AI reports - literature survey

| S. | TITLE | Journal /Year of Publication | Method | Dataset | Results | Citation - APA |
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| 1-3rd | Time-optimal trajectory planning for underactuated spacecraft  using a hybrid particle swarm optimization algorithm | Acta Astronautica(2014) | Yufei Z. et.al (2014) have proposed a hybrid algorithm combining swarm optimization with Legendre pseudospectral method (LPM) to solve the time-optimal trajectory for two-input underactuated spacecrafts. The time-optimal trajectory planning problem involving the Hamilton-Jacobi-Bellman (HJB) equations of higher dimension nonlinear dynamics in rigid spacecrafts has been a question of interest in the last decades.An optimized solution for this problem should have the ability to converge to a global optimum and make the requirement of suitable initial guesses. Initially, evolutionary algorithms (EAs) such as genetic algorithms (GA), differential evolution (DE) and particle swarm optimization were implemented successfully in the real world non linear optimal problems, but dude to their poor numerical accuracy and difficult constraint handling hybrid methods like PSO algorithm generating initial solutions to gradient based direct trajectory optimization along with LPM have been proposed. The primary aim is: first, PSO algorithm serves as a start engine which quickly converges to the approx region of global minimum with a randomly generated initial solution. Optimal solutions are obtained in flat output space to be mapped back to the state and control input spaces. The stimulation results show that the proposal is competitive in convergence rate, global searching capability and robustness than single PSO and classical optimization algorithms with gradient information. |  |  | Zhuang, Y., & Huang, H. (2014, February). Time-optimal trajectory planning for underactuated spacecraft using a hybrid particle swarm optimization algorithm. Acta Astronautica, 94(2), 690-698. |
| 2-18th | Trajectory planning of free-floating space robot using Particle  Swarm Optimization (PSO) | Acta Astronautica (2015) | Mingming Wang et.al(2015) throws light on free-floating space robot and their particular trajectory planning techniques to work out the dynamic coupling between the space manipulators and spacecraft in this paper. Previously proposed solutions were improvised for non-holonomic redundancy, a new method for trajectory planning issue of kinematically redundant manipulator was proposed. The joint trajectory shape is represented by the Bézier curve for its simplicity and normalization and the ability to limit the values of joint range, rate, and acceleration. PSO with adaptive inertia weight and various fitness functions are implemented to find out the optimal solution for the problem. The sequence of problem solving is: initializing the population of particles; known position of particle and swarm’s position(global); movement of particles is guided with local and global positions and updated in each generation; generation by generation repetition is performed until an optimal solution is found. In the future, Collision detection and avoidance is planned to be incorporated. |  |  | Wang, M., Luo, J., & Walter, U. (2015). Trajectory planning of free-floating space robot using Particle Swarm Optimization (PSO). Acta Astronautica, 112(2015), 77-88. |
| 3-15th | Collision-free optimal trajectory generation for a space robot using genetic  algorithm | Acta Astronautica (2021) | Asma Seddaoui et.al (2021) talks about use of robots for different services on the ISS and different spacecrafts as a means of performing most of the work and communication. This servicing and assembly missions will require space robots capable to be manoeuvring safely around the target. This imposes several challenges like collision free approach to the target and motion redundancy. Many algorithms like Artificial Potential Field (APF), the Rapidly exploring  Rapid Tree (RRT), Model Predictive Control (MPC) have been used to solve but pose challenges in redundancy. The paper proposes a new optimal collision-free and singularity-free trajectory generator for a CFSR. |  |  | Seddaoui, A., & Saaj, C. M. (2021, February). Collision-free optimal trajectory generation for a space robot using genetic algorithm. Acta Astronautica, 179, 311-321. |
| 4-9th | Optimal guidance and collision avoidance for docking with the rotating target spacecraft | Advances in Space Research (2019) | Zheyao Xu. et.al(2019) have worked on guidance and control strategy for spacecraft rendezvous and docking specially with chaser spacecraft docking with a rotating target spacecraft.They have used a flying-around approach , Optimal energy guidance method, In the prior they have given that spacecraft can arrive at the dicking position and maintain a fixed relative position and also relative attitude to rotating target.As this approach is not efficient optimal energy guidance algorithm is used in which they have used front docking region to avoid collisions with solar panels, expands front docking range and has better angle of incidence for docking. Ar is used for ACD , AD and DM. Relative velocity equations are used for evaluation to make relative motion to be 0. The analytical expression of minimum energy guidance is solved based on Pontryagin minimum principle.They plan to use the proposed technique for better docking system in spacecraft stations. |  |  | Zheyao Xu, Yukun Chen, Zhexuan Xu (2019, May). Optimal guidance and collision avoidance for docking with the rotating target spacecraft. Advances in Space Research, 63(10), 3223- 3234. |
