Journal of Visual Languages and Computing 25 (2014) 20–32

Contents lists available at ScienceDirect

Journal of Visual Languages and Computing

journal homepage: www.elsevier.com/locate/jvlc

Hybrid motion graph for character motion synthesis ☆

Weiwei Xing [a,*], Xiang Wei [a], Jian Zhang [a], Cheng Ren [b], Wei Lu [a]

[a] *School of Software Engineering, Beijing Jiaotong University, Beijing 100044, China*
[b] *China Coal Research Institute, Beijing 100013, China*

ARTICLE INFO

Available online 18 October 2013

Keywords:
Motion synthesis
Motion graph
Motion fields
Motion template
Motion transition

ABSTRACT

Objective: This paper proposes a novel framework of Hybrid Motion Graph (HMG) for creating character animations, which enhances the graph-based structural control by motion field representations for efficient motion synthesis of diverse and interactive character animations.
Methods: In HMG framework, the motion template of each class is automatically derived from the training motions for capturing the general spatio-temporal characteristics of an entire motion class. Typical motion field for each class is then constructed. The smooth transitions among motion classes are then generated by interpolating the related motion templates with spacetime constraints. Finally, a hybrid motion graph is built by integrating the separate motion fields for each motion class into the global structural control of motion graph through smooth transition.
Results: In motion synthesis stage, a character may freely 'switch' among different motion classes in the hybrid motion graph via smooth transitions between motion templates and 'flow' within each class through the continuous space of motion field with agile and the continuous control process.
Conclusion: Experimental results show that our framework realizes the fast connectivity among different motion classes and high responsiveness and interactivity for creating realistic character animation of rich behaviors with limited motion data and computational resources.

1. Introduction

The creation of humanlike character animation is demanded by numerous applications ranging from movie special effects, virtual environments, and military simulation, to interactive computer games, to human factors analysis, etc. However, the ranges of motions that human perform and the varieties of environments that human interact are almost endless. Furthermore, people are adept in spotting any subtle artifacts, unnaturalness and inaccuracies in human motions because they have been the observers of human motions throughout their lives. So animating virtual characters that are capable to reproduce realistic human motions and dynamic plausible responses is a challenging and multi-faceted problem, which has attracted many researchers from different disciplines and remains a difficult task in computer animation for decades. Generally, to make progress, it is necessary to limit the scope of the problem to synthesize some subsets of extremely large motion space.

In recent years, with the advancement of motion capture techniques and the popularity of motion acquisition systems, it is now relatively easy to record high-quality human motion data for a wide range of behaviors from live performers. More and more motion capture data is available to the public, such as the CMU MoCap database [1] and the HDM05 database [2]. These motion capture databases have spurred the data-driven

☆ This paper has been recommended for acceptance by Shi Kho Chang.
* Corresponding author. Tel.: +86 13691179189.
E-mail address: wwxing@bjtu.edu.cn (W.W. Xing).

1045-926X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jvlc.2013.10.001

animation techniques that utilize a set of representative motion data samples stored in motion database to synthesize long motions for character animation applications.

In particular, graph-based synthesis methods such as motion graphs and move trees have emerged as popular ways to create human motions from existing motion segments at runtime which employ the bag-of-clips data structures and generate realistic motion by concatenating short motion clips to accomplish the desired task. Since motion graphs only support transitions between similar frames, and move trees only support transitions between the end of one motion segment and the start of another, creating efficient graphs for synthesis require a great amount of expertise and manual tuning, which make it difficult to create wide variety of behaviors based on ever increasing complexity of data structures. There have been many efforts in improving the agility of graph-based methods by enhancing the ability to efficiently navigate large example dataset.

However, each motion data is rigid and static, which represents only static trajectories recording very specific instance of valid motion and provides no knowledge of how the character would interact with the surrounding world and response to user's control [3,4]. This property leads to two fundamental problems that prevent graph-based methods from being actively used in practice. First, it is difficult and infeasible to build graph that cover all possible motions of different behaviors with numerous changes in speed, direction, styles and others due to the limitations of the available motion capture data sources and runtime computational capacity in searching over graph. Second, graph-based methods lack the adequate flexibility and controllability to synthesize agile reactivity of the animated character to the dynamically changing environment and user interaction due to the sparse and finite states in the graph.

Human motion is a highly varied and continuous phenomenon, so we need to achieve agile control in continuous and smooth actions. Lee and his colleagues [3] propose a new motion representation for interactive character animation called Motion Field, which organizes training motion dataset into a high-dimensional generalization of a vector field, then generates an animation by freely flowing through the motion field in response to user commands. Motion fields significantly improve the agility and responsiveness in synthesizing character animation.

However, motion field requires enough motion data to adequately fill out the high dimensional space of poses for building a relative fully-continuous state representation of the field in order to ensure smooth character motion and retain naturalness. On the other side, since the size of searching space in the field will directly affect the speed of runtime synthesis, it is impractical to form larger, more complete motion field which covers the entire space of behaviors, so the typical motion field is usually constrained in a similar type of movements due to the limitation of computational capacity, which cannot cover a wide variety of human behaviors to meet the diversity requirement of human motion synthesis.

In this paper, we propose a novel framework Hybrid Motion Graph, which integrates motion field continuous representation into motion graph control to synthesize a rich repertoire of realistic human activities for virtual characters. In our approach, motion fields provide character the ability to agilely respond and react to the dynamic environment and user control, while the structural control of motion graph guarantees the fast connectivity and smooth transition among various behaviors.

In general, our HMG framework has the following advantages.

(1) The scale of HMG may be actually extended unlimitedly through assembling the separate motion fields of different motion classes as building blocks combined by smooth transitions, which efficiently meet the diversity requirements of character animation applications.
(2) Motion field as the local flexible continuous control mechanism is introduced into graph-based synthesis approach, which enables flexible control for producing continuous and smooth actions in agile response to dynamic environments and user input.
(3) Motion graph as the global structural control mechanism combines the separate motion fields of each class, which enables runtime direct switching behaviors and guarantees fast connectivity and smooth transition among motion fields.
(4) Motion template is added into building motion field, which enhances the continuity of field and optimizes the state space consisting of motions belonging to similar actions with many spatio-temporal variations due to styles, speeds, performers, etc.

The remainder of this paper is organized as follows. In Section 2, we review the related work. Section 3 overviews the HMG framework. Section 4 describes how to construct the HMG from motion capture dataset. Section 5 details the control of HMG synthesis. Experimental results are presented in Section 6, and conclusion in Section 7.

2. Related work

To create lifelike character animation, keyframing is the most traditional approach which gives animator the ultimate manual control over every detail of the motion. However, it requires special artistic talents and expert skills, and it is also very time and effort intensive. In the past decade, researchers have studied ways to generate human motion in an automated way, which are generally divided into two categories: physically based approaches and data-driven approaches.

Physically based approaches usually build an internal rigid body model of virtual character animated by the controller under the laws of motion. Proportional-Derivative (PD) Controllers and feedback balance controllers are commonly used for their simplicity [5–7]. However, it is difficult to model more complex physical system to simulate human characters which is a high dimensional and highly nonlinear dynamic system. Although these approaches assure physical realism, the generated motions appear robotic, furthermore, physical correctness does not guarantee motion naturalness. The key