Alinteri J. of Agr. Sci. (2021) 36(1): 412-419
e-ISSN: 2587-2249
info@alinteridergisi.com

http://dergipark.gov.tr/alinterizbd
http://www.alinteridergisi.com/
DOI:10.47059/alinteri/V36I1/AJAS21062

RESEARCH ARTICLE

Path Planning Optimization for Agricultural Spraying Robots Using Hybrid Dragonfly – Cuckoo Search Algorithm

S. Muthukumaran[1] • Manikandan Ganesan[2*] • J. Dhanasekar[3] • Ganesh Babu Loganathan[4]

[1]*Research Scholar, Department of Production Technology, MIT Campus, Anna University, India. Email: smkumaran90@gmail.com*

[2*]*Department of Electro Mechanical Engineering, Faculty of Manufacturing, Institute of Technology, Hawassa University, Hawassa, Ethiopia. Email: mani301090@hu.edu.et*

[3]*Assistant Professor, Department of Mechatronics, Bharath Institute of Higher Education and Research, Chennai, Tamil Nadu, India. E-mail: jdhanasekar81@gmail.com*

[4]*Department of Mechatronics Engineering, Tishk International University, Erbil, KRG, Iraq. E-mail: ganesh.babu@tiu.edu.iq*

ARTICLE INFO

Article History:
Received: 24.03.2021
Accepted: 25.04.2021
Available Online: 21.06.2021

Keywords:
Agricultural Routing Problem
Collision Avoidance
Dragonfly Algorithm
Cuckoo Search Algorithm
Computational Efficiency

ABSTRACT

Finding collision-free paths and optimized path coverage over an agricultural landscape has been a critical research problem among scientists and researchers over the years. Key precision farming strategies such as seeding, spraying fertilizers, and harvesting require special path planning techniques for efficient operations and will directly influence reducing the running cost of the farm. The main objective of this research work is to generate an optimized sequential route in an agricultural landscape with the nominal distance. In this proposed work, a novel Hybrid Dragonfly – Cuckoo Search algorithm is proposed and implemented to generate the sequential route for achieving spraying applications in greenhouse environments. Here the agricultural routing problem is expressed as a Travelling Salesman Problem, and the simulations are performed to find the effectiveness of the proposed algorithm. The proposed algorithm has generated better results when compared with other computational techniques such as PSO in terms of both solution quality and computational efficiency.

Please cite this paper as follows:

Muthukumaran, S., Ganesan, M., Dhanasekar, J. and Loganathan, G.B. (2021). Path Planning Optimization for Agricultural Spraying Robots Using Hybrid Dragonfly – Cuckoo Search Algorithm. *Alinteri Journal of Agriculture Sciences, 36*(1): 412-419.
doi: 10.47059/alinteri/V36I1/AJAS21062

Introduction

Agriculture has been the backbone of the economy for many countries over the years. Governments and industries have tried to impose several engineering advancements to improve the productivity of the crops and simultaneously reduce the running costs. Though several researchers have worked in agricultural robotics, very few commercial solutions exist in the market. The technological revolution has assisted in implementing modern equipment and pieces of machinery of farming lands to automate and improve production quality.

More recently, autonomous agricultural robots with specific applications are being employed in rural lands to perform tasks like sowing seeds, spraying fertilizers, inspection & weed removal, cultivation, plucking fruits, etc. Several existing agricultural robots utilize a predefined waypoint in the farming fields to perform the tasks mentioned above. But the real world needs a much more optimized way of performing tasks to save time and money.

D. Reiser et al. [1] have designed and developed a four-wheeled agricultural robot that employs a navigation system by gathering data from several wireless sensor nodes scattered across a vineyard. To ascertain the sensor node location, it exploited a predetermined direction path within vineyard sections. The signal strength is then analyzed and

* Corresponding author: mani301090@hu.edu.et

mapped to generate a new way for the autonomous vehicle using the acquired and georeferenced data. This strategy necessitated considering the vineyard's nodes to calculate the best path with the least travel time.

W. Neungmatcha et al. [2] have proposed a PSO-based routing solution to the sugarcane harvester robot. The authors have converted the sugarcane harvesting routing problem into a Travelling Salesman Problem and have tried to minimize the travelling distance and time. Mai et al. [21] have attempted to utilize the Ant Colony Optimization algorithm to solve the potato cultivation problem. Several other searching techniques such as Genetic Algorithms [19][32], Artificial Potential Fields [27], Dijkstra search [18], Dynamic window approach [24], Tabu Search [3], A* [14], RRT [11], and D* [17] algorithms are widely used to solve the point-to-point path planning problems in agricultural fields. Several pieces of research also support the use of probabilistic-based methods for solving path planning problems of farming robots [16] [17].

Numerous modifications and hybridizations have been made to the conventional algorithms to improve their efficiency [33-39]. For solving single-objective functions, traditional algorithms have worked better and generated efficient results. But in the case of multi-objective optimization, hybrid optimization algorithms have developed high-quality products [40-49]. Though hybrid algorithms developed better quality solutions, they always have suffered from higher computational complexities and higher computation time when compared with conventional algorithms.

