Predictable Behavior During Contact Simulation: A Comparison of Selected Physics Engines (Supplementary Material)

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A. Parameter Tuning in Finer Increments

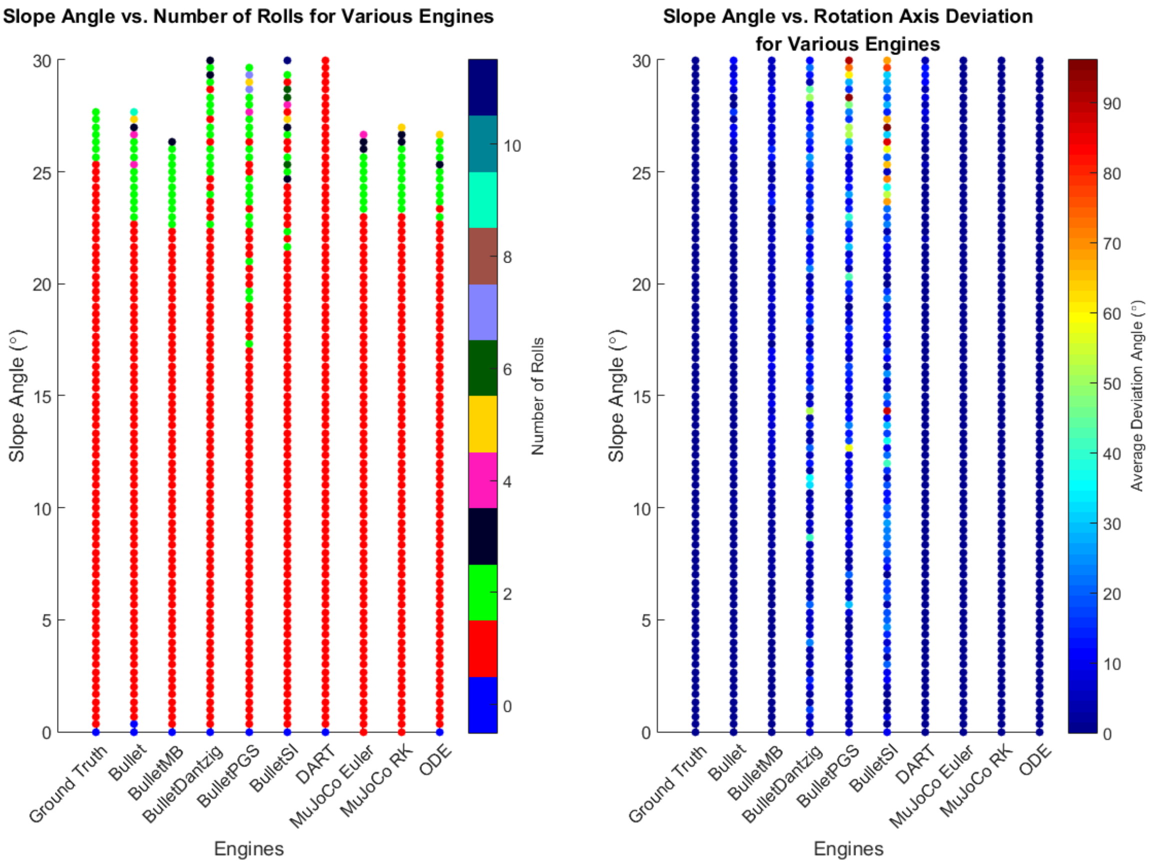
After observing some oddities in Bullet and ODE during the first experiment (section 5.1 in the main article), we have decided to run the parameter tuning in finer increments for a stricter match to the ground truth. Instead of the original 1° increments, we tried 0.33° increments.

The new chosen values are shown in table 1 with the changed values highlighted in red. We can see that Bullet and BulletMB had many of the parameters changed, which can be attributed to its less predictable simulation results. MuJoCo Euler moved toward a flat impedance function which suggests that it needed harder constraints in order to better match the ground truth number of rolls. MuJoCo RK also yielded a similar preference toward harder constraints with higher dmax, and smaller width. DART did not incur any changes in its parameter, and ODE just preferred a higher number of iterations to better match ground truth number of rolls.

