A GENERALIZED LASER SIMULATOR ALGORITHM FOR OPTIMAL PATH PLANNING IN CONSTRAINTS ENVIRONMENT

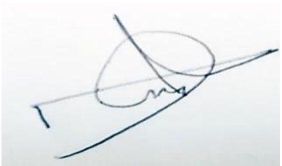
AISHA MUHAMMAD

DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.



____

(Supervisor's Signature)

Full Name : DR. MOHAMMED ABDO HASHEM

Position : SENIOR LECTURER

Date : 22/12/2021

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : AISHA MUHAMMAD

ID Number : PFD18003

Date : 21/12/2021

A GENERALIZED LASER SIMULATOR ALGORITHM FOR OPTIMAL PATH PLANNING IN CONSTRAINTS ENVIRONMENT

AISHA MUHAMMAD

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Doctor of Philosophy

Faculty of Manufacturing & Mechatronics Engineering Technology

UNIVERSITI MALAYSIA PAHANG

JANUARY 2022

ACKNOWLEDGEMENTS

My foremost thanks and appreciation goes to Almighty Allah for the gift of life, sound health and wisdom He has showered on me during the course of this study. I wish to express my profound appreciation to both my supervisor and husband: Dr. Mohammed Abdo Hashem and Ibrahim Haruna Shanono for their advice and guidance during the course of this research but for which the thesis would not have been a success. Indeed, all your help and support have been noted with the deepest of appreciation. Special appreciation goes to my sister (Dr. Ramatu Muhammad), beloved parents, brothers, and sisters for the encouragement and financial assistance.

Lastly, I wish to express my sincere appreciation to my friends and all people who in any way or the other have contributed towards the successful completion and execution of this thesis.

ABSTRAK

Pelan laluan memainkan peranan penting dalam navigasi robot mudah alih berautonomi, dan dengan itu ia telah menjadi salah satu bidang yang paling banyak dikaji dalam bidang robotik. Pelan laluan merujuk kepada proses pencarian laluan yang bebas perlanggaran dan optimum dari posisi mula ke posisi akhir pratakrif dalam persekitaran yang diberikan. Penyelidikan ini memberi tumpuan dalam membangunkan algoritma pelan laluan baru, yang dipanggil Generalized Laser Simulator (GLS), untuk menyelesaikan masalah pelan laluan robot mudah alih dalam persekitaran yang mempunyai kekangan. Pendekatan ini bertujuan membolehkan proses pencarian laluan untuk robot mudah alih dan dalam masa yang sama mengelakkan halangan, mencari satu posisi akhir, mengambil kira beberapa kekangan dan mencari laluan yang optimum semasa pergerakan robot dalam kedua-dua persekitaran yang dikenali dan tidak dikenali. Laluan boleh laksana ditentukan di antara posisi mula dan akhir dengan menjana titik gelombang dalam semua arah ke arah posisi akhir tanpa berganjak dari kekangan. Kajian simulasi menggunakan pendekatan yang dicadangkan pada tetapan peta grid untuk menentukan laluan bebas perlanggaran dari posisi mula ke akhir. Pertama, pemetaan grid bagi persekitaran ruang kerja robot dibina, dan kemudian sempadan persekitaran ruang kerja dikesan berdasarkan fungsi baru yang dicadangkan. Fungsi ini memandu robot untuk bergerak ke arah posisi yang diinginkan. Dua pendekatan telah diperkenalkan untuk menentukan posisi terbaik bagi perjalanan: jarak minimum ke posisi akhir dan jarak indeks maksimum ke sempadan, diintegrasikan oleh kebarangkalian negatif untuk menyusun posisi yang paling diutamakan bagi penentuan trajektori robot. Untuk membina laluan bebas perlanggaran yang optimum, satu langkah pengoptimuman telah dimasukkan untuk mengetahui jarak minimum dalam posisi yang telah ditentukan oleh GLS dalam masa yang sama mematuhi garis kekangan tertentu serta mengelakkan halangan. Algoritma yang dicadangkan akan menukar corak kerjanya berdasarkan matlamat minimum dan jarak indeks maksimum sempadan. Untuk mengelakkan halangan statik, sempadan halangan dianggap sebagai sempadan persekitarannya. Walaubagaimanapun, algoritma mengesan halangan sebagai sempadan baru dalam halangan dinamik apabila ianya berlaku di hadapan gelombang GLS. Kaedah yang dicadangkan telah diuji dalam beberapa persekitaran ujian dengan tahap kerumitan yang berbeza. Dua puluh persekitaran rawak yang berbeza dikategorikan kepada empat: Mudah, kompleks, sempit, dan berselirat, dengan lima persekitaran ujian dalam setiap satu. Keputusan menunjukkan bahawa kaedah yang dicadangkan boleh menjana laluan bebas perlanggaran yang optimum. Selain itu, hasil algoritma yang dicadangkan dibandingkan dengan beberapa algoritma biasa seperti algoritma A *, Probabilistic Road Map, RRT, RRT Bi-directional, dan algoritma Simulator Laser untuk menunjukkan keberkesanannya. Algoritma yang dicadangkan menunjukkan prestasi yang jauh lebih baik dari segi peningkatan kos laluan, kelancaran, dan masa carian. Ujian statistik telah digunakan untuk menunjukkan kecekapan algoritma yang dicadangkan ke atas kaedah yang dibandingkan. Nilai GLS adalah 7.8 dan 5.5 kali lebih cepat daripada A* dan LS, masing-masing menjana laluan 1.2 dan 1.5 kali lebih pendek daripada A* dan LS. Nilai min pendekatan yang dicadangkan bagi kos laluan adalah 4% dan 15% lebih rendah daripada PRM dan RRT. Nilai min kos laluan yang dijana oleh algoritma LS, sebaliknya, adalah 14% lebih tinggi daripada yang dihasilkan oleh PRM. Akhirnya, untuk mengesahkan prestasi kaedah yang dibangunkan untuk menjana laluan bebas perlanggaran, kajian eksperimen dijalankan menggunakan platform WMR sedia ada di makmal dan jalan. Kerja-kerja eksperimen mengkaji pelan laluan WMR berautonomi yang lengkap di makmal dan persekitaran jalan menggunakan strim video secara langsung. Peta setempat dibina menggunakan data daripada penstriman video secara langsung oleh pemprosesan imej masa nyata untuk mengesan segmen makmal dan persekitaran jalan. Pemprosesan imej melibatkan beberapa operasi dalam melaksanakan GLS pada peta setempat tersedia. Algoritma yang dicadangkan menjana laluan dalam peta setempat tersedia untuk mencari laluan antara posisi mula ke akhir bagi mengelakkan halangan dan tidak berganjak dari kekangan. Ujian percubaan menunjukkan bahawa kaedah yang dicadangkan boleh menjana laluan yang paling pendek dan trajektori yang lancar dari posisi mula ke posisi akhir berbanding dengan kaedah simulator laser.

ABSTRACT

Path planning plays a vital role in autonomous mobile robot navigation, and it has thus become one of the most studied areas in robotics. Path planning refers to a robot's search for a collision-free and optimal path from a start point to a predefined goal position in a given environment. This research focuses on developing a novel path planning algorithm, called Generalized Laser Simulator (GLS), to solve the path planning problem of mobile robots in a constrained environment. This approach allows finding the path for a mobile robot while avoiding obstacles, searching for a goal, considering some constraints and finding an optimal path during the robot movement in both known and unknown environments. The feasible path is determined between the start and goal positions by generating a wave of points in all directions towards the goal point with adhering to constraints. A simulation study employing the proposed approach is applied to the grid map settings to determine a collision-free path from the start to goal positions. First, the grid mapping of the robot's workspace environment is constructed, and then the borders of the workspace environment are detected based on the new proposed function. This function guides the robot to move toward the desired goal. Two concepts have been implemented to find the best candidate point to move next: minimum distance to goal and maximum index distance to the boundary, integrated by negative probability to sort out the most preferred point for the robot trajectory determination. In order to construct an optimal collision-free path, an optimization step was included to find out the minimum distance within the candidate points that have been determined by GLS while adhering to particular constraint's rules and avoiding obstacles. The proposed algorithm will switch its working pattern based on the goal minimum and boundary maximum index distances. For static obstacle avoidance, the boundaries of the obstacle(s) are considered borders of the environment. However, the algorithm detects obstacles as a new border in dynamic obstacles once it occurs in front of the GLS waves. The proposed method has been tested in several test environments with different degrees of complexity. Twenty different arbitrary environments are categorized into four: Simple, complex, narrow, and maze, with five test environments in each. The results demonstrated that the proposed method could generate an optimal collision-free path. Moreover, the proposed algorithm result are compared to some common algorithms such as the A* algorithm, Probabilistic Road Map, RRT, Bi-directional RRT, and Laser Simulator algorithm to demonstrate its effectiveness. The suggested algorithm outperforms the competition in terms of improving path cost, smoothness, and search time. A statistical test was used to demonstrate the efficiency of the proposed algorithm over the compared methods. The GLS is 7.8 and 5.5 times faster than A* and LS, respectively, generating a path 1.2 and 1.5 times shorter than A* and LS. The mean value of the path cost achieved by the proposed approach is 4% and 15% lower than PRM and RRT, respectively. The mean path cost generated by the LS algorithm, on the other hand, is 14% higher than that generated by the PRM. Finally, to verify the performance of the developed method for generating a collision-free path, experimental studies were carried out using an existing WMR platform in labs and roads. The experimental work investigates complete autonomous WMR path planning in the lab and road environments using–live video streaming. The local maps were built using data from live video streaming s by real-time image processing to detect the segments of the lab and road environments. The image processing includes several operations to apply GLS on the prepared local map. The proposed algorithm generates the path within the prepared local map to find the path between start-to-goal positions to avoid obstacles and adhere to constraints. The experimental test shows that the proposed method can generate the shortest path and best smooth trajectory from start to goal points in comparison with the laser simulator.