Novelty

This research work proposes implementing a hybrid DA-CS algorithm to solve the path planning problem in agricultural robots. Here agricultural routing problem is converted into a Travelling Salesman Problem, and the proposed algorithm is used to minimize the total distance of the route to be travelled [50-58]. One key novelty of this approach is that the TSP routes are represented using directed graphs in the earlier studies. Still, in this research work, those directed graphs are replaced with actual ways generated by probabilistic roadmaps. The performance of the proposed algorithm is based on the parameters such as Distance Travelled, Computational Time, and Convergence Time [59-64]. An attempt is made to employ the Hybrid Dragonfly - Cuckoo Search algorithm for solving path planning in agricultural robots, which is also entirely novel.

Problem Explanation

Pesticide application is critical in farming to maintain crop growth, and the autonomous vehicle should reach the specified plant in the shortest possible distance. Generally, the autonomous vehicle follows the plant rows as it moves. On the other hand, other farm contexts split the row into numerous portions to locate shortcuts for the autonomous vehicle path. The use of such row separating to compensate for shortcuts can be seen in Figure 1.

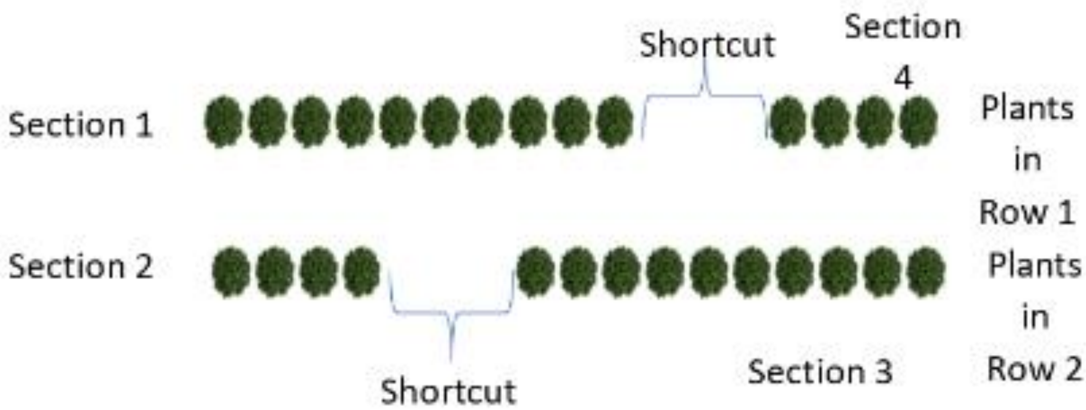

Figure 1. Sample Plants placement with shortcuts

Sections 1 and 2 were separated into two portions based on the diagram in Figure 1. The row-based travelling strategy proved ineffective in reducing the path length because alternatives and transit within rows were accessible. The optimization technique is being used to address the autonomous vehicle routing problem for sprinkling activities to reduce the agricultural autonomous vehicle path length.

The approach for solving the autonomous vehicle routing problem is depicted in Figure 2. In Figure 2, the procedure starts with the plant points being initialized, and then a stochastic map is used to design the course. Following that, the total distance travelled objective functions are determined, and the objective functions are optimized using the proposed Hybrid DA-CS algorithm.

The planter will inspect and detect the disease-affected plants to start the crop point. One typical example is that "Camellia sinensis" is a common disease in tea plantations. If left untreated, the quality of the tea leaves will highly degrade and will lead to a considerable loss. The affected region should be sprayed with a pesticide to prevent the infection from spreading in the air. As a result, an autonomous vehicle is deployed to administer the pesticide because the deadly quality of the compounds might pose a considerable hazard to the human and environment. Trajectory planning challenges for autonomous vehicles can be solved using stochastic roadmaps.