| 5-012th | The Trajectory Planning of Spacecraft Based on Optimal Quintic Polynomial | 2013 2nd International Conference on Measurement, Information and Control  <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6758098> | Yanghua.LI et.al(2013) have proposed the idea on the implementation and application of quintic polynomial in the spacecraft trajectory planning.They have worked on to optimize the spacecrafts trajectory on basis of quintic polynomial, They have used a inertial coordinate system , centroid trajectory, attitude angle. They have also made a attitude kinetic model of spacecrafts and have also implemented use of PID controller (Proportion-integral-differential). They have devised a quantic polynomial to generate a continuous smooth trajectory, linear function of parabolic fit has been used. SIMULINK has been used to simulate the trajectories to get relative error of 0.2% between expected attitude angle and the actual angle. They think by this method they can generate a trajectory whose position , speed and acceleration are all smooth and continuous as they final result they had 60˚ wide-angle maneuver within 40 seconds with control accuracy of 0.1%. |  |  | Y. Li and B. Mo, "The trajectory planning of spacecraft based on optimal quintic polynomial," Proceedings of 2013 2nd International Conference on Measurement, Information and Control, Harbin, China, 2013, pp. 865-868 |
| 6-14th | Spacecraft trajectory optimization: A review of models, objectives, approaches and solutions | Progress in Aerospace Sciences (2018) | Abolfazl Shirazia et.al (2018) have proposed a review for solving spacecraft trajectory optimizations problems , they have divided it into 4 parts , of mathematical modeling of the problem, defining the objective functions, development of an approach and obtaining the solution of the problem.  They have classified based on their characteristics. They have reflected on the previous work done by others.They found that there are various variety of solutions to problems. Solution to trajectory optimization problem that minimizes a cost function to nonlinear differential equations of motion and various types of constraint has been used. They concluded it majorily depends on what type of mission its there to use which algorithm to use maybe genetic or particle swarm.They said viewing them as general ideas allowed a broader view of the problem and discovered similarities between structure and inner workings of methods. |  |  | Abolfazl Shirazia, Josu Ceberio, Jose A. Lozano (2018, October). Spacecraft trajectory optimization: A review of models, objectives, approaches and solutions.  Progress in Aerospace Sciences, 102, 76-98. |
| 7-1st | Fast preliminary design of low-thrust trajectories for multi-asteroid exploration | Aerospace Science and Technology (2019) | Zichen Fan.et.al ( 2019 ) have worked on Multiple-asteroid exploration with low-thrust propulsion.They have used FFS method to generate flight trajectory at very short computational time and the MCTS algorithm to determine the exploration sequence in multi-asteroid exploration.They have used Fourier approximation, the goal is to visit multiple asteroids which is time-free problem ( NLP). MCTS have also been used where Earth is the root node, and each of the rest of nodes represent an asteroid.They have evaluated to visit whole sequence selection, MCTS was terminated by controlling the number of iterations.For simulations they have used GTOC-3 and had used traversal algorithm , Greedy Algorithm , Tree search algorithm with trimming strategy, MCTS algorithm. They found that for same sequence MCTS is 79% of traversal algorithm.When they reduced number of iterations to 9, MCTS took 71%  of the computation time of the traversal algorithm to obtain the quasi-optimal solution with a probability of 88% and the suboptimal solution with a probability of 12%, and the difference between the two solutions is 9.5%. |  |  | Zichen Fan, Mingying Huo, Naiming Qi, Ye Xu, Zhiguo Song (2019, October). Fast preliminary design of low-thrust trajectories for multi-asteroid exploration. Aerospace Science and Technology , 93. |
| 8-7th | Swarm Optimized Simple Adaptive Controller for Spacecraft proximity operations trajectory tracking | IFAC PapersOnLine (2020) | Andriy Predmyrskyy et.al(2020) explores the application of differential evolution on simple adaptive control law formulation and compares it to techniques like selection particle swarm optimization(SPSO) and self adaptive differential evolution(SaDE). The final DE and SaDE optimized controller compared with the manually designed SAC was able to determine significantly lower cost controllers. DE converges on the model response very quickly, SPSO likely increased convergence by moving high cost agents closer to the lower cost agents. For SPSO, 50% of the agents were used to provide updated positions of the other 50% of agents.In the SaDE search the four trial vector generation functions described were used in strategy adaptation. In the future, work in this field may include the structure of cost functions used in conjunction with adaptive controllers, techniques to minimize the search space or determine characteristics of the cost function applied may greatly improve search speeds and results. |  |  | Andriy Predmyrskyy, Steve Ulrich (2020). *Swarm Optimized Simple Adaptive Controller for Spacecraft proximity operations trajectory tracking.* IFAC PapersOnLine 53(2) , 3785-3790. |
| 9-16th | Interplanetary Trajectory Planning with Monte Carlo Tree Search | Twenty-Fourth International Joint Conference on Artificial Intelligence (IJCAI 2015) | Daniel Hennes et.al(2022) present a heuristic-free approach based on Monte Carlo Tree Search (MCTS) for automated trajectory planning. Most interplanetary missions require a well-designed trajectory that guides the spacecraft through a number of gravity-assist maneuvers, also called fly-bys. Fly-bys are executed to steal some of the planet’s orbital energy in order to limit fuel consumption. MCTS is used for finding the correct planetary sequence and time schedule that allow for the minimization of fuel consumed. MCTS goes through four steps for the required optimization: Selection, Expansion, Simulation, and Backpropagation. The evaluation of a trajectory is based on the total change in velocity during all the maneuvers. The best sequence of approach found by this model was very close to the actual approach in the case of the Cassini-Huygens mission while the trajectory options suggested in the case of the Rosetta mission were incomplete. |  |  | Hennes, D., & Izzo, D. (2015, June). Interplanetary trajectory planning with Monte Carlo tree search. In Twenty-Fourth International Joint Conference on Artificial Intelligence. |
