Springer

Self-adaptive multi-population genetic algorithms for dynamic resource allocation in shared hosting platforms

Genetic Programming and Evolvable Machines

December 2018, Volume 19, Issue 4, pp 505–534

| Cite as

Article

First Online: 04 July 2018

24

Downloads

Abstract

This paper presents a self-adaptive multi-population approach based on genetic algorithm (GA) for solving dynamic resource allocation in shared hosting platforms. The proposed method, self-adaptive multi-population genetic algorithm (SAMPGA), is a multi-population GA strategy aimed at locating and tracking optima. This approach is based on preventing populations from searching in the same areas. Two adaptations to the basic approach are then proposed to further improve its performance. The first adapted algorithm, memory-based SAMPGA, is based on using explicit memory to store promising solutions and retrieve them upon detecting change in the environment. The second adapted algorithm, immigrants-based SAMPGA, is aimed at improving the technique used by SAMPGA to maintain a sustainable level of diversity needed for quick adaptation to the environmental changes. An extensive set of experiments is conducted on a variety of dynamic resource allocation scenarios, to evaluate the performance of the proposed approach. Results are also

compared with those of self-organizing random immigrants GA using three well-known performance metrics. The experimental results indicate the effectiveness of the proposed approach.

Keywords

Shared hosting platforms Dynamic resource allocation
Multi-population genetic algorithm Dynamic optimization problems

Electronic supplementary material

The online version of this article (https://doi.org/10.1007/s10710-018-9326-3 (https://doi.org/10.1007/s10710-018-9326-3)) contains supplementary material, which is available to authorized users.

This is a preview of subscription content, log in to check access.

Notes

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Supplementary material

10710_2018_9326_MOESM1_ESM.docx (51 kb)
Supplementary material 1 (DOCX 50 kb)

References

1. B. Urgaonkar, P. Shenoy, T. Roscoe, Resource overbooking and application profiling in shared hosting platforms. SIGOPS Oper Syst Rev **36**(SI), 239–254 (2002)
CrossRef (https://doi.org/10.1145/844128.844151)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Resource%20overbooking%20and%20application%20profiling%20in%20shared%20hosting%20platforms&author=B.%20Urgaonkar&author=P.%20Shenoy&author=T.%20Roscoe&journal=SIGOPS%20Oper%20Syst%20Rev&volume=36&issue=SI&pages=239-254&publication_year=2002)
2. P. Ruth, J. Rhee, D. Xu, R. Kennell, S. Goasguen, Autonomic live adaptation of virtual computational environments in a multi-domain infrastructure, in *2006 IEEE International Conference on Autonomic Computing* (2006), pp. 5–14
Google Scholar (https://scholar.google.com/scholar?q=P.%20Ruth%2C%20J.%20Rhee%2C%20D.%20Xu%2C%20R.%20Kennell%2C%20S.%20Goasguen%2C%20Autonomic%20live%20adaptation%20of%20virtual%20computational%20environments%20in%20a%20multi-domain%20infrastructure%2C%20in%202006%20IEEE%20International%20Conference%20on%20Autonomic%20Computing%20%282006%29%2C%20pp.%205%E2%80%9314)
3. S.S. Manvi, G. Krishna Shyam, Resource management for infrastructure as a service (IaaS) in cloud computing: a survey. J. Netw. Comput. Appl. **41**, 424–440 (2014)
CrossRef (https://doi.org/10.1016/j.jnca.2013.10.004)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Resource%20management%20for%20infrastructure%20as%20a%20service%20%28IaaS%29%20in%20cloud%20computing%3A%20a%20survey&author=SS.%20Manvi&author=G.%20Krishna%20Shyam&journal=J.%20Netw.%20Comput.%20Appl.&volume=41&pages=424-440&publication_year=2014)
4. V.P. Anuradha, D. Sumathi, A survey on resource allocation strategies in cloud computing, in *International Conference on Information Communication and Embedded Systems (ICICES2014)* (2014), pp. 1–7
Google Scholar (https://scholar.google.com/scholar?q=V.P.%20Anuradha%2C%20D.%20Sumathi%2C%20A%20survey%20on%20resource%20allocation%20strategies%20in%20cloud%20computing%2C%20in%20International%20Conference%20on%20Information%20Communication%20and%20Embedded%20Systems%20%28ICICES2014%29%20%282014%29%2C%20pp.%201%E2%80%937)
5. M.R. Garey, D.S. Johnson, *Computers and Intractability: A Guide to the Theory of NP-Completeness*. (W. H. Freeman & Co., New York, NY, USA, 1990)
zbMATH (http://www.emis.de/MATH-item?0411.68039)