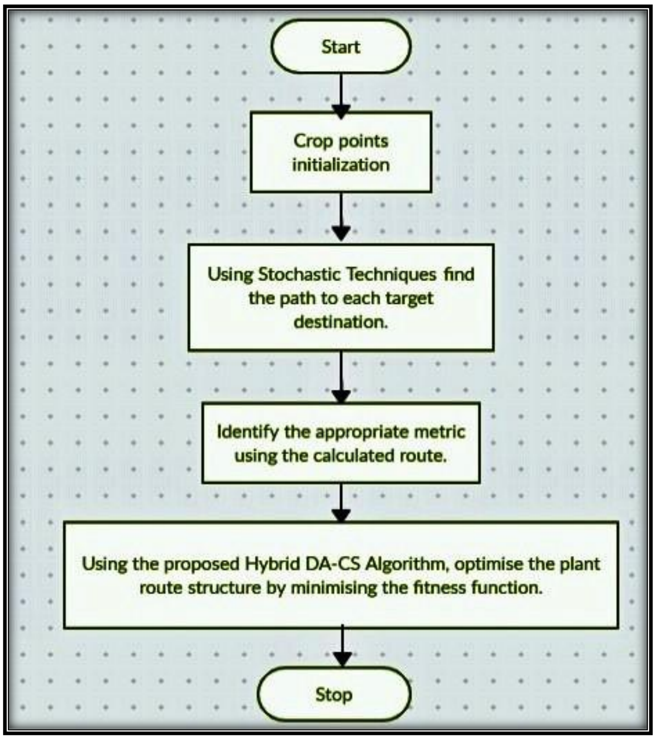

Figure 2. Process Flowchart

Environment Modelling

The simulation environment in this work was created by mimicking observations from a tea plantation. An environment was modelled and simulated in the Matlab & Simulink animation environment and is shown in Figure 3. A boolean occupancy grid was generated based on the aerial view of the model to discriminate the barriers and space across the landscape. A sample occupancy grid map is shown in Figure 4, in which the light region represents open space, and the dark area describes barriers, which includes the plants that must be handled. Then the entire boolean occupancy grid will be encoded as an (x,y) coordinate pair so that the distance between two points can be calculated using Euclidean distancing. The coordinate's numbers were sorted and labelled according to the row succession and shown in Figure. The red dot indicates the goal location (node) that the autonomous vehicle must visit. Depending on a produced trajectory from the stochastic algorithm, the distance covered between the series of nodes is determined. As a result, a stochastic roadmap is employed to design a path that avoids any barriers.

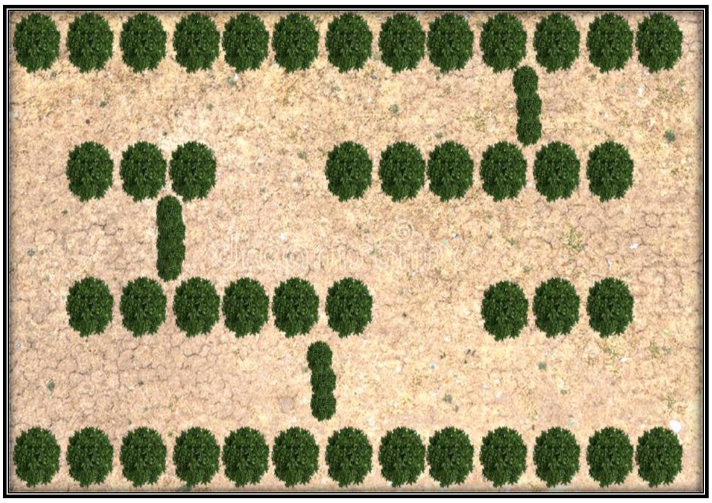

Figure 3. Sample Plantation Environment

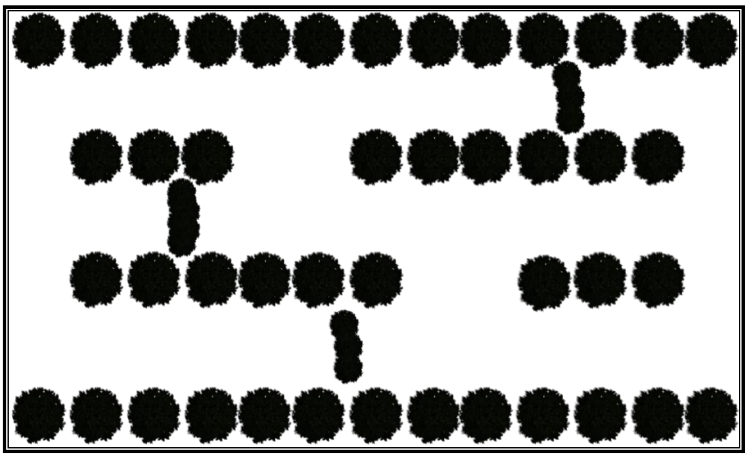

Figure 4. Boolean Occupancy Grid Map

A compilation of nodes and edges make up the binary occupancy grid map. The plant target location should be included in the sprinkling procedure, as indicated by the node in the maps. The paths generated using stochastic roadmaps across each destination are represented by the edges of a binary occupancy grid. For the optimization process, just one test fitness function, namely total distance travelled, was addressed in this research work and expressed as,

$$f(x) = \min\{\sum_{i,j \in A_{ij}} d_{ij}\} \quad (1)$$

The limitation is phrased as following for the sake of this experiment:

$$x(1) = x(end) = 1 \quad (2)$$

The limitation is trailing beginning from node one and returning to node one after the task is completed. The end expression denotes the path's last sequence in the created route.

