

The Research of Different Algorithms on Path Planning

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Abstract. The evolution of modern existence is inextricably linked to path planning. Road transportation, urban road planning, and travel plans for people's travel requirements must all be carried out and assured on the basis of effective route planning implementation. However, the path planning algorithms are not ideal. This work brings together three contemporary popular algorithms: classical algorithms, graphics algorithms, and bionics algorithms. The article presents and evaluates their functions, as well as summarizes the benefits and drawbacks of each method. Following that, the experimental data from each algorithm is gathered and compared. The performance difference between different types of methods is analyzed. The collected results are integrated with the prior analysis to form a summary. Finally, the paper summarizes and looks forward to the full text.

Keywords: Path Planning; Classical Algorithms; Graphics Algorithms; Bionics Algorithms.

1. Introduction

Path planning is a major study topic in motion planning. A path is the series of points or curves that connect the start and finish locations, and path planning is the approach for building a path. Path planning may be separated into two types based on environmental information: global path planning and local path planning [1]. The global path planning must master all environmental information and conduct path planning based on all environmental map information. Local path planning requires only that environmental information be collected in real time by sensors, that the information of the environmental map be understood, and that the location of the map and the distribution of local obstacles be determined, so that the best path from the current node to a sub-target node can be selected optimum route.

Path planning has many applications in the military field and civilian field, among the technologies that affect our daily lives are: urban road network navigation, GPS navigation system, GIS system. Reasonable urban road network planning can effectively improve the traffic situation and reduce traffic jams. In the event of an emergency, it can ensure that the rescue team arrives at the scene as quickly as possible. GPS navigation systems are inextricably linked to everyone's travel plans. A good GPS system will display the user the traffic flow of each route that must be passed from the starting point to the destination, and will make relevant modifications based on the real-time changing traffic flow while driving, saving the user as much time as possible.

At present, many algorithms have been derived in this field, such as traditional algorithms, graphics algorithms, and intelligent bionics algorithms. However, the overview and inductive articles of the relevant literature are insufficient and should be expanded. As a result, this document summarizes and describes the three methodologies indicated above. It is generated by analyzing and comparing the benefits and drawbacks of each algorithm.

2. Traditional Algorithm

2.1 Actual Situation Simulation

In traditional algorithms, many algorithms work out solutions to all similar situations through multiple simulations of an actual situation. In the field of path planning, simulated annealing and fuzzy logic are such algorithms. Simulated annealing is an efficient approximation algorithm suitable for large-scale combinatorial optimization problems, also it is a stochastic technique for approximating the global optimum of a given function [2].

A meta-heuristic is one that approximates global optimization across a wide search space of optimization problems. It is frequently employed in discrete search spaces, such as the traveling salesman problem, Boolean satisfiability problems, protein structure prediction, shop scheduling, and so on. Local optima, simulated annealing beats accurate methods such as gradient descent and branch and bound. The term metallurgical annealing refers to a process for heating and regulating the cooling of a material in order to modify its physical characteristics. Both are thermodynamic free energy qualities of materials. Temperature and thermodynamic free energy, also known as Gibbs energy, are affected by heating and cooling of materials. Simulated annealing can be used to solve extremely complex computational optimization issues that precise techniques fail to solve. An approximate solution to the global minimum may be obtained in many circumstances, which is sufficient for many practical applications. The issues tackled by simulated annealing are currently expressed as objective functions with several variables that are constrained in some way. Constraints can be punished as part of the goal function in practice. It has the benefits of a simple description, flexible usage, good operational efficiency, and minimal beginning conditions, but it has flaws such as sluggish convergence speed and unpredictability, and parameter setup is a critical link in the application process.

As for fuzzy logic algorithms, the main concept of it is to imitate the driver's physiological perception and action, and to integrate the system's real-time sensor data to accomplish course planning [3]. This strategy lowers the requirement for mathematical modeling to some amount in order to increase computer operating efficiency, but it also needs the computer to learn to adapt to human thinking tendencies and transform them into control signals with high consistency, stability, and continuity. However, because the principles of fuzzy logic algorithms are difficult to express, the computer's flexibility in dealing with the situation is limited.

