Hot Off the Press in Expert Systems on Underwater Robotic Missions: Success History Applied to Differential Evolution for Underwater Glider Path Planning

Aleš Zamuda
University of Maribor
Maribor, Slovenia
ales.zamuda@um.si

José Daniel Hernández Sosa
University of Las Palmas de Gran Canaria
Las Palmas de Gran Canaria, Spain
dhernandez@iusiani.ulpgc.es

ABSTRACT

The real-world implementation of Underwater Glider Path Planning (UGPP) over the dynamic and changing environment in deep ocean waters requires complex mission planning under very high uncertainties. Such a mission is also influenced to a large extent by remote sensing for forecasting weather models outcomes used to predict spatial currents in deep sea, further limiting the available time for accurate run-time decisions by the pilot, who needs to re-test several possible mission scenarios in a short time, usually a few minutes.

Hence, this paper presents the recently proposed UGPP mission scenarios' optimization with a recently well performing algorithm for continuous numerical optimization, Success-History Based Adaptive Differential Evolution Algorithm (SHADE) including Linear population size reduction (L-SHADE).

An algorithm for path optimization considering the ocean currents' model predictions, vessel dynamics, and limited communication, yields potential way-points for the vessel based on the most probable scenario; this is especially useful for short-term opportunistic missions where no reactive control is possible.

The newly obtained results with L-SHADE outperformed existing literature results for the UGPP benchmark scenarios. Thereby, this new application of Evolutionary Algorithms to UGPP contributes significantly to the capacity of the decision-makers when they use the improved UGPP expert system yielding better trajectories.

CCS CONCEPTS

• **Theory of computation → Shortest paths**; **Mathematical optimization**; **Random search heuristics**; **Nonconvex optimization**; **Bio-inspired optimization**; *Stochastic control and optimization*; • **Computing methodologies → Search methodologies**; **Planning under uncertainty**; **Evolutionary robotics**; *Continuous space search*; *Evolutionary robotics*; *Motion path planning*; • **Computer systems organization → Evolutionary robotics**; *Robotic autonomy*; • **General and reference →** *Evaluation*; *Performance*; • **Mathematics of computing →** *Bio-inspired optimization*; Nonparametric statistics; • **Information systems →** *Expert systems*; Sensor networks; Global positioning systems; Data mining; • **Networks →** *Location based services*; • **Applied computing →** *Environmental sciences*; Decision analysis; • **Hardware →** *Sensor applications and deployments*; *Sensor devices and platforms*; *Wireless devices*; *Electro-mechanical devices*;

KEYWORDS

Differential Evolution, Linear Population Size Reduction, Success-history based parameter adaptation, L-SHADE, Underwater Glider Path Planning, Bound-constrained optimization

ACM Reference Format:

Aleš Zamuda and José Daniel Hernández Sosa. 2019. Hot Off the Press in Expert Systems on Underwater Robotic Missions: Success History Applied to Differential Evolution for Underwater Glider Path Planning. In *Genetic and Evolutionary Computation Conference Companion (GECCO '19 Companion), July 13–17, 2019, Prague, Czech Republic.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3319619.3326763

1 INTRODUCTION

The motivation of this work is to explain the provision of an alternative to the current glider mission control systems that are based mostly on multidisciplinary human-expert teams from robotic and oceanographic areas.

Initially configured as a decision-support expert system, the natural evolution of the tool is targeting higher autonomy levels, as published recently in the journal Expert Systems with Applications [13].

2 UNDERWATER GLIDER PATH PLANNING EXPERT SYSTEM

The real-world implementation of Underwater Glider Path Planning (UGPP) over dynamic and changing environments in deep ocean waters requires complex mission planning under very high uncertainties. [13] Such a mission is also influenced to a large extent by the remote sensing for forecasting weather models' outcomes used to predict spatial currents in deep sea, further limiting the available time for accurate run-time decisions by the pilot, who needs to re-test several possible mission scenarios in a short time, usually a few minutes. [12, 14, 15].

GECCO '19 Companion, July 13–17, 2019, Prague, Czech Republic

ACM ISBN 978-1-4503-6748-6/19/07…$15.00
https://doi.org/10.1145/3319619.3326763

3 OPTIMIZATION METHODS APPLIED

Hence, this paper features the recently proposed Underwater Glider Path Planning mission scenarios' optimization with a recently well performing algorithm for continuous numerical optimization, Success-History Based Adaptive Differential Evolution Algorithm (SHADE) [7] including Linear population size reduction (L-SHADE) [8]. The L-SHADE has been applied in several application domains [1] and also extended to improved versions [9]. The paper [13] also compared several other continuous optimization algorithms, mainly Differential Evolution, which was already studied using high-performance computing earlier in works like [11], and also applied to other important challenges, like energy scheduling [3].

4 BENEFITS OF THE SYSTEM

An algorithm for path optimization considering the ocean currents' model predictions, vessel dynamics, and limited communication, yields potential way-points for the vessel based on the most probable scenario; this is specially useful for short term opportunistic missions where no reactive control is possible, and producing a new expert system joining optimization and UGPP. [12–15]

In the perspective of optimization algorithms, the set of papers [12–15] introduce also novel ways of benchmarking evolutionary algorithms by assessing operational appropriateness of the optimization algorithms compared in terms of fitness budget planning, convergence quality, and obtained solutions. Furthermore, improvements of some algorithms are also proposed along, in order to more widely include the benchmarking over well known terminologies of heuristic stochastic optimizers.

Important works from other teams like [2, 4–6, 10] also use the likes of evolutionary approaches from [12, 13], which is another important contribution to the benefits of the line of research of the system and the autonomous mission planning research topic in general.

