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Data-driven humanlike reaching behaviors synthesis

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ABSTRACT

Reaching is one of the most important behaviors in our daily life and has attracted plenty of researchers to work on it both in computer animation and robot research area. However, existing proposed methods either lack of flexibility or their results are not so convincing. In this paper, we present a novel controller-based framework for reaching motion synthesis. Our framework consists of four stationary controllers to generate concrete reaching motion and three transition controllers to stitch these stationary controllers automatically. For each stationary controller, it can either be applied alone or combined with other stationary controllers. Due to this design, our method can imitate the inherent tentative process for human reaching effectively. And our controller is able to generate continuous reaching motion based on virtual character's previous status with no need to start from one same initial pose. Moreover, we involve an important gaze simulation model into each controller, which can guarantee the consistency between the head and hand movement. The experiments show that our framework is very easy to be implemented and can generate natural-looking reaching motion in real-time.

1. Introduction

Although the problem of controlling full-body character to reach a given target has been exploited extensively, the results are still not so convincing due to lack of following details: (1) The human reaching often is a tentative process, which combines different behaviors as a consequent sequence. For example, when people want to reach a high target, he/she usually does it first while standing, once he/she finds that he/she cannot reach that target, he/she will choose to tiptoe or jump. However, most of existing techniques are not able to reflect this process. (2) For normal humans, it is very natural to reach multiple targets continuously in certain reaching way. But this humans' instinct cannot often be seen in existing reaching results except in the scenario, where the character reaches targets while he/she is standing. (3) Moreover, as we know, the eyes of normal human subjects are highly correlated with the hand movement. But most of existing mocap data does not pay enough attention to the gaze movement in minute detail, so researchers often ignore this important fact.

In order to solve aforementioned problems and synthesize natural-looking reaching motion, we present a novel controller-based reaching motion synthesis framework in this paper. Our framework is very easy to be implemented and its input includes a new target position and the character's current state, the output is a piece of reaching motion. Inspired from biomechanics literatures, we involve four kinds of reaching strategies (standing, stepping, tiptoeing and jumping) enhanced as static reaching controller into our system. In addition, three transition controllers, which will be described in controller formulation section later, are also adopted to stitch these static controllers. All of these controllers are put into a uniform framework and the tentative process for human reaching can be simulated well.

Compared to previous approaches, our reaching motion can start from any status during the reaching process naturally without particular tricks. That means, for any controller in our framework, it can treat the current state of the character as a starting point to reach a new target. If the target cannot be touched by one single controller, our framework will switch to another controller to continue this task. So our method shows great advantage for multiple continuous reaching.

For normal human, the movement of head is closely related to the hand movement. People can easily recognize the inconsistent artifacts between head and hand movement. In our framework, we put an effective gaze simulation model into each controller. At each time step, the controller will calculate the head orientation and update the status of the head, so the synthesized reaching motion will look like more natural.

2. Related work

2.1. Reaching and grasping motion synthesis

There exists a large amount of work on motion synthesis for human reaching and manipulation. Here we select some

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representative literatures to explain this kind of work briefly. Aydin and Nakajima [1] use the forward and inverse kinematics to generate the grasping motion with a large motion database. Raunhardt and Boulic [2] deal with the reaching motion synthesis in low-dimensional data space and utilize the numerical iterative method to refine the final result. Kallmann et al. [3] use path-planning technique with the mocap data to generate flexible and collision-free manipulation motion. Huang et al. [4] explore a blendable example space by a sampling-based planner, which is used to produce realistic reaching motion around obstacles. In order to create a highly skilled virtual character, Feng et al. [5] combine path planning, locomotion, reaching and grasping together into their motion system and that system can apply these skills in an interactive setting. Recently, researchers have noticed that unnatural reaching results are often caused by the simplification of the shoulder [6,7], so they are trying to simulate or reproduce more accurate movement of the shoulder using different approaches, such as [8]. These approaches are able to generate continuous reaching but are often limited to only one certain reaching scenario, such as reaching while the character is standing. By involving different reaching strategies, Lv et al. [9,10] present a biomechanics-based life-like reaching controller to generate different reaching motion. The advantage of their approach is that they extend the reachable space of virtual character largely. However, their approach cannot generate continuous and tentative reaching for their initial starting point is always a whole piece of certain motion. Some blending and slicing techniques are also used for human's upper-body motion synthesis, such as [11–13]. Same like above mentioned approaches, they still cannot realize the continuous and tentative reaching at the same time. And the biggest problem is that their reachable space is very limited.