2.2 Virtual Situation Simulation

A virtual situation simulation is a simulation of objects that have no substance, such as gravity or the way people think. In this field, the representative algorithms are Tabu search algorithm and artificial potential field method. Tabu search algorithm is a meta-heuristic random search algorithm, which starts from an initial feasible solution, selects a series of specific search directions as heuristics, and selects the move that makes the most change in the specific objective function value [4]. The main concepts of Tabu Search are [5]:

- 1) A short-term cyclic memory table (Tabu table) is built during the search. The Tabu table holds the most recent motions of $|T|$ (T is termed the Tabu table) neighbors.
- 2) To prevent returning to the original solution and becoming caught in a loop, moves into the Tabu list are banned during the next $|T|$ cycles. After $|T|$ cycles, the contraindication is lifted.

Table 1. The Pseudo-code of Tube search

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<p>Begin initialize a string s_1 at Tabu list randomly; $s_{\text{Tring}} := s_1$; repeat from the neighborhood of s_1, pick s_2; begin $s_{\text{Tring}} := s_2$; In the tabu list, replace the oldest string with s_2; end; until termination; end;</p>

- 3) During the search process, the Tabu list is modified cyclically to ensure that $|T|$ is always retained.
- 4) To keep the Tabu list from looping, the stop criteria must be added. When the best solution obtained in the iterative process cannot be improved or persists, the algorithm terminates.

Based on these steps, the pseudo-code of Tube search could be (Table 1):

The keys to the above pseudo-code are:

- 1) To select the Tabu object: the current value as the Tabu object and put it into the Tabu list, or put all the objects on the same contour as the current value into the Tabu list.
- 2) In order to reduce the amount of calculation, the set of Tabu length and Tabu table should not be too small or too large. If the Tabu length is too small, it is easy to search in a loop. And if the Tabu table is too large, it is easy to fall into the local optimal solution.
- 3) The operation of `best_so_far` in the above program segment is directly assigned as the optimal candidate solution for unbanning, but sometimes there will be a deadlock state in which no solution is greater than `best_so_far`, and all candidate solutions are banned. The best candidate solution is unbanned to be able to continue.
- 4) Termination criterion: Similar to simulated annealing, genetic algorithm, commonly used are: given a number of iteration steps; set the distance from the estimated optimal solution to be less than a certain range, terminate the search; when the distance from the optimal solution is continuous When several steps remain unchanged, the search is terminated.
- 5) Neighborhood: From the pseudocode select a new string v_n in the neighborhood of v_c , it can be seen that the system always searches for possible solutions in the neighborhood of the initial point, so a suitable neighborhood space must be defined. The optimal solution X^* , the initial search point is S_0 , then if there is no path to X^* in S_0 , the search will fall into the local optimal solution of the neighborhood of S_0 . It can be proved that if the neighborhood satisfies the symmetry condition, the global optimal solution must be searched under the assumption that the tabu table is long enough.

Tabu search approaches local optima in an entirely novel way. Create a Tabu table to record the optimization process that has been conducted, and then pick one of the optimization processes that have been recorded when the next search is needed. At the same time, it is also a simulation of the human intellectual process. By introducing a flexible storage structure and corresponding promotion rules to avoid meeting search, and to pardon some urgent good states by flouting the criterion, to achieve global optimization.

The artificial potential field approach is an alternative to the tabu search method. This is also the method for obtaining results by imitating a virtual scene [6]. It simulates the motion of objects due to gravitational repulsion, with the gravitational force represented by the target point and the moving body, and the repulsive force represented by the moving body and obstacles, and the gravitational field and repulsion field functions established by the following formulas to simulate path planning. This strategy, however, can only examine the general dynamic environment and cannot solve the problem of local optimization. As a result, the design of the gravitational field is critical to the algorithm's success.