| 10 | Optimal Spacecraft Formation Reconfiguration with Collision Avoidance Using Particle Swarm Optimization | ISSN 1392 – 124X INFORMATION TECHNOLOGY AND CONTROL, 2012, Vol. 41, No. 2 | Haibin Huang et.al(2022) present an optimal trajectory for formation reconfiguration in deep space missions. Formation reconfiguration is undertaken to determine a set of optimal transnational trajectories allowing a spacecraft to transfer its state with the required performance index.The Legendre Pseudospectral Method (LPM) is employed to convert the optimal reconfiguration problem into a parameter optimization nonlinear programming (NLP) problem.Particle Swarm Optimization (PSO) is implemented to solve the NLP. Every particle of the swarm updates their velocity based on the personal best solution and the global best solution.Collision avoidance constraints are enforced by ensuring that the particles stay apart by a certain threshold distance. To check for collision, few test points are inserted between two Legendre-Gauss-Lobatto (LGL) points where there is a likelihood of collision. Finally, it can be inferred from the results that the PSO method could avoid most collisions during whole maneuvers. So, the trajectory found without enforcing collision constraints were near to the optimal trajectory with collision constraints. |  |  | Huang, H., Ma, G., Zhuang, Y., & Lv, Y. (2012). Optimal spacecraft formation reconfiguration with collision avoidance using particle swarm optimization. Information Technology and Control, 41(2), 143-150. |
| 11-13th | Efficient Object Manipulation Planning with Monte Carlo Tree Search | arXiv preprint arXiv:2206.09023 | Huaijiang Zhu et.al(2022) found an efficient approach to object manipulation planning using Monte Carlo Tree Search (MCTS) to find contact sequences.Interaction forces and contact switches are the main challenges faced during object manipulation planning.An ADMM based trajectory optimization algorithm is used to evaluate the feasibility of possible candidate sequences. If the contact surfaces are known, then the forces and contact locations can be found efficiently. At most one end-effector can touch a contact surface and each end-effector can utmost touch only one contact surface.Only one end-effector can break contact at each time step.The method is evaluated based on the force and torque error between the desired and generated solution and the computation time for first feasible solution. This method is capable of solving both short-horizon and long-horizon tasks. The major limitation of the approach is that the object motion must be provided. The approach assumes perfect knowledge of the object and environment which is not practically feasible. |  |  | Zhu, H., Meduri, A., & Righetti, L. (2022). Efficient object manipulation planning with monte carlo tree search. arXiv preprint arXiv:2206.09023. |
| 12 | A Tutorial on Model Predictive Control for Spacecraft Rendezvous | 2015 European Control Conference (ECC) July 15-17, 2015. Linz, Austria | Edward N. Hartley used model predictive control (MPC) to review the recent advances in spacecraft rendezvous missions. MPC is a control strategy based on on-line constrained optimisation of control inputs based on future trajectories. In a rendezvous mission, there is an active vehicle (chaser) and a passive vehicle (target). The target moves in a fixed orbit, while the chaser needs to be actively controlled to transfer it into the target’s orbit, then it is made to approach the target at a safe terminal velocity. For perfect rendezvous, collision constraints are enforced. Also, a scenario has been taken into consideration where a single thruster must be re-oriented, so over-exertion must be avoided. There are multiple state constraints which lead to infeasibility. So, either the constraints need to be softened and accept a degree of constraint violation or systematically tighten the constraints based on the bounds of disturbance. MPC works well for fixed horizon, time-invariant rendezvous missions. |  |  | Hartley, E. N. (2015, July). A tutorial on model predictive control for spacecraft rendezvous. In 2015 European control conference (ECC) (pp. 1355-1361). IEEE. |
| 13-5th | Direct-Adaptive Nonlinear MPC for Spacecraft Near Asteroids | Aerospace | Madhuri Tiwari et.al(2022) proposed a modified control system to generate and track trajectories in the vicinity of asteroids. The novel system proposed here is a combination of the benefits of adaptive and optimal control systems. Adaptive control is used as a feedback controller and an MPC is used as feed-forward controller.The asteroid shape and inertia are assumed to be unknown while the total mass and its angular velocity are known.This control mechanism is called Direct-Adaptive Model Predictive Controller (DAMPC). The adaptive control increases the robustness of DAMPC.The MPC stabilizes the system and generates sub-optimal trajectories to be fed into the adaptive control. Dynamic, thrust and ellipsoidal constraints have been enforced for obstacle avoidance and to avoid overshooting the trajectory. DAMPC was numerically tested for the case of asteroid Kleoptra, for a rest-to-rest maneuver. The controller was able to generate and track collision-free trajectories and was also adept at handling noise. |  |  | Tiwari, M., Coyle, E., & Prazenica, R. J. (2022). Direct-adaptive nonlinear MPC for spacecraft near asteroids. Aerospace, 9(3), 159. |