The new number of rolls and average rotation axis deviation plots are shown in figure 1. Here, most engines do a similar job in matching the number of rolls in ground truth with comparable average rotation axis deviation. We can clearly see that Bullet's chosen Lemke solver outperforms all of the other MLCP solver options both in terms of the number of matches and the average rotation axis deviation. Bullet and ODE still show non-monotonically increasing number of rolls.

Engine	Parameters	Final Value
Bullet	μ	3.0
	ERP	0.5
	CFM	0.0 (no effect)
	Number of Iterations	10 (no effect)
	MLCP	Lemke
Bullet MB	μ	3.0
	ERP	0.0
	CFM	0.0 (no effect)
	Number of Iterations	50
DART	μ	1.0
MuJoCo Euler	μ	2.0
	dmin	1.0
	dmax	1.0
	width	0.001 (no effect)
	timeconst	0.02
	dampratio	0.5
MuJoCo RK	μ	3.0
	dmin	0.85
	dmax	0.95
	width	0.001
	timeconst	0.02
	dampratio	0.5
ODE	μ	2.0
	ERP	0.0
	CFM	1.0
	Number of Iterations	100
	Contact Surface Layer	0.0 (no effect)

Table 1: Engines, their parameters, and new values chosen. Differences from the original experiment is highlighted in red.



(a) Number of times the cube rolls down the slope for various slope angles and engines.

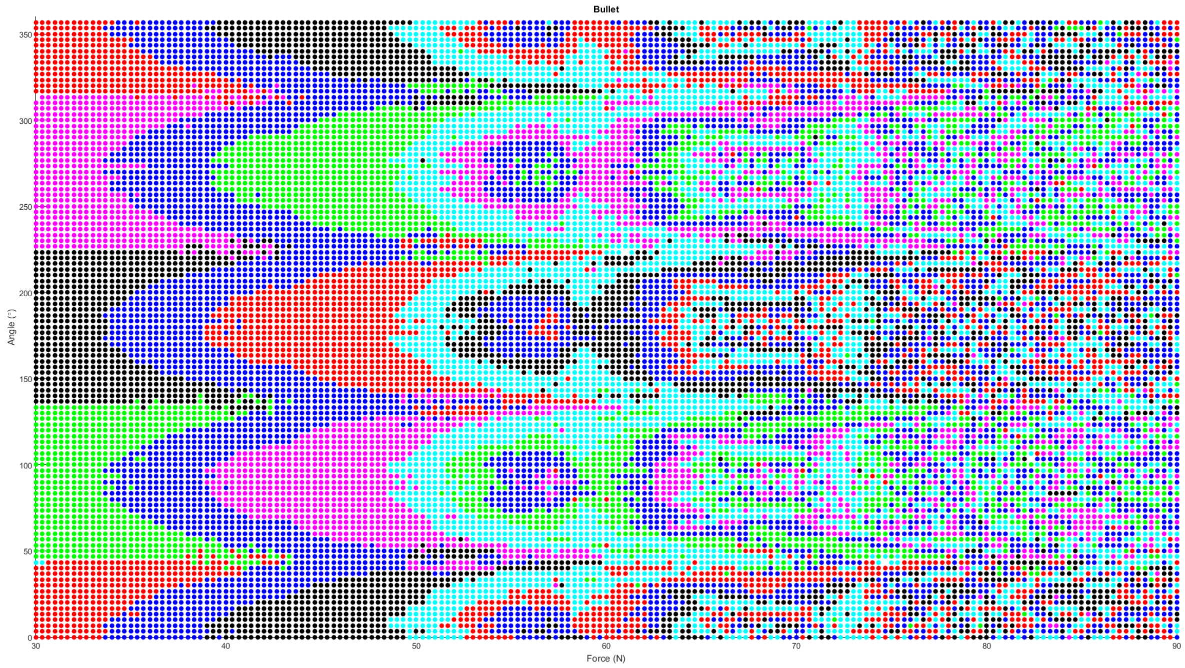
(b) Average deviation angle of rotation axis from the y-axis.