3. Graphical Methods

3.1 Graphical Construction based on Spatial Utilization

When the traditional algorithm handles the real path planning problem, owing to the complexity of the road scenario, it is difficult to represent, and the graphical approach may give the fundamental method of modeling. The C-space approach is used to expand impediments in the motion space [7]. The form has no set rules, and the majority of them are polygons. Then link the beginning point, finish point, and all vertices of the extended graph, and utilize the straight lines formed as the path range to determine the shortest path. The C-space technique has the benefit of being straightforward, and the efficiency of finding the shortest path may be increased by enlarging the graph. However,

since the environment is so large, the algorithm performs poorly in local path planning. This C-space approach is appropriate for global path planning and path planning in continuous domains, particularly for global path planning environment modeling. In other words, the c-space method's central principle is to build a free space by deconstructing the environment, then represent the free space as a linked graph and explore the graph for path planning. Because the start and finish points have shifted, it is merely comparable to their locations in the built free space and may be adjusted without redrawing the entire graph. When there are more impediments in the environment, however, the complexity of the algorithm grows, resulting in difficult implementation.

3.2 Graph Construction based on Data Structure Itinerary

Grid method [8] is used to represent the map, and the grid containing obstacles is marked as an obstacle grid, otherwise it is a free grid, and the path search is based on this. The grid method is generally used as an environmental modeling technology for path planning. As a path planning method, it is difficult to solve the problem of complex environmental information, and must be paired with other sophisticated algorithms in general.

Based on similar principles, the Voronoi diagram is a fundamental data structure that represents the geographical proximity connection. It divides the space using simple graphics called elements, determines the edge of the element by the perpendicular line between each two points, and eventually divides the entire space into many small Voronoi diagrams which is then used by the algorithm to find the polygon's edges. The benefit of Voronoi diagrams is that the path to be planned is separated into tiny portions and analyzed sequentially, which increases the likelihood of reaching the ideal solution. This extremely thorough technique will take a long time to process and is not appropriate for big dynamic situations.

4. Intelligent Bionics Algorithms

4.1 Bionics Algorithms based on Animal Habits

The ant colony algorithm comes from the research of ant colony foraging behavior [9]. In the wild, each ant in an ant colony leaves a pheromone on the path it takes while hunting for food. When verifying the location, the ants will make many efforts to find the shortest path, resulting in a high concentration of pheromones. The following ants will pick the path based on the pheromone concentration, which acts as a positive feedback loop, allowing the entire group to choose the best way. Ants use pheromones and their surroundings to locate the quickest path. Assume there are two ways to go from the ant nest to the food. Because the number of ants on the two pathways is identical at first, the ants on the shortest path have a short round-trip duration and a high repetition frequency. As a result of the enormous number of round-trip ants per unit time, the pheromone will rise, attracting more ants and leaving additional pheromones. However, for long-distance trips, the inverse is true, thus the ants will follow this pattern and cluster on the shortest path. Ants' intelligence stems from their basic behavioral guidelines, which provide them with diversity and positive feedback. Based on ant behavior, it is possible to deduce that the effect of positive feedback on boosting efficiency is a type of learning and strengthening capacity. The ingenious mix of the two results in intelligent conduct. If the diversity is too great and the system is too active, the system will become chaotic; if the diversity is insufficient, the positive feedback will be too powerful, resulting in rigidity. The groupings cannot be altered in this manner. The method achieves its purpose by mimicking the foraging activity of ant colonies repeatedly. The mentions that compared with other optimization algorithms, ant colony algorithm has the following characteristics [10]:

- 1) A positive feedback mechanism is used to keep the search process convergent until an optimal solution is reached.
- 2) Each individual has the power to influence their surroundings by emitting pheromones, to monitor changes in their surroundings, and to communicate indirectly.

- 3) The search procedure employs a distributed computing technique and parallel computing to boost the algorithm's processing power and efficiency.