Google Scholar (http://scholar.google.com/scholar_lookup?title=Computers%20and%20Intractability%3A%20A%20Guide%20to%20the%20Theory%20of%20NP-Completeness&author=MR.%20Garey&author=DS.%20Johnson&publication_year=1990)

6. K. Shen, H. Tang, T. Yang, L. Chu, Integrated resource management for cluster-based internet services. SIGOPS Oper Syst Rev **36**(SI), 225–238 (2002)
CrossRef (https://doi.org/10.1145/844128.844150)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Integrated%20resource%20management%20for%20cluster-based%20internet%20services&author=K.%20Shen&author=H.%20Tang&author=T.%20Yang&author=L.%20Chu&journal=SIGOPS%20Oper%20Syst%20Rev&volume=36&issue=SI&pages=225-238&publication_year=2002)
7. A. Karve et al., Dynamic placement for clustered web applications, in *Proceedings of the 15th International Conference on World Wide Web*, New York, NY, USA (2006), pp. 595–604
Google Scholar (https://scholar.google.com/scholar?q=A.%20Karve%20et%20al.%2C%20Dynamic%20placement%20for%20clustered%20web%20applications%2C%20in%20Proceedings%20of%20the%2015th%20International%20Conference%20on%20World%20Wide%20Web%2C%20New%20York%2C%20NY%2C%20USA%20%282006%29%2C%20pp.%20595%E2%80%93604)
8. D. Carrera, M. Steinder, I. Whalley, J. Torres, E. Ayguade, Utility-based placement of dynamic web applications with fairness goals, in *NOMS 2008—2008 IEEE Network Operations and Management Symposium* (2008), pp. 9–16
Google Scholar (https://scholar.google.com/scholar?q=D.%20Carrera%2C%20M.%20Steinder%2C%20I.%20Whalley%2C%20J.%20Torres%2C%20E.%20Ayguade%2C%20Utility-based%20placement%20of%20dynamic%20web%20applications%20with%20fairness%20goals%2C%20in%20NOMS%202008%E2%80%942008%20IEEE%20Network%20Operations%20and%20Management%20Symposium%20%282008%29%2C%20pp.%209%E2%80%9316)
9. J. Rolia, A. Andrzejak, M. Arlitt, Automating enterprise application placement in resource utilities, in *Proceedings 14th IFIP/IEEE International Workshop Distributed Systems: Operations and Management (DSOM '03)*, (2003), pp. 118–129
Google Scholar (https://scholar.google.com/scholar?q=J.%20Rolia%2C%20A.%20Andrzejak%2C%20M.%20Arlitt%2C%20Automating%20enterprise%20application%20placement%20in%20resource%20utilities%2C%20in%20Proceedings%2014th%20IFIP%2FIEEE%20International%20Workshop%20Distributed%20Systems%3A%20Operations%20and%20Management%20%28DSOM%20%E2%80%9903%29%2C%20%282003%29%2C%20pp.%20118%E2%80%93129)
10.