TABLE OF CONTENT

REFERENCE

Abbas, N.H, & Ali, F.M. (2017). Path planning of an autonomous mobile robot using enhanced bacterial foraging optimization algorithm. *Al-Khwarizmi Engineering Journal*, 12(4), 26-35.

Adham, A. & David, M.W.P. (2013). Obstacle Avoidance in a Dynamic Environment: A Collision Cone Approach. *International Journal of Advancements in Computing Technology(IJACT)*, 1-14.

Ahmed, E., Hussein, A. A., & Shawki, A. (2004). Genetic algorithm for dynamic path planning. In *Proceeding of IEEE CCECE 2004*. Canada: IEEE. 677-680

Ali, M., Mailah, M., Moiduddin, K., Ameen, W., & Alkhalefah, H. (2020). Development of an Autonomous Robotics Platform for Road Marks Painting Using Laser Simulator and Sensor Fusion Technique. *Robotica*, 1-22. doi:10.1017/S0263574720000831

Alajlan, M, Koubaa, A. Chaari, I, Bennaceur, H. & Ammar, A. (2013). Global path planning for mobile robots in large-scale grid environments using genetic algorithm. In *proceedngs of IEEE International Conference on Individual and Collective Behaviors in Robotics*, Sousse, Tunisia,. 1–8.

Ameni, A., & Khaled N. (2017). Path planning for autonomous mobile robot using the Potential Field method. In *Proceedings of 2017 International Conference on Advanced Systems and Electric Technologies (IC_ASET)*. Hammamet, Tunisia: IEEE. doi: 10.1109/ASET.2017.7983725, 389-394.

Amrit, K, Dheerendra K, Jha, & Sangheeta, M. (2014). Path Planning by a Robot is Static Environment using Hybridization of Particle Swarm Optimization and A* Algorithm. *International Journal of Computer Architecture and Mobility*.

Anders, L.C., Rehan, O., & Marco D. (2008). Synchronization and Fault Detection in Autonomous Robots. In *Proceedings of International Conference on Intelligent Robots and Systems* 4130-40. France: IEEE.

Anish, P., Rakesh K.S, Krishna, K.P., & Parhi, D. R. (2014). Path planning navigation of mobile robot with obstacles avoidance using fuzzy logic controller. In *Proceedings of IEEE 8th International Conference on Intelligent Systems and Control (ISCO)*. 39-41. Coimbatore: IEEE. doi:10.1109/ISCO.2014.7103914

Anmin, Z. & Simon, X.Y. (2009). An adaptive neuro-fuzzy controller for robot navigation. *Recent Advances in Intelligent Control Systems*, 277–307.

Anthony, S. (1995). The focussed D* algorithm for real-time replanning. IJCAI'95 *Proceedings of the 14th international joint conference on Artificial intelligence*. 1652–1659. Montreal, Quebec, Canada: Morgan Kaufmann Publishers.

Antonelo, E.A. & Schrauwen, B. (2010). Supervised learning of internal models for autonomous goal-oriented robot navigation using reservoir computing. In *Poceedings of IEEE International Conference on Robotics and Automation*, ICRA, Alaska USA, 2959–2964.

Arafat, M.H. & , Israt, F. (2015). Autonomous robot path planning in dynamic environment using a new optimization technique inspired by bacterial foraging technique. *Robotics and Autonomous Systems*, 16, 137-141.

Arindam, J., Garima, S., Pratyusha, R., Amit, K., Eunjin, K., & Atulya, K.N. (2012). A hybridization of improved harmony search and bacterial foraging for multi-robot motion planning. *Evolutionary computation (CEC),* IEEE (pp. 1-8). Brisbane, QLD, Australia: IEEE.

Arindam, S., Anjan, K.R, & Arun, B.S. (2017). Navigation of mobile robot in a grid-based environment using local and target weighted neural networks. In *Proceedings of 8th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. 1-6. Delhi, India: IEEE. doi:10.1109/ICCCNT.2017.8204115

Ashleigh, S., & Ferrari, S. (2010). A cell decomposition approach to cooperative path planning and collision avoidance via disjunctive programming. *49th IEEE Conference on Decision and Control (CDC)*. 6329-6336. Atlanta, GA, USA: IEEE. doi:10.1109/CDC.2010.5717137

Asita, K.R., Dayal R.P., Harish C.D., Manoj K.M., & Priyadarshi B.K. (2018). Analysis and use of fuzzy intelligent technique for navigation of humanoid robot in obstacle prone zone. *Defence Technology*, 1-6. doi:https://doi.org/10.1016/j.dt.2018.03.008

Asma, A, & Sadok, B. (2017). Collision-Free Optimal Paths for Multiple Robot Systems Using a New Dynamic Distributed Particle Swarm Optimization Algorithm. In *Proceedings of the 2017 18th International Conference on Advanced Robotics (ICAR)* pp. 493-497). Hong Kong, China: IEEE.

Avinash, S., Kanika, G, Anirudha, K., Aishwarya, S. & Rajesh K. (2017). Model based path planning using Q-Learning. In *Proceedings of IEEE International Conference on Industrial Technology (ICIT)* 837-842. Toronto, ON, Canada: IEEE. doi:10.1109/ICIT.2017.7915468

Azzeddine, B., Abdelfetah, H., Hakim, B., Abderraouf, M. Ouarda, H., & Brahim, B. (2017). Optimal path planning and execution for mobile robots using genetic algorithm and adaptive fuzzy-logic control. *Robotics and Autonomous Systems*, 89, 95-109.

Bai, J. L. (2012). Robot path planning based on random expansion of ant colony optimization,. *Lect. Notes Electr. Eng*., 125, 141–146.

Bai, W, Wu, X, Xie, Y, Wang, Y, Zhao, H, Chen, K, Li, Y, Hao, Y. A cooperative route planning method for multi-uavs based-on the fusion of artificial potential field and b-spline interpolation, In *Proceedings of 37th Chinese Control Conference*

(CCC), 2018.

Baofang, W. Sheng, L, Jian, G., & Qingwei, C. (2018). Car-like mobile robot path planning in rough terrain using multi-objective particle swarm optimization algorithm. *Neurocomputing*, 282, 42-51. doi:https://doi.org/10.1016/j.neucom.2017.12.015

Beloglazov, D.A., Finaev, V.I., Titov, A.E, Shapovalov, I.O. & Soloviev, V.V. (2016). Group robot control in non-deterministic environments using the potential field method. In *Proceedings of 2016 16th International Conference on Control, Automation and Systems (ICCAS) (pp. 371-376)*. Gyeongju, South Korea: IEEE. doi:10.1109/ICCAS.2016.7832346

Bence, K., Géza, S., Ferenc, T., Mauricio, B., & Péter, K. (2016). A novel potential field method for path planning of mobile robots by adapting animal motion attributes. *Robotics and Autonomous Systems*, 82, 24-34. doi:doi:https://doi.org/10.1016/j.robot.2016.04.007

Benders. S, Schopferer, S. (2017)A line-graph path planner for performance constrained fixed-wing uavs in wind fields. In *Proceedings of Unmanned Aircraft Systems (ICUAS)*.

Bhagade, A.S, & Puranik, P.V. (2012). Artificial bee colony (ABC) algorithm for vehicle routing optimization problem. *International Journal Soft Computer Engineering*, 2(2), 329-333.

Bhattacharjee, P, Rakshit P, Goswami, I, Konar A, & Nagar, AK. (2011). Multi-robot path planning using artificial bee colony optimization algorithm. In *Proceedings of the third World Congress on Nature and Biologically Inspired Computing*. 219-224. Salamanca, Spain: IEEE.

Bi, Z., Yimin, Y & Wei, Y. (2008). Hierarchical path planning approach for mobile robot navigation under the dynamic environment. In *Proceedings of IEEE Conference on Industrial Informatics*, Daejeon, Korea, 372–376.

Bing, F., Lin, C., Yuntao, Z., Dong, Z., Zhiqi, W., Jun D., & Haihong, P. (2018). An improved A* algorithm for the industrial robot path planning with high success rate and short length. *Robotics and Autonomous Systems*, 106, 26–37.

