Advisor CV: Stephen Kelly spkelly@mcmaster.ca (902) 233-0758 creativealgorithms.ca

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Employment
2022 - Present: Assistant Professor, Department of Computing and Software, Faculty of Engineering, McMaster University
2022 - 2023: Visiting Faculty Researcher, Google Brain

Education
2019 - 2022: Postdoctoral Researcher, BEACON Center for the Study of Evolution in Action, Michigan State University
2012 - 2018: PhD, Computer Science, Dalhousie University
2009 - 2012: Master of Computer Science, Dalhousie University
1996 - 2001: Bachelor of Fine Arts, Nova Scotia College of Art and Design (NSCAD) University

Selected Publications
Naqvi, A., Kelly, S. (2026). Dynamic Vector and Matrix Memory for Tangled Program Graphs. In: Manzoni, L., Cussat-Blanc, S., Chen, Q. (eds) Genetic Programming. EuroGP 2026. Lecture Notes in Computer Science, vol 16521. Springer, Cham. https://doi.org/10.1007/978-3-032-23005-8_11

Naqvi, A., Djavaherpour, T., Vacher, Q., Kelly, S. (2025). Integrating Neuroplasticity into Genetic Programming Agents for Adaptive Decision Making. In Proceedings of the Artificial Life Conference 2025: Ciphers of Life. (pp. 69). ASME. https://doi.org/10.1162/ISAL.a.897

Vacher, Q., Kelly, S., Naqvi, A., Beuve, A., Djavaherpour, T., Dardaillon, M., and Desnos, K. (2025). MAPLE: Multi-Action Programs through Linear Evolution for Continuous Multi-Action Reinforcement Learning. In Proceedings of the Genetic and Evolutionary Computation Conference (GECCO '25). Association for Computing Machinery, New York, NY, USA, 1062–1071. https://doi.org/10.1145/3712256.3726400

Kelly, S., Schossau, J. (2024). Evolutionary Computation and the Reinforcement Learning Problem. In: Banzhaf, W., Machado, P., Zhang, M. (eds) Handbook of Evolutionary Machine Learning. Genetic and Evolutionary Computation. Springer, Singapore. https://doi.org/10.1007/978-981-99-3814-8_4

Kelly, S., Park, D. S., Song, X., McIntire, M., Nashikkar, P., Guha, R., Banzhaf, W., Deb, K., Boddeti, V. N., Tan, J., Real, E. (2023). Discovering Adaptable Symbolic Algorithms from Scratch, 2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 3889-3896, doi: https://doi.org/10.1109/IROS55552.2023.10341979.

Kelly, S., and Heywood, M. I; Emergent Solutions to High-Dimensional Multitask Reinforcement Learning. Evolutionary Computation 2018; 26 (3): 347–380. doi: https://doi.org/10.1162/evco_a_00232

Kelly, S., Voegerl, T., Banzhaf, W., and Gondro, C. (2021). Evolving hierarchical memory-prediction machines in multi-task reinforcement learning. Genetic Programming and Evolvable Machines 22, 4 (Dec 2021), 573–605. https://doi.org/10.1007/s10710-021-09418-4

Funding
2025: Mitacs Accelerate Grant, Natural Sciences and Engineering Research Council of Canada
2024: Connection Grant, Social Sciences and Humanities Research Council of Canada
2023: Discovery Grant, Natural Sciences and Engineering Research Council of Canada

Supervision of Early-Stage Researchers
2025 - Present: Ali Naqvi, PhD - Computer Science, McMaster University
2025 - Present: Xiao Shao, PhD - Computer Science, McMaster University
2025 - Present: Yasmin Ahmadi, Master of Science - Computer Science, McMaster University
2025 - Present: Xavier Hill Roy, Master of Science - Computer Science, McMaster University
2023 - 2025: Tanya Djavaherpour, Master of Science - Computer Science, McMaster University
2023 - 2025: Lihao Bi, Master of Engineering - Computing and Software, McMaster University
2023 - 2025: Pawan Kumar, Master of Engineering - Computing and Software, McMaster University
2023 - 2025: Yiding Li, Master of Engineering - Computing and Software, McMaster University

Teaching
2024 - Present: Embedded Systems Design I, McMaster University
2023 - Present: Evolutionary Computation, McMaster University
2023 - Present: Data Structures and Algorithms for Mechatronics, McMaster University
2017 - 2018: Art and Artificial Life, NSCAD University