Figure 1: Cube downhill rolling simulation results with final parameters.

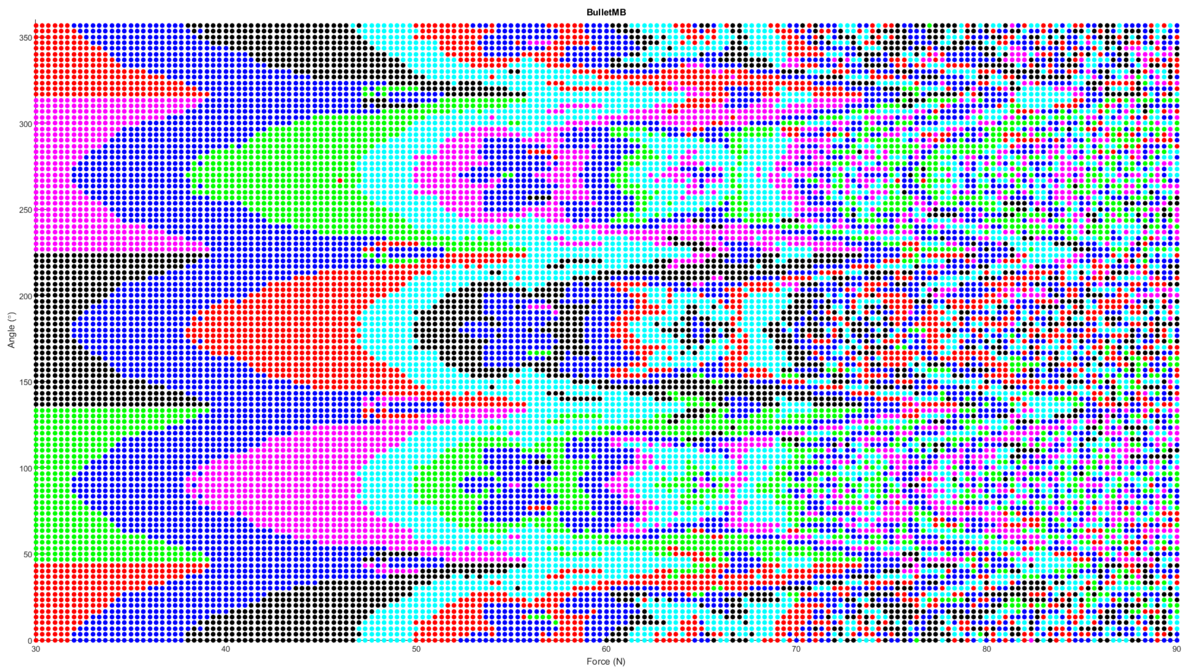
B. Rolling on a Flat Ground in Various Directions in Finer Increments

We have also performed a finer increment of simulation for the second experiment in the main paper using the new parameters found in section A. These results are shown in figure 2. Bullet still has many irregularities and asymmetric regions in its pattern as it did in the main paper. Oddities in Bullet MB, DART, MuJoCo Euler, MuJoCo RK, and ODE are much less pronounced than in the plot from the main article, which means that these engines have predictable behavior most of the time.

