Abstract: Evolving a Neural Controller for Fault-Tolerant Four-Legged Robots using Parallel Genetic Algorithm

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Abstract

It is expected that robots could operate autonomously in extreme environments without human intervention. However, it is not a trivial task to design robots robust to all kinds of faults. Biological entities have capability to create new behaviors overcoming unexpected damage on their body. This is also one of desirable properties for industrial robots operating remotely in extreme conditions. In this paper, we propose to use a bio-inspired learning algorithm to generate new behaviors on a four-legged robot against unexpected body damages. Since the learning algorithm can be accelerated using parallelism on multiple machines, it is possible to adapt to changes (damages) quickly using remote computational resources. Experimental results show that the robot could adapt to damages on different part of robot's body successfully.

Animals' brain is resilient to physical damage on their body allowing organism to survive for long-time. For example, a lizard uses four legs with one tail to generate its movements and the animal could recover its motion from losing one leg or tail by slightly adapting its behavioral patterns. This property is also desirable for mechanical robots operating in extreme environments without human operator [1]. Since humans are not close to the robot, the machine's failures significantly reduce the probability of successful mission completion.

The easiest way to make the robot as fault-tolerant is to have redundant hardware [2]. However, redundancy is costly expensive and it often makes the control system complex. It is not possible to consider all possible faults prior to damage but stores all the solutions for known faults. To overcome those limits, it needs a mechanism to recover from unexpected damages [3]. In this approach, the robot executes machine learning algorithms to learn a new behavior if it detects broken part of body. Because the old control mechanism designed for intact body would fail to work correctly, it is necessary to learn new skills suitable for the new body. This allows the robot lose its functionality gracefully instead of radical performance degradation.

In this paper, we propose to use Parallel Genetic Algorithm (PGA) to generate a new compensatory behavior for unexpected damage on robot's body. Genetic Algorithms (GA) mimics the nature's process to reproduce new genes adaptable to changing environments [4]. It has been widely used to solve engineering optimization problems and known to be strong for global search [5][6]. Initially, it generates a population of solutions represented as a bit-string randomly and evaluates their goodness. Based on the fitness to the problem, they can reproduce their offspring (slightly modified solutions) for the next generation using mutation and crossover operations. It is possible to accelerate the speed of the genetic algorithm using parallelism with a cluster of computers, or General Purpose Graphic Processing Units (GPGPU). It allows the rapid adaptation of robot controllers for the emergency situations.

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