A cooperative game for automated learning of constitutive models with AI-guided experimentation

Foundations of Data Science
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Automated data collections and learning of material constitutive models

We introduce a meta-modeling approach to find the optimal configuration of a constitutive law that hybridizes existing theory from domain experts and data-driven models for blind predictions. In the case where availability of data is limited, the meta-modeling algorithm also explores the weakness links in the constitutive laws and explore the optimal set of experiments to yield the best forward predictions under a limited budget.

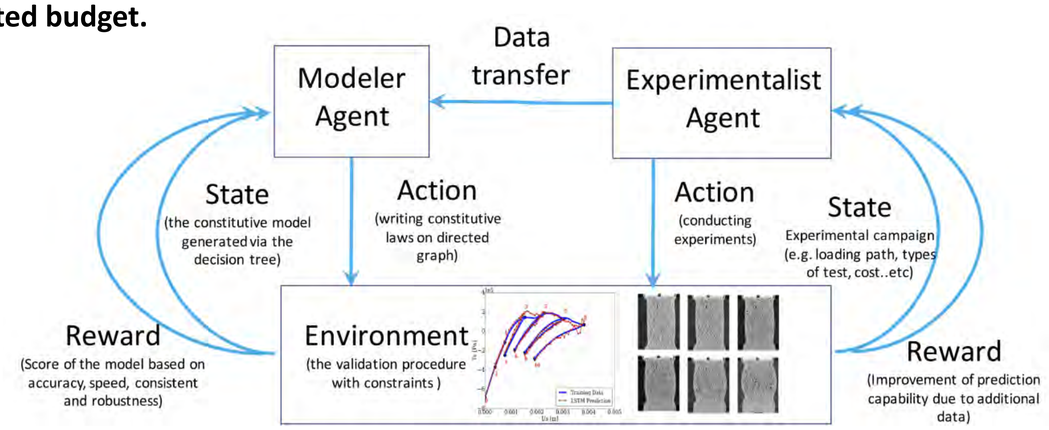


Figure 1. Scheme of the reinforcement learning algorithm in which two agents interact with environment and receives rewards for their corresponding actions (writing models and conducting experiments)

Method: Deep reinforcement learning of directed multi-graphs of material constitutive models

The constitutive models are conceptualized as information flow in directed graphs. The process of writing constitutive models is simplified as a sequence of forming graph edges with the goal of maximizing the model score. The computer agent is able to efficiently self-improve the constitutive model it generated through self-playing, in the same way AlphaGo Zero improves its gameplay.

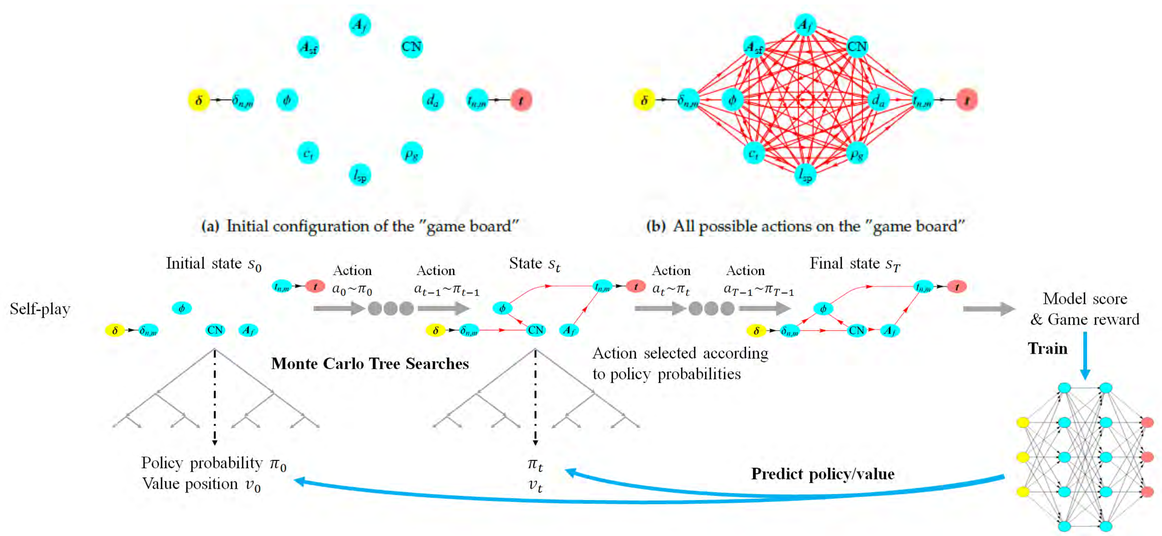
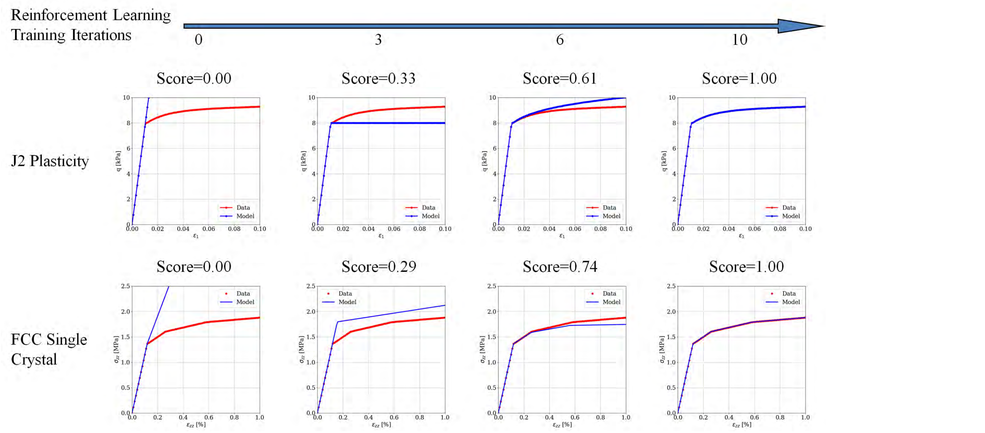