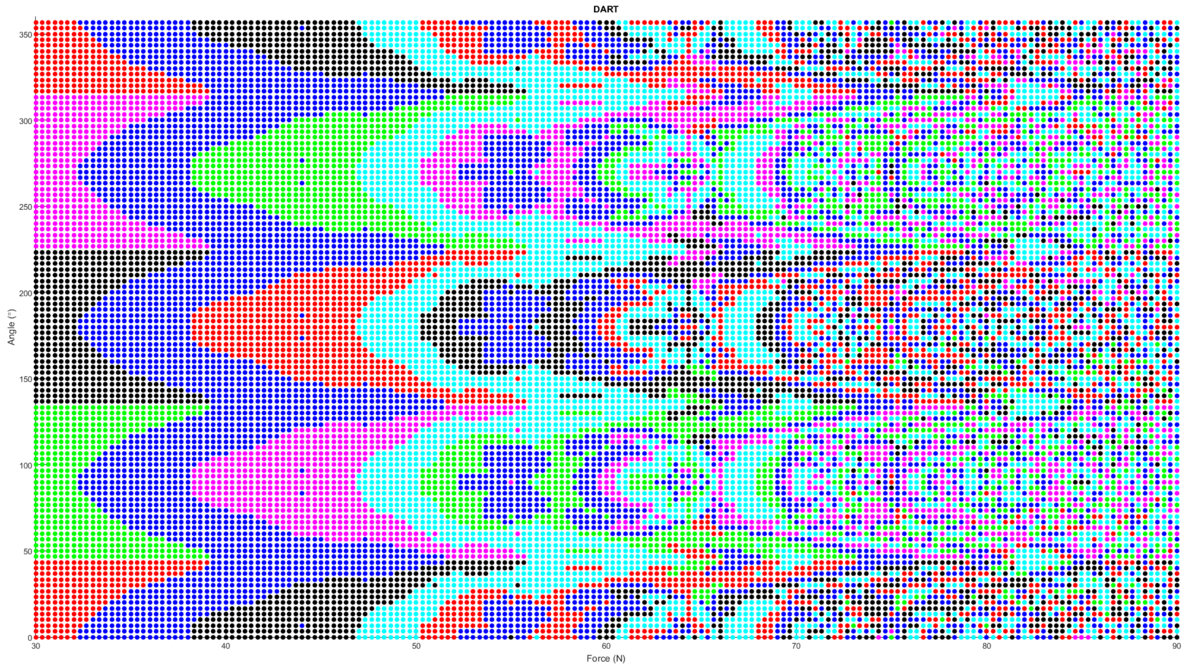
As in the main article, we have experimented with the effect of the damping parameter in MuJoCo. The results for the second experiment with damping set to 1 (critically damped) is shown in figure 3. We saw that for both MuJoCo Euler and MuJoCo RK, the damping parameter did not make much difference.



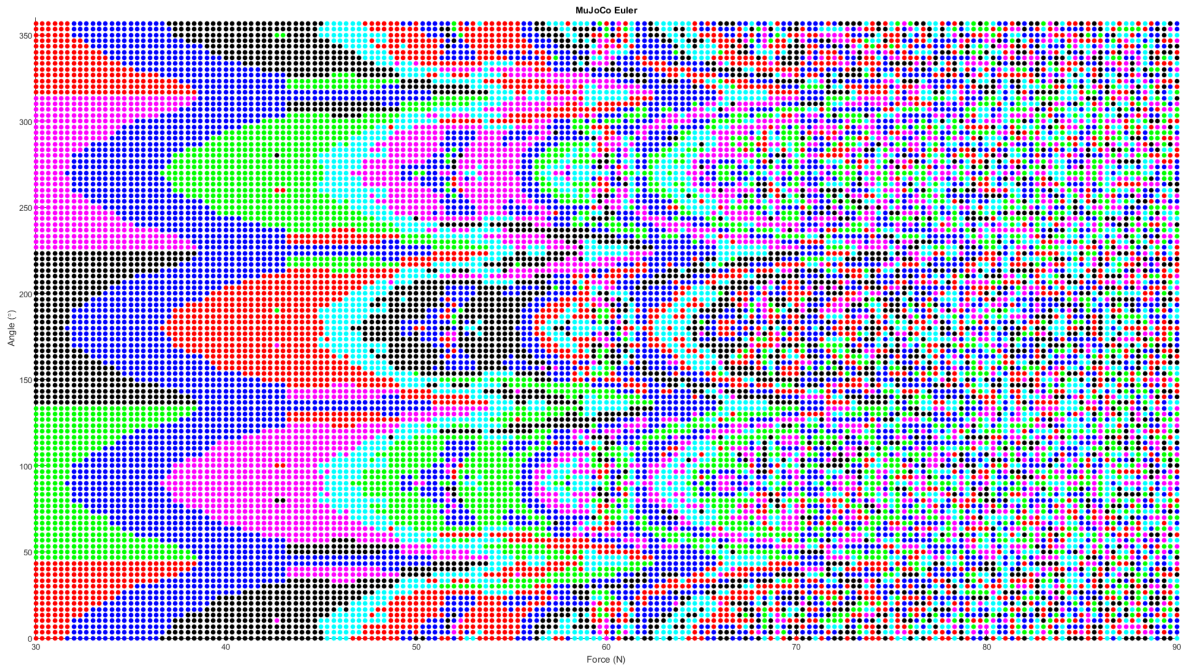
(a) Bullet.



