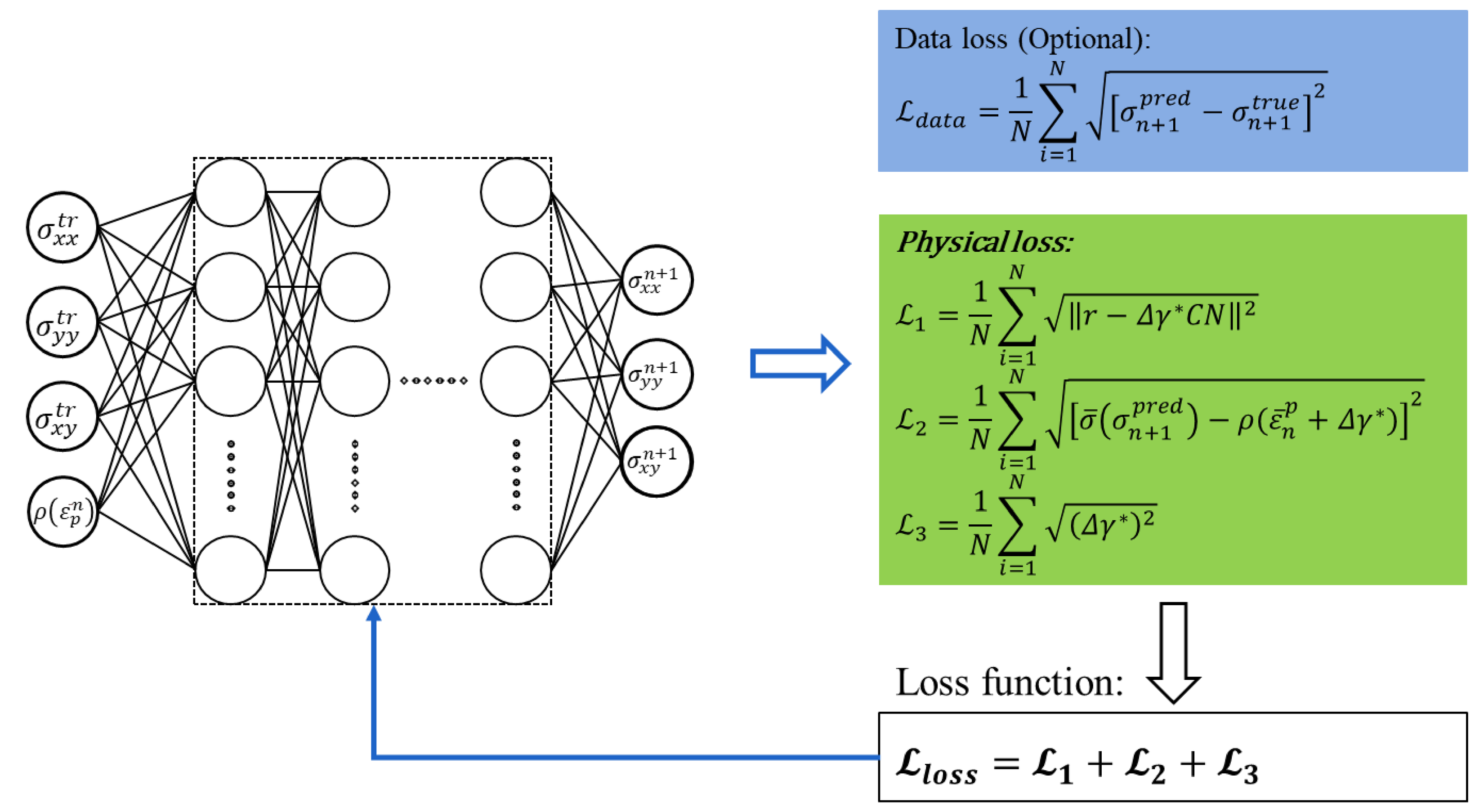
This work proposed a PINN-based constitutive model for learning the stress-update mapping of a plane-stress elastoplastic system characterized by anisotropic yielding and isotropic hardening. The proposed approach is built upon the classical fully implicit return-mapping algorithm and aims to replace the nonlinear plastic correction step with a trained neural network while preserving intrinsic physical consistency.