5 CONCLUSIONS

Over this mission planning task, the newly obtained results with L-SHADE published in [13] outperformed existing literature results for the Underwater Glider Path Planning benchmark scenarios. Thereby, this new application of Evolutionary Algorithms to UGPP contributed significantly to the capacity of the decision-makers for mission plannings, as they are using the improved UGPP expert system yielding better trajectories.

ACKNOWLEDGMENTS

The work was supported in part by the Slovenian Research Agency, under Research Program P2-0041. This work was also supported by Spanish research ministry under FLUXES project, and MacPAM project funded by Loro Parque Foundation. This article is also based upon work from COST Action CA15140 'Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice (ImAppNIO)' and COST Action IC1406 'High-Performance Modelling and Simulation for Big Data Applications (cHiPSet)', supported by COST (European Cooperation in Science and Technology). The high cost of the real missions would make it difficult to perform extensive experimentation without a big budget, so, in this sense, we want to thank ULPGC's SITMA service and Rutgers University for the valuable support received during the execution of the glider missions. The author AZ also acknowledges EU support under Project No. 5442-24/2017/6 (HPC – RIVR) and Interreg Apline space project SmartVillages. Part of the codes in Matlab for extending the optimization algorithms utilized are provided by Qingfu Zhang at http://dces.essex.ac.uk/staff/qzhang/code/, and by Ryoji Tanabe at https://sites.google.com/site/tanaberyoji/home. The high cost of the real missions would make it difficult to perform extensive experimentation without a big budget, so in this sense we sincerely appreciate the collaboration facilities offered by Pablo Sangrá (PI of the PUMP project) and Rui Caldeira (Head of OOM).

REFERENCES

[1] Rawaa Dawoud Al-Dabbagh, Ferrante Neri, Norisma Idris, and Mohd Sapiyan Baba. 2018. Algorithmic design issues in adaptive differential evolution schemes: Review and taxonomy. *Swarm and Evolutionary Computation* 43 (2018), 284–311.

[2] Kai Olav Ellefsen, Herman Augusto Lepikson, and Jan C Albiez. 2017. Multi-objective coverage path planning: Enabling automated inspection of complex, real-world structures. *Applied Soft Computing* 61 (2017), 264–282.

[3] A. Glotić and A. Zamuda. 1 March 2015. Short-term combined economic and emission hydrothermal optimization by surrogate differential evolution. *Applied Energy* 141 (1 March 2015), 42–56.

[4] Shubhasri Kundu and Dayal R Parhi. 2016. Navigation of underwater robot based on dynamically adaptive harmony search algorithm. *Memetic Computing* 8, 2 (2016), 125–146.

[5] Somaiyeh MahmoudZadeh, Amir Mehdi Yazdani, Karl Sammut, and David MW Powers. 2018. Online path planning for AUV rendezvous in dynamic cluttered undersea environment using evolutionary algorithms. *Applied Soft Computing* 70 (2018), 929–945.

[6] Dayal R Parhi and Shubhasri Kundu. 2017. Navigational control of underwater mobile robot using dynamic differential evolution approach. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment* 231, 1 (2017), 284–301.

[7] Ryo Tanabe and Akira Fukunaga. 2013. Evaluating the performance of SHADE on CEC 2013 benchmark problems. In *2013 IEEE Congress on Evolutionary Computation*. IEEE, 1952–1959.

[8] Ryoji Tanabe and Alex S Fukunaga. 2014. Improving the search performance of SHADE using linear population size reduction. In *2014 IEEE Congress on Evolutionary Computation*. IEEE, 1658–1665.

[9] Adam Viktorin, Roman Senkerik, Michal Pluhacek, Tomas Kadavy, and Aleš Zamuda. Available online 12 November 2018. Distance Based Parameter Adaptation for Success-History based Differential Evolution. *Swarm and Evolutionary Computation* (Available online 12 November 2018). https://doi.org/10.1016/j.swevo.2018.10.013

[10] Chengke Xiong, Zheng Zeng, and Lian Lian. 2018. Path Planning of Multi-Modal Underwater Vehicle for Adaptive Sampling Using Delaunay Spatial Partition-Ant Colony Optimization. In *2018 OCEANS-MTS/IEEE Kobe Techno-Oceans (OTO)*. IEEE, 1–8.

[11] A. Zamuda and J. Brest. 2015. Self-adaptive control parameters' randomization frequency and propagations in differential evolution. *Swarm and Evolutionary Computation* 25 (2015), 72–99.

[12] A. Zamuda and José Daniel Hernández Sosa. 2014. Differential Evolution and Underwater Glider Path Planning Applied to the Short-Term Opportunistic Sampling of Dynamic Mesoscale Ocean Structures. *Applied Soft Computing* 24 (2014), 95–108.

[13] Aleš Zamuda and José Daniel Hernández Sosa. 2019. Success history applied to expert system for underwater glider path planning using differential evolution. *Expert Systems with Applications* 119, 1 April 2019 (2019), 155–170.

[14] A. Zamuda, J. D. HernÃąndez Sosa, and L. Adler. 2016. Constrained Differential Evolution Optimization for Underwater Glider Path Planning in Sub-mesoscale Eddy Sampling. *Applied Soft Computing* 42 (2016), 93–118.

[15] A. Zamuda, J. D. Hernandez Sosa, and L. Adler. 2016. Improving Constrained Glider Trajectories for Ocean Eddy Border Sampling within Extended Mission Planning Time. In *2016 IEEE Congress on Evolutionary Computation*. 1727–1734.