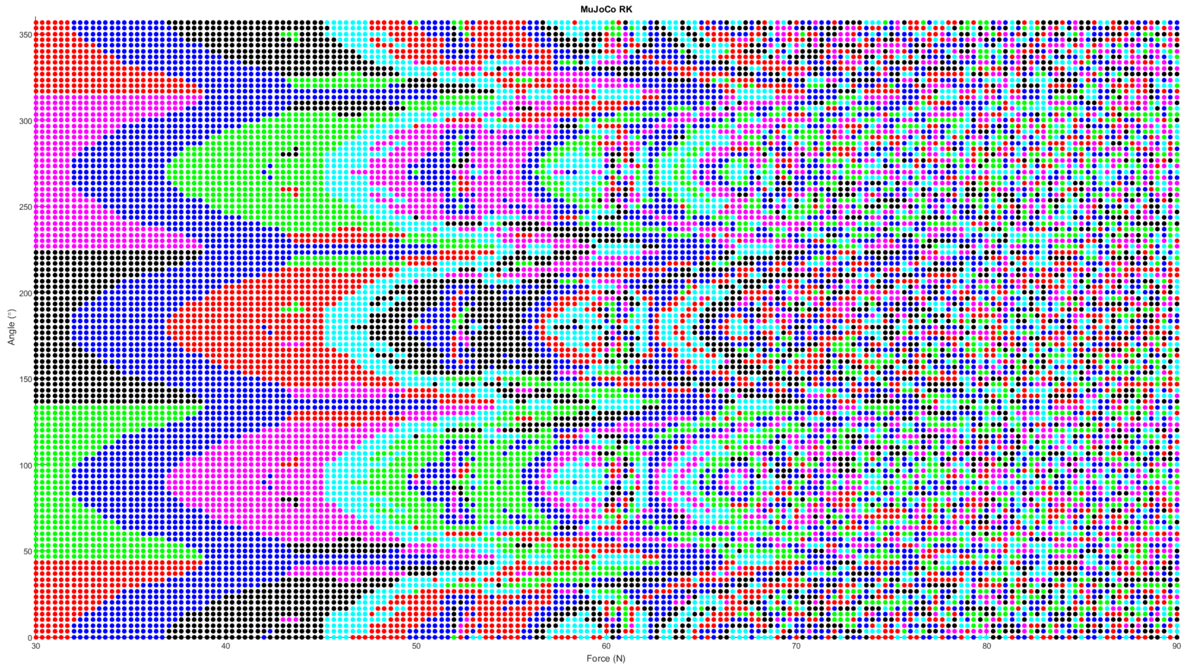
(b) Bullet MB.



