View-Dependent Articulated Body Simulation with Adaptive Forward Dynamics

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1 Introduction

As virtual worlds become larger in size and individual objects get more complicated, various approximation techniques have been developed to render and simulate them. In the literature on rendering, especially visibility culling and view-dependent multi-resolution techniques have been well studied and shown great enhancement on rendering performance. However, applying these view-dependent simplification techniques to dynamics of objects in virtual worlds is much more challenging since their dynamics must be updated continuously regardless of whether or not they are out of the view or how far each of them is from the view. In order to address this problem, we propose the view-dependent simplification techniques for articulated body simulation using the adaptive forward dynamics scheme [7]. Our scheme saves computation time by not only rigidifying each object's links which are out of the view or occluded by obstacles but also reducing the number of joints simulated depending on how small each object seems on the screen. In this paper we also present a scheme to generate globally natural dynamic scene by minimizing the global error metric value which is the sum of motion error values of all the articulated objects simulated in the virtual world. This scheme efficiently distributes the computation resource to each articulated object. With these simplification and global resource distribution schemes the articulated body simulation can be appropriately simplified to save computation time and can generate the scene which has the minimum motion error metric value.

2 Related work

In contrast to geometric simplification schemes in computer graphics, researches on simulation levels of detail (SLODs) related to dynamics are relatively few. Carlson and Hodgin presented techniques for reducing the computational cost of simulating groups of simple hopping robots [1]. They presented as approximation models the hybrid model which relies on recorded kinematic data and partially on dynamics simulation and the point-mass model. In order to support the hybrid model, however, we need to record motion parameters from the dynamics simulation of the target model as a preprocessing step. Chenney and Forsyth investigated view-dependent culling of dynamic objects in a virtual amusement park [2]. They used a culling method not to solve the equations of motion of objects that don't affect the view. But not solving the equations of motion results in two inherent problems; consistency and completeness. In order to address these two problems, they studied statistical models. But this scheme requires the user to identify what are qualitative dynamic properties of objects and what is their proper statistical model.

Our work, however, requires neither recording of motion nor statistical model in contrast to two previous SLOD techniques since our simplification scheme does not depend on any specific type of dynamic objects. Our framework is applicable to any type of articulated rigid bodies.

The forward dynamics simulation of many articulated bodies is often very time-consuming, even though we use the known optimal solutions [3, 6] which are linear in the number of joints. In order to address this problem, Redon and his colleagues proposed the multilevel forward dynamics algorithm for articulated body simulation [7]. This algorithm is based on the divide and conquer algorithm to solve the forward dynamics of articulated bodies presented by Featherstone [4, 5]. It can adaptively simplify dynamics of articulated bodies with customizable motion error metrics and the user-defined threshold. Our work can be regarded as an extension of their work by combining their adaptive dynamics with the view-dependent simplification techniques. But our work can also provide globally more natural-looking motions by minimizing the global error metric value.

3 Overview

Redon and his colleagues proposed the multilevel forward dynamics algorithm for the articulated body simulation[7]. Their key observation was that we don't need to simulate all of the joints of an articulated body to keep its plausible dynamics. The simplification is governed basically by two customizable factors: the motion error metrics and the user-defined threshold. The motion error metrics are used to determine which joint is first simulated and the user-defined threshold bounds SLODs of an articulated body.

In order to save more computation time, our work aims to adaptively control these two factors according to the visibility information of each articulated object. For each articulated body in the virtual world, our framework identifies less important links which are occluded by some obstacles or out of the view through the visibility test. Then it makes those links rigidified by adjusting weight values of the motion error metrics to save computation time. And in the case of distant articulated bodies, their user-defined thresholds are modified to give themselves less freedom in accordance with their relative size to the view size.

The global motion error value is also considered. This is the sum of motion errors of all articulated bodies in the virtual world that are inherently caused by approximation of dynamics. Let's assume that the user wants to simulate only 1000 joints for each time step but in the virtual world there are 100 articulated bodies each of which has 50 joints. For briefness, let's ignore the view-dependent simplification scheme in this scenario. The total number of joints in the virtual world is 5000 joints. Now the problem is this: we have to appropriately distribute simulation budget 1000 joints to each articulated body to best approximate 5000 joints' simulations. The most proper way to solve this problem would be to make the global motion error value minimal. This can be simply accomplished by the global search with the global priority queue. The global search determines with the global priority queue which joint is globally important by considering all the articulated bodies in the virtual world at the same time. By keeping the global error metric value minimal, we can guarantee the near-optimal approximation of articulated body simulation. We will talk about this scheme later in more detail.

References

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