Proposed Algorithm

Dragonfly Algorithm

The Dragonfly Algorithm (DA) is based on dragonflies' static and dynamic swarming movements, which symbolize the exploratory and exploitative stages of metaheuristic optimization. Five elementary characteristics of insect swarming, such as separation, alignment, cohesiveness, attraction to the food supply, and a distraction from adversaries, were used to imitate dragonfly characteristics. These five critical variables significantly impact dragonfly behaviour, and their associated equations are listed below.

$$S_{(i)} = -\sum_{j=1}^{N} Y - Y_{(j)} \quad (3)$$

$$A_{(i)} = \frac{\sum_{j=1}^{N} Y_{(j)}}{N} \quad (4)$$

$$C_{(i)} = \frac{\sum_{j=1}^{N} Y_{(j)}}{N} - Y \quad (5)$$

$$F_i = Y^+ - Y \quad (6)$$

$$E_i = Y^- + Y \quad (7)$$

The exploratory and exploitative stages of the optimization are determined by s, a,c,f,e. Reduced cohesion and significant alignment factors are utilized during the exploring stage. During the exploitative stage, large cohesiveness and reduced alignment factors are also used. Levy flights are used to enhance stochastic behaviour in the exploration phase. These two vectors' primary formulae are listed here.

$$\Delta Y_{(t+1)} = \left(s * S_{(i)} + a * A_{(i)} + c * C_{(i)} + f * F_{(i)} + e * E_{(i)}\right) + w * \Delta Y_{(t)} \quad (8)$$

$$Y_{(t+1)} = Y_{(t)} + \Delta Y_{(t+1)} \quad (9)$$

The process begins by generating a random population of individuals. Dragonfly placements and step vectors are determined at random. The method repeats the following stages in each iteration until the termination requirement is met. To begin, each person in the population is assessed using a fitness function. The significant coefficients are then updated. Finally, Eqs. (3)-(7) are used to update the separation (S), alignment (A), and cohesion (C), as well as the food source (F) and enemy (E) (5). Finally, Eqs. (8) and (9) are used to update the step vectors and position accordingly. Eventually, the best solution that has been discovered thus far is presented.

Cuckoo Search Algorithm

The Cuckoo Search (CS) algorithm was motivated by some cuckoo species' reproductive habits of releasing their eggs in the nests of other species. If the host bird realizes that the eggs in their nests do not pertain to them, the foreign eggs are either removed from the perch or discarded. The survivability and production of cuckoo breeds are greatly improved as a result of this. The following are the rules for CS algorithms:

- Every cuckoo only deposits one egg at a time in a nest that is picked arbitrarily.
- The high-quality egg nests will be passed on to the upcoming generation.
- With a certain degree of chance, a host bird will find an alien egg. The host bird will either throw the egg or quit the nest in such instances.

The following equation is used to produce a new solution $X^{(t+1)}$, for a cuckoo *I*, by a levy flight:

$$X_i^{t+1} = X_i^t + \propto \oplus\, levy\,(\lambda) \quad (10)$$

where $\propto$ is the step size and $\oplus$ is the entry-wise product operator.

Hybrid Dragonfly - Cuckoo Search Algorithm

A new hybrid algorithm is suggested by merging the Dragonfly algorithm's unique traits with the cuckoo search method. Because it uses the Levy flight to augment the stochastic behaviour in the searching process, DA is good at exploration. DA, on the other hand, takes far too long to find the best option. CS, on the other hand, has a high level of global convergence capability. By combining the excellent exploration of DA with the good convergence capabilities of CS, the hybrid DA-CS algorithm was suggested to solve these challenges.

The Dragonfly-Cuckoo Algorithm (DA-CS) integrates the recursive swarming actions of Dragonflies with the CS algorithm's worst nest replacement technique. Three idealized Cuckoo Search algorithm criteria are defined, and the last criterion of eliminating the most flawed candidates is then applied to the Dragonfly method. The DA-CS algorithm follows the steps below to get the best answer.

1. To begin, the algorithm generates a random beginning population.
2. The step and location vectors for dragonflies are generated at random.
3. The algorithm repeats the four actions in each iteration until the end requirement is met.
    - An objective function is used to assess each element in the population.
    - Find the local best, global best, and worst-performing dragonflies and rank them.
    - Update your food supply and enemy information.
    - The significant coefficients like w, s, a, c, f, and e are updated.

- Compute the separation (S), alignment (A), and cohesion (C), as well as the food source (F) and enemy (E).
- Updating the radius of neighbours.

1. If the dragonfly has at minimum one in adjoining radius, use equations to adjust step and position vectors; otherwise, use Levy flights to change step and position vectors.
2. Depending on the variable bounds, double-check and correct the new placements.
3. A fraction pa of the worst-performing particle is picked after each iteration in terms of the fitness function. The chosen particles should be discarded, and new ones created randomly inside the search space should be used in their stead.
4. Last but not least, the best answer identified thus far is returned.
5. Repeat steps 1–8 until all of the termination conditions have been met.

Results and Discussion

A performance comparison between the proposed Hybrid DA-CS and the PSO was undertaken based on convergence time, computational time, and solution quality. Several iterations between multiple nodes are simulated to identify the shortest path were made, and found that the proposed Hybrid DA-CS algorithm performs better in all parameters.