Brand, M. & Yu, X. (2013). Autonomous robot path optimisation using firefly algorithm. In *Proceedings of International conference on machine learning and cybernetics*, 14-17. Tianjin: IEEE.

Budiyanto, A, Cahyadi, A, Adji, TB, Wahyunggoro, O. Uav obstacle avoidance using potential field under dynamic environment. In *Proceedings of Control, Electronics, Renewable Energy and Communications (ICCEREC)*, 2015

Chakravarthy, A. & Ghose, D. (1998). Obstacle Avoidance in a Dynamic Environment: A Collision Cone Approach. *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans*, 562-574.

Chang, L. & Zhenghua, L. (2016). Design of Two-stage Fuzzy Controller for Mobile

Robot Using Vision Navigation. In *Proceedings of 2016 IEEE Chinese Guidance, Navigation and Control Conference* 872-877. Nanjing, China: IEEE.

Chang, L., Yuxin, Z., Feng, G., & Liqiang, L. (2015). Three-dimensionalThree-dimensional path planning method for autonomous underwater vehicle based on modified firefly algorithm. *Mathematical Problems in Engineering*, 1-10.

Chang, H. & Jin, T. (2013). Command fusion based fuzzy controller design for moving obstacle avoidance of mobile robot, In: *Future Information Communication Technology and Applications. Lecture Notes in Electrical Engineering*, 905–913.

Chao, C.H. Hsueh, B., Hsiao, M. Tsai, S. & Li, T. (2009). Fuzzy target tracking and obstacle avoidance of mobile robots with a stereo vision system. *International Journal Fuzzy System*, 11, 183–191.

Chaymaa, L , Said, B., & Ali, B. (2018). Genetic Algorithm Based Approach for Autonomous Mobile Robot Path Planning. In *Proceedings of the First International Conference On Intelligent Computing in Data Sciences* 180–189. Morocco: Elsevier. B. V.

Chen, G., Hou, J., Dong, J., Li, Z., Gu, S., Zhang, B., Knoll, A. (2021). Multiobjective Scheduling Strategy With Genetic Algorithm and Time-Enhanced A* Planning for Autonomous Parking Robotics in High-Density Unmanned Parking Lots. *IEEE/ASME Transactions on Mechatronics*, 26(3), 1547 - 1557.

Chen, J. Zhu, H., Bai, W, Wu, X, Xie, Y, Wang, Y, Zhao, H, Chen, K, Li, Y, Hao, Y. (2018). A cooperative route planning method for multi-uavs based-on the fusion of artificial potential field and b-spline interpolation, In *Proceedings of 37th Chinese Control Conference (CCC)*, 2018

Chen T, Zhang G, Hu X, Xiao J. (2018). Unmanned aerial vehicle route planning method based on a star algorithm. In 13th IEEE Conference on Industrial Electronics and Applications (ICIEA),

Chen, X., & Yudi, A. (2018). Multi — UAV path planning based on improved neural network. In *Proceedings of 2018 Chinese Control And Decision Conference (CCDC)* 355-359. Shenyang, China: IEEE. doi:10.1109/CCDC.2018.8407158

Chen, X, Kong, Y.,Fang, X. & Wu, Q. (2013). A fast two–stage ACO algorithm for robotic path planning. *Neural Comput. Appl*., 22, 313–319.

Chen, X. & Li, Y. (2006). Smooth formation navigation of multiple mobile robots for avoiding moving obstacles. *Int. J. Control Autom. System*, 4(4), 466–479.

Cheng, K. P., Mohan, R. E., Nhan, N. H., & Le, A. V. (2020). Multi-Objective Genetic Algorithm-Based Autonomous Path Planning for Hinged-Tetro Reconfigurable Tiling Robot. *IEEE Access*, 8, 121267 - 121284.

Chengjun Z, Xiuyun M. (2017). Spare a∗ search approach for uav route planning. In *Unmanned Systems (ICUS)*, IEEE International Conference, 2017

Chenghui C. & Ferrari, S. (2009). Information-driven sensor path planning by approximate cell decomposition. *IEEE Transactions on Systems Man and Cybernetics, Part B(Cybernetics)*, 39(3).

Chiang, H. , Malone, N., Lesser, K., Oishi, M. & Tapia, L. (2015). Path–guided artificial potential fields with stochastic reachable sets for motion planning in highly dynamic environments. In *Proceedings of IEEE International Conference on Robotics and Automation, ICRA*, Washington, USA, 2347–2354.

Christian, S. &, Uwe, E. Z. (2011). Path planning method for palletizing tasks using workspace cell decomposition. In *Proceedings of 2011 IEEE International Conference on Robotics and Automation*. Shanghai, China: IEEE. doi:10.1109/ICRA.2011.5980573

Coelho, L.D.S & Sierakowski, C.A. (2005). Bacteria colony approaches with variable velocity applied to path optimization of mobile robots. *ABCM Symposium Series in Mechatronics*, 2, 297-304.

Coelho, L.S., & Camila, C. (2006). Improved bacterial foraging strategy for controller optimization applied to robotic manipulator system. In *Proceedings of IEEE International Conference on Control Applications*, 1276-1281. Munich, Germany: IEEE.

Cosio, F.A. & Castaneda, M.A.P. . (2004). Autonomous robot navigation using adaptive. potential fields, *Math. Comput. Modelling*, 40, 1141–1156.

Couceiro, M.S. , Machado, J.A.T. Rocha, , R.P. & Ferreira, N.M.F. . (2012). A fuzzified systematic adjustment of the robotic Darwinian PSO. *Robotics and Autonomous System*, 60, 1625–1639.

Dai, J, Wang, Y, Wang, C, Ying, J, Zhai, (2018) J. Research on hierarchical potential field method of path planning for uav. In *2nd IEEE Advanced*, 2018.

Dachuan, L., Qing, L., Nong, C. & Jingyan S. (2012). Extended RRT-based path planning for flying robots in complex 3D environments with narrow passages. In *Proceedings of 2012 IEEE International Conference on Automation Science and Engineering (CASE)* 1173-1178. Seoul, South Korea: IEEE. doi: 10.1109/CoASE.2012.6386513

Das, P.K, Sahoo, B.M. , Behera, H.S. & Vashisht, S. (2016). An Improved Particle Swarm Optimization for Multi-Robot Path Planning. In *Proceedings of 2016 1st International Conference on Innovation and Challenges in Cyber Security (ICICCS 2016)* 97-106. IEEE.

Dave, F., Maxim, L. & Anthony, S. (2005). A Guide to Heuristicbased Path Planning. In *Proceedings of The International Conference on Automated Planning and Scheduling (ICAPS).*

Dezfoulian, S.H. , Wu, D. & Ahmad, I.S. . (2013). A generalized neural network approach to mobile robot navigation and obstacle avoidance. *Intelligent Autonomous Systems* 12, AISC, 193, 25–42.

Dijkstra, E. W. (1959). A Note on Two Problems in Connexion with Graphs. *Numerische* *mathematik*, 1(1), 269-271.

Doh, N. L., Cho, N., Lee, K., Lee, J., Chung, W. K. & Oh, S. R. (2005). A Systematic Representation of Edges in Topological Maps for Mobile Robots using Wavelet Transformation. In *Proceedings of IEEE ICRA*, 2822-2827.

Donny, S., Paul, L., Christoph, M., & Mark, R. (2013). Collective-adaptive levy flight for underwater multi-robot exploration. In *Proceedings of International conference on mechatronics and automation* 456-462. Japan: IEEE.

Dunlaing, C.O, & Yap, CK. (1985). A retraction method for planning the motion of a disc. *Journal of Algorithms*, 104-111.

Masehian, E. & D. S. (2010). Multi–objective PSO and NPSO based algorithms for robot path planning. *Adv. Electr. Comput. Eng.*, 10(4), 69-76.

Elshamli, A., Hussein, A. A. & Shawki, A. (2004). Genetic algorithm for dynamic path planning. In *Proceeding of IEEE CCECE* 2004, Canada

Engedy, I. & Horvath, G. (2009). Artificial neural network based mobile robot navigation. In *Proceedings of IEEE International Symposium on Intelligent Signal Processing Budapest*, Hungary, 241–246.

Englot, B. & Hover, F. (2011). Multi-goal feasible path planning using ant colony optimization. In *Proceedings of IEEE International Conference on Robotics and Automation ICRA*, Shanghai, China,, 2255–2260.

Eshaghnezhad, M., Rahbarnia, F., Effati, S., & Mansoori, A. (2019). An Artificial Neural Network Model to Solve the Fuzzy Shortest Path Problem. *Neural Processing Letters*, 50(1), 1527–1548.

Farhad, B., Sepideh, N. & Morteza, A. (2018). Mobile robots path planning: Electrostatic potential field approach. *Expert Systems With Applications*, 100, 68–78.