However, the disadvantage of the algorithm is also obvious, when it has a large amount of calculation, it is easy to fall into the local optimal solution.

The leapfrog method is a brand-new heuristic swarm evolution algorithm with high global search ability and economical processing performance [11]. The frog leaping algorithm is derived from the following: a bunch of frogs lives in a swamp, and there are numerous stones walking at the same time. To get food, frogs hop between several stones. Communication allows each individual frog to transmit information, allowing succeeding frogs to discover a suitable path more quickly. In this example, the whole frog population in wetlands is divided into distinct sub-populations, each with its own local search technique. Each member of the subgroup inspires others by disseminating its own approach. Influenced by other people and changing as subpopulations do. When the sub-group reaches a specific degree of development, each sub-group will exchange ideas in order to actualize the mixed operation amongst the sub-groups until the given requirements are met. An enhanced leapfrog algorithm based on the threshold selection strategy is presented to address the problem of the individual spatial location changing significantly before and after the update operation caused by the method's local update strategy, which decreases the convergence speed. Individual spatial discrepancies are decreased by not updating individual components that do not fulfill the threshold criteria, which improves the algorithm's performance. Numerical experiments verify the enhanced algorithm's efficacy, and the improved algorithm's threshold values are calibrated.

4.2 Bionics Algorithm based on Human Features

The artificial neural network algorithm is a very excellent and important algorithm in the field of artificial intelligence [12]. When processing the environment, it first turns all remaining data into ideas and expresses them with symbols, and then logically infers the symbols in a serial fashion, during which the computer executes the resulting instructions (Figure 1).

Logical thinking is the process of reasoning according to logical rules. However, intuitive thinking is the synthesis of information that has been distributed stored, and the outcome is a flash of insight or a problem-solving thought. The following two points are where the core idea of this manner of thinking rests:

- 1) By distributing excitation patterns across neurons, information is stored on the network;
- 2) The dynamic process of simultaneous neuronal contact is how information is processed.

Systems using artificial neural networks (ANNs) first emerged after the 1940s. It possesses the attributes of widespread dispersed information storage, many neurons with programmable connection weights, and strong self-organization and self-learning capabilities. A supervised learning technique in artificial neural networks is the BP (Back Propagation) algorithm, commonly referred to as the error back propagation algorithm. The BP neural network technique has high nonlinear mapping capabilities and may theoretically mimic any function. Its fundamental structure is made up of nonlinear change units. Furthermore, the network's learning coefficient and other parameters, which include the number of intermediate layers, the number of processing units for each layer, and others, may be adjusted based on a variety of factors, giving it an extremely flexible design. It is widely employed in a variety of industries, including optimization, intelligent control, signal processing, and fault diagnostics. An artificial neural network is a nonlinear adaptive dynamic system made of a large number of simple basic pieces - neurons coupled to one another. Individual neurons have very simple structures and functions, but the behavior of the system as a result of their interconnections is enormously complicated when vast numbers of neurons are treated as groups. Artificial neural networks imitate some key elements of human brain function, but they are not accurate representations of biological systems; rather, they are imitations, simplifications, and abstractions of organic systems.