| 14 | Optimal Interplanetary Spacecraft Trajectories via a Pareto Genetic Algorithm | The Journal of the Astronautical Sciences, Vol. 46, No.3, July-September 1998, pp. 267-282 | John W. Hartmann et.al(1998) applied the Pareto Genetic algorithm for optimisation of low-thrust interplanetary spacecraft trajectories.Low-thrust trajectory optimisation has gained interest due to high-propellant efficiencies of the system which would allow cost-cutting. Pareto optimization is a multiobjective optimization which combines multiple objectives into a single objective by using weight vectors. Genetic algorithms used here employ selection, crossover and mutation to perform evolutionary search. Niching is also done to distribute members over large portions of search space and avoid premature convergence to a single solution. Based on the degree of proximity of the members, they are penalized at the end of each generational cycle. A solution is Pareto optimal if there exists no set of solutions that is superior to the current solution in all objectives. The Pareto Genetic algorithm is a non-dominated sorting genetic algorithm (NGSA). In each iteration, a Pareto front is assigned then the penalties are calculated. This continues till all individuals are assigned a front. The algorithm worked optimally for three simulations: Earth-Mars flyby, Earth-Mars rendezvous and Earth-Mars rendezvous on-demand. |  |  | Hartmann, J. W., Coverstone-Carroll, V. L., & Williams, S. N. (1998). Optimal interplanetary spacecraft trajectories via a Pareto genetic algorithm. The Journal of the Astronautical Sciences, 46, 267-282. |
| 15 | ENHANCED CONTINUOUS TABU SEARCH IN A HYBRID EVOLUTIONARY ALGORITHM FOR THE OPTIMIZATION OF INTERPLANETARY TRAJECTORIES | Journal of Spacecraft and Rockets | Lorenzo Casalino et.al(2009) applied a hybrid evolutionary algorithm to the optimisation of space missions with multiple impulses and gravity assists. Evolutionary algorithms (EAs) are procedures which search for the global optimal solution in the given search space for the given function. The algorithms used in the paper are Genetic algorithms (GAs), differential evolution (DE), particle swarm optimisation (PSO) and tabu search (TS). Information is shared amongst algorithms used in hybrid EAs, to improve the performance. The population of the Hybrid EA is the set of candidate solutions, and a cost/merit function determines their suitability to the environment and evolution occurs accordingly. GA chooses the best suited solution to be part of the next generation. DE generates new solutions by taking the weighted difference of existing ones. PSO modifies the solutions based on the personal and global best value.TS generates a list of promising solutions whose elements are centers of these promising regions and new solutions are added only if they don't belong to these regions. This combination of models is highly efficient and robust for optimizing spacecraft trajectories with multiple impulses and gravity assists as compared to the individual models. |  |  | Sentinella, M. R., & Casalino, L. (2009). Hybrid evolutionary algorithm for the optimization of interplanetary trajectories. Journal of Spacecraft and Rockets, 46(2), 365-372. |
| 16 | Dynamic Travel Path Optimization System Using Ant Colony Optimization | 2014 UKSim-AMSS 16th International Conference on Computer Modelling and Simulation | J.Kponyo et.al(2014) in their work establish that ant colony optimization can efficiently improve the traffic situation in any environment and hence, can also find the optimal path to be taken to reach the destination. A Dynamic Travel Path Optimization System (DTPOS) establishes a vehicular ad hoc network and uses communication amongst vehicles to relay traffic status information. DTPOS is based on ant colony optimization (swarm intelligence), where ants use pheromone to relay information about the optimum path from a food source back to their nest. Its aim is to minimize both the total mean transit time and total variance in transit time. An improvement in ACO, is the previous path replacement (PPR). PPR involves comparing the best path with any new path found and then storing the best of the two. Results of their work clearly indicate that DTPOS with PPR provides the most efficient solution followed by DTPOS without PPR, followed by just PPR, and finally no ACO. |  |  | Kponyo, J., Kung, Y., & Zhang, E. (2014, March). Dynamic travel path optimization system using ant colony optimization. In 2014 UKSim-AMSS 16th International Conference on Computer Modelling and Simulation (pp. 142-147). IEEE. |
| 17 | PERFORMANCE EVALUATION OF RENDEZVOUS USING MODEL PREDICTIVE CONTROL | AIAA Guidance, Navigation, and Control Conference and Exhibit,11-14 August 2003, Austin, Texas | Arthur Richards et.al(2003). in their work discusses about a newly developed form of Model Predictive Control (MPC). The drawback of existing MPC is that it requires the target to be an unforced equilibrium or the cost function imposes a penalty on the difference between the control inputs and the equilibrium forcing necessary required to remain at the target. In the new MPC, firstly, MILP optimization is used, which allows the inclusion of non-convex constraints. Second, assurance of robust completion in finite time, for that assumption is taken of bounded disturbance. Then, 3 different forms of MPC were compared with one another and the glideslope algorithm in two test conditions, which are intrack approach and radial approach. In the first set of simulations no disturbances were taken and in the second set of simulations constant and random disturbances were considered. In all the cases MPC performed better than the glideslope algorithm. |  |  | Richards A., & How J. (2003, August 14). PERFORMANCE EVALUATION OF RENDEZVOUS USING MODEL PREDICTIVE CONTROL. AIAA Guidance, Navigation, and Control Conference and Exhibit, 11. |
| 18 | Ascending Trajectory Optimization of Near-space Airship Based on Genetic Algorithm | In *2013 IEEE 8th Conference on Industrial Electronics and Applications (ICIEA)* (pp. 918-922). IEEE. | Xiaoguang Di et.al(2013) discuss how ascending trajectory optimization can be done in the case of near-space airships with fully considering the disturbance caused by wind. Near space is the air space from 10km to 100km above the sea level. The genetic algorithm performs better than the SQP algorithm in the case of complex non-linear programming and also the SQP algorithm is sensitive to the initial value of the problem. The whole trajectory is divided into 3 phases, the first is 0km-5km, the second is 5km-15km, and the third is 15km-22km. Using direct collocation dynamic optimization problem is then converted into a parameter optimization problem which is then can be solved using the Genetic algorithm. The advantages of the Genetic algorithm in the following case include optimal solution from the beginning of a population instead of a point, no need of high order information and use of probability search which results in the global optimal solution |  |  | Di, X., & Yang, Y. (2013, June). Ascending trajectory optimization of near-space airship based on Genetic Algorithm. In *2013 IEEE 8th Conference on Industrial Electronics and Applications (ICIEA)* (pp. 918-922). IEEE. |