Table 1. Simulation Results

Sl. No	Traversing Nodes (N)	Algorithm Name	Path Length (m)	The iteration at Convergence (no's)	Obstacle Avoidance	Target Reached
1.	N12 – N4	Hybrid DA-CS	39.12	35	Yes	Yes
2.	N12 – N4	PSO	42.44	43	Yes	Yes
3.	N15 – N2	Hybrid DA-CS	36.34	30	Yes	Yes
4.	N15 – N2	PSO	38.25	37	Yes	Yes
5.	N11 – N5	Hybrid DA-CS	33.64	30	Yes	Yes
6.	N11 – N5	PSO	35.28	33	Yes	Yes
7.	N9 – N8	Hybrid DA-CS	30.87	29	Yes	Yes
8.	N9 – N8	PSO	32.54	31	Yes	Yes
9.	N9 – N13	Hybrid DA-CS	42.14	42	Yes	Yes
10.	N9 – N13	PSO	45.69	48	Yes	Yes
11.	N14 – N5	Hybrid DA-CS	50.49	51	Yes	Yes
12.	N14 – N5	PSO	52.76	57	Yes	Yes

With a total distance of 38.26 m, the Proposed Hybrid DA-CS algorithm with a reinforced memory for exploitation produced a more excellent optimal solution than the conventional PSO, which had a total distance of 41.22 m, as shown in Fig. 5. In the perspective of convergence time depending on iterations, the Proposed Hybrid DA-CS converged faster at the 32^{nd} iteration, while the PSO converged at the 44th iteration. According to numerical simulations, using the Proposed Hybrid DA-CS method to determine an agricultural autonomous vehicle navigation issue takes 16 seconds longer than using the PSO. But considering the vital objective as accuracy, the difference in time can be considered negligible. Here the improvement in the path length from the proposed hybrid DA-CS algorithm is due to the excellent exploration feature of the Dragonfly algorithm along with the exploitation features of the cuckoo search algorithm.

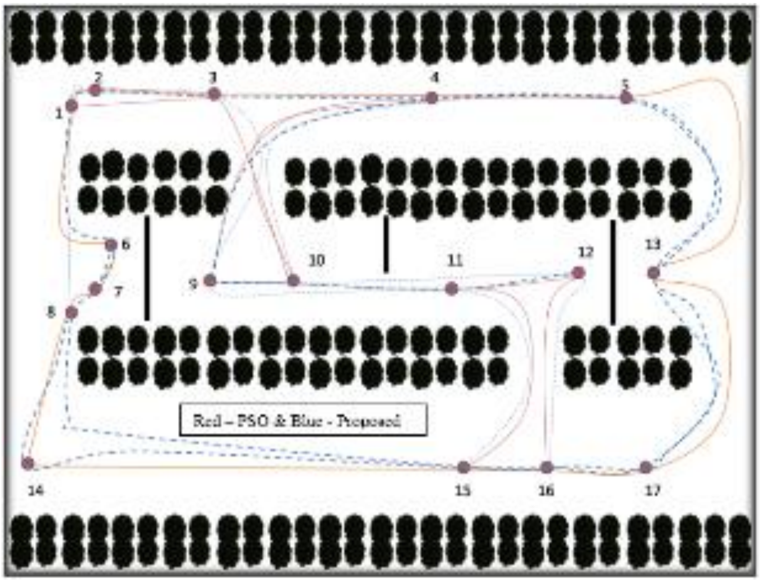

Figure 5. Paths generated by PSO & Proposed algorithm in a Boolean Occupancy Grid Map

Conclusion & Future Work

The efficiency of the proposed Hybrid DA-CS algorithm was implemented in this article to tackle a single-objective agricultural mobile robot routing issue. The travelling salesman problem, which is extensively utilized in combinatorial optimization, was used to create the navigation issue. Convergence time, solution quality, and computing time were all factors in the evaluation. When the Hybrid DA-CS was used to solve the agricultural mobile robot routing problem, it performed better and discovered the best solution for distance travelled and computing time.

In this work, only one mobile robot with a single objective function was taken into consideration. In the near future, the result may be extended to multiple robots with multiple objective functions.

References

D. Reiser, D.S. Paraforos, M.T. Khan, H.W. Griepentrog, M. Vazquez-Arellano, "Autonomous field navigation, data acquisition and node location in wireless sensor networks," *Precision Agriculture,* 18(3), 279-292, 2017.

K. Sethanan and W. Neungmatcha, "Multi-objective particle swarm optimization for mechanical harvester route planning of sugarcane operation," *European Journal of Operational Research,* 252, 969-984, 2016.

O. Pedro, R. Saldanha, R. Camargo, "A tabu search approach for the prize collecting travelling salesman problem," *Electronic Notes in Discrete Mathematics, 41,* 261-268, 2013.