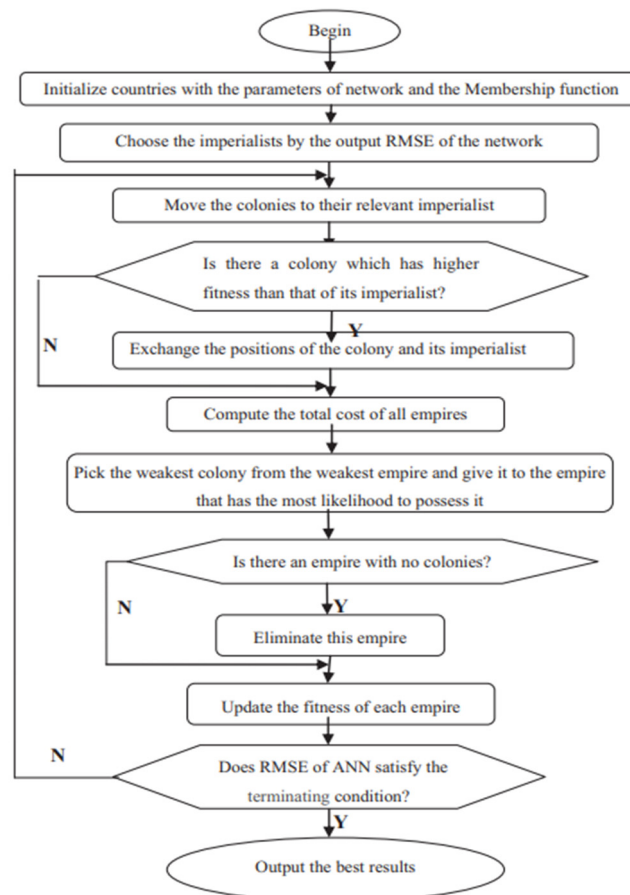


Fig 1. Artificial neural network operation

Artificial neural networks outperform digital computers in terms of operating principles and functional properties, and they better mimic the patterns of the human brain. It does not do actions strictly according to the steps provided by the programmer, but may adapt to the environment, summarize the rules, make necessary adjustments, and perform specialized operations depending on the scenario. If the artificial neural network can be employed in a flexible manner, it will provide several benefits for path planning:

- 1) Because the human brain is highly adaptable and structured, improved learning and training may result in a variety of unanticipated outcomes. For example, when their eyesight is compromised, blind persons rely on their ears and hands to acquire information from the outside world, thus hearing and touch are extraordinarily sensitive; sportsmen who prepare for a specific event have significantly better personal skills than regular people, and so on. Because a regular computer's operation is dependent on the information and abilities provided by the software. After passing the initial self-adaptation and self-organization capacity, the artificial neural network may continually alter and grow through this ability, and adjust the synaptic weight value throughout the learning or training process to adapt to the requirements of the surrounding environment. The learning ability of an artificial neural network can continue to improve and perhaps surpass the designer's initial knowledge level. Typically, its learning techniques can be separated into two types: using a provided sample standard to categorize or copy; and specifying the learning method or certain rules, and the specific learning material is created according to the system's environment. With a function more comparable to the human brain, the system can automatically detect the traits and regularities of the environment as it changes.

- 2) The algorithm is capable of generalization. Generalization ability refers to the capacity to anticipate and regulate untrained samples. The network has strong prediction performance, especially when there are some noisy samples.
- 3) The capacity of an artificial neural network to do nonlinear mapping is excellent. When the system is highly complicated, this feature reduces the need to utilize numerical analysis, partial differential equations, or other mathematical approaches to develop correct mathematical models. To some extent, this reduces the design challenge.
- 4) The method has a high degree of parallelism since neural network research covers several domains that integrate, penetrate, and encourage each other. Many scientists begin with the interests and qualities of their specific specialty, then ask new questions and approach research from several viewpoints.

In fact, the road condition is complicated and changing, and it is impossible to completely represent it with a specific mathematical formula or algorithm, thus the actual combat impact in the field of path planning is poor. In other words, neural networks' capacity to generalize is an unavoidable limitation. The neural network, on the other hand, has good learning ability and stability, and combining these properties with other path planning algorithms might mitigate its faults.

5. Algorithm Comparison

In order to show the advantages and disadvantages of different algorithms intuitively, this paper selects a representative algorithm from the traditional algorithm, graphical algorithm and intelligent bionics algorithms for comparison. In [13], Hui Miao and Yu-Chu Tian tested the simulated annealing algorithm in four different environments. Each one of the four environments contains static and dynamic obstacles. The first and second environments simulate the simple case where the dynamic obstacles move straight and in the same direction, since there is no randomness in the first two environments, the route was successfully calculated in a short time.