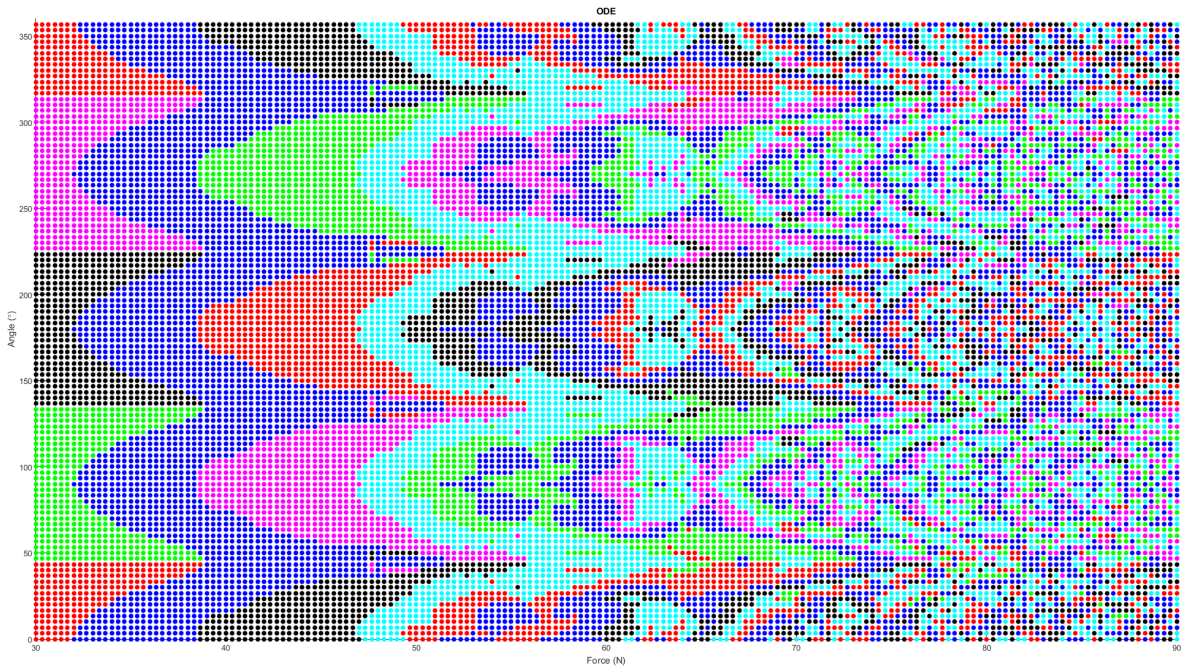
(c) DART.



(d) MuJoCo Euler.