Farshchi, S.M.R. ,Hoseini, S.A.N. & Mohammadi, F. (2011). A novel implementation of G-fuzzy logic controller algorithm on mobile robot motion planning problem. *Computer and Information Science*, 4(2), 102–114.

Fedorenko, R, Gabdullin, A. (2018) Global UGV path planning on point cloud maps created by uav. In P*roceedings of 3rd IEEE International Conference on Intelligent Transportation Engineering (ICITE)*, 2018

Fei, X., ShaoChang,W., WeiXia, Y. (2018). Local logic optimization algorithm for autonomous mobile robot based on fuzzy logic. In *Proceedings of 2018 Chinese Control And Decision Conference (CCDC)* 4160-4165. Shenyang, China: IEEE. doi: 10.1109/CCDC.2018.8407847

Filippis, D.L, Guglieri, G. & Quagliotti, F. (2012). Path planning strategies for UAVS in 3D environments. *Journal of Intelligent and Robotic Systems*, 65(1-4), 247–264.

Foudil, A., Mohammed,F., Muhammed, E., Ramdane, H., Khalid, A.M. , Mansour, A. & Hassan, M. (2014). A hierarchical fuzzy control design for indoor mobile robot.

International Journal Advance Robotic System, 1-16.

Frazzoli, E. & Karaman, S. (2010). Optimal kinodynamic motion planning using incremental sampling-based methods. In *Proceedings of 49th IEEE Conference on Decision and Control (CDC '10)* 7681-7687. Atlanta, Ga, USA: IEEE.

Furlán,F., Rubio, E. ,Sossa, H. & Ponce, V. (2017). Humanoid robot hierarchical navigation using Petri nets and fuzzy logic. In *Proceedings of 56th Annual Conference of the Society of Instrument and Control Engineers of Japan (SICE)* 1521-1526. Kanazawa: IEEE. doi:10.23919/SICE.2017.8105756

Gai-ge, W., Lihong, G., Hong D., Luo L., & Heqi W. (2012). A modified firefly algorithm for UCAV path planning. *International Journal ofHybrid Information Technology,* 5(3), 123-144.

Gao, W., Tang, Q., Ye, B., Yang, Y., & Yao, J. (2020). An enhanced heuristic ant colony optimization formobile robot path planning. *Soft Computing,* 24, 6139–6150.

Garcia, M.A.P. , Montiel, O. Castillo, O. & Sepulveda, R. (2007). Optimal path planning for autonomous mobile robot navigation using ant colony optimization and a fuzzy cost function evaluation. *Adv. Soft Comput.*, 41, 790–798.

Gasparetto, A, Boscariol, P, Lanzutti, A, Vidoni, R. (2015). Path Planning and Trajectory Planning Algorithms: A General Overview. *Motion and Operation Planning of Robotic Systems,* 29, 3-27. doi: DOI: 10.1007/978-3-319-14705-5_1

Gasparri A, Prosperi, M. (2008). A bacterial colony growth algorithm for mobile robot localization. *Autonomous Robots,* 24(4), 349-364.

Guo, J., Li, C., & Guo, S. (2020). A Novel Step Optimal Path Planning Algorithm for the Spherical Mobile Robot Based on Fuzzy Control. IEEE Access, 8, 1394 - 1405

Hao, Y., Zu, W. & Zhao, Y. (2007). Real-time obstacle avoidance method based on polar coordination particle swarm optimization in dynamic environment. 2nd IEEE Conference on Industrial Electronics and Applications, Harbin, China, 1612–1617.

Hart, P. , Nilsson, N. & Raphael, B. (1986). A Formal Basis for the Heuristic Determination of Minimum Cost Paths. I*EEE Transactions on Systems Science and Cybernetics,* 4(2), 100-107.

He, Z, Zhao, L. (2017). The comparison of four uav path planning algorithms based on geometry search algorithm. In *Proceedings of Intelligent Human-Machine Systems and Cybernetics (IHMSC).*

Hexmoor, G. & Vachtsevanos, H. (1986). A fuzzy logic approach to robotic path planning with obstacle avoidance. In *Proceedings of IEEE Int. Conf. on Decision and Control*, 25, 1262-1264.

Hidalgo-Paniagua, A, Miguel A, VegaeRodriguez, Ferruz J, Pavon N. (2017). Solving the multi-objective path planning problem in mobile robotics with a fireflybased approach. *Soft Computing,* 21(4), 949–964.

Hidalgo-Paniagua, A, Miguel, A, VegaeRodriguez, F.J, & Pavon N. (2015). Solving the multi-objective path planning problem in mobile robotics with a fireflybased approach. *Soft computing*, 1-16.

Hong, T.S., Nakhaeinia, D. & Karasfi, B. (2012). Application of fuzzy logic in mobile robot navigation. *Fuzzy Logic - Controls, Concepts, Theories and Applications*,, 21-36.

Howie, C., Kevin, M.L., Seth H., George, K., Wolfram, B., Lydia, K., & Sebastian T. (2005). *Principles of Robot Motion: Theory, Algorithms, and Implementations. Cambridge*: MIT Press.

Hsu, D., Latombe, J.C. & Kurniawati, H. (2006). On the probabilistic foundations of probabilistic roadmap planning. *Int. J. Robot. Res. (IJRR)*, 25(7), 627–643.

Huang, H.C. & Tsai, C.C . (2011). Global path planning for autonomous robot navigation using hybrid meta heuristic GA–PSO algorithm. In *Proceedings of IEEE SICE Annual Conference, SICE*, Tokyo, Japan, 1338–1343.

Huang, L. (2007). A potential field approach for controlling a mobile robot to track a moving target. In *Proceedings of IEEE 22nd International Symposium on Intelligent Control* 65–70. Singapore, Singapore: IEEE. doi: 10.1109/ISIC.2007.4450862

Hue, C.K., Jaeseok, K., Yong, K.J., & Jahng, H.P. (2013). Path planning of swarm mobile robots using firefly algorithm. *Journal of Institute of Control, Robotics and Systems*, 19(5), 435-441.

Hui, N.B, Mahendar, V. & Pratihar, D.K. (2006). Time-optimal, collision-free navigation of a car-like mobile robot using neuron-fuzzy approaches. *Fuzzy Sets and Systems*, 2171–2204.

Hui, N.B. & Pratihar, D.K. (2009). A comparative study on some navigation schemes of a real robot tackling moving obstacles,. *Robot. Comput.-Integr. Manufacturing*, 810–828.

Huiming, Y., Chia-Jung, C., Tong, S., & Qiang, B. (2001). Hybrid evolutionary motion planning using follow boundary repair for mobile robots. *Journal of Systems Architecture*, 47(7), 635 – 647.

Hyman, J. (1983). Accurate monotonicity preserving cubic interpolation. SIAM. SIAM *J. Sci Stat. Comput.*, 4(4), 645–654.

Iluminada, B., & Andres A.G. (2007). A Simple Neuro-Fuzzy Controller for Car-Like Robot Navigation Avoiding Obstacles. In P*roceedings of 2007 IEEE International Fuzzy Systems Conference*. London, UK: IEEE. doi:10.1109/FUZZY.2007.4295621

Iser, R. & Wahl, F.M. (2010). AntSLAM: Global map optimization using swarm intelligence,. In *Proceedings of International Conference on Robotics and Automation, ICRA* Alaska, USA, 265–272.

Janglova, D. (2004). Neural networks in mobile robot motion. *International Journal of Advance Robotic System*, 1, 15-22.

Jianhao, T., Luodi, Z., Yaonan, W., Yiwei , Z., Lu, L. (2016). The 3D Path Planning Based on A* Algorithm and Artificial Potential Field for the Rotary-Wing Flying Robot. In *Proceedings of 2016 8th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC)* 551-556. Hangzhou, China: IEEE. doi:10.1109/IHMSC.2016.155

Jinghua, L., Yibin, H., Zhao, X., Jing, W., & Mou, C. (2017). Path planning of UAV based on hierarchical genetic algorithm with optimized search region. In *Proceedings of 13th IEEE International Conference on Control & Automation (ICCA)*, 1033-1038. Ohrid, Macedonia: IEEE. doi:10.1109/ICCA.2017.8003203

Joshi, M.M. & Zaveri, M.A. (2011). Reactive navigation of autonomous mobile robot using neuron-fuzzy System. *International Journal of Robot. Autom. (IJRA)*, 2(3), 128-145.

Junyi, L. & Kintak, U. (2017). Mobile robot navigation based on adaptive neuro-fuzzy inerence ssystem with virtual target strategy. In *Proceedings of International Conference on Wavelet Analysis and Pattern Recognition (ICWAPR*). 132-136. Ningbo, China: IEEE. doi:10.1109/ICWAPR.2017.8076677

Kamil, F, Tang, SH, Khaksar W, Zulkifli N, Ahmad SA. (2015). A Review on Motion Planning and Obstacle Avoidance Approaches in Dynamic Environments. *Advances in Robotics & Automation,* 4(2), 1-8. doi:http://dx.doi.org/10.4172/2168-9695.1000134

Kang, Y., Lee, M., Kim, C., Yoon, S. & Noh, C. (2011). A study of cluster robots line formatted navigation using potential field method. In *Proceedings of IEEE International Conference on Mechatronics and Automation*, Beijing, China,, 1723–1728.

