A Dynamic Topology in Particle Swarm Optimization for Constrained Problems

Arturo Marquez-Flores

https://github.com/arturomf94/PSO

22 august, 2019

Overview

Introduction
- Motivation
- Literature Review

Theory

Experiments & Results
- Experiments
- Results

Conclusions

INTRODUCTION

MOTIVATION

What is Particle Swarm Optimization(PSO)?

PSO

What is Particle Swarm Optimization(PSO)?

A stochastic optimization method proposed originally by Kennedy and Eberhart in [KE95].

PSO

How does it work?

A population of potential solutions are evaluated and iteratively improve their *fitness* based on their past evaluations and the information the receive from their neighbours in a communication topology.

PSO

Advantages:

- Easy implementation.
- Rapid convergence.

Limitations:

- Premature convergence.
- Transformation invariance.

Solutions?

- Communcation topology.
- Model coefficients.
- Popoulation size.
- Update rules.
- Hybrid models.

PSO

Most efforts have focused on unconstrained optimization problems...

Topology

A modified topology has a considerable effect on the convergence rate and the diversity of the population.

Topology

- Higher connectivity $\rightarrow$ Faster convergence, less diversity.
- Lower connectivity $\rightarrow$ Slower convergence, more diversity.

Topology

Topologies can be dynamic and adaptive.

Focus

We will focus on dynamic topologies in constrained problems.

LITERATURE REVIEW

Useful Reviews

Extensive reviews by Bonyadi in [BM17] and Jordeh in [Jor15].

Topology and Unconstrained Problems

A first approach by Kennedy in [Ken99] experiments with 4 topologies and 4 benchmark functions and concludes that the global topology promotes exploitation, while the local topology promotes exploration.

Topology and Unconstrained Problems

Kennedy and Mendes follow the same direction in [KM02] and [MKN04], resepectively, but they lack statistical rigour.

Topology and Unconstrained Problems

In [Eng13] Engelbrecht carries out a more meticulous study and shows that the difference between the performance of different topologies depends highly on the objective function at hand.

Topology and Unconstrained Problems

More recently, in [BK18], Blackwell shows that topologies with a greater degree of *locality*, as the local topology, are better for *harder* problems.

Topology and Unconstrained Problems

Other topologies have been considered in the literature, such as the dynamic hierarchy by Janson in [JM05], the scale-free topology by Zhang in [ZY11] and the small-world topology by Gong in [GZ13].

Dynamic and Adaptive Topologies

In [Cle06] Clerc and in In [LI14] Lim have proposed algorithms whose topologies are adapted according to the performance feedback. In [Sug99] and [MM13] Suganthan and Marinakis, respectively, propose algorithms that starts with the local topology and its connectivity is gradually increased until it reaches a global topology.

PSO for constrained problems

One first approach by Parsopulos in [PV02] used penalty functions. Other methods include the preservation of feasible solutions, the closeness to the feasible region and penalty functions were used in [HE02], [PC04] y [CH03], by Xiahoui, Pulido and Coath, respectively. Other approaches can be found in [PE07], [HW07], [BLM13] y [ESM13], and for a focus on feasibility rules a complete review can be found in [AAMC16] by Aguilera.

Dynamic Topologies in Constrained Problems

In general, there is a lack of research that overlaps both dynamic topologies and constrained problems. However, an important reference would be [BM14] by Bonyadi, where an algorithm is proposed, that is based on ϵ-level constraint satisfaction. This algorithm was extended in [BLM14], again by Bonyadi, with a dynamic topology that is based on the one used in [Sug99].

Dynamic Topologies in Constrained Problems

Our focus combines a dynamic topology similar to the one used in [Sug99] by Suganthan, the preservation of feasible solutions in [HE02] and feasibility rules reviewed in [AAMC16].

THEORY

EXPERIMENTS

RESULTS

CONCLUSIONS

V. Aguilera-Rueda, M. Ameca-Alducin, E. Mezura-Montes, and N. Cruz-Ramrez.
Particle swarm optimization with feasibility rules in constrained numerical optimization. a brief review.
In *2016 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC)*, pages 1–6, Nov 2016.

T. Blackwell and J. Kennedy.
Impact of communication topology in particle swarm optimization.
IEEE Transactions on Evolutionary Computation, pages 1–1, 2018.

Mohammadreza Bonyadi, Xiang Li, and Zbigniew Michalewicz.
A hybrid particle swarm with velocity mutation for constraint optimization problems.
In *Proceedings of the 15th Annual Conference on Genetic and Evolutionary Computation*, GECCO '13, pages 1–8, New York, NY, USA, 2013. ACM.

Mohammad Reza Bonyadi, Xiang Li, and Zbigniew Michalewicz.
A hybrid particle swarm with a time-adaptive topology for constrained optimization.
Swarm and Evolutionary Computation, 18:22 – 37, 2014.