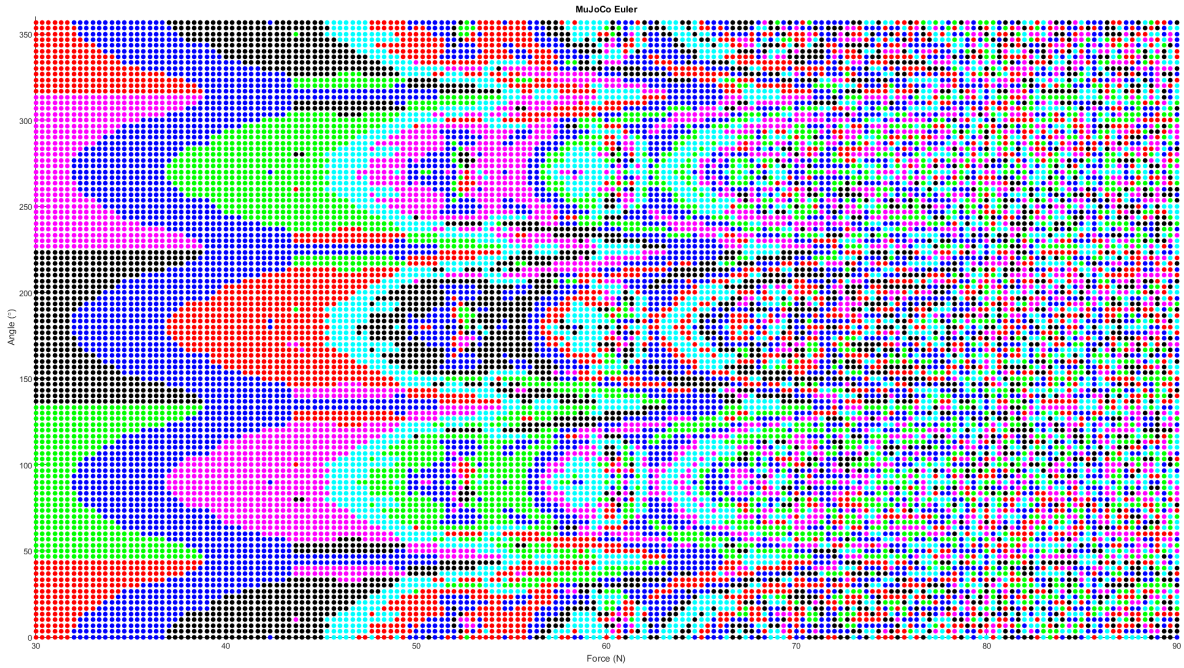


(e) MuJoCo RK.

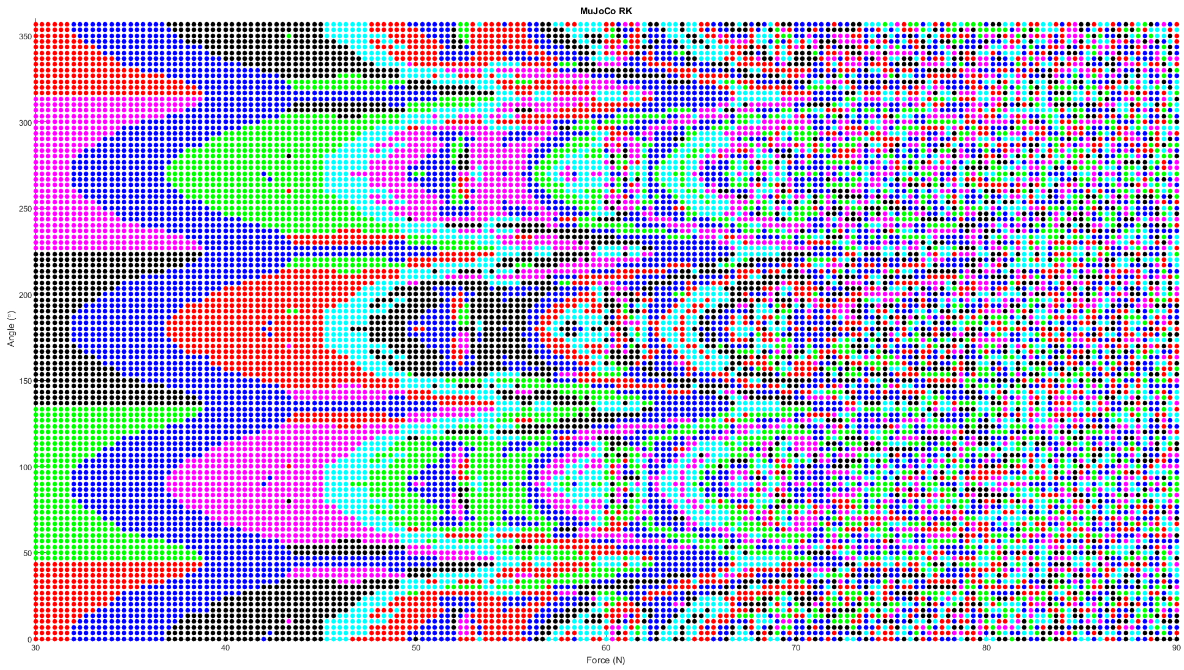


(f) ODE.

Figure 2: Cube side that ends up on top after various magnitude of force has been applied in various directions.



(a) MuJoCo Euler with damping set to 1.0.



(b) MuJoCo RK with damping set to 1.0.

Figure 3: Cube side that ends up on top after various magnitude of force has been applied in various directions.