Advancing Deep Learning by Leveraging Physical Knowledge for Scientific Discovery

Motivation
• We aim to build new physics-guided machine learning methods that leverage complementary strengths of physics and machine learning
• Physics-based (mechanistic) models use approximations and imperfect parameterization and thus are approximations of reality.
• Machine learning methods often require large training data and also cannot generalize to out-of-sample scenarios.

Project Description
• We will explore new methods to integrate physical knowledge into machine learning
  • New deep learning architectures that naturally incorporate relationships amongst physical variables
  • New learning strategies that can leverage physical simulations
  • Implement algorithms for monitoring water temperature in Delaware River Basin

Promise
• Initial results: incorporating physics into an RNN model can significantly improve the predictive model given limited training samples.

Figure: Physics-guided deep learning outperforms both process-based and blackbox deep learning approaches for predicting lake water temperature, across the entire range of training temperature profiles.

Potential Impact
• This project, if successful, will advance existing machine learning algorithms to be better suited for scientific problems.
• This research will have a broad reach and will contribute to real-world problems of great societal needs.

Project Deliverables
• New deep learning architectures that integrate interactions amongst rivers, climate, and reservoirs in Delaware River Basin.
• The proposed method can be widely applied to a broad range of scientific problems where physics-based models are being used.
• We will publish our methods and results in data mining and AI conferences.
• We will also work with government agencies to apply proposed methods for predicting water temperature in large-scale river networks.

References and/or Acknowledgements

• Can we build new deep learning architectures that reflect relationships amongst modular or functional components in physics-based models?
• Can we better leverage physical simulations?