M. Bichler, T. Setzer, B. Speitkamp, Capacity planning for virtualized servers. Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 1025862 (2007)
Google Scholar (https://scholar.google.com/scholar?q=M.%20Bichler%2C%20T.%20Setzer%2C%20B.%20Speitkamp%2C%20Capacity%20planning%20for%20virtualized%20servers.%20Social%20Science%20Research%20Network%2C%20Rochester%2C%20NY%2C%20SSRN%20Scholarly%20Paper%20ID%201025862%20%282007%29)

11. A. Xiong, C. Xu, Energy efficient multiresource allocation of virtual machine based on PSO in cloud data center. Math. Probl. Eng. **2014**, 816518 (2014)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Energy%20efficient%20multiresource%20allocation%20of%20virtual%20machine%20based%20on%20PSO%20in%20cloud%20data%20center&author=A.%20Xiong&author=C.%20Xu&journal=Math.%20Probl.%20Eng.&volume=2014&pages=816518&publication_year=2014)
12. Z. Zheng, R. Wang, H. Zhong, X. Zhang, An approach for cloud resource scheduling based on parallel genetic algorithm, in *2011 3rd International Conference on Computer Research and Development*, vol. 2 (2011), pp. 444–447
Google Scholar (https://scholar.google.com/scholar?q=Z.%20Zheng%2C%20R.%20Wang%2C%20H.%20Zhong%2C%20X.%20Zhang%2C%20An%20approach%20for%20cloud%20resource%20scheduling%20based%20on%20parallel%20genetic%20algorithm%2C%20in%202011%203rd%20International%20Conference%20on%20Computer%20Research%20and%20Development%2C%20vol.%202%20%282011%29%2C%20pp.%20444%E2%80%93447)
13. D. Gmach, J. Rolia, L. Cherkasova, G. Belrose, T. Turicchi, A. Kemper, An integrated approach to resource pool management: policies, efficiency and quality metrics, in *2008 IEEE International Conference on Dependable Systems and Networks With FTCS and DCC (DSN)* (2008), pp. 326–335
Google Scholar (https://scholar.google.com/scholar?q=D.%20Gmach%2C%20J.%20Rolia%2C%20L.%20Cherkasova%2C%20G.%20Belrose%2C%20T.%20Turicchi%2C%20A.%20Kemper%2C%20An%20integrated%20approach%20to%20resource%20pool%20management%3A%20policies%2C%20efficiency%20and%20quality%20metrics%2C%20in%202008%20IEEE%20International%20Conference%20on%20Dependable%20Systems%20and%20Networks%20With%20FTCS%20and%20DCC%20%28DSN%29%20%282008%29%2C%20pp.%20326%E2%80%93335)
14. J.S. Chase, D.C. Anderson, P.N. Thakar, A.M. Vahdat, R.P. Doyle, Managing energy and server resources in hosting centers, in *Proceedings of the Eighteenth ACM Symposium on Operating Systems Principles*, New York, NY, USA (2001), pp. 103–116

Google Scholar (https://scholar.google.com/scholar?q=J.S.%20Chase%2C%20D.C.%20Anderson%2C%20P.N.%20Thakar%2C%20A.M.%20Vahdat%2C%20R.P.%20Doyle%2C%20Managing%20energy%20and%20server%20resources%20in%20hosting%20centers%2C%20in%20Proceedings%20of%20the%20Eighteenth%20ACM%20Symposium%20on%20Operating%20Systems%20Principles%2C%20New%20York%2C%20NY%2C%20USA%20%282001%29%2C%20pp.%20103%E2%80%93116)

15. C.T. Joseph, K. Chandrasekaran, R. Cyriac, A novel family genetic approach for virtual machine allocation. Procedia Comput. Sci. **46**, 558–565 (2015)
CrossRef (https://doi.org/10.1016/j.procs.2015.02.090)
Google Scholar (http://scholar.google.com/scholar_lookup?title=A%20novel%20family%20genetic%20approach%20for%20virtual%20machine%20allocation&author=CT.%20Joseph&author=K.%20Chandrasekaran&author=R.%20Cyriac&journal=Procedia%20Comput.%20Sci.&volume=46&pages=558-565&publication_year=2015)

