AID: A Reinforcement Learning Framework for Iterative Optimization of Aerodynamic Elements

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The engineering design process uses repeated steps to produce the desired design. It starts by identifying a problem, researching it, brainstorming solutions, prototyping, testing, and iterating until a satisfactory result is reached. Yet, engineers face a major challenge: regulation. Engineering systems must undergo rigorous testing before deployment, making the process very time-consuming as design, optimization, testing, and trial and error aim to meet or bypass regulatory demands. Often, engineers must repeatedly create or modify designs using CAD software, build prototypes, test them, and start again. What if AI could assist in this process? Methods for generating and editing 3D meshes exist, such as LLaMA-Mesh, but these are data-driven, with actions based on learned patterns instead of clear, step-by-step reasoning. Earlier work in iterative design used reinforcement learning to optimize airfoil designs by adjusting spline control points, though that applied only to 2D airfoils. In this work, we develop a reinforcement-learning-powered pipeline to optimize 3D models while enforcing physical constraints from fluid simulations to aid human design. The pipeline uses a mathematical encoding/decoding method with 256x256 spherically parameterized geometry images and a pixel-based reinforcement learning algorithm. For proof-of-concept, we focus on optimizing a drone propeller mesh to improve its lift-to-drag ratio from a baseline, though the pipeline can adapt to most aerodynamic designs by modifying the CFD environment and the reinforcement learning loss function. The pipeline proved effective: a low quality propeller's lift improved from 3.879N to 14.44N, drag stayed around 2.76N, and the lift-to-drag ratio rose from 1.4 to 2.3.

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