PROJECT SUMMARY: Research on

Correcting Numerical Errors in Multi-Rigid-Body Physics Simulation

Accurately simulating rigid body dynamics (i.e., assuming bodies do not flex over time and are subject to Newton-Eulerian Mechanics) in 3D with frictional contact is notoriously difficult. One of the main problems is the generation of numerical errors during the process of simulation. During every single step, small errors are generated and accumulated. After enough steps, the error becomes large enough that the simulation becomes unrealistic. For example, if a box is spinning on the ground, it will gradually sink into the ground.

To overcome this challenge, the proposed research is aiming for a correction algorithm. Although there are outlying methods to solve this problem, they are either hard to implement robustly, or lacking efficiency. The algorithm the research is aiming for will have three properties. First, it should be able to detect interpenetrations and correct them at the end of every simulation step. Secondly, a minimum amount of energy should be added or removed from the system during the correction. Finally, the algorithm should be efficient enough to not drastically slow down the simulation.

To see if the algorithm has the three properties, it will be implemented under Moby, a dynamic robotic simulation software written by Positronics Lab from George Washington University. The algorithm will then be tested for its correctness, robustness and efficiency. For correctness, the intensity of incorrect interactions (such as how deep the interpenetration is) generated before and after the algorithm is applied will be analyzed. For robustness, the performance of the algorithm on different cases will be analyzed. For efficiency, the time efficiency of the algorithm for both the worst cases and the average cases will be analyzed.

The proposed research will address the following questions: *(1) Which way is the best way for correcting errors, exerting forces on bodies to push them apart, or adjusting their positions directly? (2) If the former, which parts of the bodies will the forces act on, and what directions will they be in?*

Intellectual Merit. Correctly simulating physical bodies is very crucial since physical simulation is widely used in various fields, such as robotics. The proposed research will directly contribute to the simulation field by providing a fast and accurate solution for collision simulation. Even if the algorithm does not work for extreme cases it will support further research and will make it easier for others to expand on the topic.

Broader Impacts. The purposed research would allow students to practice their skill and enhance their knowledge of numerical computation and physics simulation. The proposed algorithm can also be reused and implemented in other physics simulation software to enhance their performance. Finally, a more accurate simulation can benefit a lot of fields using it. Taking Robotics as an example, because the cost of a robot is very high, a lot of the experiments are done in simulation to prevent damage to equipment. A reliable simulation will give engineers extra confidence in how robots will perform in the real world.