E.L. Kavraki, P. Svetska, J.C. latombem H.M. Overmars, "Probabilistic roadmap for path planning in high dimensional configuration spaces," *IEEE Transaction on Robotics and Automation,* 12(4), 566-579, 1996.

J. Kennedy, R.C. Eberhart, "Particle swarm optimization," presented at the *IEEE International Conference on Neural Networks,* Perth, Western Australia, 27 November- 1 December, 1995.

Mohd Saiful Azimi Mahmud, Mohamad Shukri Zainal Abidin, Zaharuddin Mohamed, "Solving an Agricultural Robot Routing Problem with Binary Particle Swarm Optimization and a Genetic Algorithm", *International Journal of Mechanical Engineering and Robotics Research* Vol. 7, No. 5, September 2018

W. Pang, K. Wang, C. Zhou, L. Dong, "Fuzzy discrete particle swarm optimization for solving particle swarm optimization problem," *The Fourth International Conference on Computer and Information Technology,* Wuhan, China, 16- 18 September, 2004.

L. Davis, "Applying adaptive algorithms to epistatic domains," presented at the *International Joint Conference on Artificial Intelligence, Los Angeles,* CA, 18-23 August, 1985.

M. Leshcheva and A. Ivolga, "*Human resources for agricultural organizations of agro-industrial region, areas for improvement." J. Subic, B. Kuzman, and A.J. Vasile, Eds. Belgrade,* Serbia: Institute of Agricultural Economics, 2018, pp. 386–400.

A. McBratney, B. Whelan, T. Ancev, and J. Bouma, "Future directions of precision agriculture," *Precision agriculture,* 6(1), 7–23, 2005.

F.N. Dos Santos, H. Sobreira, D. Campos, R. Morais, A.P. Moreira, and O. Contente, "Towards a reliable robot for steep slope vineyards monitoring," *Journal of Intelligent & Robotic Systems,* 83(3-4), 429–444, 2016.

G. Liu and R. Palmer, "Efficient field courses around an obstacle," *Journal of Agricultural Engineering Research,* vol. 44, pp. 87–95, 1989.

M. Pivtoraiko, R. A. Knepper, and A. Kelly, "Differentially constrained mobile robot motion planning in state lattices," *Journal of Field Robotics,* Vol. 26, no. 3, pp. 308–333, 2009.

T. Goto, T. Kosaka, and H. Noborio, "On the heuristics of a* or a algorithm in its and robot path-planning," in *Proceedings 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003)* (Cat. No. 03CH37453), Vol. 2. IEEE, 2003, 1159–1166.

Y. Zhang, D. wei Gong, and J. hua Zhang, "Robot path planning in uncertain environment using multi-objective particle swarm optimization," *Neurocomputing,* 103, 172 – 185, 2013.

http://www.sciencedirect.com/science/article/pii/S0925231212007722

E. Galceran and M. Carreras, "A survey on coverage path planning for robotics," *Robotics and Autonomous systems,* 61, 12, 1258– 1276, 2013.

H. Choset, "Coverage for robotics–a survey of recent results," *Annals of mathematics and artificial intelligence,* Vol. 31, no. 1-4, pp. 113–126, 200.

E.U. Acar, H. Choset, Y. Zhang, and M. Schervish, "Path planning for robotic demining: Robust sensor-based coverage of unstructured environments and probabilistic methods," *The International journal of robotics research,* 22(7-8), 441–466, 2003.

T.R. Schafle, S. Mohamed, N. Uchiyama, and O. Sawodny, "Coverage path planning for mobile robots using genetic algorithm with energy optimization," *in 2016 International Electronics Symposium (IES). IEEE,* 2016, 99–104

L. Santos, F. Santos, J. Mendes, P. Costa, J. Lima, R. Reis, and P. Shinde, "Path planning aware of robot's center of mass for steep slope vineyards," *Robotica,* 1–15.

T. Mai, S. Shao, and Z. Yun, "The path planning of agricultural agv in potato ridge cultivation," *Annals of Advanced Agricultural Sciences,* 3(2), 2019.

M. Pichler-Scheder, R. Ritter, C. Lindinger, R. Amerstorfer, and R. Edelbauer, "Path planning for semi-autonomous agricultural vehicles," in *Reinventing Mechatronics.* Springer, 2020, 35–53.

I.A. Hameed, "Intelligent coverage path planning for agricultural robots and autonomous machines on three-dimensional terrain," *Journal of Intelligent & Robotic Systems,* 74(3-4), 965–983, 2014.

T. Blender, T. Buchner, B. Fernandez, B. Pichlmaier, and C. Schlegel, "Managing a mobile agricultural robot swarm for a seeding task," in *IECON 2016-42nd Annual Conference of the IEEE Industrial Electronics Society.* IEEE, 2017, 6879–6886.

Muthukumaran, Sivaramakrishnan, "Optimal Path Planning for An Autonomous Mobile Robot Using Dragonfly Algorithm", *International Journal of Simulation Modelling (IJSIMM)*. 2019, 18(3), 397-407.