SPECIES Scholarship 2026

Prospective advisor: **Stephen Kelly**
Host institution: **McMaster University**

1 Description of the research group

The Creative Algorithms Lab (`https://creativealgorithms.ca/`) is an interdisciplinary research group in the Department of Computing and Software at McMaster University led by Dr. Stephen Kelly. Our research focuses on nature-inspired computation, especially genetic programming and related evolutionary methods, in dynamic, partially observable, and multi-task sequential decision-making environments. We study how emergent forms of memory, hierarchy, and modularity allow digital evolution to produce adaptive and interpretable behaviour.

Through several active collaborations, current research in the lab spans evolutionary computation, artificial life, reinforcement learning, computational neuroscience, evolutionary robotics, and a distinctive research-creation practice. Recent outputs include work on dynamic vector and matrix memory for Tangled Program Graphs (Naqvi and Kelly 2026), neuroplasticity in genetic programming agents (Naqvi et al. 2025), multi-action evolutionary control (Vacher et al. 2025), and creative cyber-physical systems (Andry et al. 2024).

Dr. Kelly is an Assistant Professor in the Department of Computing and Software at McMaster University and a professional media artist. He holds a PhD from Dalhousie University and a BFA from the Nova Scotia College of Art and Design. He completed an NSERC postdoctoral fellowship at the BEACON Center for the Study of Evolution in Action at Michigan State University and a year-long visiting faculty researcher position at Google Brain.

2 Description of the work to be carried out by the student

Modularity, Hierarchy, and Memory in Developmental Genetic Programming

Evolved policies in Genetic Programming (GP) can support problem decomposition when specialized components emerge and are reused in teams, policy graphs, or other modular decision structures (Kelly and Heywood 2017; Lichodzijewski and Heywood 2008). Prior work on Tangled Program Graphs and related memory-utilizing policy graph agents has also shown the importance of hierarchical organization, which can promote *evolutionary* emergence and refinement of reusable sub-policies, especially in multi-task and partially observable environments (Kelly et al. 2019; Djavaherpour et al. 2025). In this context, modularity and hierarchy are the results of a population-based evolutionary search. However, much less research has been done on modular and hierarchical emergence during the *lifetime* of a single digital organism as it interacts with data/observations from a particular problem. As such, this project will investigate indirect encodings (e.g. (Clune et al. 2011)) and developmental GP representations (e.g. (Miller 2020)) that allow radical transformations of an organism during its lifetime. We are specifically interested in analysing transformations that exploit reusable structures, hierarchy, and major transitions in response to a particular environment.

In collaboration with the student, this work will: 1. Test which developmental mechanisms promote these structures beyond what the representation imposes (McKay et al. 2006), 2. Design measurements to quantify the emergence of such structures, and 3. Show if/when they improve adaptive control over direct encodings. The experiments will compare direct, indirect, and developmental representations on control tasks that demand decomposition and/or memory. As a starting point, we plan on using the MODES toolbox to characterize evolutionary dynamics (Dolson et al. 2019) and then design separate structural metrics to quantify modularity, hierarchy, and memory organization in single-task and multi-task settings.

References

Andry, Sofian, Stephen Kelly, and Samuel St-Aubin (2024). *Vessels*. Accessed: 2026-05-05. URL: `https://creativealgorithms.ca/vessels/`.

Clune, J., K. O. Stanley, R. T. Pennock, and C. Ofria (June 2011). "On the Performance of Indirect Encoding Across the Continuum of Regularity". In: *Trans. Evol. Comp* 15.3, pp. 346–367. ISSN: 1089-778X. DOI: `10.1109/TEVC.2010.2104157`. URL: `https://doi.org/10.1109/TEVC.2010.2104157`.

Djavaherpour, Tanya, Ali Naqvi, Reyhaneh Norouziani, Quentin Vacher, and Stephen Kelly (2025). "Genetic Encoding and Shared Knowledge in Reinforcement Learning with Structured Memory". In: *Artificial Life Conference Proceedings 37*. Vol. 2025. 1. MIT Press One Rogers Street, Cambridge, MA 02142-1209, USA journals-info . . ., p. 30.