Karaboga, D. (2005). An idea based on honey bee swarm for numerical optimization. Engineering Faculty, Computer Engineering Department.: *Technical Report TR06, Erciyes University*.

Karaman, S. &. (2011). Sampling-based algorithms for optimal motion planning. *Int. J. Robot. Res. (IJRR)*, 30(7), 846–894.

Karami, A.K. & Hasanzadeh, M. (2015). An adaptive genetic algorithm for robot motion planning in 2D complex environments. *Comput. Electr. Eng.,* 1-13.

Karim, B. & Zhu, Q. (2013). Genetic fuzzy Logic control technique for a mobile robot tracking a moving target. *Int. J. Comput. Sci. Issues*, 10(1), 607–613.

Kumar,A. Biplab, K.P., P.R. Dayal. Intelligent navigation of humanoids in cluttered environments using regression analysis and genetic algorithm. *Arabian J Sci Eng* (2018) 1-24

Ke C. & Yong, L. (2017). Optimal complete coverage planning of wall-climbing robot using improved biologically inspired neural network. In P*roceedings of IEEE*

International Conference on Real-time Computing and Robotics (RCAR) 587-592. Okinawa: IEEE. doi:10.1109/RCAR.2017.8311926

Kikuo, F. & Hanan, S. (1989). A hierarchical strategy for path planning among moving obstacles. *IEEE Transactions on Robotics and Automation*, 5(1).

Kim, D. (2009). Escaping route method for a trap situation in local path planning. *International Journal for Control Automation System*, 495–500.

Kim, D.H. & Shin, S. (2006). Local path planning using a new artificial potential function configuration and its analytical design guidelines. *Advance Robot*, 115-135.

Koenig, S. & Likhachev, M. (2002). Improved fast replanning for robot navigation in unknown terrain. In *Proceedings of IEEE International Conference on Robotics and Automation (Cat. No.02CH37292)* 968–975. Washington, DC, USA, USA: IEEE.

Koenig, S., Likhachev, M. & Furcy, D. (2004). Lifelong Planning A*. *Artificial Intelligence*, 155(1-2), 93-146.

L.Huang. (2009). Velocity planning for a mobile robot to track a moving target a potential field approach. *Robotis and Autonomou System*, 57(1), 55–63. doi:https://doi.org/10.1016/j.robot.2008.02.005

Ladd, A.L. & Kavraki, L. (2004). Measure theoretic analysis of probabilistic path planning. *IEEE Trans. Robot. Automation*, 20(2), 229–242.

Lai, X., Li, J., & Chambers, J. (2021). Enhanced Center Constraint Weighted A* Algorithm for Path Planning of Petrochemical Inspection Robot. *Journal of Intelligent & Robotic Systems, 102*(78), 1-15.

Lee, J. K. (2014). A selective retraction-based RRT planner for various environments. *IEEE Trans. Robot.*, 30(4), 1002–1011.

Leena, N & Saju, K.K. (2014). A survey on path planning techniques for autonomous mobilerobots. In *Proceedings of IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 76-79.

Lee, T. & Wu, C. (2003). Fuzzy motion planning of mobile robots in unknown environments. *Journal of Intelligent Robot System*, 177–191.

Li J, Deng G, Luo C, Lin Q, Yan Q, Ming Z. (20160. hybrid path planning method in unmanned air/ground vehicle (uav/ugv) cooperative systems. *IEEE Transaction on Vehicular Technology*. 65(12):. 9585–9596

Liang, C., Zhang, X., Watanabe, Y., & Deng, Y. (2021). Autonomous Collision Avoidance of Unmanned Surface Vehicles Based on Improved A Star And Minimum Course Alteration Algorithms. *Applied Ocean Research*, 113, 1-11.

Liang, J.H. & Lee, CH. (2015). Efficient collision-free path-planning of multiple mobile robots system using efficient artificial bee colony algorithm. *Advance Engineering Software*, 79, 47-56.

Liang, M., Jianru, X., Jihua, Z., Chao, M. & Nanning Z. (2014). A Fast RRT Algorithm for Motion Planning of Autonomous Road Vehicles. In *Proceedings of 2014 IEEE 17th International Conference on Intelligent Transportation Systems (ITSC).* 7033-7038. Qingdao, China: IEEE. doi:10.1109/ITSC.2014.6957824

Liang, Y., & Wang, L. (2020). Applying genetic algorithm and ant colony optimization algorithm into marine investigation path planning model. *Soft Computing*, 24(1), 8199–8210.

Likhachev, M., Ferguson, D. ,Gordon, G. Stentz, A. & Thrun, S. (2008). Anytime search in dynamic graphs. *Artificial Intelligence*, 172(14), 1613 – 1643.

Lin, Y, Saripalli S. (2017) Sampling-based path planning for uav collision avoidance. *IEEE Trans. Intell. Transp. Syst*., 18(11): 3179–3192

Lingelbach, F. (2004). Path planning for mobile manipulation using probabilistic cell decomposition. In *Proceedings of 2004 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* 2807-2812. Sendai, Japan: IEEE. doi: 10.1109/IROS.2004.1389834

Luo, M., Hou, X., & Yang, S. X. (2019). A Multi-Scale Map Method Based on Bioinspired Neural Network Algorithm for Robot Path Planning. *IEEE Access*, 7, 142682 - 142691.

Luo, Q., Wang, H., Zheng, Y., & He, J. (2020). Research on path planning of mobile robot based on improved ant colony algorithm. *Neural Computing and Applications*, 32, 1555–1566.

Mac, TT, Copot, C, Hernandez, A, & De Keyser, R. (2016). Improved potential field method for unknown obstacle avoidance using uav in indoor environment, in: Applied Machine Intelligence and Informatics (SAMI). In *4th International Symposium on Applied Machine Intelligence and Informatics (SAMI).*

Marco, A.C., Victor, A., & Uriel, H. H. (2015). Mobile robot path planning using artificial bee colony and evolutionary programming. *Applied Soft Computing*, 30, 319-328.

Mitić, M. & Zoran, M. (2015). Bio-inspired approach to learning robot motion trajectories and visual control commands. *Expert Systems with Applications*, 42(5), 2624-2637.

Masehian, E, & Sedighizadeh, D. (2007). Classic and heuristic approaches in robot motion planning-a chronological review. *World Academy of Science, Engineering and Technology*, 29, 101-106.

Masehian, E. & Sedighizadeh, D. (2010). Multi–objective PSO and NPSO based algorithms for robot path planning. *Adv. Electr. Comput. Eng.*, 10(4), 69-76.

Maxim, L., Dave, F., Geoff, G., Anthony, S., & Sebastian T. (2005). nytime dynamic A*: An anytime, replanning algorithm. In *Proceedings of International Conference on Automated Planning and Scheduling (ICAPS)*. American Association for Artificial Intelligence.

Meihua, W., Erkui, C., Qianqian, S., Luan, Z., Zhiqiang, C. & Mengfan, L. (2017). Path planning of mobile robot based on improved genetic algorithm. In *Proceedings of 2017 Chinese Automation Congress (CAC)* 6696-6700. Jinan, China: IEEE. doi: 10.1109/CAC.2017.8243983

Meijer, J., Lei, Q. & Wisse M. (2017). An empirical study of single-query motion planning for grasp execution. *Proceedings 2017 IEEE International Conference on Advanced Intelligent Mechatronics*. Netherland.

Mengfan, L., Chuanjiang, W., Zhiqiang, C. & Xiao, L. (2017). Path Planning of Mobile Robot Based on Genetic Algorithm and Gene Rearrangement. *Chinese Automation Congress (CAC)*, 6999-7004. doi:doi: 10.1109/CAC.2017.8244039

Mester, G. (2008). Obstacle avoidance and velocity control of mobile robots. In *Proceedings of International Symposium on Intelligent Systems and Interpretation,* Subotica Serbia, 1–5.

Michael, H., Simon, S., & Ken, F. (2009). he quantitative crunch: The impact of bibliometric research quality assessment exercises on academic development at small conferences. *Campus-Wide Information Systems*, 26(3), 149-167.

Milos, S. (2007). Roadmap method vs. cell decomposition in robot motion planning. *Proceedings of the 6th WSEAS International Conference on Signal Processing, Robotics and Automation*, 16-19. Corfu Island, Greece,.

Ali, M , Mailah ,M. & Tang H.H. (2012). Path planning of mobile robot for autonomous navigation of road roundabout intersection. *International Journal of Mechanics,* 6(4), 203-211.

Ali, M , Mailah ,M, M., Waheb, A. A., Khaja, M., Wadea, A. and Hisham, A. (2020). Autonomous Road Roundabout Detection and Navigation System for Smart Vehicles and Cities Using Laser Simulator-Fuzzy Logic Algorithms and Sensor Fusion. *Sensors*, 20, 1-26.

