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Discovering interpretable physical models using Symbolic Regression and Discrete Exterior Calculus

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Computer simulations aim to replicate physical phenomena as precisely as possible, but they often require extensive knowledge and rely on differential equations, which typically lack analytical solutions. The recent rise of Machine Learning, driven by large amounts of data, has offered an alternative to traditional human-designed methods. However, these data-driven approaches produce complex, black-box models that are hard to manage and interpret. To address this, Symbolic Regression (SR) has gained popularity for its ability to derive understandable mathematical equations from data. Nevertheless, most prior research only focused on re-discovering conventional physics equations or dynamical systems described by ordinary differential equations.
To further push the boundaries of the existing methods, we developed a framework that integrates SR with Discrete Exterior Calculus (DEC) for automated discovery of field theories. DEC provides a discrete geometric representation of physics, avoiding the need for differential formulations and employing a concise set of operators. This approach significantly reduces the SR search space, improving generalization even with limited data. We validated our framework by successfully re-discovering multiple Continuum Physics models using synthetic experimental data.

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