J. Zoto, M.A. Musci, A. Khaliq, M. Chiaberge, and I. Aicardi, "Automatic path planning for unmanned ground vehicle using uav imagery," *In International Conference on Robotics in Alpe-Adria Danube Region*. Springer, 2019, 223–230.

A. Ruiz-Larrea, J.J. Roldan, M. Garz' on, J. del Cerro, and A. Barrientos, "A ugv approach to measure the ground properties of greenhouses," *in Robot 2015: Second Iberian Robotics Conference*. *Springer*, 2016, 3–13.

ASABE S495. *Uniform Terminology for Agricultural Machinery Management;* ASABE: St. Joseph, MI, USA, 2005.

S Muthukumaran, R Sivaramakrishnan, *"Optimization of Mobile Robot Navigation Using Hybrid Dragonfly-Cuckoo Search Algorithm",* Tierärztliche Praxis, 2020

Mr.Manikandan Ganesan, Mrs.Ishwarya K.R, Demoz Lisanework, Ayenachew Hailu Mengiste. (2021). Investigation on autonomous pesticide spraying robotic vehicle in agriculture field. *International Journal of Modern Agriculture, 10*(1), 382-386. http://www.modern-journals.com/index.php/ijma/article/view/585

Utamima, A., Reiners, T., Ansaripoor, A., Seyyedhasani, H. *Contemporary Approaches and Strategies for Applied Logistics.* In The Agricultural Routing Planning in Field Logistics; Wood, L.C., Ed.; IGI Global: Hershey, PA, USA, 2018; 261–283.

Mohammed, M.A.; Abd Ghani, M.K.; Hamed, R.I.; Mostafa, S.A.; Ahmad, M.S.; Ibrahim, D.A. Solving vehicle routing problem by using improved genetic algorithm for optimal solution. *J. Comput. Sci.* 2017, 21,

Kapila Uma Shankar (Dr. Uma Shankar), (2017), Prospects and Challenges in GST Implementation – An India Perspective. *Printing Area International Research Journal* 5(35), 0130 - 0137. 18.

Kapila Uma Shankar (Dr.Uma Shankar), (2017),Digital Economy in India: Challenges and Prospects. *International Journal of Research in Management Studies (a peer review open access international journal – www.ijrms.com),* 2(11), 6 -11. 19.

Kapila Uma Shankar (Dr. Uma Shankar), (2017), *International Journal of Research in Management Studies (A peer review open access international journal - www.ijrms.com),* 2(9), 20 - 28. 20.

Kapila Uma Shankar (Dr. Uma Shankar), (2016), Benefits of the Adoption of International Financial Reporting Standards (IFRS) in INDIA - A Study, *International Journal of Multidisciplinary Research Review - Peer Reviewed Journal, 1*(21), 103 -108.

Kapila Uma Shankar (Uma Shankar), B.R. Megha Raj, (2015), The Relationship Between Exchange Rate and Selected Information Technology Stocks Listed in Bombay Stock Exchange of India, *Indian journal of applied research,* 3.6241, 5(6),498 -500.

Dr.P. Govindasamy; Dr. Kapila Uma Shankar; R. Ravimohan. "Modeling of dividend payout, retention, yield, capital gains and irrelevance and its impact on value of the firm". *Journal of Contemporary Issues in Business and Government*, *27*(2), 2021, 5166-5178.

doi:10.47750/cibg.2021.27.02.528.

Ganesh Babu Loganathan, Praveen M., Jamuna Rani D., "Intelligent classification technique for breast cancer classification using digital image processing approach" *IEEE Xplore Digital Library* 2019, 1-6.

M. Viswanathan, Ganesh Babu Loganathan, and S. Srinivasan, "IKP based biometric authentication using artificial neural network", *AIP Conference Proceedings* (2020), 2271(1), 030030.

Mohammed Abdulghani Taha and Ganesh Babu Loganathan, "Hybrid algorithms for spectral noise removal in hyper spectral images" *AIP Conference Proceedings* (2020), Volume 2271, Issue 1, 030013.

Dr. Idris Hadi Salih, Ganesh Babu Loganathan, "Induction motor fault monitoring and fault classification using deep learning probablistic neural network" *Solid State Technology* (2020), *63*(6), 2196-2213.

Ganesh Babu Loganathan "Design and analysis of high gain Re Boost-Luo converter for high power DC application", *Materials Today: Proceedings* (2020), 33(1), 13-22.

Ganesh Babu Loganathan, Dr.E. Mohan, R. Siva Kumar, "Iot Based Water and Soil Quality Monitoring System", *International Journal of Mechanical Engineering and Technology (IJMET)* (2019), 10(2), 537-541.

Suganthi K, Idris Hadi Salih, Ganesh Babu Loganathan, and Sundararaman K, "A Single Switch Bipolar Triple Output Converter with Fuzzy Control", *International Journal of Advanced Science and Technology,* (2020), 29(5), (2020), 2386 – 2400.