Ali, M ,& Mailah ,M. (2019). Path planning and Control of Mobile Robot in Road Environments using Sensors Fusion and Active Force Control. *IEEE Transactions on Vehicular Technology*., 68(3), 2176-2195.

Ali, M , Mailah ,M. & Tang H.H. (2014). Implementation of laser simulator search graph approach for detection and path planning in roundabout environments. *WSEAS Transactions on Signal Processing*, 10(1), 106-115.

Ali, M ., Wan Azhar B. W. Y., Zamzuri B. H., Zulkifli B. M. Y., & Musa M. (2016). Global mobile robot path planning using laser simulator. In *Proceedings of 2016 2nd IEEE International Symposium on Robotics and Manufacturing Automation (ROMA).* Ipoh, Malaysia: IEEE. doi:10.1109/ROMA.2016.7847828

Ali, M & Mailah ,M.. (2018). Laser simulator: A novel search graph-based path planning approach. *International Journal of Advanced Robotic Systems,* 15(5), 1-16.

Mohanty P.,K, Parhi, D.R. (2015). A new hybrid optimization algorithm for multiple mobile robots navigation based on the CS-ANFIS approach. *Memetic Computing,* 7(4), 255-275.

Mohd, N.Z. & Mohanta, J.C. (2018). Methodology for Path Planning and Optimization of Mobile Robots: A Review. In *Proceedings of International Conference on Robotics and Smart Manufacturing (RoSMa2018)* 141-152. India: Elsevier Ltd.

Moran, A. (2017). Autonomous Path Following of Truck-Trailer Vehicles Using Linear-Fuzzy Control. In *Proceedings of 3rd International Conference on Control, Automation and Robotics*, 651-657.

Najmuddin, A. & Ramachandran S. (2018). Hardware Realization of Neural Network Based Controller for Autonomous Robot Navigation. In *Proceedings of International Conference on Computing Methodologies and Communication (ICCMC)*. 243-248. Erode, India: IEEE. doi: 10.1109/ICCMC.2017.8282684

Nazarahari, M., Khanmirza, E., & Doostie, S. (2019). Multi-objective multi-robot path planning in continuous environment using an enhanced genetic algorithm. *Expert Systems With Applications, 115*(1), 106-120.

Nazif, A.N. , Davoodi, A. & Pasquier, P. (2011). Multi-agent area coverage using a single query road-map: A swarm intelligence approach, In: *Advances in Practical Multi-Agent Systems. Studies in Computational Intelligence*, 325, 95-112.

Olzhas, A. & Huseyin, A.V. (2017). A novel RRT*-based algorithm for motion planning in Dynamic environments. In *Proceedings of 2017 IEEE International Conference on Mechatronics and Automation (ICMA)* 1416-1421. Takamatsu, Japan: IEEE. doi:10.1109/ICMA.2017.8016024

Panagiotis,T. & , Efstathios, B. (2007). A hierarchical on-line path planning scheme using wavelets. *Proceedings of the European Control Conference* 2806-2812. Greece: Kos.

Panda, M.R., Priyadarshini, R. & Pradhan, S.K. (2016). Autonomous Mobile Robot Path Planning Using Hybridization of Particle Swarm Optimization and Tabu Search. In *Proceedings of IEEE International Conference on Computational Intelligence and Computing Research*. India.: IEEE.

Parhi, D. (2008). Neuro-fuzzy Navigation Technique for Control of Mobile Robots. *Techechnology*, 409–432.

Parvathy J. & Supriya, P. (2016). Implementation of Robotic Path Planning using Ant Colony Optimization Algorithm. In *Proceedings of International Conference on Inventive Computation Technologies (ICICT)*. Coimbatore, India: IEEE. doi:10.1109/INVENTIVE.2016.7823281

Passino, K. (2002). Biomimicry of bacterial foraging for distributed optimization and control. *IEEE Control Systems Magazine*, 22(3), 52-67.

Patle, B.K, Pandey, A, Jagadeesh A. & Parhi, D.R.K. (2018). Path planning in uncertain environment by using firefly algorithm. *Defence Technology*, 14(6), 691-701.

Patle, B.K, Parhi, D.R, Jagadeesh, A. & Kashyap, S.K. (2017). On firefly algorithm:

optimization and application in mobile robot navigation. *World Journal of Engineering*, 4(1), 65-76.

Patle, B.K., Ganesh, B.L, Anish P. , Parhi,D.R.K. & Jagadeesh, A. (2019). A review: On path planning strategies for navigation of mobile robot. *Defence Technology*, 1-25.

Peri, V.M. & Simon, D. (2005). Fuzzy logic control for an autonomous robot. Fuzzy Information Processing Society, *Annual Meeting of the North American*, 337–342.

Pooya, M., Sohrab, K. & Sehraneh, G. (2013). An efficient fuzzy method for path planning a robot in complex environments. In *Proceedings of 21st Iranian Conference on Electrical Engineering (ICEE)*. Mashhad, Iran: IEEE. doi:10.1109/IranianCEE.2013.6599536

Pothal, J.K., Parhi. (2015). Navigation of multiple robots in a highly clutter terrains using adaptive neuro-fuzzy inference system. *Robotics and Automation*, 72, 48-58

Pradhan, S.K, Parhi, D.R. & Panda, A.K. . (2006). Neuro-fuzzy technique for navigation of multiple mobile robots. *Fuzzy Optim. Dec. Mak.*, 5, 255–288.

Pradhan, S.K. , Parhi, D.R., Panda, A.K. & Behera, R.K. . (2006). Potential field method to navigate several mobile robots. *Appl. Intell.*, 321–333.

Prases, K.M. & Dayal, R. P. (2016). Optimal path planning for a mobile robot using cuckoo search algorithm. *Journal of Experimental & Theoretical Artificial Intelligence*, 28(1-2), 35-52.

Priyadarshi, B. & Marina, L.G. (2008). Roadmap-based path planning using the Voronoi diagram for a clearance-based shortest path. *IEEE Robotics and Automation Magazine*, 58-66.

Qi-Lei, X.U, Man-Man, C. & Lei-Hong Z.. (2017). The robot path planning based on ant colony and particle swarm fusion algorithm. In *Proceedings of Chinese Automation Congress (CAC)*, 411-415. doi:10.1109/CAC.2017.8242802

Qin, Y.Q, Sun, D,B., Li, N. & Cen, Y.G. (2004). Path planning for mobile robot using the particle swarm optimization with mutation operator. International Conference on Machine learning and Cybernetics, Shanghai,, Conference on Machine learning and Cybernetics, Shanghai,.

Qing-Quan, W., Ying-Jun L., & Xiang-Qiang. Liu. (2017). Real-Time globally optimized path planning in a dynamic environment combing artificial potential field and fuzzy neural network. In *Proceedings of 13th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAMTIP)* 114-118. Chengdu, China: IEEE. doi: 10.1109/ICCWAMTIP.2016.8079817

Raghavendra, V.C. &, Panagiotis T. (2012). Multi-resolution motion planning for autonomous agents via wavelet-based cell decompositions. *IEEE Transactions on Systems, Man. and Cybernetics:Part B (Cybernetics)*, 1455-1469.

Raghavendra,V.C. & Panagiotis, T. (2008). Multiresolution path planning with wavelets: a local replanning approach. In *Proceedings of American Control Conference* 1220-1225. Washington: Seattle.

Raghavendra,V.C. & Panagiotis, T. (2012). Hierarchical motion planning with dynamical feasibility guarentees for mobile robotic Vehicles. *IEEE Transactions on Robotics*, 28(2)

Raja, P. & Pugazhenthi, S. (2012). Optimal path planning of mobile robots: A review. *International journal of physical sciences*, 7(9), 1314-1320. doi: 10.5897/IJPS11.1745

Rajat, K.P. & Choudhury, B.B. (2015). An Effective Path Planning of Mobile Robot Using Genetic Algorithm. In *Proceedings of IEEE International Conference on Computational Intelligence & Communication Technology* 287-291. Ghaziabad, India: IEEE. doi:10.1109/CICT.2015.145

Ramalingam, G, Thomas, R. (1996). An Incremental Algorithm for a Generalization of the Shortest-Path Problem. *Journal of Algorithms*, 21(2):267-305

Razif, R., Perumal, N., Elamvazuthi, I. & Momen, K.T. (2016). Mobile Robot Path Planning Using Ant Colony Optimization. In P*roceedings of 2nd IEEE International Symposium on Robotics and Manufacturing Automation (ROMA)* 1-6. Ipoh, Malaysia: IEEE. doi:10.1109/ROMA.2016.7847836

Rekha, R. & Ashish, D. (2017). Path Planning in Dynamic Environment for a Rover using A* and Potential Field Method. 578-582. Hong Kong, China: IEEE.

Roland, S. & IllahR, N. (2004). Introduction to autonomous mobile robots. London, England: *The MIT Press* Cambridge, Massachusetts London.