16. M. Aron, P. Druschel, W. Zwaenepoel, Cluster reserves: a mechanism for resource management in cluster-based network servers, in *Proceedings of the 2000 ACM SIGMETRICS International Conference on Measurement and Modeling of Computer Systems*, New York, NY, USA (2000), pp. 90–101
Google Scholar (https://scholar.google.com/scholar?q=M.%20Aron%2C%20P.%20Druschel%2C%20W.%20Zwaenepoel%2C%20Cluster%20reserves%3A%20a%20mechanism%20for%20resource%20management%20in%20cluster-based%20network%20servers%2C%20in%20Proceedings%20of%20the%202000%20ACM%20SIGMETRICS%20International%20Conference%20on%20Measurement%20and%20Modeling%20of%20Computer%20Systems%2C%20New%20York%2C%20NY%2C%20USA%20%282000%29%2C%20pp.%2090%E2%80%93101)

17. G. Pacifici, M. Spreitzer, A.N. Tantawi, A. Youssef, Performance management for cluster-based web services. IEEE J. Sel. Areas Commun. **23**(12), 2333–2343 (2005)
CrossRef (https://doi.org/10.1109/JSAC.2005.857208)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Performance%20management%20for%20cluster-based%20web%20services&author=G.%20Pacifici&author=M.%20Spreitzer&author=AN.%20Tantawi&author=A.%20Youssef&journal=IEEE%20J.%20Sel.%20Areas%20Commun.&volume=23&issue=12&pages=2333-2343&publication_year=2005)

18. D. Kumar, B. Sahoo, B. Mondal, T. Mandal, A genetic algorithmic approach for energy efficient task consolidation in cloud computing. Int. J. Comput. Appl. **118**(2), 1–6 (2015)

Google Scholar (http://scholar.google.com/scholar_lookup?title=A%20genetic%20algorithmic%20approach%20for%20energy%20efficient%20task%20consolidation%20in%20cloud%20computing&author=D.%20Kumar&author=B.%20Sahoo&author=B.%20Mondal&author=T.%20Mandal&journal=Int.%20J.%20Comput.%20Appl.&volume=118&issue=2&pages=1-6&publication_year=2015)

19. M. Stillwell, D. Schanzenbach, F. Vivien, H. Casanova, Resource allocation algorithms for virtualized service hosting platforms. J. Parallel Distrib. Comput. **70**(9), 962–974 (2010)
CrossRef (https://doi.org/10.1016/j.jpdc.2010.05.006)
zbMATH (http://www.emis.de/MATH-item?1233.68087)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Resource%20allocation%20algorithms%20for%20virtualized%20service%20hosting%20platforms&author=M.%20Stillwell&author=D.%20Schanzenbach&author=F.%20Vivien&author=H.%20Casanova&journal=J.%20Parallel%20Distrib.%20Comput.&volume=70&issue=9&pages=962-974&publication_year=2010)

20. S. Ali, J.-K. Kim, H.J. Siegel, A.A. Maciejewski, Static heuristics for robust resource allocation of continuously executing applications. J. Parallel Distrib. Comput. **68**(8), 1070–1080 (2008)
CrossRef (https://doi.org/10.1016/j.jpdc.2007.12.007)
zbMATH (http://www.emis.de/MATH-item?1243.68271)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Static%20heuristics%20for%20robust%20resource%20allocation%20of%20continuously%20executing%20applications&author=S.%20Ali&author=J-K.%20Kim&author=HJ.%20Siegel&author=AA.%20Maciejewski&journal=J.%20Parallel%20Distrib.%20Comput.&volume=68&issue=8&pages=1070-1080&publication_year=2008)