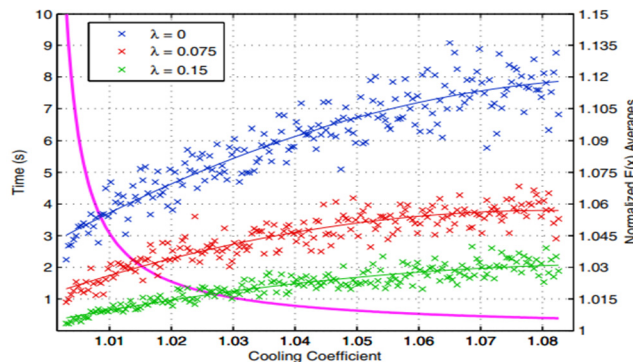


Fig 2. Result for the tests in four environments [13]

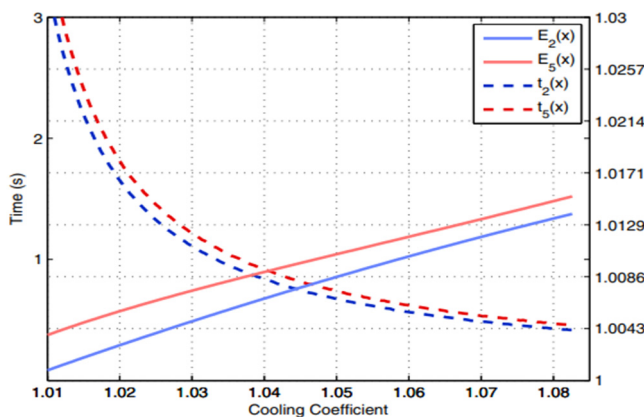


Fig 3. Average Value in four tests [13]

However, to test the real performance of simulated annealing, more complex simulations were performed in environment four. There are 6 dynamic obstacles which appear randomly and move in different directions and 14 static obstacles. The computer effectively recognized superfluous dynamic impediments throughout the path planning process and avoided collision with additional obstacles in the planning output. At the same time, Figures 2 and 3 show that the simulated annealing approach performs well in a variety of situations, however there is a sluggish convergence issue. For grid method in graphical algorithm, it had been tested in six different fields [8]: Field D*, Angle-Propagation Theta*, Basic Theta*, Shortest Paths, A*, and A* with Post-Smoothing. All of the six fields run on the same path planning problems (Table 2).

Table 2. Experimental Results: Path Length (in Parenthesis: Run Times)

		FD*	Basic Theta*	AP Theta*	Shortest Path	A*	A* PS
100×100	Game Maps Random 0%	41.98(0.0126)	41.92(0.0063)	42.01(0.0070)	41.89(0.0029)	43.80(0.0029)	42.00(0.0060)
	Random 5%	51.88(0.0109)	51.80(0.0026)	51.80(0.0034)	51.80(0.0020)	54.63(0.0015)	51.80(0.0057)
	Random 10%	48.83(0.0097)	48.74(0.0022)	48.74(0.0038)	48.69(0.0311)	51.24(0.0013)	48.99(0.0048)
	Random 20%	50.64(0.0120)	50.53(0.0028)	50.54(0.0051)	50.45(0.1173)	53.11(0.0014)	50.91(0.0054)
	Random 30%	48.65(0.135)	48.54(0.0034)	48.55(0.0065)	48.43(0.4594)	50.86(0.0019)	49.04(0.0054)
		50.19(0.0153)	50.10(0.0045)	50.11(0.0081)	49.98(1.0769)	52.25(0.0028)	50.61(0.0058)
500×500	Game Maps Random 0%	205.60(0.1916)	205.28(0.0098)	206.20(0.1624)	N/A	214.80(0.0661)	205.64(0.1040)
	Random 5%	259.65(0.1231)	259.24(0.0288)	259.24(0.0113)	N/A	273.11(0.0045)	259.24(0.1688)
	Random 10%	257.19(0.1538)	256.58(0.0390)	256.60(0.0523)	N/A	270.40(0.0053)	259.14(0.1747)
	Random 20%	259.37(0.1795)	258.62(0.0577)	258.65(0.0870)	N/A	271.77(0.0108)	261.62(0.1783)
	Random 30%	258.71(0.2219)	257.88(0.0882)	257.93(0.1384)	N/A	270.60(0.0273)	261.36(0.1871)
		266.49(0.3207)	265.84(0.1244)	256.90(0.2000)	N/A	277.57(0.0628)	269.60(0.1951)