Rosell, J. & Iniguez, P. (2005). Path planning using harmonic functions and probabilistic cell decomposition. In P*roceedings of International Conference on Robotics and Automation ICRA*, Barcelona, Spain, 1803–1808.

Rui, A. (2006). Prune-able fuzzy ART neural architecture for robot map learning and navigation in dynamic environments. *IEEE Trans. Neural Network*, 17(5), 1235–1249.

Saffari, M. H. & Mahjoob, M.J. (2009). Bee colony algorithm for real-time optimal path planning of mobile robots. In *Proceedings of Fifth International Conference on Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control*. Famagusta, Cyprus: IEEE.

Sagban, M.A. & Dhaouadi, R. (2012). Neural-based navigation of a differential-drive mobile robot. *Control Automation Robotics and Vision*, ICARCV, 353–358.

Santiago, G., Luis,M., Dolores, B. & Piotr, J. (2011). Path Planning for Mobile Robot Navigation using Voronoi Diagram and Fast Marching. *International Journal of Robotics and Automation (IJRA)*, 2(1), 42-64.

Sedighizadeh, D. & Ellips M. (2007). Classic and heuristic approaches in robot motion planning-a chronological review. *International Journal of Mechanical and Mechatronics Engineering*, 1(5), 228-233.

Sfei, J., Saad, M., & Hassane, H.S. . (2011). An improved artificial potential field approach to real-time mobile robot path planning in an unknown environment. In *Proceedings of IEEE International Symposium on Robotic and Sensors Environments*, Montreal, QC, 208-213.

Sharma, K.D., Chatterjee, A. & Rakshit, A. (2012). A PSO–Lyapunov hybrid stable adaptive fuzzy tracking control approach for vision-based robot navigation. *IEEE Trans. Instrum. Meas.*, 61, 1908–1914.

Shen Z, Cheng X, Zhou S, Tang XM, Wang H. (2017). A dynamic airspace planning framework with ads-b tracks for manned and unmanned aircraft at lowaltitude sharing airspace. In *Proceedings of Digital Avionics Systems Conference (DASC)*

Shkolnik, A. & Tedrake, R. (2009). Path planning in 1000+ dimensions using a task-space Voronoi bias. In *Proceedings of IEEE International Conference on Robotics and Automation*. Kobe, Japan: IEEE.

Shou-Tao, L. & Yuan-Chun, L. (2004). Neuro/fuzzy behavior-based control of a mobile robot in unknown environments. *Proceedings of the Third International Conference on Machine Learning and Cybernetics*. 86-811. Shanghai: IEEE. doi: DOI: 10.1109/ICMLC.2004.1382296

Singh, M.K & Dayal RP. (2009). Intelligent neuron controller for navigation of mobile robot. ICAC3 '09 *Proceedings of the International Conference on Advances in Computing, Communication and Control* 123–128. Mumbai, India: Proceeding. doi:10.1145/1523103.1523129

Singh, M.K. & Parhi, D.R. (2011). Path optimisation of a mobile robot using an artificial neural network controller. *International Journal of Systems Science*, 42(1), 107–120. doi:https://doi.org/10.1080/00207720903470155

Singh, N. H., & Thongam, K. (2019). Neural network-based approaches for mobile robot navigation in static andmoving obstacles environments. *Intelligent Service Robotics, 12*(1), 55–67

Song, P.-C., Pan, J.-S., & Chu, S.-C. (2020). A parallel compact cuckoo search algorithm for three-dimensional path planning. *Applied Soft Computing Journal*, 94.

Sonmez, E. Kocyigit, E. Kugu. E. (2015). Optimal path planning for uavs using genetic algorithm. In Unmanned Aircraft Systems (ICUAS), 2015 International Conference.

Sreenatha, G.A, Sobers L.X.F. & Matthew, G. (2015). Path-Planning Modules for Autonomous Vehicles: Current Status and Challenges. In *Proceedings of Advanced Mechatronics, Intelligent Manufacture, and Industrial Automation 2015 (ICAMIMIA 2015)* 205-214. Indonesia: IEEE.

Stentz, A. T. (1994). The D* Algorithm for Real-Time Planning of Optimal Traverses. *Robotics Institute*, Pittsburgh, PA, Tech. Rep.

Stentz, D. & Ferguson, A. (2005). Field D*: An Interpolation-Based Path Planner and Replanner. *The International Symposium on Robotics Research (ISRR)*. 1926–1931. Springer Tracts in Advanced Robotics book series(STAR).

Sun C. , He, W., Hong J. J. (2018). Neural network control of a flexible robotic manipulator using the lumped spring-mass model. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 47, 1863-1874.

Sun C. , He, W, W. Ge, Chang, C. (2017). Adaptive neural network control of biped robots. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 47, 315-326.

Sun, X. ,Yeoh, W. & Koenig, S. (2009). Dynamic fringe-saving A*. In *Proceedings of 8th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2009)*. 2, pp. 891–898. Budapest, Hungary: Richland, SC:

Sutantyo, D. & Levi P. (2015). Decentralized underwater multi robot communication using bio-inspired approaches. *Artificial Life Robot*, 152-158.

Tadeu, AC., Tito, L. M. Santos, A.G. S. & Conceic¸A. (2016). A New Approach Based in Potential Fields with Obstacles Avoidance for Mobile Robots. In *Proceedings of 2016 XIII Latin American Robotics Symposium and IV Brazilian Robotics Symposium (LARS/SBR)* 229-233. Recife, Brazil: IEEE. doi: 10.1109/LARS-SBR.2016.45

Tan, F. Yang,J. Huang, J. , Jia, T., Chen, W. & Wang, J. (2010). A navigation system for family indoor monitor mobile robot. In *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS*, Taipei, Taiwan, 5978–5983.

Tanaka,Y., Ji,Y., Yamashita, A. & Asama,H. (2015). Fuzzy based traversability analysis for a mobile robot on rough terrain. In *Proceedings of IEEE International Conference on Robotics and Automation,* ICRA, Washington, USA,, 3965–3970.

Tang, S.H., Danial, N. & Babak, K. (2012). Application of Fuzzy Logic in Mobile Robot Navigation. In *Fuzzy Logic-Controls, Concepts, Theories and Applications,*. doi:10.5772/36358

Tang, S.H, Khaksar, W, Ismail, N.B, Ariffin, M.K.A. (2012). A Review on Robot Motion Planning Approaches. *Pertanika Journal of Science and Technology*, 20, 15-29.

Thi, T.M., Cosmin, C., Duc, T.T. & Robin, K. (2016). Heuristic approaches in robot path planning: A survey. *Robotics and Autonomous Systems*, 86, 13-28. doi:https://doi.org/10.1016/j.robot.2016.08.001

Thongam,K., Jie, H. & Somen, D. (2012). Path planning of mobile robot with neuro-fuzzy technique. In *Proceedings of 12th International Conference on Intelligent Systems Design and Applications*, 149-154. Kochi, India: IEEE. doi: 10.1109/ISDA.2012.6416528

Ugur, C., Mustafa, O. & Ozgur K.S. (2016). Multi Colony Ant Optimization for UAV Path Planning with Obstacle Avoidance. 2016 In *Proceedings of International Conference on Unmanned Aircraft Systems (ICUAS)* 47-52. Arlington, VA USA:

IEEE.

Valbuena, L. & Tanner, H.G. (2012). Hybrid potential field based control of differential drive mobile robots. *Journal of Intelligent Robot. System*, 68, 307–322.

Velappa, G., Soh, C.Y. & Tee W.C. (2011). Enhanced D* Lite Algorithm for Autonomous Mobile Robot. I*nternational Journal of Applied Science & Technology*, 1(1), 58-73.

Verscheure, L, Peyrodie L, Makni N, Betrouni N, Maouche S, Vermandel M. (2010). Dijkstra's algorithm applied to 3D skeletonization of the brain vascular tree: evaluation and application to symbolic. In *Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC '10)*, Buenos Aires, Argentina.

Vincent, R. Tarbouchi, M, Labonté, G. (2018). Fast genetic algorithm path planner for fixed-wing military UAV using GPU, *IEEE Trans Aerosp Electron Syst*.

Walker, K. and Esterline, A. C. (2000). Fuzzy motion planning using the Takagi-Sugeno method. Proc. *IEEE Southeas*, 56 – 59.

Wan M, Liang Z, Ke Q, Hong L, Bitter I, Kaufman A. (2002). Automatic centerline extraction for virtual colonoscopy. *IEEE Transactions on Medical Imaging*, 21(12):1450–1460

Wang, D., Chen, S., Zhang, Y., & Liu, L. (2021). Path planning of mobile robot in dynamic environment: fuzzy artificial potential field and extensible neural network. *Artificial Life and Robotics*, *26*(1), 129–139.

Wang, G., Guo, L., Duan, H., Wang, H., Liu, L. & Shao, M. (2012). A hybrid metaheuristic DE/CS algorithm for UCAV three-dimension path planning. *Science World Journal*, 1-12.

