PARAMETRIC MECHANISM DESIGN THROUGH NUMERICAL OPTIMIZATION AND PHYSICS SIMULATION. A. Schepelmann, NASA Glenn Research Center, 21000 Brookpark Rd., Cleveland, OH 44135

Design-Build-Test approaches for developing space-flight hardware are prohibitively time and cost intensive and often lead to suboptimal mechanism designs [1]. Approaches that couple machine learning and high-fidelity physics simulation could eliminate the need for hardware prototyping and dramatically accelerate the engineering design cycle, ultimately reducing cost [2][3]. This work presents a modular NASA-developed toolchain to optimize hardware mechanisms in a virtual environment using numerical optimization and multi-body physics simulation.

The developed toolchain enables multi-objective optimization, generates parametric CAD files that can be further post-processed by an end user, and can be expanded to optimize full systems and non-mechanical parameters such as feedback control variables. We demonstrate the toolchain through an independently verifiable design problem that optimizes wheel radius to achieve a desired linear velocity in a rigid-body physics environment when the wheel rotates at a constant angular speed (Figs. 1-2), and then post-process the parametric CAD file of the optimal design generated by the tool (Fig. 3) before ultimately manufacturing it via 3D printing (Fig. 4). We end with a discussion of how the toolchain can incorporate other analysis tools, including finite element analysis, computational fluid dynamics, and granular media simulations.

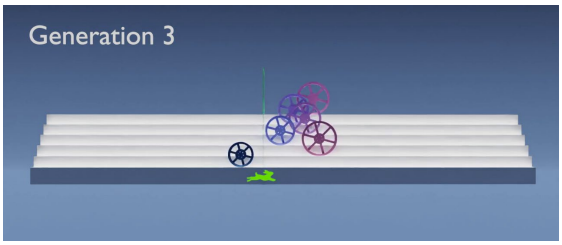

Figure 1: Simulation environment.

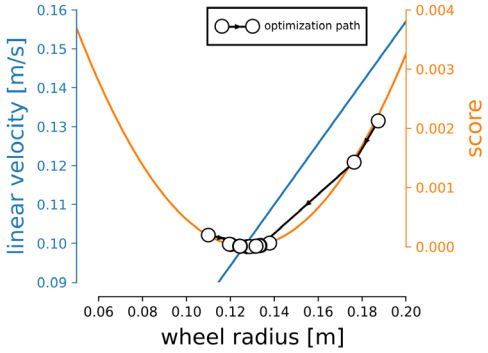

Figure 2: Cost space and optimization path.

Figure 3: Optimized mechanism (L) and post-processed geometry.

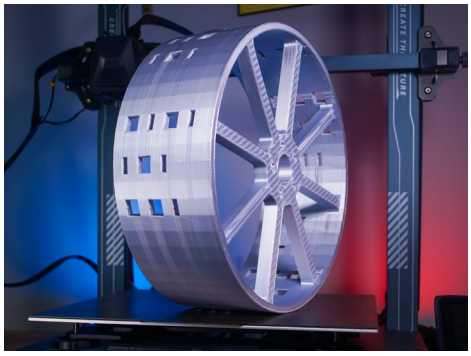

Figure 4: Manufactured hardware.

References:

[1] Inotsume, H. et al. (2019) "Parametric study and design guidelines for rigid wheels for planetary rovers." *J. Terramechanics*, 85, 39-57.

[2] Schepelmann, A. et al. (2018) "Experimental evaluation of robust swing-leg placement controls in robotic limb testbeds." *CMU-RI-TR-18-62*.

[3] Schepelmann, A. et al. (2022) "High-fidelity simulation of the Advanced Planetary Excavator (APEX) manipulator for in-situ resource utilization technology development." *Space Resources Roundtable XXII Meeting*.