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Steps Toward Intelligent Physical Control

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Abstract

We provide an interface for controlling humanoid characters under physical simulation. This interface permits a user to control the character at a variety of different semantic levels. The character can be instructed at a high level, such as by issuing a walk command, or at a low level, such as by specifying poses with interactive keyframe selection. In addition, the character can perform autonomously in that it possesses a variety of reactive skills that can be performed when needed. Our work brings together interactive control with reactive control under physical simulation as a major step towards a larger system for an intelligent, controllable and interactive character.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Line and Curve Generation

1. Introduction

Developing plausible motion for animated characters is difficult. There are a variety of different techniques that are used to control interactive characters including the use of motion capture, dynamics and optimization. However, no currently known technique can perform a complete range of motions while interacting dynamically with the environment. We combine reactive control [FvdPT01] with interactive control [LvdPF00] under physical simulation in order to accommodate a wide range of behaviors. The character understands basic reactive and protective behavior. Through user-selected keyframed controllers, the character is able to perform custom tasks that can be adapted to any situation.

A user may instruct the character to perform specific tasks by selecting a keyframe that indicates the desired pose of the character. We use proportional-derivative (PD) controllers to drive the character from their current position to the desired position. The keyframe may also contain information about the gains used as input to the PD controller. The keyframed poses can be used in sequence to achieve a walk cycle, throw punches or kicks, hop, lean backwards, pick up objects and so forth.

Simple pose-based control is not enough to guarantee that the dynamic character will achieve the desired position. Our character also adjusts its poses by applying heuristics in order to better achieve its goals of movement, balance and interaction. For example, a pose indicating a punch will be adjusted automatically to raise or lower the arms to better contact the objects around them. A pose in a walking cycle will automatically trigger the synchronization of the character's arms in order to achieve better balance.

The character's reactive skills permit the animated character to recover from various undesirable positions and situations, such as being prone or supine on the ground, or under attack from another character. The user can explicitly activate the reactive behavior at any time. This is done, for example, if the character is falling and the user wants the character to gracefully handle the fall. The reactive behaviors will activate a series of controllers that will attempt to reorient the character into a safe state, such as standing or resting. In addition, the user can allow the reactive controller to run passively in the background, allowing it to usurp control from the user automatically.

2. Implementation

Our characters exist in R^3 and have 18 degrees of freedom (DOF). For the purposes of balance and better control, we have constrained the root joint to one rotational axis, which allows our characters to have static balance. Changes in the orientation of the root axis can be made through simple kine-

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matic "hops", which allow the characters to reorient themselves and move in 3D. We use the DANCE [SFNTH05] system for physical simulation and character generation.

Thus, our interactive character has three layers of control: 1) a keyframed pose control, 2) a set of heuristics used to achieve better poses under dynamics, and 3) a layer of reactive control that can be activated during physical interaction or imbalanced states. This division of control layers also allows users from different areas to contribute towards a more robust, interactive character. Animators and lay users can specify keyframed poses and interactively control the characters, while more technical users can contribute reactive controllers and better heuristics.

3. Challenges of Interactive Dynamic Control

Developing dynamic controllers [HWBO95, SPF03] for autonomous behavior is a very difficult task. Techniques range from hand-coding based on intuition, to borrowing techniques from robotics, to tracking motion capture. Most dynamic controllers for animated characters are either simple or brittle. The simple controllers can only perform basic tasks, while the brittle controllers only succeed under specific environments.

Interactively controlling physically-based characters is also difficult. The difficulty stems from both the high number of parameters needed to control an interactive character as well as the difficulty in specifying proper parameters to accomplish meaningful movements. Recent attempts to do so have either used low dimensionality characters or restricted environments. [LNS05] uses a two dimensional character with predictive simulation. [ZvdP05] uses a three-dimensional character to control both the ballistic motion of a diver and the balancing and aerial movements of a snowboarder/skier. The three-dimensional snowboarding/skiing characters do not suffer from typical bipedal balance problems because their snowboards and skis help them achieve such balance.

Keyframing is a common and useful technique for animating kinematic characters. It is a powerful technique because it allows the animator to express a nearly unlimited variety of movement and behavior. In addition, the barrier for entry for designing keyframed animation is relatively low. Thus, a large number of animators can develop a wide range of motion and behavior. On the other hand, no such tool or technique yet exists for the development of dynamic control and interactive physical control. Therefore, the development of dynamic controllers is left in the hands of the experts in robotics, graphics, artificial intelligence and similar technical fields. This is a major obstacle in the development and use of dynamic control in character animation.

Motion capture synthesis, keyframing, dynamic control and hybrid techniques must be combined in order to generate high-level, autonomous and interactive behavior that is effective under a wide range of circumstances. We present this application as a first step towards combining a number of these disparate techniques in order to achieve the goal of an intelligent, controllable character.

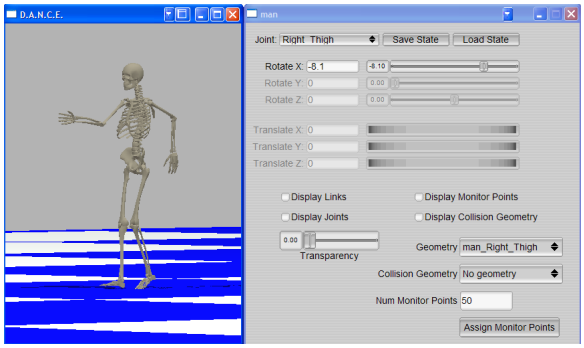

Figure 1: *Generating a controller via keyframed pose.*

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