Wang, J., Zhong, T., & Zhou, H. (2019). Fuzzy neural network model construction based on shortest path. *Cluster Computing, 22*, 3413–3418.

Wang, W., Tao, Q., Cao, Y., Wang, X., & Xu, Z. (2020). Robot Time-Optimal Trajectory Planning Based on Improved Cuckoo Search Algorithm. *IEEE Access*, *8*, 86923-86933.

Wang, X. Shi, Y. Ding, D. Gu X. (2016). Double global optimum genetic algorithmparticle swarm optimization-based welding robot path planning. *Eng Optim*, 48, 299-316.

Wang, Y., Chen, P. & Jin, Y. (2009). Trajectory planning for an unmanned ground vehicle group using augmented particle swarm optimization in a dynamic environment. In *Proceedings of IEEE International Conference on Systems, Man, and Cybernetics*, San Antonio, TX, USA, 4341–4346.

Wen N, Zhao L, Su X, Ma P. (2015). Uav online path planning algorithm in a low altitude dangerous environment. *J. Autom. Sin*, 2: 173–185

Widodo, B., Achmad, J. & Djoko, P. (2010). Indoor Navigation using Adaptive Neuro Fuzzy Controller for Servant Robot. In *Proceedings of Second International Conference on Computer Engineering and Applications* 582-586. Bali Island, Indonesia: IEEE. doi: 10.1109/ICCEA.2010.119

Xiao-dan, L, Liang-yu, L., Ji-gang, W. & Han-ning, C. (2013). Mobile robot path planning based on adaptive bacterial foraging algorithm. *Journal of Central South University*, 20(12), 3391–3400.

Xiaoxun, S. & Sven, K. (2007). The Fringe-Saving A* Search Algorithm — A Feasibility Study. In *Proceedings of the 20th international joint conference on Artifical intelligence, (IJCAI'07)* 2391–2397. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc.

Xiaoxun, S, Sven, K. & William, Y. (2008). Generalized Adaptive A*. In *Proceedings of The International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2008)*. 1, 469–476. Estoril, Portugal: Padgham, Parkes, Müller and Parsons (eds.).

Xiaoxun, S, William, Y. & Sven, K. (2010). Generalized Fringe-Retrieving A*: faster moving target search on state lattices. In *Proceedings of 9th International Conference on Autonomous Agents and Multiagent Systems*. 1-3. 1081–1088. Toronto, Canada: IFAMAAS.

Xiaoyuan, L., Jiange, W. & Xiaolei, L. (2017). Joint Grid Network and Improved Particle Swarm Optimization for Path Planning of Mobile Robot. *Proceedings of the 36th Chinese Control Conference*, 8304-8309. Dalian, China.

Xin, C. & Yangmin, Y. (2006). Smooth path planning of a mobile robot using stochastic particle swarm optimization. *IEEE Mechatronics Autom*., 1722–1727.

Xin, L., Yin, Y. & Lin, C.J. (2009). A new potential field method for mobile robot path planning in the dynamic environmenT. *Asian J. Control*, 11(2), 214–225.

Xu, C, Duan, H. & Liu, F. (2011). Chaotic artificial bee colony approach to Uninhabited Combat Air Vehicle (UCAV) path planning. *Aero Science Technology*, 14(8), 534-541.

Yalong, Z., Zhenghua, L., Le, C. (2017). A new adaptive artificial potential field and rolling window method for mobile robot path planning. In *Proceedings of the 29th Chinese Control And Decision Conference (CCDC)* 7144-7148. Chongqing, China: IEEE. doi:10.1109/CCDC.2017.7978472

Yang, L., Rongxin,C., Chenguang,Y. & Demin X. (2013). Multi-robot path planning based on the developed RRT* algorithm. *Proceedings of the 32nd Chinese Control Conference* 7049-7053. Xi'an, China: IEEE.

Yang, X.S. & Deb, S. (2009). Cuckoo Search via Lévy flights. In *Proceedings of World Congress on Nature & Biologically Inspired Computing (NaBIC)* 210-214. Coimbatore, India: IEEE.

Yang, I. (2008). Nature-inspired Metaheuristic Algorithms. New York: *Luniver press*.

Yang, S.X. & Meng, M. (2000). An efficient neural network approach to dynamic robot motion planning. *Neural Network*, 138, 143–148.

Yang,S.X, Hu, Y. & Meng, M.Q.H. . (2006). Knowledge based GA for path planning of multiple mobile robots in dynamic environments. In *Proceedings of IEEE Conference on Robotics, Automation and Mechatronics*, Bangkok, Thailand, 1–6.

Yang, Q., Yoo S.J. (2018). Optimal uav path planningSensing data acquisition over iot sensor networks using multi-objective bioinspired algorithms. *IEEE Access*, 13671–13684.

Yanrong, H. & Simon, X.Y. (2004). A knowledge based genetic algorithm for path planning of a mobile robot. In *Proceedings of IEEE International Conference on Robotics and Automation, ICRA*, New Orleans, LA, USA, 4350–4355.

Yen, C.-T., & Cheng, M.-F. (2018). A study of fuzzy control with ant colony algorithm used in mobile robot for shortest path planning and obstacle avoidance. *Microsystem Technologies, 24*(1), 125–135.

Yershova, A. Jaillet, L. Simeon, T. & LaValle, S. M. (2005). Dynamic-Domain RRTs: Efficient Exploration by Controlling the Sampling Domain. In *Proceedings of IEEE International Conference on Robotics and Automation*. 3856-3861. Barcelona, Spain, Spain: IEEE.

Yijing, Z., Zheng, Z. & Yang, L. (2018). Survey on Computational-Intelligence-Based UAV Path Planning. *Knowledge-Based Systems*, 158, 54-64. doi:10.1016/j.knosys.2018.05.033

Yit, K.K., P. Rajendran, Rainis, R., Ibrahim, W. M. (2015). Investigation on selection schemes and population sizes for genetic algorithm in unmanned aerial vehicle path planning. In *International Symposium on Technology Management and Emerging Technologies (ISTMET)*.

Yong,G., Meiyun,D., Chengshui, N., Qinglian, M. & Yu-an, Z. (2017). Path planning of mobile robot based on genetic algorithm with predictive operator and dynamic parameters. In *Proceedings of the 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD)* 761-767. Guilin, China: IEEE. doi:10.1109/FSKD.2017.8393369

Yun, S.C., Parasuraman, S. & Ganapathy, V. (2011). Dynamic path planning algorithm in mobile robot navigation. *IEEE Symposium on Industrial Electronics and Applications*, Langkawi, Malaysia, 364–369.

Zadeh, L. (1965). Fuzzy sets*. *Information and Control*, 8(3), 338-353. doi:https://doi.org/10.1016/S0019-9958(65)90241-X

Zhang, C. Hu, H., Wang, J. (2017). An adaptive neural network approach to the tracking control of micro aerial vehicles in constrained space. *Int Journal of Syst Sci*, 48, 84-94.

Zhang, D., Xu, Y. Yao X. (2018). An improved path planning algorithm for unmanned aerial vehicle based on RRT-connect. In P*roceedings of 37th Chinese Control Conference (CCC)*,.

Zhang, H, Butzke, J., & Likhachev, M. (2012). Combining global and local planning with guarantees on completeness. In *Proceedings of IEEE International Conference on Robotics and Automation*, 4500–4506.

Zhang, Q. Yue, S., Yin, Q. & Zha, Y. (2013). Dynamic obstacle-avoiding path planning for robots based on modified potential field method. *Intell. Comput. Theor. Technol.*, 7996, 332–342.

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

Zhao, D. & Yi, J. (2006). Robot planning with artificial potential field guided ant colony optimization algorithm. *Lecture Notes in Comput. Sci*., 4222, 222–231.

Zhi, Y., Nicolas, J. & Arab, A.C. (2013). Adaptive cross sampling based probabilistic road-map for multi-robot motion planning. Intelligent Autonomous Systems 12, *Advances in Intelligent Systems and Computing*, 193, 843–851.

Zhu, A. & Yang, S.X. (2004). A fuzzy logic approach to reactive navigation of behaviorbased mobile robots. In *Proceedings of IEEE International Conference on Robotics and Automation, ICRA*, New Orleans, LA, 5045–5050.

Zhu, D., Tian, C., Sun, B., & Luo, C. (2019). Complete Coverage Path Planning of Autonomous Underwater Vehicle Based on GBNN Algorithm. *Journal of Intelligent & Robotic Systems*, *94*, 237–249.

Zhu, D.J. & Latombe, J.C. . (1991). New heuristic algorithms for efficient hierarchical path planning. I*EEE Transactions on Robotics and Automation*, 7(1).

Zhuo, G & Lei, N. (2008). An improved real 3d a∗ algorithm for difficult path finding situation. In *Proceedings of International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 927-930. Beijing, China.

Zou,A.M. , Hou, Z.G. , Fu, S.Y. & Tan, M. (2006). Neural Networks for Mobile Robot Navigation: A Survey. *Springer–Verlag*, Berlin, Heidelberg, 1218–1226.