Parallelization of a Genetic Algorithm for Snake Robot Motion Control

Dustyn James Tubbs, Pallavi Srivastava, Tao Sun, Xiaotian Zhang

Background

Snake robots have strong adaptability to complicated environments, and are redundant to be robust against mechanical failures, making them advantageous toward their counterparts having wheels and legs. However, the locomotion mechanisms are relatively hard to analysis and model. In a previous work [1], the locomotion motion of a snake robot was analyzed based upon a simplified mathematical model consisting of n rigid links with torque actuators at $(n-1)$ joints. The model for the friction interaction between the snake robot and the underneath horizontal plane was also proposed. These models and analysis lay the mathematical foundation for the motion control of the snake robots.

Essentially the serpenoid moving configuration suggested by the mathematical model is a wave. The problem of motion control is reduced to selection of controlling parameters for the robot to match its motion with the traveling wave formula $\Phi(t) = A \cdot sin(\omega \cdot t + \phi)$. In the area of robotic motion control, the genetic algorithm (GA) has got the greatest propagation [2], with a trial and error process. The basic GA process has the following cycle: parameter sets population generation, fitness evaluation, genetic operation (crossover and mutation) to form new populations and go on until the termination criterial is met. In our problem, the fitness evaluation could be calculating the difference between the generated moving configuration and the targeted traveling wave moving configuration. Another advantage of GA is that it is an embarrassingly parallel problem where the task could be decomposed into different processes and little communication is needed. Parallel implementations of GA could have two flavors [3]. Coarse-grained parallel GA assumes a population on each of the computer nodes and migration of individuals among the nodes. Fine-grained parallel GA assume an individual on each processor node which acts with neighboring individuals for selection and reproduction.

Project Goals

The proposed project has the following 3 steps.

1. Simulate an articulated snake robot consisting of 5 rigid links with 4 torque actuators at the joints. Implementing a sequential GA to control the snake's motion, making it moving along a straight line with the moving configuration to match with the travelling wave suggested by the mathematical model [1].

2. Parallize the sequential GA code with OpenMP and MPI. Both coarse-grained and fine-grained parallelization schemes would be performed [3]. The results would be checked against the sequential version.

3. Compare the effect of the parallelization under different schemes with different methods. Analyze the results and explain.

References

[1] Masashi Saito et. al *Serpentine Locomotion with Robotic Snakes* IEEE Control Systems Magazine, 2002.

[2] Juan Manuel Ahuactzin et.al *Using Genetic Algorithm for Robot Motion Planning* Laugier C. (eds) Geometric Reasoning for Perception and Action. Lecture Notes in Computer Science, vol 708. Springer, Berlin, Heidelberg, 1993

[3] Erick Cantu-Paz *A Survey of Parallel Genetic Algorithms* IlliGAL report 97003, 1997.