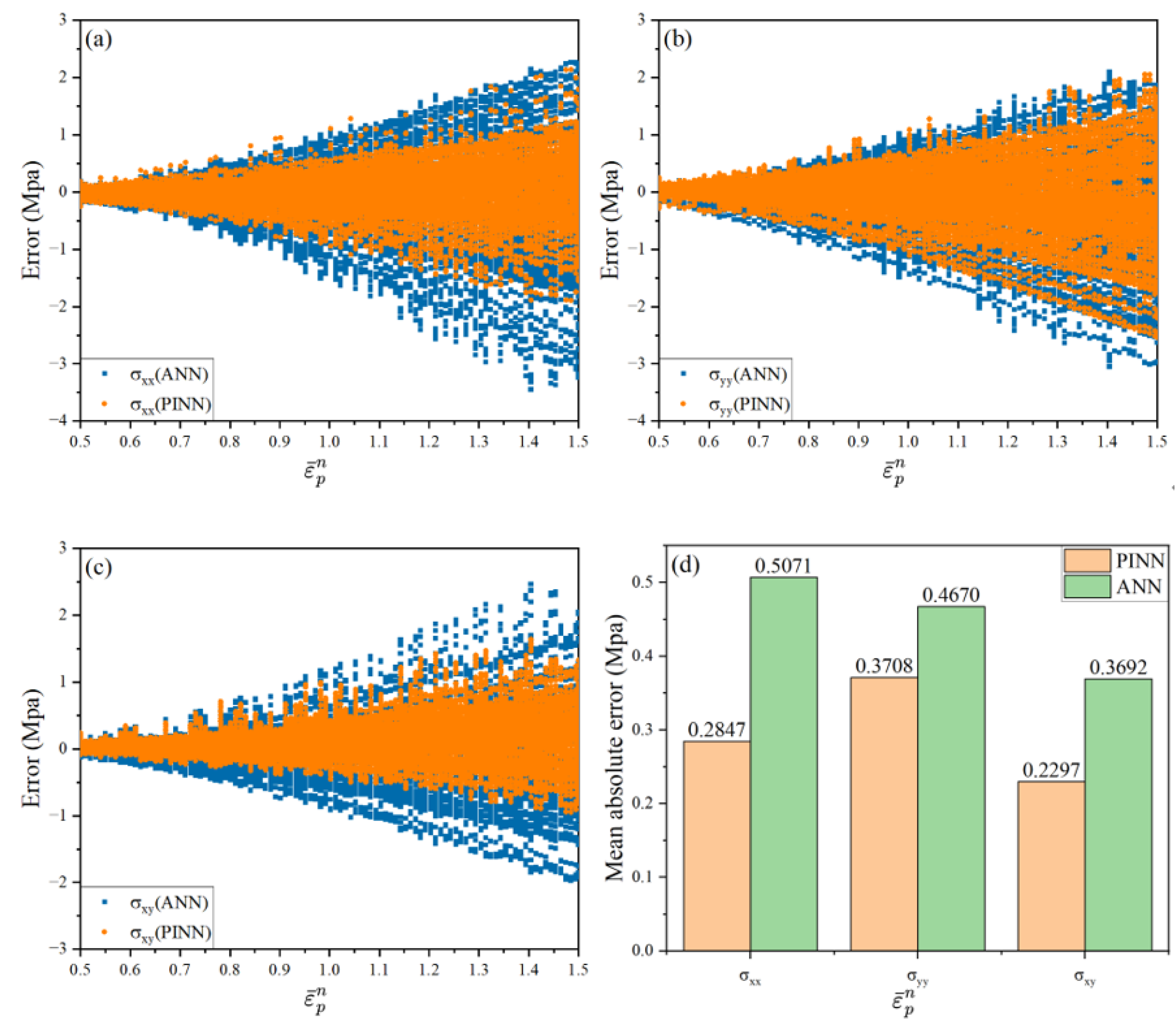
Methods

Reference stress updates are generated using CPPM, which provides a physically consistent foundation for dataset construction and network training. By embedding constitutive principles such as yield criterion, plastic flow rule, and consistency requirements into the loss function, the proposed PINN offers a promising framework for developing robust and physically consistent constitutive surrogate models.

Graphics / Images







Conclusions

By embedding yield consistency condition into the physics loss, the proposed PINN is able to recover an accurate stress-update operator and can be directly integrated into an Abaqus UMAT for finite element simulations. Comprehensive validations were performed at both the material-point and structural levels. PINN-based constitutive model reproduces the analytical CPPM-based model reference responses with high fidelity in single-element benchmark tests and maintains stable performance in a circular cup deep drawing simulation. Moreover, when evaluated on an out-of-domain strain interval not included in training domain, PINN exhibits lower prediction errors than a purely data-driven ANN, indicating the benefit of incorporating physics constraints in the learning process.