2.2. Model-based motion synthesis

Those methods presented in last section are designed to synthesize reaching motion specially, while model-based algorithms are more generative for various types of motion synthesis. Reaching is so common behavior in daily life that these algorithms can also be used for reaching motion synthesis. Rose et al. [14] explore an efficient inverse-kinematics method based on the interpolation of example motions and positions. Mukai and Kuriyama [15] treat motion interpolations as statistical predictions of missing data in an arbitrarily definable parametric space and introduce universal kriging to estimate the correlations between the dissimilarity of motions and the distance in the parametric space statistically. Grochow et al. [16] present a scaled Gaussian process latent variable model to learn human poses in an inverse kinematics system and can produce different styles of IK through training the model on different input data. Min et al. [17] present a new low-dimensional deformable motion model for human motion modeling and synthesis. Through continuously adjusting the values of deformable parameters to match user-specified constraints, their method can generate the desired animation. Levine et al. [18] present a probabilistic motion model to drive the character to perform user-specified tasks. Their method uses a low-dimensional space learned from example motion to control virtual character to accomplish some special tasks continuously.

Above methods are all built upon motion capture data, the advantage is that they can use small amount of data to generate new motion through predicting or interpolating. In order to generate flexible and natural reaching motion, a large amount of example motion data is very necessary. However, model training of these methods based on such amount of data is extremely time-consuming and the efficiency of their motion synthesis will also be decreased greatly. If their models are trained on different reaching behavior data separately, although it can reduce the training data for single model, it will be very complex and difficult to combine these separate model together to generate flexible reaching motion naturally.

2.3. Composite controller for motion synthesis

Controller-based motion synthesis methods show great power on dealing with complex problems and these controllers can often be combined together or reused. Faloutsos et al. [19] propose a framework for composing controllers in order to enhance the motor abilities of dynamic, anthropomorphic figures. The key contribution of their framework is an explicit model of the pre-conditions under which motor controllers are expected to function properly. Sok et al. [20] develop an optimization method to transform either motion-captured or kinematically synthesized biped motion into a physically-feasible, balance-maintaining simulated motion. Their controller learning algorithm facilitates the creation and composition of robust dynamic controllers. da Silva et al. [21] involve linear Bellman combination to reuse existing controllers. Given a set of controllers for related tasks, their combination approach can create an appropriate controller to perform a new task. Muico et al. [22] realize their composite controllers by tracking multiple trajectories in parallel instead of sequentially switching from one control to the other. The composite controllers can blend or transit between different paths at arbitrary time according to the current system state. Huang et al. [23] propose a hierarchical control system for coordinating the movement of arms, spine and legs of the articulated character by a novel controller scheduling algorithm. It is to be mentioned that these controllers are drawn from the analytical formula of the movement of body joints.

Inspired by these methods, we also try to solve reaching motion synthesis using composite controller method. So we modify and extend the work in [9] and present a controller-based framework to generate more natural-looking reaching motion.

3. Framework overview

Our reaching framework consists of four stationary controllers as standing, stepping, tiptoeing and jumping, and three transition controllers as stand2step, stand2tiptoe and tiptoe2jump. Each stationary controller can handle the reaching target in its own reachable space, if one new target can be reached by this controller, it will continue the reaching task from last reached position. If the new target cannot be reached by this controller, our framework will switch to another controller automatically and continue the reaching process. In Fig. 1, the initial state can be any pose during the reaching process, not only the default standing pose like in [9]. As the arrow shows, the transient processes are all unidirectional, which are designed in this way based on two considerations. The first is the fact that most of human beings follow these unidirectional behaviors to reach. The second is that each stationary controller can recover to the default standing pose directly and it is unnecessary to realize this goal through transition controller. In order to imitate realistic human reaching behavior, when a new target is given, our framework usually begins the reaching motion synthesis with the standing controller, but users can also choose a certain controller to do the same job.

4. Controller formulation

As mentioned before, our data-driven reaching controllers are separated into two classes: stationary controller and transition