

Preface

Stroll the meadows on a dark summer night and you may catch a glimpse of glowworms that illuminate the night with brilliant flashes of light, thereby making themselves conspicuously visible over long distances. Glowworms produce an emission of natural glow through a process called bioluminescence. They exploit the property of bioluminescence in a variety of ways for the purposes of mating and species preservation. Glowworms use photic signaling and attraction mechanisms to rendezvous on trees and form large swarms, resembling fiery clouds that flash synchronously. Firsthand accounts of this unique group behavior have been reported by many naturalists in the past.

The focus of this book is on the development of glowworm swarm optimization (GSO), a swarm intelligence algorithm inspired by the behavior of glowworms (also known as fireflies or lightning bugs). GSO belongs to a broad class of synthetic swarm algorithms that are modeled after natural swarms. The underlying designs either closely, or loosely, mimic the individual behaviors of their natural counterparts; in other frameworks, the mirrored principles may be modified to some extent based on the target problem. GSO is originally developed for numerical optimization problems that involve computing multiple optima of multimodal functions, as against other algorithms, which aim to identify the global optimum. The problem that GSO solves is inspired by swarm robotics applications involving search for possibly multiple unknown signal sources.

The behavior of natural glowworms to vary bioluminescence and glow at different intensities is replicated in GSO. Each synthetic glowworm glows with an intensity proportional to its fitness and moves toward a stochastically chosen neighbor with a relatively higher glow. An adaptive neighborhood range discounts the effect of distant members whenever a glowworm has a plenty of neighbors or the range goes beyond its perception limit. These taxis behaviors (based only on local information and selective neighbor interactions) enable the swarm to split into disjoint subgroups that converge to multiple high function value points.

The generality of the GSO algorithm can be evidenced in its application by independent researchers to a variety of problems ranging from optimization to robotics. Examples include computation of multiple optima, annual crop

planning, cooperative exploration, distributed search, multiple source localization, contaminant boundary mapping, wireless sensor networks, clustering, knapsack, numerical integration, solving fixed point equations, solving systems of nonlinear equations, and engineering design optimization. Further, other researchers have also developed several variants of GSO in order to improve its convergence properties.

Overview of the Book

This book provides a comprehensive account of the glowworm swarm optimization algorithm. Various aspects of GSO including the underlying ideas, theoretical foundations, algorithm development, computer programs, possibly interesting research problems, and its variations are provided. The book is divided into eight chapters.

Chapter 1 provides an overview of natural and synthetic swarm intelligence. A brief account of bioluminescence in natural glowworm swarms is provided. The underlying ideas of the GSO algorithm and the behavior patterns that are borrowed from natural glowworms are described. The primary target problems solved by GSO are briefly described.

Chapter 2 presents the algorithm development of GSO. The various algorithm steps of the basic algorithm are described. GSO, in its present form, has evolved out of several significant modifications incorporated into the earlier versions of the algorithm. Many ideas were considered in the development process before converging upon the current GSO version. Some of the important steps in this evolution are briefly discussed. Simulations to illustrate the basic capability of the algorithm are presented. The various features of GSO are compared with those of other popular swarm intelligence algorithms. Additional notes on independent works on GSO are provided at the end of the chapter. A more in-depth treatment of this topic is deferred to Chap. 8.

Chapter 3 deals with the theoretical foundations of GSO. Initially, a characterization of the swarming behavior of agents in GSO is carried out, which guides the formulation of a framework used to analyze the algorithm. A theoretical model of GSO is obtained by using assumptions that make it amenable to analysis, yet reflecting most of the features of the original algorithm. Next, local convergence results for this GSO model are provided. Some illustrative simulations are presented to support these theoretical findings.

In Chap. 4, numerical simulation results to evaluate the efficacy of GSO in capturing multiple optima of multimodal optimization problems are presented. For this purpose, several benchmark multimodal functions are considered that pose a wide range of complexities. The parameter selection problem is addressed by conducting experiments to show that only two parameters need to be selected by the user. Next, simulation experiments are used to compare GSO with Niche-PSO, a PSO variant that is designed for the simultaneous computation of multiple optima. Finally, algorithmic behavior is examined in the presence of noise.

In Chap. 5, the potential of GSO for signal source localization is demonstrated by using physically realistic simulations and experiments with real robots. The modifications incorporated into the algorithm in order to make it suitable for a robotic implementation are described. Results from Player/Stage simulations and sound source localization and light source localization experiments are presented to test the potential of robots using GSO for localizing signal sources.

In Chap. 6, a GSO variant for a heterogeneous swarm of mobile and stationary agents is developed and its application to ubiquitous computing environments is discussed. In particular, a GSO-based ubiquitous computing environment is proposed to address the problem of sensing hazards. Simulation experiments are performed to demonstrate the efficacy of the algorithm in tackling such hazardous situations. It is shown that the deployment of stationary agents in a grid-configuration leads to multiple phase-transitions in a graph of minimum number of mobile agents required for 100.

In Chap. 7, the behavior of GSO agents in the presence of mobile sources is investigated. In particular, a coordination scheme based on GSO is developed that enables a swarm of glowworms to pursue a group of mobile signal sources. Some theoretical and numerical results that provide upper bounds on the relative speed of the mobile source in different cases are presented.

Chapter 8 presents a survey on applications of GSO and its extensions. Work on GSO that appeared in the recent literature can be primarily classified into three categories. Researchers in the first category proposed modifications of GSO, which were mainly focused on either improving the convergence properties of original GSO or modifying GSO for global optimization problems. In the second category, researchers used basic GSO in different applications. In the third category, other researchers modified GSO and used them in some applications. A summary of these independent works is provided.

Each chapter ends with a set of thought exercises and computer exercises. A long list of references on the GSO algorithm, along with its variants, and GSO applications are provided. Finally, GSO code in MATLAB and C++ and some useful external links are provided in the appendix.

The book is intended primarily for researchers in swarm intelligence and computational intelligence and graduate and undergraduate students working on these topics.

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