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Muhammad, A.[a] , Ali, M.A.H.[b] , Turaev, S.[c] , Abdulghafor, R.[d] , Shanono, I.H.[e] , Alzaid, Z.[f] , Alruban, A.[g] , Alabdan, R.[h] , Dutta, A.K.[i] , Almotairi, S.[f j]

A Generalized Laser Simulator Algorithm for Mobile Robot Path Planning with Obstacle Avoidance
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[a] Department of Mechatronics Engineering, Faculty of Technology, Bayero University, Kano, 700241, Nigeria
[b] Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, Kuala Lumpur, 50603, Malaysia
[c] Department of Computer Science and Software Engineering, College of Information Technology, United Arab Emirates University, P.O. Box 15556, Al-Ain, United Arab Emirates
[d] Department of Computer Science, Faculty of Information and Communication Technology, International Islamic University Malaysia, Kuala Lumpur, 53100, Malaysia
[e] Department of Electrical Engineering, Faculty of Technology, Bayero University, Kano, 700241, Nigeria
[f] Department of Computer Science, Faculty of Computer and Information Systems, Islamic University of Medinah, Medinah, 42351, Saudi Arabia
[g] Department of Information Technology, College of Computer and Information Sciences, Majmaah University, Al Majmaah, 11952, Saudi Arabia
[h] Department of Information Systems, Faculty of Computer and Information Sciences College, Majmaah University, Al Majmaah, 11952, Saudi Arabia
[i] Department of Computer Science and Information Systems, College of Applied Sciences, Al Maarefa University, Riyadh, 13713, Saudi Arabia
[j] Department of Natural and Applied Sciences, Faculty of Community College, Majmaah University, Majmaah, 11952, Saudi Arabia

Abstract
This paper aims to develop a new mobile robot path planning algorithm, called generalized laser simulator (GLS), for navigating autonomously mobile robots in the presence of static and dynamic obstacles. This algorithm enables a mobile robot to identify a feasible path while finding the target and avoiding obstacles while moving in complex regions. An optimal path between the start and target point is found by forming a wave of points in all directions towards the target position considering target minimum and border maximum distance principles. The algorithm will select the minimum path from the candidate points to target while avoiding obstacles. The obstacle borders are regarded as the environment's borders for static obstacle avoidance. However, once dynamic obstacles appear in front of the GLS waves, the system detects them as new dynamic obstacle borders. Several experiments were carried out to validate the effectiveness and practicality of the GLS algorithm, including path-planning experiments in the presence of obstacles in a complex dynamic environment. The findings indicate that the robot could successfully find the correct path while avoiding obstacles. The proposed method is compared to other popular methods in terms of speed and path length in both real and simulated environments. According to the results, the GLS algorithm outperformed the original laser simulator (LS) method in path and success rate. With application of the all-direction border scan, it outperforms the A-star (A*) and PRM algorithms and provides safer and shorter paths. Furthermore, the path planning approach was validated for local planning in simulation and real-world tests, in which the proposed method produced the best path compared to the original LS algorithm.

Author Keywords
generalized laser simulator; global path planning; local path panning; obstacle; path planning; wheeled mobile robot

Index Keywords
Collision avoidance, Motion planning, Robot programming, Simulators; Avoiding obstacle, Dynamic obstacles, Generalized laser simulator, Global path planning, Laser simulators, Local path panning, Obstacle, Obstacles avoidance, Robot path-planning, Wheeled mobile robot; Mobile robots

References

- Muhammad, A., Ali, M.A.H., Turaev, S., Shanono, I.H., Hujainah, F., Zubir, M.N.M., Faiz, M.K., Abdulghafor, R.
  Novel Algorithm for Mobile Robot Path Planning in Constrained Environment
  (2021) *Comput. Mater. Contin*, 71, pp. 2697-2719.

- Leena, N., Saju, K.
  A survey on path planning techniques for autonomous
  (2014) *IOSR J. Mech. Civ. Eng*, 11, pp. 76-79.

- Han, J., Seo, Y.
  Mobile robot path planning with surrounding point set and path improvement
  (2017) *Appl. Soft Comput*, 57, pp. 35-47.

- Victerpaul, P., Saravanan, D., Janakiraman, S., Pradeep, J.
  Path planning of autonomous mobile robots: A survey and comparison
  (2017) *J. Adv. Res. Dyn. Control Syst*, 9, pp. 1535-1565.

- Ankit, R.A., Ravankar, A., Emaru, T., Kobayashi, Y.
  HPPRM: Hybrid Potential Based Probabilistic Roadmap Algorithm for Improved Dynamic Path Planning of Mobile Robots
  (2020) *IEEE Access*, 8, pp. 221743-221766.

