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Potential Field Guided Inverse Kinematics for Human Characters

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Abstract

Inverse kinematics using the Jacobian matrix is a valuable tool for posing and animating articulated characters such as virtual humans, but requires many constraints from the user to create quality motions. We present a method for guiding the IK solution towards natural poses to generate believable poses with smooth motions. We use a large motion library to create a lightweight database with the most likely poses for possible queries and use an algorithm based on artificial potential fields to guide the IK solution towards better poses. We demonstrate that this approach can be used to create smooth motions with natural-looking poses while satisfying constraints.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism – Animation

1. Introduction

Interactive character posing using inverse kinematics (IK) is a useful tool for character animation. The classical method of solving IK numerically using the Jacobian matrix is an efficient way but tends to create poses that appear unnatural unless many constraints are carefully specified. There have been improvements on classical IK with existing pose data using methods based on learning weights [LXW07]. Alternatively, a number of systems have been developed to solve the IK problem without using the Jacobian matrix, but using statistical models [GMHP04] and machine learning [CH05]. We believe that an algorithm that is simple to implement, requires minimal user constraints, is scalable to handle a large variety of poses, and is efficient enough to be part of a computation-intensive interactive application is still desired.

We present a simple and efficient IK system that can generate smooth animations using natural-looking poses for human characters at interactive rates. We use poses from a large pose library as examples to guide classical IK that we compute numerically using a Jacobian matrix between the shoulder and the hand. Our system controls the character to create smooth reaching motions towards moving targets for the end-effectors while staying close to the space of natural poses. Using example poses enables controlling the rest of the body to cooperate with the reaching motion and to react appropriately so that the motion of the character appears consistent. Our method is a simple addition to the classical IK solution that has a small memory footprint and processing requirement, and can be useful where an efficient and simple IK system is required.

2. Overview

The problem we want to solve is to create smooth reaching motions driven by moving targets while staying close to the space of natural poses. For this purpose, we store a small representative subset of the entire pose library as the preprocessing step and create a pose database. Then we use this database in runtime to efficiently access relevant poses that will guide the IK process.

2.1. Preprocessing

To efficiently retrieve a small number of relevant poses in runtime, we preprocess the motion library to create a light motion database that contains a variety of poses that are close to satisfying every possible hand position in the library. We do this by aligning all the poses in the library using a common coordinate frame, and dividing the 3D space into grid cells. We separate the poses in the entire library into buckets that are assigned to the grid cells, and for every bucket we use k-means clustering to select a small number of representative poses to be stored in that bucket. This makes sure that we save a small number of poses that cover the entire hand position domain of the library and keep a number of poses to reflect the variety around every possible position. This way, we can consider a variety of poses that have the hand within a certain radius around the desired position that includes multiple grid cells.

2.2. Runtime

At every time step in runtime, we retrieve a small number of relevant poses from this database that will guide the character's motion. We control the character as a dynamically weighted combination of classical IK and attraction of the selected poses. Using the small number of selected poses, we create an artificial potential field (APF) in which poses attract the character based on their importance. The dynamically adjusted importance value ensures that we choose poses that are close to the current pose and also are close to satisfying the hand position. This simple scheme is enough to keep the character's hand in the general area where the target is. The contribution of classical IK complements this by making sure that the hand gets very close to the target position.

In APF, the dynamical importance adjustment of candidate poses ensures that the rest of the body contributes enough to the satisfaction of the hand position constraint. It helps avoid cases in which IK pulls the hand so that the arm is stretched all the way and the APF would not make the rest of the body move, preventing the character from reaching further. Similarly, it helps avoid the case in which the hand gets too close to the shoulder. Such cases are also singular cases for the numerical IK solution, so helping the character avoid and leave such cases improves the stability of the IK component. We do this by favoring poses that have the hand closer to the target, over poses that are closer to the current pose when the arm is close to the singular cases. In addition, our dynamic weighting scheme between IK and APF components ensures that IK does not simply override APF while making sure that the hand gets very close to the target. As the distance between the actual hand position and the target hand position gets smaller, it increases the weight of IK and makes sure the hand can get even closer to the target.

2.3. Discussion and Limitations

Our algorithm provides a simple and efficient method that can cover the entire region of available hand positions in a pose library and make the character smoothly reach to points in that region while keeping a natural-looking pose. When the target position is out of reach, the character gets close to it while trying to keep close to natural-looking poses. Our algorithm performs best for upper body motions in which the character is reaching with one hand. When creating full-body motions, it performs reasonably well in cases when the target position is closer to the ground, as long as the motion of the target position is in areas naturally reachable by the character. It does result in some discontinuities when the target position moves arbitrarily and the APF includes discontinuities due to sample poses being very different. The current APF implementation does not treat cases in which the candidate poses are very different than each other. We are planning to address this by making sure that the APF reflects a continuous manifold of poses. Discontinuities in the root orientation result in the the most visible glitches and we are planning to create a better estimation strategy for the root bone. Our current extension for multiple constraints uses a Cartesian product to create higher dimensional grid cells, and is not scalable to handling many constraints, which was not our main goal. However, using a better data structure and including an approximate nearest neighbor scheme, we are planning to make our algorithm scalable to more constraints.

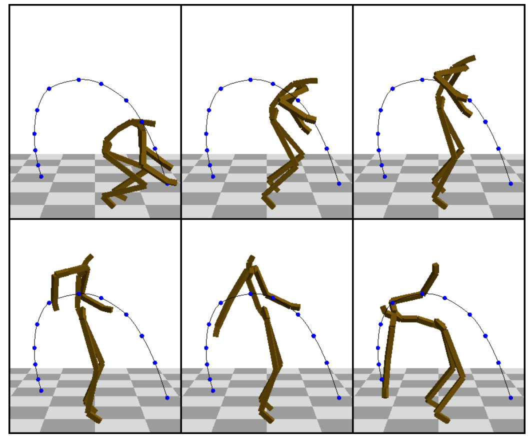

Figure 1: *Full-body animation generated using the hand target position moving on a curve specified by the user.*

References

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