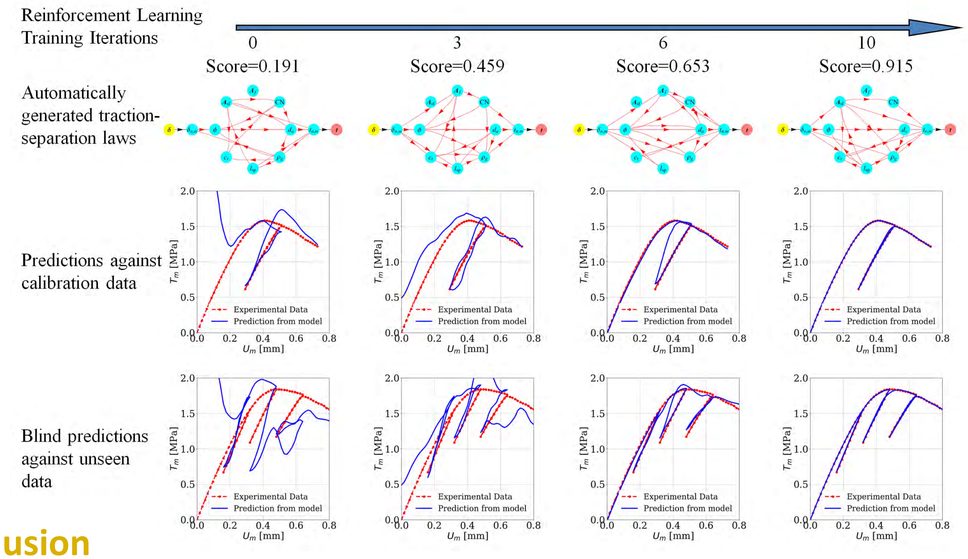
Figure 2. Self-play reinforcement learning of traction-separation models from experimental data.

Numerical Experiments

Knowledge of elasto-plastic models learned by deep reinforcement learning



Data-driven discovery for enhancement of traction-separation models



Conclusion

The meta-modeling approach automates the data collections and the model discover processes, which provides great assistance to both experimentalists and modelers. The framework is generic and easily expandable. It can handle different situations with different data, objective functions and rules set by human without additional derivation, implementation and validation.

Acknowledgments

The corresponding authors' work is supported by the National Science Foundation under grant contract CMMI-1462760, and the 2018 Interdisciplinary Research Seed funding from Columbia University.

References

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2. **Wang, Kun, and WaiChing Sun. "Meta-modeling game for deriving micro-structural traction-separation laws via deep reinforcement learning." arXiv preprint arXiv:1810.10535 (2018).**