PROPOSAL: FAST OPTIMIZATION OF HIGHLY DYNAMIC CONTROLLERS FOR HUMANOID CHARACTERS

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Sehoon Ha

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PROPOSAL: FAST OPTIMIZATION OF HIGHLY DYNAMIC CONTROLLERS FOR HUMANOID CHARACTERS

Approved by:

Professor C. Karen Liu, Advisor
School of Computer Science
Georgia Institute of Technology

Professor Greg Turk
School of Computer Science
Georgia Institute of Technology

Professor Jarek Rossignac
School of Computer Science
Georgia Institute of Technology

Professor Jun Ueda
School of Mechanical Engineering
Georgia Institute of Technology

Date Approved: 1 July 2010

SUMMARY

As technology of computer animation and robotics advances, controlling highly dynamic motions has been great milestones for both virtual and real humanoid characters. However, developing controllers for dynamic motor skills is yet a challenging problem which usually requires substantial amount of design efforts and optimization time due to its complexity. In this dissertation, we introduce a set of techniques to expedite the optimization process of dynamic controllers for various dynamic motor skills, such as jumping, rolling, vaulting, and landing.

First, we develop an online algorithm to control falling and landing motions from a wide range of heights and initial speeds, which is an essential motor skill to ensure the safety of human and robots. We demonstrate that simple momentum planning with the proxy model of inertia and feedback-based rules can generate the natural landing motions without large stresses on the joints. Further, we propose an optimization algorithm for multi-contact falling motions of a real robot for minimizing the damage and protecting the important body parts. Unlikely the existing techniques which usually consider the contacts as invariant features, we searches over a sequence of contacts to find the best falling motion.

We also show that the sampling-based optimization of dynamic controllers can be accelerated by our new technique, Covariance Matrix Adaptation with Classification (CMA-C), which utilizes failed simulations to approximate an infeasible region. In addititition, we introduce a new fast optimization algorithm for solving a parameterized objective function. Inspired by Schmidt's Variability Practice Hypothesis, our algorithm simultaneously solves a continuous set of optimizers for parameterized motions at the interactive rate by sharing the simulation samples across the parameterized

goals.

By incorporating the propose techniques, we can produce highly-dynamic motions of virtual characters and real robots with minimal optimization time.

CHAPTER I

INTRODUCTION

Performing highly dynamic motions with agility and grace has been one of the greatest challenges in sports, computer animation, and robotic. A wide variety of athletic, such as acrobatic or free running, demonstrate the efficient and artistic movements which involve the abrupt changes of momentum and contacts. Furthermore, these motor skills are transferred to virtual characters in animation and game to express the intention of artists. Robotics, another application of dynamic controllers, also started to incorporate the agile movements and demonstrated running, jumping, and landing motions with real hardwares. Despite the recent progress, the development of controllers for dynamic motions is still a very difficult problem. First, highly dynamic motions need to accurately manage multiple physical properties simultaneously, such as momentum, inertia, contacts, and even damages at the impact moment. Furthermore, non-linear and discontinuous behaviors of motions makes the optimization of the controllers hard to be solved efficiently.

Learning a dynamic motor skill, such as a precision jump in Parkour or a flip in gymanstics usually requires an iterative training process with interactive coaching and repetitive practices. Even though details of the learning process remain unknown, Pitts and Posner [1] hypothesize the three stages of the skill acquisition process: the cognitive stage, the associative stage, and the autonomous stage. The cognitive stage is when the trainee gathers information about the new skill or receives the feedback on the existing skills from the coach via instructions. In the associative stage, the learner translates the declarative knowledge to functional movements after an unspecified amount of practice and few mistakes. In the autonomous stage, the skill has become almost automatic or habitual so that it can be executed with minimal amount of efforts. A key of this hypothesis is an iterative process between cognitive learning and physical training. With this intuition, we propose a human-in-the-loop optimization framework to design dynamic controllers for virtual characters, which consists of the "coaching" stage for receiving user instructions and the "practicing" stage for optimizing control parameters.

In fact, the iterative training system can greatly simplify the design process of dynamic controllers by exploiting the same mechanism as human. Moreover, since our system incrementally develops the controller by accumulating human knowledge, the existing controllers can be easily adapted, extended, or concatenated for new situations. However, several new research questions arise when we formalize the elusive principles of human learning into mathematical models for designing physics-based controllers, such as mapping the human instruction to low-level control variables or representing the accumulated knowledge on motor skills. To resolve the issues, we introduce a new hierarchical representation of motor skills, the "motor tree", to simulate the phenomenon of skill abstraction and accumulation. To increase the responsiveness, the motor tree is optimized at interactive rates by exploiting the previous failure history or idle time of the system.

CHAPTER II

ITERATIVE CONTROLLER DESIGN

Resembles learning by demonstration,

2.1 System Overview

coaching and training

2.2 Controller

Our controller produces a torque

2.3 Instruction

our instruction are following:

CHAPTER III

TIMELINE FOR PROPOSED RESEARCH

- 2014, Apr: present proposal to committee
- 2014, Apr - May: setup a virtual/real robot
- 2014, May - Aug: internship @ Disney Research
- 2014, Sep: submit the first part to ICRA
- 2014, Sep - Oct: re-formulate the research problem
- 2015, Feb: submit the second part to IROS
- 2015, Feb - May : write thesis
- 2015, May: defense thesis

REFERENCES

[1] Fitts, P. M. and Posner, M. I., "Human performance.," 1967.