Evolutionary Behavior Acquisition for Humanoid Robots

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Abstract. This paper describes and analyzes a series of experiments to develop a general evolutionary behavior acquisition technique for humanoid robots. The robot's behavior is defined by joint controllers evolved concurrently. Each joint controller consists of a series of primitive actions defined by a chromosome. By using genetic algorithms with specifically designed genetic operators and novel representations, complex behaviors are evolved from the primitive actions defined. Representations are specifically tailored to be useful in trajectory generation for humanoid robots. The effectiveness of the method is demonstrated by two experiments: a handstand and a limbo dance behavioral tasks (leaning the body backwards so as to pass under a fixed height bar).

1 Introduction

The recent remarkable progression of robotics research makes highly precise and advanced robots available today. Despite the availability of sophisticated robots, acquisition of behavioral tasks remains as a big hurdle in the field. Currently, several approaches are prominent in evolutionary behavior acquisition. [1], [2], [3] investigate appropriate neural network architectures using genetic algorithms for the adjustment of network parameters. Authors of these papers try to evolve behavioral tasks mainly based on navigation in a constructed environment for the wheeled robot Khepera. Although the results from these experiments are promising in terms of conceptual findings, there exist very few applications of the neuro-evolutionary techniques for more complex and high mobility robots such as humanoid robots. Another approach in evolutionary behavior acquisition is evolutionary gait optimization undertaken by the authors [4], [5]. These experiments involve optimization of a readily available controller for a previously specified behavior, such as quadruple walking. Main drawback here is the assumption that a hand designed controller is readily available. In this paper, we take a slightly different approach than the techniques discussed above. Rather than optimizing a hand designed controller or trying to evolve primitive behaviors conceptualized with neural networks, we consider the behavior acquisition task as a combinatorial optimization task where the task at hand is decomposable into primitive actions, and the goal is to find the optimum sequence (behavioral sequence) of those primitive actions which constitute the desired complex behavior. In this regard, evolving feedback controllers is beyond the scope and aim of this paper. Before

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delving into details of the devised GA architecture we would like to discuss the difficulties and restrictions regarding the humanoid robots.

2 Peculiarities of Humanoid Robots

Balancing requirements for biped humanoid robots are governed by complex equations and are mostly specific to the generated motion patterns. One general approach in controlling the balance of a walking biped humanoid robot is Zero Moment Point (ZMP) [7]. ZMP computation requires the precise knowledge of robot dynamics, center of mass location and inertia of each link involved in the motion pattern. Another approach which requires relatively limited knowledge of robot dynamics is Inverted Pendulum Model (IPM). However, IPM is inapplicable in cases where the foot must be placed in specified locations during the phase of a motion (Fig.1a.) In order to resolve this issue, hybrid approaches, combining ZMP and IPM methods are also proposed [8]. The main difficulties with these approaches are the need for the precise knowledge of robot dynamics which is not available all the time, and the customization or in some cases redesign of the dynamics models for each individual motion. Moreover, ZMP based approaches are not directly applicable in situations where the robot's feet have no contact with the ground as demonstrated in the handstand task (Fig. 1b) or in case of interacting with a third object such as kicking a ball (Fig. 1c).

(a) (b) (c)

Fig. 1. Typical examples where traditional methods fall short. (a) Walking on specified locations (b) Handstand task (c) Ball kicking.

There exist also motion generation techniques based on Interactive Evolutionary Computation (IEC) for people who have no specialized knowledge of humanoid robots [9]. However, IEC methods suffer from the subjective evaluation criteria incurred by the human factor involved and still require the developer to account for the inverse kinematics equations governing the balancing issues between the key frames of a motion [10]. Addressing these issues, we devise a general learning scheme based on genetic algorithms which requires only minimum knowledge of humanoid robot dynamics and the balancing requirements of a particular motion pattern. With the proper selection of a primitive action, the genetic algorithm implicitly accounts for the balancing requirements and the acquisition of desired behavior, where traditional methods would require custom balancing methods based on ZMP and/or IMP along