Control of Complex, Physically Simulated Robot Groups

David C. Brogan
University of Virginia
Charlottesville, Virginia

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Abstract

Actuated systems such as robots take many forms and sizes but each requires solving the difficult task of utilizing available control inputs to accomplish desired system performance. Coordinated groups of robots provide the opportunity to accomplish more complex tasks, to adapt to changing environmental conditions, and to survive individual failures. Similarly, groups of simulated robots, represented as graphical characters, can test the design of experimental scenarios and provide autonomous interactive counterparts for video games. The complexity of writing control algorithms for these groups currently hinders their use. A combination of biologically inspired heuristics, search strategies, and optimization techniques serve to reduce the complexity of controlling these real and simulated characters and to provide computationally feasible solutions.

Keywords: Multiagent, dynamic simulation, group navigation, herds, swarms

1 Introduction

Animated characters are needed to play the role of teachers or guides, teammates or competitors, or just to provide a source of interesting motion in virtual environments. The characters in a compelling virtual environment

Figure 1: Images of 105 simulated one-legged robots and 6 simulated bicycle riders.

must have a wide variety of complex and interesting behaviors and must be responsive to the actions of the user. The difficulty of constructing such synthetic characters currently hinders the development of these environments, particularly when realism is required. In this paper, we describe one approach to populating graphical environments, using dynamic simulation to generate the motion of characters (Figure 1).

Motion for characters in virtual environments can be generated with keyframing, motion capture, or dynamic simulation. All three approaches require a tradeoff between the level of control given to the animator and the automatic nature of the process. Animators require detailed control when creating subtle movements that are unique or highly stylized. Generating expressive facial animations usually requires this low level of control. Automatic methods are benecial because they can interactively produce motion for characters based on the continuously changing state of the user and other characters in the virtual environment.

Keyframing requires that the animator specify critical, or key, positions for the animated objects. The computer then fills in the missing frames by smoothly interpolating between those positions. The specification of keyframes for some ob jects can be partially automated with techniques such as inverse kinematics, but keyframing still requires that the animator possess a detailed understanding of how moving objects should behave over time as well as the talent to express that information through the conguration of the character. A library of many keyframed animations can be generated off-line and subsequently accessed in an interactive environment to provide the motion for a character that interacts with the user.

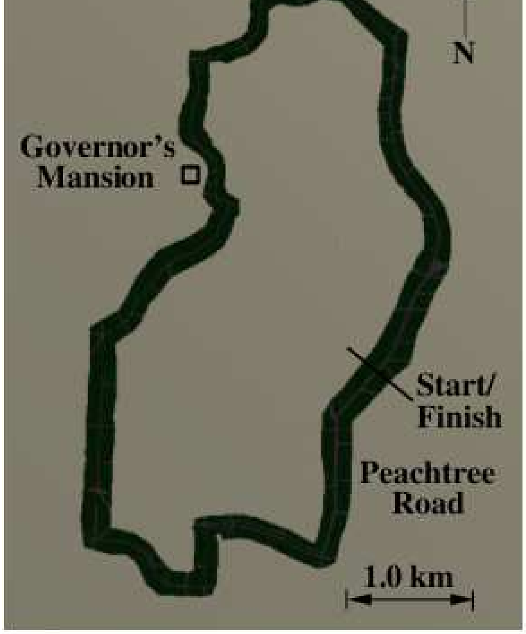

Figure 2: The 13-kilometer race course from the 1996 Olympics. This graphical course captures the elevation, side streets, and surrounding terrain of the streets from Atlanta, Georgia where the race was held.

To illustrate the use of dynamically simulated characters, we created a group of simulated human bicyclists and a group of alien bicyclists that ride on a bicycle race course (figure 2). Our earlier results indicate 1,2 that we can generate algorithms that support characters of different types and groups of varying size, however, manual tuning was required to obtain good performance. In this paper we describe automatic tuning methods and algorithms that generate improved group performance.

2 Background

Herding, flocking, and schooling behaviors of animals have been studied extensively over the past century, and this research has stimulated attempts to create robots and simulated characters with similar skills. Biologists have found that groupings in animals are created through an attraction that modulates the desire of each member to join the group with the desire to maintain a sufficient distance from nearby characters.[**?**] As an example of this attraction, Cullen, Shaw, and Baldwin[**?**] report that the density of fish is approximately equal in all planes of a school, as if each fish had a sphere around its head with which it wished to contact the spheres of other fish. Biologists have found that herding benefits group members by limiting the average number of encounters with predators (data summarized in Veherencamp). Group behaviors also allow animals to hunt more powerful animals than those they could overpower as individuals. The success of behaviors such as these in biological systems argues the merit of exploring their use in robotic systems. An understanding of these behaviors is essential for realistic characters in virtual environments.