21. H. Van Nguyen, F. Dang Tran, and J.-M. Menaud, Autonomic virtual resource management for service hosting platforms, in *Proceedings of the 2009 ICSE Workshop on Software Engineering Challenges of Cloud Computing*, Washington, DC, USA (2009), pp. 1–8
Google Scholar (https://scholar.google.com/scholar?q=H.%20Van%20Nguyen%2C%20F.%20Dang%20Tran%2C%20and%20J.-M.%20Menaud%2C%20Autonomic%20virtual%20resource%20management%20for%20service%20hosting%20platforms%2C%20in%20Proceedings%20of%20the%202009%20ICSE%20Workshop%20on%20Software%20Engineering%20Challenges%20of%20Cloud%20Computing%2C%20Washington%2C%20DC%2C%20USA%20%282009%29%2C%20pp.%201%E2%80%938)

22. M.A. Bender, S. Chakrabarti, S. Muthukrishnan, Flow and stretch metrics for scheduling continuous job streams. SODA **98**, 270–279 (1998)
MathSciNet (http://www.ams.org/mathscinet-getitem?mr=1642937)

zbMATH (http://www.emis.de/MATH-item?0929.68012)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Flow%20and%20stretch%20metrics%20for%20scheduling%20continuous%20job%20streams&author=MA.%20Bender&author=S.%20Chakrabarti&author=S.%20Muthukrishnan&journal=SODA&volume=98&pages=270-279&publication_year=1998)

23. T.T. Nguyen, S. Yang, J. Branke, Evolutionary dynamic optimization: a survey of the state of the art. Swarm Evol. Comput. **6**, 1–24 (2012)
CrossRef (https://doi.org/10.1016/j.swevo.2012.05.001)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Evolutionary%20dynamic%20optimization%3A%20a%20survey%20of%20the%20state%20of%20the%20art&author=TT.%20Nguyen&author=S.%20Yang&author=J.%20Branke&journal=Swarm%20Evol.%20Comput.&volume=6&pages=1-24&publication_year=2012)

24. H.G. Cobb, An investigation into the use of hypermutation as an adaptive operator in genetic algorithms having continuous, time-dependent nonstationary environments. Technical Report AIC-90-001, Naval Research Laboratory, Washington, USA (1990)
Google Scholar (https://scholar.google.com/scholar?q=H.G.%20Cobb%2C%20An%20investigation%20into%20the%20use%20of%20hypermutation%20as%20an%20adaptive%20operator%20in%20genetic%20algorithms%20having%20continuous%2C%20time-dependent%20nonstationary%20environments.%20Technical%20Report%20AIC-90-001%2C%20Naval%20Research%20Laboratory%2C%20Washington%2C%20USA%20%281990%29)

25. F. Vavak, K.A. Jukes, T.C. Fogarty, Performance of a genetic algorithm with variable local search range relative to frequency of the environmental changes, in *Proceedings of the 3rd Annual Conference on Genetic Programming,* (1998), pp. 602–608
Google Scholar (https://scholar.google.com/scholar?q=F.%20Vavak%2C%20K.A.%20Jukes%2C%20T.C.%20Fogarty%2C%20Performance%20of%20a%20genetic%20algorithm%20with%20variable%20local%20search%20range%20relative%20to%20frequency%20of%20the%20environmental%20changes%2C%20in%20Proceedings%20of%20the%203rd%20Annual%20Conference%20on%20Genetic%20Programming%2C%20%281998%29%2C%20pp.%20602%E2%80%93608)

26. F. Vavak, K. Jukes, T.C. Fogarty, Learning the local search range for genetic optimisation in nonstationary environments, in *IEEE International Conference on Evolutionary Computation, 1997* (1997), pp. 355–360
Google Scholar (https://scholar.google.com/scholar?q=F.%20Vavak%2C%20K.%20Jukes%2C%20T.C.%20Fogarty%2C%20Learning%20the%20local%20search%20range%20for%20genetic%20optimisation%20in%20nonstationary%20environments%2C%20in%20IEEE%