Dolson, Emily, Anya Vostinar, Michael Wiser, and Charles Ofria (Apr. 2019). "The MODES Toolbox: Measurements of Open-Ended Dynamics in Evolving Systems". In: *Artificial Life* 25, pp. 50–73. DOI: 10.1162/artl_a_00280.

Kelly, Stephen and Malcolm I. Heywood (2017). "Emergent Tangled Graph Representations for Atari Game Playing Agents". In: *Genetic Programming*. Ed. by James McDermott, Mauro Castelli, Lukas Sekanina, Evert Haasdijk, and Pablo García-Sánchez. Cham: Springer International Publishing, pp. 64–79. ISBN: 978-3-319-55696-3.

Kelly, Stephen, Robert J. Smith, and Malcolm I. Heywood (2019). "Emergent Policy Discovery for Visual Reinforcement Learning Through Tangled Program Graphs: A Tutorial". In: *Genetic Programming Theory and Practice XVI*. Ed. by Wolfgang Banzhaf, Lee Spector, and Leigh Sheneman. Cham: Springer International Publishing, pp. 37–57. ISBN: 978-3-030-04735-1. DOI: 10.1007/978-3-030-04735-1_3. URL: https://doi.org/10.1007/978-3-030-04735-1_3.

Lichodzijewski, Peter and Malcolm I. Heywood (2008). "Managing team-based problem solving with symbiotic bid-based genetic programming". In: *Proceedings of the 10th Annual Conference on Genetic and Evolutionary Computation*. GECCO '08. Atlanta, GA, USA: Association for Computing Machinery, pp. 363–370. ISBN: 9781605581309. DOI: 10.1145/1389095.1389162. URL: https://doi.org/10.1145/1389095.1389162.

McKay, Robert Ian (Bob), Tuan Hao Hoang, Daryl Leslie Essam, and Xuan Hoai Nguyen (2006). "Developmental Evaluation in Genetic Programming: The Preliminary Results". In: *Genetic Programming*. Ed. by Pierre Collet, Marco Tomassini, Marc Ebner, Steven Gustafson, and Anikó Ekárt. Berlin, Heidelberg: Springer Berlin Heidelberg, pp. 280–289. ISBN: 978-3-540-33144-5.

Miller, Julian Francis (July 2020). "Evolving developmental neural networks to solve multiple problems". In: vol. ALIFE 2020: The 2020 Conference on Artificial Life. ALIFE 2022: The 2022 Conference on Artificial Life, pp. 473–482. DOI: 10.1162/isal_a_00252. eprint: https://direct.mit.edu/isal/proceedings-pdf/isal2020/32/473/1908578/isal_a_00252.pdf. URL: https://doi.org/10.1162/isal_a_00252.

Naqvi, Ali, Tanya Djavaherpour, Quentin Vacher, and Stephen Kelly (2025). "Integrating Neuroplasticity into Genetic Programming Agents for Adaptive Decision Making". In: *Artificial Life Conference Proceedings 37*. Vol. 2025. 1. MIT Press One Rogers Street, Cambridge, MA 02142-1209, USA journals-info . . ., p. 69.

Naqvi, Ali and Stephen Kelly (2026). "Dynamic Vector and Matrix Memory for Tangled Program Graphs". In: *Genetic Programming*. Ed. by Luca Manzoni, Sylvain Cussat-Blanc, and Qi Chen. Cham: Springer Nature Switzerland, pp. 173–188. ISBN: 978-3-032-23005-8.

Vacher, Quentin, Stephen Kelly, Ali Naqvi, Nicolas Beuve, Tanya Djavaherpour, Mickaël Dardaillon, and Karol Desnos (2025). "MAPLE: Multi-Action Programs through Linear Evolution for Continuous Multi-Action Reinforcement Learning". In: *Proceedings of the Genetic and Evolutionary Computation Conference*. GECCO '25. NH Malaga Hotel, Malaga, Spain: Association for Computing Machinery, pp. 1062–1071. ISBN: 9798400714658. DOI: 10.1145/3712256.3726400. URL: https://doi.org/10.1145/3712256.3726400.

3 Other relevant information

McMaster University is a public research university in Hamilton, Ontario, Canada, with a strong research and graduate training environment across multiple disciplines. For more information, see Discover McMaster.

Facilities and resources: The student will be provided with a dedicated workspace in a shared graduate student lab. They will have access to high-performance computing resources though the Digital Research Alliance of Canada for running experiments.