Chapter 1

Introduction

1.1 Problem Statement and Overview

Particle Swarm Optimization (PSO) is a recent, novel optimization algorithm, inspired by simulations of the social behavior of flocks of birds [49]. Numerous studies have shown the PSO to be a very effective optimization algorithm, outperforming the traditional genetic algorithm (GA). The algorithm is simple to implement, and does not depend on problem specific recombination and selection operators to achieve maximum effectiveness.

Two distinct features of the PSO algorithm's swarming behavior makes it an effective optimizer:

- each particle in a swarm retains a memory of the best solution that it has found, and
- all particles constantly move towards the best solution found by the entire swarm.

This approach allows the algorithm to quickly traverse a search space and rapidly converge. The fact that each particle in a swarm represents an *independent* candidate solution, makes the algorithm largely insensitive to multimodal optimization domains where other numerical techniques may find suboptimal solutions.

Niching techniques extend the search capabilities of population based optimization techniques to locate multiple solutions in a single search space. Numerous optimization

problems with multiple, equally acceptable solutions, such as solving systems of equations, exist. Niching techniques have been investigated in the genetic algorithm (GA) research field, with very little particle swarm optimization (PSO) based research undertaken on this subject. This thesis investigates the possible application of GA-based niching techniques to the PSO algorithm, and introduces two new unique PSO-based niching techniques that utilize the characteristics of the PSO algorithm.

1.2 Objectives

The main objective of this thesis is to study niching in the context of particle swarm optimization. In reaching this goal, the following subobjectives are identified:

- To provide an overview of existing GA–based and PSO niching techniques.
- To present and analyze the novel *nbest* and NichePSO algorithms.
- To compare the performance of the above algorithms to well-known GA niching algorithms.
- To show that the unique swarming nature of the PSO algorithm is a promising tool when investigating new niching algorithms.

1.3 Contribution

The main contributions of this thesis are:

- The conclusion that GA niching algorithms may not necessarily directly apply to the PSO algorithm.
- The introduction of a PSO niching technique, developed specifically to solve systems of linear and non-linear equations.
- The development of a PSO niching algorithm that use multiple swarms to maintain several solutions concurrently in a single search space.

1.4 Thesis Outline

Chapter 2 presents an introduction to the theory of optimization. A general evolutionary computing framework is then given, with specific focus on genetic algorithms. A complete presentation of the PSO algorithm is then given, including a number of optimizations and extensions.

Chapter 3 reviews the evolutionary motivation behind niching techniques. A number of GA niching algorithms are then discussed, followed by an existing PSO-based niching algorithm. The application of GA niching techniques to the PSO are considered.

Chapters 4 and 5 respectively present the *nbest* and NichePSO algorithms. The characteristics of each of these algorithms are analyzed and considered, and experimental results are presented to illustrate their effectiveness. Chapters 6 presents an empirical comparison of both these techniques to existing GA niching techniques.

Chapter 7 presents a summary of the research done in this thesis. A number of future research topics are identified.

An appendix presents a list of publications that followed from the presented work.