| 19-23rd | Model Predictive Control of Swarms of Spacecraft Using Sequential Convex Programming | JOURNAL OF GUIDANCE, CONTROL, AND DYNAMICS Vol. 37, No. 6, November–December 2014 | Daniel Morgan et.al(2013) talks about the model predictive algorithm for the optimal guidance and configuration of swarms of spacecraft having lots of agents with limited capabilities. Sequential Convex Programming is not effective due to a high number of collision-avoidance constraints. So, Model predictive control-SCP i.e. MPC-SCP is used which decentralizes the communications required for swarm configuration with collision avoidance and also reduces the size of the problem resulting in less run time. Femtosat communication and computation are greatly reduced by decentralising the swarm guidance algorithm. The SCP algorithm is run multiple times to account for errors or uncertainties in the desired and actual trajectories when computing future trajectories which is the reason for some robustness as compared to running SCP one or two times. Later, a receding horizon was introduced and again MPC-SCP was applied, which decreased the number of variables and constraints which allowed smaller time steps in the optimizations. |  |  | Morgan D., Chung S. J., & Hadaegh, F. Y. (2013). Decentralized model predictive control of swarms of spacecraft using sequential convex programming. Advances in the Astronautical Sciences, (148), 1-20. |
| 20-6th | A self-learning Monte Carlo tree search algorithm for robot path planning | Frontiers in Neurorobotics (2023) | Wei Li. et.al (2023) have proposed a self learning Monte Carlo Tree Search( SL-MCTS) which can continuously improve its problem-solving ability in single-player scenarios.They have used a two-branch neural network (PV-Network), it outputs the selection probabilities p which is then evaluated by comparing it with optimal models.Evaluation is done using Proximal Policy Optimization algorithm , additionally they also compared other variants of algorithms such as MCTS , SP-MCTS, SP-MCTS-CRIPPA.Elo-rating is used for number of evaluations. SL-MCTS explores only 28.9% of the environment space and solves the problem in 25.48s, its simulation counts were 30 , compared to 50-150 for SP-MCTS. Results showed them SL-MCTS can find the solutions with better quality in half the time required by MCTS-50.In future they want to further explore applying self-learning collective intelligence algorithms in field of path planning problems. |  |  | Li W, Liu Y, Ma Y, Xu K, Qiu J and Gan Z (2023) A  self-learning Monte Carlo tree search algorithm  for robot path planning.  Front. Neurorobot. 17:1039644. |
| 21 | Multi-spacecraft Trajectory Optimization and Control Using Genetic Algorithm Techniques | I In *2000 IEEE Aerospace Conference. Proceedings (Cat. No. 00TH8484)* (Vol. 7, pp. 99-108). IEEE.  Isme se dekhlke jo chahiye mujhe smjh nhi aata | Robert Smith et.al(2000) in their work discusses trajectory planning for multiple spacecraft. Generally, constraints like collision avoidance and limited fuel usage make the problem nonlinear and multi-modal, which does not allow us to use gradient descent or calculus. Also, a general solution can not be found when we are dealing with N spacecraft. Genetic Algorithm techniques can be used to find autonomous spacecraft trajectories as they serve as good global optimizers. Genetic Algorithm advantages include generating a large and diverse number of solutions from which one can be selected which performs best. Constraints for trajectory optimization for N-spacecraft problem are - collision-free, shortest path, minimum time and fuel usage and uniform fuel distribution at the end of maneuver. One problem with the genetic algorithm is that as it converges towards a single type of individual, the remaining population becomes unimportant. The Niched Pareto Genetic Algorithm which is a modified version of the genetic algorithm which solves this problem by maintaining diverse and steady state population as the final result. This type of version can solve multi-objective optimization problems w.r.t. all criterias mentioned above. |  |  | Li S., Mehra R., Smith, R., & Beard, R. (2000, March). Multi-spacecraft trajectory optimization and control using genetic algorithm techniques. In 2000 IEEE Aerospace Conference. Proceedings (Cat. No. 00TH8484) (Vol. 7, pp. 99-108). IEEE. |

|  | TITLE | Journal / Year of Publication | Method | Dataset | Results | Citation - APA |
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| 22-8th | Trajectory Optimization of the Exploration of Asteroids Using Swarm Intelligent Algorithms | TSINGHUA SCIENCE AND TECHNOLOGY ISSNll1007-0214ll02/21llpp7-11 Volume 14, Number S2, December 2009 | ZHU Kaijian et.al(2009) in the paper compares the different realistic global optimization algorithms, which include genetic algorithm, particle swarm optimization, differential evolution algorithm and two hybrid algorithms. Assumptions taken are quare inverse gravity field between the planets, time of spacecraft passing through influence sphere of the planet is negligible, spacecraft is considered mass point. GA cannot get optimal solution for some benchmarks, because of presence of more than 30 parameters to be optimized resulting in the invalidation of binary coded GA. Differential Evolution is similar to EA in structure but differs in case of generating new candidate solutions and using a greedy selection algorithm.It has lots of potential in numerical benchmark problems and real-world applications. In hybrid algorithm of PSO and SA(simulated annealing) principle of SA is applied in the process of renewing the position and velocity of the individuals in the population. Another hybrid algorithm is composed of PSO and DE which takes advantage of both algorithms and delivers results which are very close to optimum. |  |  | Zhu K., Li J., & Baoyin H. (2009). Trajectory optimization of the exploration of asteroids using swarm intelligent algorithms. *Tsinghua Science & Technology*, *14*, 7-11. |