Ganesh Babu Loganathan, "Can Based Automated Vehicle Security System", *International Journal of Mechanical Engineering and Technology (IJMET)* (2019), 10(07), 46-51.

Loganathan, Ganesh Babu, Vanet Based Secured Accident Prevention System (2019). *International Journal of Mechanical Engineering and Technology,* 10(6), 2019, 285-291. https://ssrn.com/abstract=3451201

B.K. Patle, Ganesh Babu L, Anish Pandey, D.R.K. Parhi, A. Jagadeesh, A review: On path planning strategies for navigation of mobile robot, *Defence Technology,* 15(4), 2019, 582-606.

Dr.A. Senthil Kumar, Dr. Venmathi AR, L. Ganesh Babu, Dr.G. Suresh, "Smart Agriculture Robo With Leaf Diseases Detection Using IOT". *European Journal of Molecular & Clinical Medicine,* 07(09), 2462-2469.

Ganesh Babu L 2019. Influence of benzoyl chloride treatment on the tribological characteristics of Cyperus pangorei fibers based nonasbestos brake friction composites *Mater. Res. Express* 7 015303.

A. Devaraju, P. Sivasamy, Ganesh BabuL oganathan, "Mechanical properties of polymer composites with ZnO nano-particle", *Materials Today: Proceedings* (2020), 22(Part 3), 531-534.

Ellappan Mohan, Arunachalam Rajesh, Gurram Sunitha, Reddy Madhavi Konduru, Janagaraj Avanija, Loganathan Ganesh Babu. A deep neural network learning-based speckle noise removal technique for enhancing the quality of synthetic-aperture radar images.

Concurrency and Computation-Practice & Experience, https://doi.org/10.1002/cpe.6239

Ganesh Babu Loganathan, Idris Hadi Salih, A.Karthikayen, N. Satheesh Kumar, Udayakumar Durairaj. (2021). EERP: Intelligent Cluster based Energy Enhanced Routing Protocol Design over Wireless Sensor Network Environment. *International Journal of Modern Agriculture, 10*(2), 1725 - 1736. http://www.modern-journals.com/index.php/ijma/article/view/908

Dr.A. Senthil Kumar, Dr.G. Suresh, Dr.S. Lekashri, L. Ganesh Babu, R. Manikandan. (2021). Smart Agriculture System with E – Carbage Using Iot. *International Journal of Modern Agriculture, 10*(1), 928 - 931. http://www.modern-journals.com/index.php/ijma/article/view/690

Qaysar Salih Mahdi, Idris Hadi Saleh, Ghani Hashim, Ganesh Babu Loganathan, "Evaluation of Robot Professor Technology in Teaching and Business", *Information Technology in Industry,* 09(01), 1182-1194.

Dr. Kapila Uma Shankar, Dr. Waqar Ahmad, Sallar Ashqi Kareem, "beta volatility and its consequences for hedging systematic risk with reference to stock market during covid-19", *Information Technology in Industry,* 09(03), 2021, 482 – 492.

Dr. Uma Shankar, "Debt Restructuring to Elongate Asset Quality of Banks in India", *Solid State Technology* (2020), 63(6), 14540-14549.

Dr. Kapila Uma Shankar, "Analysis on Social Banking for Sustainable Growth and Satisfaction on Social Targets", *International Journal of Advanced Science and Technology,* 29(7), 14487-14491.

P. Govindasamy, Kapila Uma Shankar, *"Covid-19 And Global Financial Markets with Special Focus to Gdp Growth Projection, Capital Mobilization and Performance of Stock Market"* XI(VII), 1-9.

Dr. Uma Shankar. (2021). Impact of Quantitative Easing on Economic Crisis During Pandemic. *International Journal of Modern Agriculture*, *10*(2), 3342 - 3350. http://www.modern-journals.com/index.php/ijma/article/view/1168

Dr. Uma Shankar. (2021). Influence of Financial Statement Comparability on Applicability of Earnings. *International Journal of Modern Agriculture*, *10*(2), 3323 - 3332. http://www.modern-journals.com/index.php/ijma/article/view/1166.

Babu Loganathan, ganesh; E. Mohan, Dr. High Quality Intelligent Database Driven Microcontroller Based Heartbeat Monitoring System. *International Journal of Engineering & Technology*, [S.l.], 7(4.6), 472-476.

G. Sharma, A. Rajesh, L Ganesh Babu, E Mohan, "Three-Dimensional Localization in Anisotropic Wireless Sensor Networks Using Fuzzy Logic System", *Adhoc & Sensor Wireless Networks,* (2019), 45(1), 29-57.

Dr. Othman, M.M., Ishwarya, K.R., Ganesan, M. and Babu Loganathan, G. (2021). A Study on Data Analysis and Electronic Application for the Growth of Smart Farming. *Alinteri Journal of Agriculture Sciences, 36*(1): 209-218. doi:10.47059/alinteri/V36I1/AJAS21031