- Muhammad, A., Ali, M.A., Shanono, I.H.
  Path Planning Methods for Mobile Robots: A systematic and Bibliometric Review
  (2020) *Elektr. J. Electr. Eng*, 19, pp. 14-34.

- Chao, N., Liu, Y.-K., Xia, H., Ayodeji, A., Bai, L.
  Grid-based RRT* for minimum dose walking path-planning in complex radioactive environments
  (2018) *Ann. Nucl. Energy*, 115, pp. 73-82.

- Shuma, A., Morrisa, K., Khajepourb, A.
  Direction-dependent optimal path planning for autonomous vehicles
  (2015) *Robot. Auton. Syst*, 70, pp. 202-214.

- Zhang, Y., Gong, D.W., Zhang, J.H.
  Robot path planning in uncertain environment using multi-objective particle swarm optimization
  (2013) *Neurocomputing*, 103, pp. 172-185.

- Choset, H., Lynch, K.M., Hutchinson, S., Kantor, G.A., Burgard, W.
  (2005) *Principles of Robot Motion: Theory, Algorithms, and Implementation*,
  MIT Press, Cambridge, MA, USA

- Bakdi, A., Hentout, A., Boutami, H., Maoudj, A., Hachour, O., Bouzouia, B.
  Optimal path planning and execution for mobile robots using genetic algorithm and adaptive fuzzy-logic control
  (2017) *Robot. Auton. Syst*, 89, pp. 95-109.

- Perez, T.L., Wesley, M.A.
  An algorithm for planning collision-free paths among polyhedral obstacles
  (1979) *Commun. ACM*, 22, pp. 560-570.

- Jinglun, Y., Yuancheng, S., Yifan, L.
  The Path Planning of Mobile Robot by Neural Networks and Hierarchical Reinforcement Learning
  (2020) *Front. Neurorobotics*, 14, pp. 1-12.

- Aisha, M., Mohammed, A.H.A., Ibrahim, H.S.
  A review: On Intelligent Mobile Robot Path Planning Techniques
  Proceedings of the 2021 IEEE 11th IEEE Symposium on Computer Applications & Industrial Electronics (ISCAIE), pp. 53-58.
  Penang, Malaysia, 3–4 April 2021

- Karur, K., Sharma, N., Dharmatti, C., Siegel, J.
  A Survey of Path Planning Algorithms for Mobile Robots
  (2021) *Vehicles*, 2021, pp. 448-468.

- Minguez, J., Lamiraux, F., Laumond, J.
  Motion Planning and Obstacle Avoidance

(2016) *Springer Handbook of Robotics*, pp. 827-852.
2nd ed., Springer, Berlin/Heidelberg, Germany

- Takahashi, O., Schilling, R.
Motion planning in a plane using generalized Voronoi diagrams
(1989) *IEEE Trans. Robot. Autom*, 5, pp. 143-150.

- Al-Dahhan, M.H., Schmidt, K.W.
Voronoi Boundary Visibility for Efficient Path Planning
(2020) *IEEE Access*, 8, pp. 134764-134781.

- Maekawa, T., Noda, T., Tamura, S., Ozaki, T., Machida, K.-I.
Curvature continuous path generation for autonomous vehicle using B-spline curves
(2010) *Comput. Des*, 42, pp. 350-359.

- Borenstein, J., Koren, Y.
Real-time obstacle avoidance for fast mobile robots
(1989) *IEEE Trans. Syst. Man Cybern*, 19, pp. 1179-1187.

- Orozco-Rosas, U., Picos, K., Montiel, O.
Hybrid Path Planning Algorithm Based on Membrane Pseudo-Bacterial Potential Field for Autonomous Mobile Robots
(2019) *IEEE Access*, 7, pp. 156787-156803.

- Ravankar, A., Ravankar, A.A., Kobayashi, Y., Emaru, T.
SHP: Smooth Hypocycloidal Paths with Collision-Free and Decoupled Multi-Robot Path Planning
(2016) *Int. J. Adv. Robot. Syst*, 13, p. 133.

- Kala, R., Shukla, A., Tiwari, R.
Robotic path planning in static environment using hierarchical multi-neuron heuristic search and probability based fitness
(2011) *Neurocomputing*, 74, pp. 2314-2335.

- Khatib, O.
Real-time obstacle avoidance for manipulators and mobile robots
(1985) *Int. J. Robot. Res*, 5, pp. 90-98.

- Barraquand, J., Langlois, B., Latombe, J.-C.
Numerical Potential Field Techniques for Robot Path Planning
(1992) *IEEE Trans. Syst. Man Cybern*, 22, pp. 224-241.