| 23-15h | Many-Objective Optimization of interplanetary Space Mission Trajectories | IEEE Congress on Evolutionary Computation (CEC) (2015)  <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7257297&tag=1> | Martin S. et.al (2015) have shed light on optimization of interplanetary space mission trajectories.They found that Ant colony Optimization (ACO) has been remarkably optimal in Ceriotti , Vasile and Schlueter.They have proposed a better approach Utopia-Nadir-Balance Decomposition, with parallelization framework ACOMOD ( Master-Slave Model) . To test their model they have used an interplanetary design problem from ESA GTOP - 8 .They got 12635 non-dominated solutions for the 4 objectives.They saw that ACOMOD had similar results with HV indicator, whereas the proposed utopia-nadir had a small advantage of about 1%. In the area of weighted sum, utopia-nadir had 3% over ACOMOD. In the second level of two parallelization utopia-nadir had 4.6% advantage over others.They hope that their work shows a new way of fully automated, deep space mission design planning which also takes in mission parameters at the same time. |  |  | M. Schlueter, C. H. Yam, T. Watanabe and A. Oyama, "Many-objective optimization of interplanetary space mission trajectories," *2015 IEEE Congress on Evolutionary Computation (CEC)*, Sendai, Japan, 2015, pp. 3256-3262, doi: 10.1109/CEC.2015.7257297. |
| 24-21st | Research and Optimization of D-Start Lite Algorithm in Track Planning | IEEE Access, 8 | KAILI XIE et.al(2020) discuss the safety and efficiency of aircraft during flight. A\* Algorithm is used in a static environment for the purpose of trajectory planning, but in the case of a dynamic environment, Dynamic A\* Algorithm that is D\* algorithm is used. Since the D\* algorithm is more complicated, Lifelong Planning A\* (LPA\*) is an extension of the A\* algorithm and its search efficiency is higher which is achieved by multiplexing environmental information. Later, fast D\* Lite was introduced with better search efficiency than LPA\*. The key highlight of fast D\* lite was that it completely or partially avoids re-planning and calculation of some nodes. The problem in D\* Lite algorithm is that the path planned by it is very close to obstacles, in real-world scenarios making it unsafe. This paper proposes the improved D\* Lite algorithm, in which nodes with obstacles around are not taken for node search calculations and to avoid increased path nodes and turning points, Euclidean distance is replaced by Chebyshev distance. |  |  | Xie K., Qiang J., & Yang, H. (2020). Research and optimization of d-start lite algorithm in track planning. IEEE Access, 8, 161920-161928. |
| 25-11th | Quantum-behaved particle swarm optimization for far-distance rapid cooperative rendezvous between two spacecraft | Advances in Space Research 62 (2018)  [paper link](https://pdf.sciencedirectassets.com/271642/1-s2.0-S0273117718X00222/1-s2.0-S027311771830615X/main.pdf?X-Amz-Security-Token=IQoJb3JpZ2luX2VjELL%2F%2F%2F%2F%2F%2F%2F%2F%2F%2FwEaCXVzLWVhc3QtMSJHMEUCIBfRsoy9JXSGBkl2ISSxGW0sqeETvBbsy9Xke%2FXyAnnmAiEAuhDetEymd%2FalohuluqS0jCij9uuYzPNeao45WdFrXUUquwUIqv%2F%2F%2F%2F%2F%2F%2F%2F%2F%2FARAFGgwwNTkwMDM1NDY4NjUiDHHnCTPW7vaVxBUeKCqPBYvvufXdZx81ZyD8vRuKmUck3k0ewUiUcy6CEws%2BbtR6PM388vWm13li2NVhkxHb6%2Fx0r%2FPVovzEZfAqPo966%2FAvmXcueOro6854yAn4z8CNozN%2FmBekZ9JE6jIUztHak3widNfMmvdS7rNquYTQ8wwPktgZrXwS0RfU%2FRHfr5aqk7oWshW5wr%2FEvX5vQelsQ1UO8ajeklZfx%2FtxguSKgEoROoeHprze6J0EHAzUzF5XQKPw3jiejj9CY5bZYJdNSrvIiZDABHtYl7%2FiWkHwhkG9RtfEMlLLUqF8iddtnfzUhkUoLv7TOpRlBdiVdfqzLRUuq19iUhL37T1Rvz3WxEl5ioILlQJhqIMOke42GUwcgdtMn4pqDfNIJovYa2Hq7Czvr%2F97U5Dxpkhp2VGf67QQUHXYjWxH55UeP9hgM2PaW6eBDKwkuogv7%2BD0zm66CdnMHi1Agf8Fiy1T7%2FhhKc0%2BiZg7sCGHxZfPnMF5%2F3KM%2FYvY69Zm7FKAzKzrq%2Fc%2FDfWewbDyX%2F6%2Bo7MSFfsCaGsdVXdjmbgr8v9uvA1oOK1Wo7pmr0EfRpZOsIPlXXhl6j7bECUX89SPXbrNPMdufujYT2Vy1O76lsiXsLRyRczGo8uOOGRwSp4R13xTkbuN3wRrHn0qkVWWPGSWAzw5UkxLrWRkriD77pZvw3lzOgE89WX%2FziWB3aHcVZoEMlyTCKC3YGBRpGqFtnraxI1SImhXC5nEWUjHMOuIzcPHWR%2FJVreMk8adcvm5rV16lJzOi5gU1GdCs6bMFpG3ETquF9jdC1FOfEpf3Ku63aSem%2FwojMwby8vrOr4%2F5FuFP0QoLMbEWiT%2BluV4fpcHlfIsYGJFvDWzsjUWHgNaY8%2Fcub0w%2BujWqAY6sQHSGZRILfkppApStNKHBk9POs%2FdXV5nBnM%2FBoa4PNmR33rv3m0%2FMnhJ1Drhx9fu2xllkaYckdz5edkE1xxFfunGLSvDdEuyjBOsct9taRn37b96oCY1QRSatQ0AU3tgRodxBtwpzjXgEgn6%2BM1X6aAEStmoShl3vjBUVqTXJLid7T8QiGEVBuW4GxjTgd9UEt9XDyJY7pujr1i10wARRW8Tdo9LLNuMGDunNpOHt2aWUiI%3D&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Date=20230928T183008Z&X-Amz-SignedHeaders=host&X-Amz-Expires=300&X-Amz-Credential=ASIAQ3PHCVTY2LLZ5EG6%2F20230928%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Signature=2d5ac9ae81f79893c579930a5cc99448632670e4fed671fae28d929c6ab133d1&hash=5a359f23098f827a7b3db541f7c592a8c7972fb720b655dbd1492c4ad1ad3aff&host=68042c943591013ac2b2430a89b270f6af2c76d8dfd086a07176afe7c76c2c61&pii=S027311771830615X&tid=spdf-0630b1dc-d376-4f06-978b-a4b1ecf0c5be&sid=aafb7c82251df147c65b1e9442882320580agxrqb&type=client&tsoh=d3d3LnNjaWVuY2VkaXJlY3QuY29t&ua=130e5857040b5e07520b&rr=80de0e4e49959367&cc=in) | Kun Y. et.al ( 2018 ) have proposed a solution to the problem of far-distance rapid cooperative rendezvous between two spacecrafts, specifically when two spacecrafts are orbiting on non-coplanar orbits and their apsidal lines are different. They found that PSO can’t be used here as it falls into local optimal and cannot converge to a global optimal solution.They concluded even if it did converge optimal fuel consumption would still be really large.The results of classical PSO are not stable to be initial values of SQP.They put light onto using QPSO as it increased convergence speed , convergence accuracy and stablity. It uses the ability to generate a rough range of optimal solution quickly and precisely, but lacks the local search of SQP. They used QPSO-SQP by taking initial value of it. The mean time of calculations came out to be 25.074 min for QPSO-SQP and 68.31 min for PSO-SQP.Overall it was found that QPSO can converge more rapidly and is hence most preferred. |  |  | Yang, K., Feng, W., Liu, G., Zhao, J., & Su, P. (2018, August 13). Quantum-behaved particle swarm optimization for far-distance rapid cooperative rendezvous between two spacecraft. Advances in Space Research, 62. |