20International%20Conference%20on%20Evolutionary%20Computation%2C%201997%20%281997%29%2C%20pp.%20355%E2%80%93360)

27. J.J. Grefenstette, Genetic algorithms for changing environments. PPSN **2**, 137–144 (1992)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Genetic%20algorithms%20for%20changing%20environments&author=JJ.%20Grefenstette&journal=PPSN&volume=2&pages=137-144&publication_year=1992)

28. H.C. Andersen, An investigation into genetic algorithms, and the relationship between speciation and the tracking of optima in dynamic functions. Queensland Univ. Technol. Honours thesis, 1991
Google Scholar (https://scholar.google.com/scholar?q=H.C.%20Andersen%2C%20An%20investigation%20into%20genetic%20algorithms%2C%20and%20the%20relationship%20between%20speciation%20and%20the%20tracking%20of%20optima%20in%20dynamic%20functions.%20Queensland%20Univ.%20Technol.%20Honours%20thesis%2C%201991)

29. R.W. Morrison, Designing evolutionary algorithms for dynamic environments. Ph.D. thesis, George Mason University, Fairfax, VA, USA, 2002
Google Scholar (https://scholar.google.com/scholar?q=R.W.%20Morrison%2C%20Designing%20evolutionary%20algorithms%20for%20dynamic%20environments.%20Ph.D.%20thesis%2C%20George%20Mason%20University%2C%20Fairfax%2C%20VA%2C%20USA%2C%202002)

30. J. Branke, T. Kaußler, C. Schmidth, H. Schmeck, A multi-population approach to dynamic optimization problems, in *Proceedings of the 4th International Conference on Adaptive Computing in Design and Manufacturing*, (2000), pp. 299–308
Google Scholar (https://scholar.google.com/scholar?q=J.%20Branke%2C%20T.%20Kau%C3%9Fler%2C%20C.%20Schmidth%2C%20H.%20Schmeck%2C%20A%20multi-population%20approach%20to%20dynamic%20optimization%20problems%2C%20in%20Proceedings%20of%20the%204th%20International%20Conference%20on%20Adaptive%20Computing%20in%20Design%20and%20Manufacturing%2C%20%282000%29%2C%20pp.%20299%E2%80%93308)

31. F. Oppacher, M. Wineberg, The shifting balance genetic algorithm: improving the GA in a dynamic environment, in *Proceedings of the 1st Annual Conference on Genetic and Evolutionary Computation—Volume 1*, San Francisco, CA, USA (1999), pp. 504–510
Google Scholar (https://scholar.google.com/scholar?q=F.%20Oppacher%2C%20M.%20Wineberg%2C%20The%20shifting%20balance%20genetic%20algorithm%3A%20improving%20the%

20GA%20in%20a%20dynamic%20environment%2C%20in%20Proceedings%20of%20the%201st%20Annual%20Conference%20on%20Genetic%20and%20Evolutionary%20Computation%E2%80%94Volume%201%2C%20San%20Francisco%2C%20CA%2C%20USA%20%281999%29%2C%20pp.%20504%E2%80%93510)

32. R.K. Ursem, Multinational GA optimization techniques in dynamics environments, in *Genetic and Evolutionary Computation Conference* (2000), pp. 19–26
Google Scholar (https://scholar.google.com/scholar?q=R.K.%20Ursem%2C%20Multinational%20GA%20optimization%20techniques%20in%20dynamics%20environments%2C%20in%20Genetic%20and%20Evolutionary%20Computation%20Conference%20%282000%29%2C%20pp.%2019%E2%80%9326)

