Chapter 1

Introduction

1.1 Motivation

Traditional single trajectory algorithms based on the simple gradient descent algorithm, when applied to global optimization problems, all have one great common drawback, namely the tendency to become 'stuck' in a local minima during the search. Numerous approaches have been formulated to overcome this drawback. A good review of global optimization algorithms is presented by Törn and Zilinskas [1]. Recently, multi-start methods [2] have been proposed to overcome this drawback, where parallel or sequential searches are executed with each trajectory origin randomly positioned in the search space. This is done in the hope that at least one of the search trajectories will terminate at the global optimum. A major drawback however is that information gathered by each search trajectory is usually unavailable to the others, or discarded in subsequent searches.

With population based methods it is attempted to retain and share the fitness information that has been obtained previously and, by using this information, direct subsequent function evaluations in a more intelligently coordinated search pattern to improve performance and avoid entrapment in local minima.

The most commonly used population-based evolutionary methods are based on, or inspired by, phenomena found in nature. Several different types of evolutionary search methods were developed independently. These include genetic programming (GP) [3], which evolve programs, evolutionary programming (EP) [4], which focus on optimizing continuous functions without recombination, evolutionary strategies (ES) [5], which focus on optimization of continuous functions with recombination, and genetic algorithms (GAs) [6], which focus on optimizing general combinatorial problems. (For a brief description of these and other related methods, see Appendix C).

While population based methods compare badly in terms of cost effectiveness with finely tuned gradient based trajectory methods, they do tend to be more robust (i.e more resistant to being trapped in a local minima) in complex global optimization problems, especially those with excessive numerical 'noise', when the use of gradient methods become an 'art' indeed.

In this dissertation such a recently introduced population based method, namely the particle swarm optimization paradigm, is implemented, analyzed and applied to a number of global and structural optimization problems.

1.2 Objectives

The objective of this work is to contribute to the development of a reliable and efficient global optimization algorithm based on the the particle swarm optimization algorithm. It is also the intention to analyse the various variants which have recently been proposed to improve upon the PSOA's performance on a common test set, as they have previously been studied in isolation by their respective authors, and usually for different problems.

In addition, the developed algorithm is to be applied to an engineering problem of practical importance, namely the optimal design of truss structures. To accomplish this, the accomodation of constraints into the PSOA is to be studied.

The final objective is to obtain a general purpose particle swarm algorithm which will strike an acceptable balance between reliability and cost.

1.3 Thesis overview

In Chapter 2 a brief historical overview of the particle swarm optimization algorithm is presented, followed by a discussion of the benefits of population based algorithms. The formal mathematical formulation of the PSOA is then detailed, with the remainder of the chapter taken up by an analysis and identification of shortcomings of the PSOA.

Chapter 3 is concerned with a number of variants on the original PSOA, which were proposed in order to improve performance in terms of reliability and cost. These variants are formulated and discussed.

Chapter 4 introduces the global programming problem and the extended Dixon-Szegö test set, which is used in a comparative study of the abovementioned variants.

In Chapter 5 a detailed parameter sensitivity study is performed on the most successful of the PSOA modifications.

In Chapter 6 the results of the parameter study are used in applying the selected PSOA variants with optimized parameters to a set of structural truss design problems.

Finally, conclusions and recommendations for future study are made in Chapter 7.