| 26 | A global optimization method for the design of space  trajectories | Computational Optimization and Applications ( 2011 ) | Addis B. et.al(2011) have given the work for optimally designing a trajectory for space mission.GTOP database has been used on different models.They suggested that problems can be simplified using simple global optimization on standard models for local optimization. They have used Multiple Gravity Assist (MGA) , MGADSM Models for Multi- start algorithms where standard local searches are replaced by middle searches returning funnel bottoms. It was carried through Basin Hopping or Monotonic Basin hopping approach.They have used a technique called implicit-filtering algorithm(IF) using SQP code SNOPT.They incorporated Variable scaling and Periodic variables, everything was tested on ESA ACT. They tested out various space missions such as Rosetta , Cassini-Huygens,etc.Future research will be carried out to extending the range of applicability of Basin Hopping to space trajectory, and final algorithm proposed is Differential Algorithm with Basin Hopping scheme. | GTOP Database  <http://www.esa.int/gsp/ACT/inf/op/globopt.htm>).  SNOPT |  | Addis, B., Cassioli, A., Locatelli, M. et al. A global optimization method for the design of space trajectories. Comput Optim Appl 48, 635–652 (2011) |
| 27-10th | Genetic algorithms applied to the solution of hybrid  optimal control problems in astrodynamics | Journal of Global Optimization ( 2008 ) | Bradley J. Wall et.al (2008) have proposed hybrid optimal control problem solution algorithm, which works with GA’s and are employed in both inner-loop and outer-loop solvers.They used shape-based method which performed better than direct method in collocation with NLP(DCNLP) or RK parallel shooting(DTRK). 4 asteroid sequence had 12 min using shape based and 7 hrs using DTRK solver. They suggested that for low-thrust arcs its best to use GA outer-loop solver anc combining with inner -loop. B&B tree for GTOC2 problem had 910 one-asteroid sequences, 580,000 two-asteroid seq. And 230 million three-asteroid seq, and 41 billion 4-asteroid sequences.They found cause of this heavy computation they presented idea of pre-pruning such as sequences which go out to outer orbit then return back to inner orbit , they found it would eliminate 50% of 41 billion sequences of GTOC2 problem.Their final verdict was that GA+GA method for the solution of HOCP’s is better as it removes the work of pre-pruning of possible sequences. |  |  | Wall, B.J., Conway, B.A. Genetic algorithms applied to the solution of hybrid optimal control problems in astrodynamics. J Glob Optim 44, 493–508 (2009) |
| 28-4th | A new genetic algorithm for solving optimization problems | Engineering Applications of Artificial Intelligence(2014)  [paper link](https://pdf.sciencedirectassets.com/271095/1-s2.0-S0952197613X00107/1-s2.0-S0952197613001875/main.pdf?X-Amz-Security-Token=IQoJb3JpZ2luX2VjEK7%2F%2F%2F%2F%2F%2F%2F%2F%2F%2FwEaCXVzLWVhc3QtMSJGMEQCIDCTwnMol4WQJJDyHq60mZQ%2BLJ%2F8FR65pB0u5yUR9FIPAiBqwdm2ISMy%2FtAfkU4kv0JCHcOXBKVNCGLyqvwU3qOjACq8BQim%2F%2F%2F%2F%2F%2F%2F%2F%2F%2F8BEAUaDDA1OTAwMzU0Njg2NSIMQomeF4Qu4Ksq34IZKpAFUjcsRLWKuLpbrgbB5OZMPAdIf%2BIdLDnz9Tth%2FIcBnKTdrHuNJ0bPySPTAynslt1HXUFbwmLJIv%2F5lqPbNhJ0dZxExQjDNlD1NOBzTDvBA3X67RxiQOIf08GMO3RL0sSMOwnGJZtwQEGSR0Xx85D5xQqqkJG13b3jjJF8MZvbtP5dwMI%2BVBY2ixDGb6Ql4gPAXoViMYCvp2sUgG8trojSBj1wg82Y%2BikcNinf9k4nzZ6SnYGpsjFd5xKx4aJIiTkkjjTyBrq3cO0xsci3cJwBVLvORSNYI0wKV3GsjUsEp3Ad6aAUm5xcncd6wlt8%2FSL8v3l4wrJiJ3QcEllkBEBua6zHtUGMFn84V8nYiSOV2M4A1z8hruX%2F1nWmRdW81MTIVza4yfIaW8%2B8wyRvEQPqj2vDcZcjgbLpHjvP98r9fPpA4vsQfGHssthv%2BsC6jkRcSvohSKbPPcx7BHBi9oIARWYa0UgbZCjxDPssPGJelHaAQs06cKzPAbZhtwq1qab0Uz96%2FSsAvaQ3LpmXzzkPLXqcOkzAkbvhgiPTZdt8WYzw2FqOyVJK4ZAF2lRRdFbf4PMRvEasCsOTX8eceXDdTdjz6X5PoSbht5plcQETipqbk1jJPW2IeJQNFRGRSj243MGljE4wtflXWMJ9KDdsBGrdTxqqRgMxYmZt9YE%2FZ3PY4WdG8JU59bjGoceNv1lMDYyv2qn%2F%2BxGxMEJ%2BhFSZOQXL%2F6tMk0g6bZft5mOdXqmktByE4AmFrsHyQFnYQxTAiKIr25GIH9Bj%2BJv5j6CXzvooivZ5Uel74yIzvQcgor55e3uxH8aIzfruAEuYq%2FBG%2BO0CJ34rdUSlzg7pNhotJjBgg9kCDrYsAd%2FuG%2BO2bb4w5fnVqAY6sgHizfzntgmDsNGx3lcV1l2zXw36osl8dyFisLb2jSZXhbw%2BQ8wCnW9szzGPtsI4bqUmgO4TG8uZSYnccs5Bko2nhO%2B1s8ISOpqN7EUpM4lmFvIn1lkelufFDYkENR%2FVETrgXQjQB6WGEh2WFBmmHUp3%2BNcsnngzZBQ3%2FUlY224afulpEr252d%2FWlIuITgrmeTjPCtYUM2upcBk1mmx0BC00JUQZgs78vIQXaUsSl0Fm9tWR&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Date=20230928T140514Z&X-Amz-SignedHeaders=host&X-Amz-Expires=300&X-Amz-Credential=ASIAQ3PHCVTYRDPY5LUF%2F20230928%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Signature=dc0f2739b811b2292d9ec974071a7fa039bfdd335d916af7882dc60d449bd5d2&hash=fe7c0be8abe854df625ebf0c985e99b6e8002c47f5503e5d21d0bee47d602e0a&host=68042c943591013ac2b2430a89b270f6af2c76d8dfd086a07176afe7c76c2c61&pii=S0952197613001875&tid=spdf-8c587b6b-591f-4b82-87a6-0bec69ebbf7e&sid=aafb7c82251df147c65b1e9442882320580agxrqb&type=client&tsoh=d3d3LnNjaWVuY2VkaXJlY3QuY29t&ua=130e5857040d5603525c&rr=80dc8a422b6317af&cc=in) | Saber M. Elsayed et.al (2014) have worked on a newer path for genetic algorithm for solving optimization problems. They proposed GA with multi-parent crossover (GA-MPC) , its coming from heuristic crossover.They proposed a diversity operator , they didnt use mean centric probability distribution such as UNDX and SPX nor apparent-centric PCX. They describe a 24 known constrained benchmark problems such as Parameter estimation for frequency-modulated (FM) , Lennard-Jones potential problem , optimal control of a non-linear stirred tank reacto, static economic load dispatch(ELD) etc.After using GA-MPC , it was 100% while SBX-NU was 89% on feasibility ratio and PCX-NU was 83%.They have also performed Wilcoxon Signed Rank Test to judge for differences between algorithms. Results showed GA-MPC , APF-GA,MDE and ECHT-EP2 reached optimal solutions for 22,17,20 and 19 problems , on this GA-MPC was better than APF-GA in terms of better average results. For future work , they intend to conduct further theoretical analysis of their proposed algorithm. |  |  | Elsayed, S. M., Sarker, R. A., & Essam, D. L. (2014). A new genetic algorithm for solving optimization problems. Engineering Applications of Artificial Intelligence, 27, 57-69. |