- Cetin, O., Zagli, I., Yilmaz, G.
Establishing Obstacle and Collision Free Communication Relay for UAVs with Artificial Potential Fields
(2012) *J. Intell. Robot. Syst*, 69, pp. 361-372.

- Borenstein, J., Koren, Y.
The vector field histogram-fast obstacle avoidance for mobile robots
(1991) *IEEE Trans. Robot. Autom*, 7, pp. 278-288.

- Ulrich, I., Borenstein, J.
VFH*: Local obstacle avoidance with look-ahead verification
Proceedings of the Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No.00CH37065), pp. 2505-2511.
San Francisco, CA, USA, 24–28 April 2000

- Ulrich, I., Borenstein, J.
VFH+: Reliable Obstacle Avoidance for Fast Mobile Robots

Proceedings of the 1998 IEEE International Conference on Robotics and Automation, pp. 1572-1577.
Leuven, Belgium, 20 May 1998

- Ravankar, A., Ravankar, A.A., Watanabe, M., Hoshino, Y., Rawankar, A.
Multi-robot path planning for smart access of distributed charging points in map
(2020) *Artif. Life Robot*, 26, pp. 52-60.

- Tuncer, A., Yildirim, M.
Dynamic path planning of mobile robots with improved genetic algorithm
(2012) *Comput. Electr. Eng*, 38, pp. 1564-1572.

- Ayawli, B.B.K., Mei, X., Shen, M., Appiah, A.Y., Kyeremeh, F.
Mobile Robot Path Planning in Dynamic Environment Using Voronoi Diagram and Computation Geometry Technique
(2017) *IEEE Access*, 7, pp. 86026-86040.

- Ravankar, A., Ravankar, A.A., Hoshino, Y., Kobayashi, Y.
Virtual Obstacles for Safe Mobile Robot Navigation
Proceedings of the 2019 8th International Congress on Advanced Applied Informatics (IIAI-AAI), pp. 552-555.
Toyama, Japan, 7–11 July 2019

- Ravankar, A., Ravankar, A.A., Kobayashi, Y., Emaru, T.
Hitchhiking Robots: A Collaborative Approach for Efficient Multi-Robot Navigation in Indoor Environments
(2017) *Sensors*, 17.

- Ravankar, A., Ravankar, A.A., Hoshino, Y., Emaru, T.
Symbiotic Navigation in Multi-Robot Systems with Remote Obstacle Knowledge Sharing
(2017) *Sensors*, 17.

- Elbanhawi, M., Simic, M.
Sampling-Based Robot Motion Planning: A Review
(2014) *IEEE Access*, 2, pp. 56-77.

- Kavraki, L.E., Svestka, P., Latombe, J.C., Overmars, M.H.
Probabilistic roadmaps for path planning in high-dimensional configuration spaces
(1996) *IEEE Trans. on Robot. Aut*, 12, pp. 566-580.

- LaValle, S.M., Kuffner, J.J.
Randomized Kinodynamic Planning
(2001) *Int. J. Robot. Res*, 20, pp. 378-400.

- Qureshi, A.H., Ayaz, Y.
Potential functions based sampling heuristic for optimal path planning
(2016) *Auton. Robot*, 40, pp. 1079-1093.

- Janson, L., Ichter, B., Pavone, M.
Deterministic sampling-based motion planning: Optimality, complexity, and performance
(2018) *Int. J. Robot. Res*, 37, pp. 46-61.

- Fu, B., Chen, L., Zhou, Y., Zheng, D., Wei, Z., Dai, J., Pan, H.
An improved A* algorithm for the industrial robot path planning with high success rate and short length
(2018) *Robot. Auton. Syst*, 106, pp. 26-37.

- Wang, W., Zuo, L., Xu, X.
A Learning-based Multi-RRT Approach for Robot Path Planning in Narrow Passages

(2017) *J. Intell. Robot. Syst*, 90, pp. 81-100.

- Xinyu, W., Xiaojuan, L., Yong, G., Jiadong, S., Rui, W.
Bidirectional Potential Guided RRT* for Motion Planning
(2019) *IEEE Access*, 7, pp. 95046-95057.

- Bohlin, R., Kavraki, L.
Path planning using lazy PRM
Proceedings of the Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No.00CH37065), pp. 521-528.
San Francisco, CA, USA, 24–28 April 2000

- Morales, M., Rodriguez, S., Amato, N.M.
Improving the connectivity of PRM roadmaps
Proceedings of the 2003 IEEE International Conference on Robotics and Automation (Cat. No.03CH37422), pp. 4427-4432.
Taipei, Taiwan, 14–19 September 2003

- Karaman, S., Frazzoli, E.
Sampling-based algorithms for optimal motion planning
(2011) *Int. J. Robot. Res*, 30, pp. 846-894.

