PROJECT SUMMARY: Research on
Correcting Numerical Errors in Multi-Rigid-Body Physics Simulation

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 both accurately and quickly has been an ongoing problem since the beginning of numerical computation. One of the main reasons that is causing this to be an ongoing problem is the numerical errors that are generated during the process of floating-point arithmetic. During every single step of the simulation, small errors are generated and accumulate. After enough number of steps, the error becomes large enough such that the simulation will become unrealistic. For example, if a box is placed on the ground and spinning, it will gradually penetrates into the ground. These interpentraion will never occur in reality and therefore, a correction is necessary for us to get a more reliable simulation result.

The proposed research is aiming for an correction algorithm for overcoming this challenge. Although nowadays, there are already methods to solve this problem, the methods are either hard to implement robustly, or the efficiency of the algorithm is too poor to be used in a simulation. The algorithm the research is aiming for will have three properties. First of all, it should be able detect interpentration and correct the interpenetration, so that at the end of every simulation step, there will not be any unrealistic interpenetration. Secondly, while the algorithm is correcting the error of the system, a minimum signed work should be done, that is, a minimum amount of energy should be added or removed from the system. Thirdly, the algorithm itself should be efficient so that the efficiency of the simulation will not be greatly affected by the extra amount of computation required by the correction algorithm. The algorithm will be implemented and tested under Moby, which is a dynamic robotic simulation software written by Positronics Lab from George Washington University. The algorithm will be tested and analyzed from its correctness, robustness and efficiency. First of all, for correctness testing, the amount of error generated before and after the algorithm is applied will be analyzed. Secondly, for robustness testing, the performance of the algorithm on different cases will be analyzed. Thirdly, for efficiency testing, the time efficiency of the algorithm for both the worst case and the average case will be analyzed.

The proposed research will be addressing on the following question: *(1) Which way will be a better way for correcting errors, exerting force on bodies to push them apart, or adjusting their position directly so that there will be no interpenetration? (2) If a force is required to be exerted, which part of the bodies will it act on, and what direction will the force be in?*

Intellectual Merit. Correctly simulating physical bodies is very crucial since physical simulation is widely used in various fields, such as robotics simulation. The proposed research will directly contribute to this field since with the new algorithm developed and implemented, the simulation will become more accurate than it is now. Even the algorithm may not work for some extreme cases, the field that need to be focus on can be also shorten.

Broader Impacts. The purposed research will allow student to practice their skill and enhance their knowledge in numerical computation and physics simulation area. The proposed algorithm can also be reused and implemented in other physics simulation software to enhance their performance. Finally, with a more accurate simulation, a lot of other fields that are using simulation can be benefits. Taking Robotics as an example, because the cost of a robot is very high, a lot of the experiments are done in simulation instead in real world directly so that the robot will not be broken because of bad code. A reliable simulation will be very useful, because we can then be more confidence in how the robot will perform if
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