Table 2 shows the results, Basic Theta* and AP Theta* have the best performance, both of the Theta* are able to find paths of close-to-minimal length. The experimental results verify the good performance of the grid method in the basic environment. However, it can also be seen from the results that when the environment becomes complex, the computing power and performance of the grid method decrease significantly. This is one of the reasons why the grid method cannot be used as an independent algorithm in the problem of path planning.

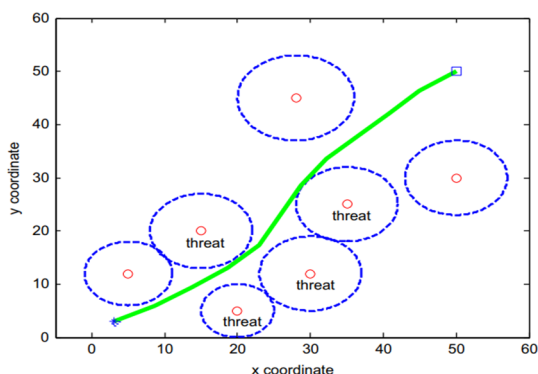


Fig 4. Artificial Neural Network results [13]

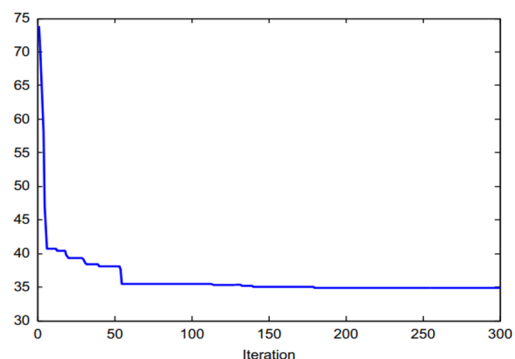


Fig 5. Artificial Neural Network Iteration [13]

Figure 4 depicts an artificial neural network's route planning for an environment after learning [13]. The planned path avoids all dangers and successfully arrives at the destination, demonstrating the artificial neural network's developability and dependability. Figure 5 depicts the phenotypic after numerous cycles, demonstrating the updated algorithm's lack of generalization capacity.

6. Conclusion

This paper analyses three popular algorithms: classical algorithms, graphics algorithms, and bionics algorithms about path planning. As can be seen from the research above, each system algorithm has distinct advantages and weaknesses. The classic approach performed well in testing in a variety of contexts, and it can fairly avoid unobjectionable touch when identifying barriers in order to select the best route. This is also reflected in traditional algorithms that offer clear benefits over alternative algorithms in terms of flexibility, operational efficiency, minimal beginning conditions, and outstanding outcomes. However, the standard method has significant flaws when it comes to dealing with local optimization and modeling. The relative graphics method may build a comprehensive model and assist the system in splitting and combining the target space, allowing the computer to optimize the details to the maximum degree possible. This also improves the overall path planning. However, the graphics algorithm's tremendous deconstruction ability renders it deficient in search ability, and as the target environment gets huge and complicated, the graphics algorithm will perform badly owing to the increased quantity of work. Intelligent bionic algorithms, on the other hand, can handle complicated circumstances quite effectively. Intelligent bionic algorithms may continually grow to build the best path in the face of complicated settings because of the computer's self-learning and self-improvement capabilities. However, because each intelligent bionics algorithm is usually employed in a specific context, the algorithm's overall generalization ability is relatively weak, which is not favorable to the algorithm's popularization and deployment.

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