- Lynch, K.M., Park, F.C.
(2017) *Modern Robotics*,
Cambridge University Press, Cambridge, UK

- Ravankar, A., Ravankar, A.A., Kobayashi, Y., Hoshino, Y., Peng, C.C.
Path smoothing techniques in robot navigation: State-of-the-art, current and future challenges
(2018) *Sensors*, 18.

- Ravankar, A., Ravankar, A.A., Rawankar, A., Hoshino, Y., Kobayashi, Y.
ITC: Infused Tangential Curves for Smooth 2D and 3D Navigation of Mobile Robots
(2019) *Sensors*, 19.

- Lamini, C., Benhlima, S., Elbekri, A.
Genetic Algorithm Based Approach for Autonomous Mobile Robot Path Planning
(2018) *Procedia Comput. Sci*, 127, pp. 180-189.

- Hu, Y., Yang, S.
A knowledge based genetic algorithm for path planning of a mobile robot
Proceedings of the IEEE International Conference on Robotics and Automation, pp. 4350-4355.
New Orleans, LA, USA, 26 April–1 May 2004

- Karami, A.H., Hasanzadeh, M.
An adaptive genetic algorithm for robot motion planning in 2D complex environments
(2015) *Comput. Electr. Eng*, 43, pp. 317-329.

- Huang, H.C., Tsai, C.C.
Global path planning for autonomous robot navigation using hybrid metaheuristic GA-PSO algorithm
Proceedings of the SICE Annual Conference 2011, pp. 1338-1343.
Tokyo, Japan, 13–18 September 2011

- Bi, Z., Yimin, Y., Wei, Y.
Hierarchical path planning approach for mobile robot navigation under the dynamic environment
Proceedings of the 2008 6th IEEE International Conference on Industrial

Informatics, pp. 372-376.
Daejeon, Korea, 13–16 July 2008

- Zhang, K., Niroui, F., Ficocelli, M., Nejat, G.
Robot Navigation of Environments with Unknown Rough Terrain Using deep Reinforcement Learning
Proceedings of the 2018 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), pp. 1-7.
Philadelphia, PA, USA, 6–8 August 2018

- Zhang, H.-Y., Lin, W.-M., Chen, A.-X.
Path Planning for the Mobile Robot: A Review
(2018) *Symmetry*, 10.

- Patle, B., Pandey, A., Parhi, D., Jagadeesh, A.
A review: On path planning strategies for navigation of mobile robot
(2019) *Def. Technol*, 15, pp. 582-606.

- Seçkin, A.
A Natural Navigation Method for Following Path Memories from 2D Maps
(2020) *Arab. J. Sci. Eng*, 45, pp. 10417-10432.

- Stenning, B.E., McManus, C., Barfoot, T.D.
Planning using a Network of Reusable Paths: A Physical Embodiment of a Rapidly Exploring Random Tree
(2013) *J. Field Robot*, 30, pp. 916-950.

- Khan, A.H., Li, S., Luo, X.
Obstacle Avoidance and Tracking Control of Redundant Robotic Manipulator: An RNN-Based Metaheuristic Approach
(2020) *IEEE Trans. Ind. Inform*, 16, pp. 4670-4680.

- Khan, A.H., Li, S., Cao, X.
Tracking control of redundant manipulator under active remote center-of-motion constraints: An RNN-based metaheuristic approach
(2021) *Sci. China Inf. Sci*, 64, pp. 1-18.

- Ali, M.A.H., Mailah, M.
Path Planning and Control of Mobile Robot in Road Environments Using Sensor Fusion and Active Force Control
(2019) *IEEE Trans. Veh. Technol*, 68, pp. 2176-2195.

- Ali, M.A.H., Mailah, M., Jabbar, W.A., Moiduddin, K., Ameen, W., Alkhalefah, H.
Autonomous Road Roundabout Detection and Navigation System for Smart Vehicles and Cities Using Laser Simulator–Fuzzy Logic Algorithms and Sensor Fusion
(2020) *Sensors*, 20.

- Ali, M.A., Mailah, M.
Laser simulator: A novel search graph-based path planning approach
(2018) *Int. J. Adv. Robot. Syst*, 15, pp. 1-16.

- Ali, M.A.H., Mailah, M., Moiduddin, K., Ameen, W., Alkhalefah, H.
Development of an Autonomous Robotics Platform for Road Marks Painting Using Laser Simulator and Sensor Fusion Technique
(2020) *Robotica*, 39, pp. 535-556.

Correspondence Address
Ali M.A.H.; Department of Mechanical Engineering, Malaysia; email: hashem@um.edu.my
Almotairi S.; Department of Computer Science, Saudi Arabia; email: almotairi@mu.edu.sa

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