Mohammad reza Bonyadi and Zbigniew Michalewicz.
Locating Potentially Disjoint Feasible Regions of a Search Space with a Particle Swarm Optimizer, pages 205–230.
12 2014.

Mohammad Reza Bonyadi and Zbigniew Michalewicz.
Particle swarm optimization for single objective continuous space problems: A review.
Evolutionary Computation, 25(1):1–54, 2017.

PMID: 26953883.

G. Coath and S. K. Halgamuge.
A comparison of constraint-handling methods for the application of particle swarm optimization to constrained nonlinear optimization problems.
In *The 2003 Congress on Evolutionary Computation, 2003. CEC '03.*, volume 4, pages 2419–2425 Vol.4, Dec 2003.

M. Clerc.
Standard pso 2006.
Technical report, 2006.
Available at `http://www.particleswarm.info/Programs.html`.

A. P. Engelbrecht.
Particle swarm optimization: Global best or local best?
In *2013 BRICS Congress on Computational Intelligence and 11th Brazilian Congress on Computational Intelligence*, pages 124–135, Sep. 2013.

S. M. Elsayed, R. A. Sarker, and E. Mezura-Montes.
Particle swarm optimizer for constrained optimization.
In *2013 IEEE Congress on Evolutionary Computation*, pages 2703–2711, June 2013.

Yue-jiao Gong and Jun Zhang.
Small-world particle swarm optimization with topology adaptation.
In *Proceedings of the 15th Annual Conference on Genetic and Evolutionary Computation*, GECCO '13, pages 25–32, New York, NY, USA, 2013. ACM.

Xiaohui Hu and R Eberhart.
Solving constrained nonlinear optimization problems with particle swarm optimization.

Citeseer, 2002:203–206, 01 2002.

Qie He and Ling Wang.
An effective co-evolutionary particle swarm optimization for constrained engineering design problems.
Engineering Applications of Artificial Intelligence, 20(1):89–99, 2 2007.

S. Janson and M. Middendorf.
A hierarchical particle swarm optimizer and its adaptive variant.
IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), 35(6):1272–1282, Dec 2005.

A. Rezaee Jordehi.
A review on constraint handling strategies in particle swarm optimisation.
Neural Computing and Applications, 26(6):1265–1275, Aug 2015.

James Kennedy and Russell C. Eberhart.
Particle swarm optimization.
In *Proceedings of the IEEE International Conference on Neural Networks*, pages 1942–1948, 1995.

J. Kennedy.
Small worlds and mega-minds: effects of neighborhood topology on particle swarm performance.
In *Proceedings of the 1999 Congress on Evolutionary Computation-CEC99 (Cat. No. 99TH8406)*, volume 3, pages 1931–1938 Vol. 3, July 1999.

J. Kennedy and R. Mendes.
Population structure and particle swarm performance.
In *Proceedings of the 2002 Congress on Evolutionary Computation. CEC'02 (Cat. No.02TH8600)*, volume 2, pages 1671–1676 vol.2, May 2002.

Wei Hong Lim and Nor Ashidi Mat Isa.
Particle swarm optimization with increasing topology connectivity.
Engineering Applications of Artificial Intelligence, 27:80 – 102, 2014.

R. Mendes, J. Kennedy, and J. Neves.
The fully informed particle swarm: simpler, maybe better.
IEEE Transactions on Evolutionary Computation, 8(3):204–210, June 2004.

Yannis Marinakis and Magdalene Marinaki.
A hybridized particle swarm optimization with expanding neighborhood topology for the feature selection problem.
In María J. Blesa, Christian Blum, Paola Festa, Andrea Roli, and Michael Sampels, editors, *Hybrid Metaheuristics*, pages 37–51, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg.

G. T. Pulido and C. A. C. Coello.
A constraint-handling mechanism for particle swarm optimization.
In *Proceedings of the 2004 Congress on Evolutionary Computation (IEEE Cat. No.04TH8753)*, volume 2, pages 1396–1403 Vol.2, June 2004.

Ulrich Paquet and Andries P. Engelbrecht.
Particle swarms for linearly constrained optimisation.
Fundam. Inf., 76(1-2):147–170, January 2007.

Konstantinos E. Parsopoulos and Michael N. Vrahatis.
Particle swarm optimization method for constrained optimization problems.
In *In Proceedings of the Euro-International Symposium on Computational Intelligence 2002*, pages 214–220. IOS Press, 2002.

P. N. Suganthan.

Particle swarm optimiser with neighbourhood operator.
In *Proceedings of the 1999 Congress on Evolutionary Computation-CEC99 (Cat. No. 99TH8406)*, volume 3, pages 1958–1962 Vol. 3, July 1999.

Chenggong Zhang and Zhang Yi.
Scale-free fully informed particle swarm optimization algorithm.
Inf. Sci., 181:4550–4568, 10 2011.