| 29-2nd | Spacecraft reentry trajectory optimization by heuristic optimization  methods and optimal control theory | International Journal of Dynamics and Control (2023) | Alireza E.et.al (2022) have proposed hybrid method for trajectory optimization of renentry spacecraft.They tried solving the problem of heat reduction in early phases of reentry. They have tried using 3 global optimization methods ( ABC , GA and GA-PSO) and used to them to determine the best profile of the bank angle and angle of attack.ABC is swarm based algorithm and for randomosity PSO-GA is used. Bank angle and angle of attack function was made using Polynomial and sine functions.They have divided 2 phases , first one being heat reduction and next one to satisfy final conditions , parameter k optimization methods.GA-PSO yielded the best results , their heat reduction was 6% lower, Heat Transmission in [140-250s] time period is lowered by 11%.they also found that current method reduces the maximum heat rate by around 12%, and final mistakes were less than 2%. The present study will be used to reduce the heat rate of an SRV without sacrificing final conditions. |  |  | Ekrami Kivaj, A., Basohbat Novinzadeh, A. & Pazooki, F. Spacecraft reentry trajectory optimization by heuristic optimization methods and optimal control theory. Int. J. Dynam. Control 11, 1132–1141 (2023) |
| 30-15th | Search Space Pruning and Global Optimization of Multiple Gravity  Assist Trajectories with Deep Space Manoeuvres | 2007 IEEE Congress on Evolutionary Computation (CEC 2007) | V.M Becerra et.al (2007) have given a design of optimal multiple gravity assist trajectories with deep space maneuvers.They have located feasible vectors using local optimization and applied a clustering algorithm to find reduced bounding boxes. They have used Global optimization method of Differential Equation  They have formulated problem into multi-stage optimization (MSOP) and used GASP( Gravity Assist Space Pruning) . It includes powered gravity assist at intermediate planets and braking manoeuvre.A model is made , a patched conic, and is assumed to be two-body problem. They have found leg trajectory through the solution of 2 Lambert problems, using Battin’s method for Lambert problems. 3 algorithms have been used , pruning the first phase , pruning the second phase and Global Optimisation on the pruned search space, in that they have used Stochastic global optimisation algorithm.A simple Earth - Mars mission has been designed to compare the results with Earth-Venus-Mars mission.For tolerance of lambert solver was 10-14 and 10-6 for differential Evolution Optimization phase. |  |  | Becerra, V. M., Nasuto, S. J., Anderson, J., Ceriotti, M., & Bombardelli, C. (2007, September). Search space pruning and global optimization of multiple gravity assist trajectories with deep space manoeuvres. In 2007 IEEE Congress on Evolutionary Computation (pp. 957-964). IEEE. |
| 31 | Autonomous Trajectory Generation Comparison for De-Orbiting with Multiple Collision Avoidance | Sensors MDPI, 2022 | Karla. R et.al (2022) have given an autonomous trajectory maneuver to de-orbit spacecraft back to Earth using collision avoidance techniques.They have compared two methods, sinusoidal and Pontryagin, they tracked Euler angle spacecraft and found differences. Pontryagin’s trajectory had a 15 min lower computation time .Simulink was used to model Euler Angles, way-point guidance , controls , sensors and natural forces.The model was made (PID controllers) to handle quaternion kinematics along with Direction Cosine Matrix, to mimic spacecraft trajectory accurately.Sinusoidal Approximation and Pontryagin’s Optimal Trajectory were performed , by minimising cost functions. They finally calculated Way-Point Guidance Method , atan = miss dist/ for. Travel dist. Mass of 100kg was taken with altitude of 1000km abd total of 600s with 4 way-point guidance maneuvers. Overall it was found Pontryagin method was more optimal with 37.9% fuel conserving and 40.5% less time.They plan to expand their research by increasing the breadth of the simulation to include a touch down model on Earth’s Surface. |  |  | Raigoza, K.; Sands, T.  Autonomous Trajectory Generation  Comparison for De-Orbiting with  Multiple Collision Avoidance. Sensors  2022, 22, 7066. https://doi.org/  10.3390/s22187066 |
| 32-17th | Minimizing the Effects of Navigation Uncertainties on  the Spacecraft Rendezvous Precision | Journal of Guidance, Control, and Dynamics, 2014, | Deaconu. G et.al(2014) have proposed a Model Predictive Control(MPC) as a potent strategy capabl e of accommodating mission-specific constraints and minimizing fuel consumption. Feeback control MPC is used as feedback policies instead of control actions.It approaches for circular and eccentric orbits, leveraging static feedback terms and time-varying feedback policies. Tube-based MPC concepts are utilized to achieve robust fixed-time spacecraft rendezvous while considering navigation uncertainties and actuator constraints, aiming to minimize fuel consumption and ensure precise rendezvous.  The variable change has been used ny Tschauner & Hempel to obtain linearised spacecraft relative dynamics for arbitrary eccentricity.They got final error eN  Into computing the smallest ellipsoidal set E(0,Qf-1). Minimizing it enables problems linked to infeasibility when satellites get close range.They were able to use MPC disturbance feedback for better prori for closed loop system behaviour for any value of uncertainty. |  |  | Deaconu,, G., Louembet,, C., & Théron, A. (n.d.). Minimizing the Effects of Navigation Uncertainties on the Spacecraft Rendezvous Precision. Journal of Guidance, Control, and Dynamics, 2014,  37 (2), pp.695-700. ff10.2514/1.62219ff. ffhal-01078527ff |
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Topic Introduction

The ability to robustly and precisely control the spacecraft relative motion will play an important role in future on-orbit inspection and on-orbit servicing missions.

Have proposed a prediction model