33. P. Barham et al., Xen and the art of virtualization, in *Proceedings of the Nineteenth ACM Symposium on Operating Systems Principles*, New York, NY, USA (2003), pp. 164–177
Google Scholar (https://scholar.google.com/scholar?q=P.%20Barham%20et%20al.%2C%20Xen%20and%20the%20art%20of%20virtualization%2C%20in%20Proceedings%20of%20the%20Nineteenth%20ACM%20Symposium%20on%20Operating%20Systems%20Principles%2C%20New%20York%2C%20NY%2C%20USA%20%282003%29%2C%20pp.%20164%E2%80%93177)

34. M. Stillwell, F. Vivien, H. Casanova, Dynamic fractional resource scheduling for HPC workloads, in *2010 IEEE International Symposium on Parallel Distributed Processing (IPDPS)* (2010), pp. 1–12
Google Scholar (https://scholar.google.com/scholar?q=M.%20Stillwell%2C%20F.%20Vivien%2C%20H.%20Casanova%2C%20Dynamic%20fractional%20resource%20scheduling%20for%20HPC%20workloads%2C%20in%202010%20IEEE%20International%20Symposium%20on%20Parallel%20Distributed%20Processing%20%28IPDPS%29%20%282010%29%2C%20pp.%201%E2%80%9312)

35. M. Stillwell, D. Schanzenbach, F. Vivien, H. Casanova, Resource allocation using virtual clusters, in *Proceedings of the 2009 9th IEEE/ACM International Symposium on Cluster Computing and the Grid*, Washington, DC, USA (2009), pp. 260–267
Google Scholar (https://scholar.google.com/scholar?q=M.%20Stillwell%2C%20D.%20Schanzenbach%2C%20F.%20Vivien%2C%20H.%20Casanova%2C%20Resource%20allocation%20using%20virtual%20clusters%2C%20in%20Proceedings%20of%20the%202009%209th%20IEEE%2FACM%20International%20Symposium%20on%20Cluster%20Computing%20and%20the%20Grid%2C%20Washington%2C%20DC%2C%20USA%20%282009%29%2C%20pp.%20260%E2%80%93267)

36. T. Blackwell, Particle swarm optimization in dynamic environment, in *Evolutionary Computation in Dynamic and Uncertain Environments,*

Studies in Computational Intelligence, ed. by S. Yang, Y.-S. Ong, Y. Jin (Springer-Verlag, NJ, USA, 2007), pp. 28–49
Google Scholar (http://scholar.google.com/scholar_lookup?title=Particle%20swarm%20optimization%20in%20dynamic%20environment&author=T.%20Blackwell&pages=28-49&publication_year=2007)

37. T. Blackwell, J. Branke, Multi-swarm optimization in dynamic environments, in *Applications of Evolutionary Computing*, ed. by G.R. Raidl et al., Lecture Notes in Computer Science (Springer-Verlag, Berlin, Germany, 2004), vol. 3005, pp. 489–500
Google Scholar (http://scholar.google.com/scholar_lookup?title=Multi-swarm%20optimization%20in%20dynamic%20environments&author=T.%20Blackwell&author=J.%20Branke&pages=489-500&publication_year=2004)

38. K. Trojanowski, Z. Michalewicz, Evolutionary optimization in non-stationary environments. J. Comput. Sci. Technol. **1**(2), 93–124 (2000)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Evolutionary%20optimization%20in%20non-stationary%20environments&author=K.%20Trojanowski&author=Z.%20Michalewicz&journal=J.%20Comput.%20Sci.%20Technol.&volume=1&issue=2&pages=93-124&publication_year=2000)

39. S. Yang, H. Cheng, F. Wang, Genetic algorithms with immigrants and memory schemes for dynamic shortest path routing problems in mobile ad hoc networks. IEEE Trans. Syst. Man Cybern. Part C Appl. Rev. **40** (1), 52–63 (2010)
CrossRef (https://doi.org/10.1109/TSMCC.2009.2023676)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Genetic%20algorithms%20with%20immigrants%20and%20memory%20schemes%20for%20dynamic%20shortest%20path%20routing%20problems%20in%20mobile%20ad%20hoc%20networks&author=S.%20Yang&author=H.%20Cheng&author=F.%20Wang&journal=IEEE%20Trans.%20Syst.%20Man%20Cybern.%20Part%20C%20Appl.%20Rev.&volume=40&issue=1&pages=52-63&publication_year=2010)

