PROPOSAL:
LEARNING DYNAMIC MOTOR SKILLS FOR VIRTUAL AND REAL HUMANOIDS

A Thesis Proposal
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
School of Computer Science

Georgia Institute of Technology
April 2014

PROPOSAL:
LEARNING DYNAMIC MOTOR SKILLS FOR VIRTUAL AND REAL HUMANOIDS

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SUMMARY

As technology of computer animation and robotics advances, controlling highly dynamic motions has been a great milestone 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 proposal, we introduce a set of technique for training various highly dynamic motor skills, such as jumping, rolling, vaulting, and landing, to virtual characters and real robots.

First, we introduce new algorithms to generate falling and landing motions, which are essential motor skills to ensure the safety of human and robots. We propose an online algorithm to control falling and landing motions of virtual characters from a wide range of heights and initial speeds, which can potentailly cause huge damages. With the suggested algorithm, 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. Inspired by falling of a virtual character, we develop an optimization algorithm for multi-contact falling motions of a real robot for minimizing the damage at the impact. Unlikely the existing techniques which usually consider the desired contacts as invariant features, we searches over a sequence of contacts to find the best falling motion which can handle a wider range of situations.

Second, we propose a human-in-the-loop (HITL) system to develop dynamic controllers under the guidance of a human coach. In this system, the user can provide a sequence of high-level instructions to iteratively train dynamic controllers of characters as if coaching a human trainee. To facilitate the mapping between high-level instructions and control variables, we introduce a new representation of dynamic

controllers, the “motor tree”, which also enables flexible re-assembly and efficient re-optimization by preserving the invariant features of motor skills. Further, the optimization process is accelerated by utilizing the failed previous trials. Using our proposed system, we also train a real robot to perform dynamic motor skills such as rolling under enough consideration on noises over control and simulation.

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

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 and designers. 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.

In computer animation and robotics community, different categories of approaches have been applied to control virtual and real characters. For generating a sequence of dynamic motion, two approaches has been frequently applied to control problems: tracking the reference motion, or solving the space-time optimization problem under the physics constraints. Both methods demonstrated that a variety of motions can be achieved by solving the optimization problem which considers the entire sequence of motions. However, the optimization over the entire motion usually requires a long optimization time and further falls short of abilities for adapting the motion to new environments. On the other hand, abstract model based controllers can be interactively adapted to a wide range of situations by capturing the essential features of the dynamic motion. This approach shows the robust control over various motions, such as walking, balancing, and falling, but hard to consider the very detailed features such as the exact boundary of characters or a sequence of contacts. A sampling-based optimization for the parameterized controllers has proven effective for optimizing the motion within a realistic simulation environment, but it also takes a long time to be optimizzed, especially when the objective function is parameterized or concatenated for long term goals.

In this proposal, we tackle the problem of controlling safe falling and landing motion for virtual characters and robots, which is a fundamental motor skill because highly dynamic motions involve the abrupt changes of contacts and can cause huge damages on the body parts. While absorbing the shock at the impact, a successful landing controller also should be able to maintain readiness for the next action by managing the momentum properly. For the virtual character, we introduce a fast and robust optimization algorithm for controlling falling and landing motions of virtual characters from a wide rage of heights and initial speeds. while reducing joint stress. Further, we tackle a safe falling of a robot by planning a sequence of multiple contacts, which endures larger external perturbatations comparing to the existing methods.

Further, we propose new algorithms for accelerating sampling-based optimization methods, which is popular for optimizing dynamic controllers due to its robustness. Especially, we assume two difficult optimization problems, multiple constraints and parameterized objective functions, which usually require longer computational time. For the highly constrained problem, we introduce a new optimization algorithm, Covariance Matrix Adaptation with Classification (CMA-C), which efficiently solves the constrained problem by estimating the infeasible region from bad samples. In addition, instead of solving the parameterized goals sequentially, we solve them simultaneously by directly optimizing a mean segment from the shared simulation samples.

Since the mean segment is confined by an explicit equation, we can produce a continuous set of optimizers which has a coherent style over the solutions.

In this proposal, 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.

1.1 Organizations

The rest of sections are organized as follows:

- **Optimization of Falling and Landing motions for characters** In this section, ..
- **Optimization of Multi-contact Falling sequences for robots** In this section, ..
- **Fast sampling-based optimization based on failed samples** In this section, ..
- **Fast Optimization of Parameterized Objective Goals** In this section, ..

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.