40. J. Branke, H. Schmeck, Designing evolutionary algorithms for dynamic optimization problems, in *Theory and Application of Evolutionary Computation: Recent Trends*, ed. by S. Tsutsui, A. Ghosh (Springer-Verlag, Berlin, Germany, 2002), pp. 239–262
Google Scholar (http://scholar.google.com/scholar_lookup?title=Designing%20evolutionary%20algorithms%20for%20dynamic%20optimization%20problems&author=J.%20Branke&author=H.%20Schmeck&pages=239-262&publication_year=2002)

41. K. Trojanowski, Z. Michalewicz, Searching for optima in non-stationary environments, in *Proceedings of the 1999 Congress on Evolutionary Computation-CEC99 (Cat. No. 99TH8406)*, vol. 3 (1999), p. 1850

Google Scholar (https://scholar.google.com/scholar?q=K.%20Trojanowski%2C%20Z.%20Michalewicz%2C%20Searching%20for%20optima%20in%20non-stationary%20environments%2C%20in%20Proceedings%20of%20the%201999%20Congress%20on%20Evolutionary%20Computation-CEC99%20%28Cat.%20No.%2099TH8406%29%2C%20vol.%203%20%281999%29%2C%20p.%201850)

42. A.E. Ranginkaman, J. Kazemi Kordestani, A. Rezvanian, M.R. Meybodi, A note on the paper 'A multi-population harmony search algorithm with external archive for dynamic optimization problems' by Turky and Abdullah. Inf. Sci. **288**, 12–14 (2014)
CrossRef (https://doi.org/10.1016/j.ins.2014.07.049)
Google Scholar (http://scholar.google.com/scholar_lookup?title=A%20note%20on%20the%20paper%20%E2%80%98A%20multi-population%20harmony%20search%20algorithm%20with%20external%20archive%20for%20dynamic%20optimization%20problems%E2%80%99%20by%20Turky%20and%20Abdullah&author=AE.%20Ranginkaman&author=J.%20Kazemi%20Kordestani&author=A.%20Rezvanian&author=MR.%20Meybodi&journal=Inf.%20Sci.&volume=288&pages=12-14&publication_year=2014)

43. R. Tinós, S. Yang, A self-organizing random immigrants genetic algorithm for dynamic optimization problems. Genet. Program Evolvable Mach. **8**(3), 255–286 (2007)
CrossRef (https://doi.org/10.1007/s10710-007-9024-z)
Google Scholar (http://scholar.google.com/scholar_lookup?title=A%20self-organizing%20random%20immigrants%20genetic%20algorithm%20for%20dynamic%20optimization%20problems&author=R.%20Tin%C3%B3s&author=S.%20Yang&journal=Genet.%20Program%20Evolvable%20Mach.&volume=8&issue=3&pages=255-286&publication_year=2007)

Copyright information

© Springer Science+Business Media, LLC, part of Springer Nature 2018

About this article

Cite this article as:
Shirali, A., Kazemi Kordestani, J. & Meybodi, M.R. Genet Program Evolvable Mach (2018) 19: 505.
https://doi.org/10.1007/s10710-018-9326-3

DOI
https://doi.org/10.1007/s10710-018-9326-3

Publisher Name
Springer US

Print ISSN
1389-2576

Online ISSN
1573-7632

About this journal

Reprints and Permissions

SPRINGER NATURE

© 2017 Springer Nature Switzerland AG. Part of Springer Nature.
Not logged in · Not affiliated · 194.225.108.119