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Based on the MATLAB simulation of the optimal motion sailing route planning research and application of the model

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ABSTRACT

According to the actual situation of the sailing events, according to the thought of dynamic planning, for navigation route planning method of optimal motion state is studied. According to the low efficiency of local search of dynamic programming, such as slow convergence speed disadvantage, put forward based on the theory of evolutionary programming sailing route dynamic programming optimal movement. Using MATLAB simulation test simulation of two kinds of path planning method and comparison analysis, manifests the sailing ship based on the theory of evolutionary programming the superiority of the optimal path and dynamic programming method.

KEYWORDS

Optimization theory, Dynamic planning, Optimal Sport Route, Matlab Simulation Test.

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INTRODUCTION

Sailing is sailing athletes in the game speed within a prescribed distance of a sport. Like other sports, sailing has very serious uncertainty. Sailing is driven by the wind, the wind through the sail on the hull motivation, its uncertainty mainly lies in the features of the wind. How to according to the Marine meteorological information of the game, the optimal trajectory is an important part of the competition[1].

This article from the constraint conditions of line sailing decision-making evaluation function of solving boils down to the optimal routes of constrained optimization problem. For constrained optimization problems, the use of traditional algorithms such as based on calculation method, the enumeration method and simulated annealing method to solve the disadvantage of are different. In view of this situation, based on dynamic programming is proposed the optimal path planning research, sailing, in turn, on this basis, find a new method based on evolutionary programming sailing ships of the theory of dynamic programming optimal route. At last, through the MATLAB simulation results to compare the two methods.

OPTIMAL ROUTE PLANNING SAILING BASED ON DYNAMIC PLANNING THEORY RESEARCH

Dynamic planning basic principles[2]

In the beginning of 1950s, when American mathematician R.E. Bellman and others made research on multistage decision process optimization problems, they proposed famous optimization principle, converted multistage process into a series of single stage problems and solved them one by one, and created the kind of process optimization problems new solution –dynamic planning. Dynamic planning theory basis includes two aspects as following:

Bellman optimization principle. Optimal strategy has such property that no matter how its initial state and initial strategy are, its future multiple strategies to system that taken the first decision formed state as initial state, it should form into optimal strategy.

Bellman recurrence formula. For n stage problems, optimal strategy can be solved by following recurrence formula:

$$f_k(s)=\underset{u_k(s)}{opt}\{r_k(s,u_k(s))\oplus f_{k+1}(u_k(s))\} \qquad k=1,2,\cdots,n \tag{1}$$

$$f_{n+1}(s)=e$$

Among them, e is some regulated value: s is the k stage state variable, u_k is decision variable, $r_k(s,u_k(s))$ is stage efficiency:

$$f_k(s)=\underset{u_k-u_n}{opt}\{r_k(s,u_k(s))\oplus r_{k+1}(s_{k+1},u_{k+1}(s_{k+1}))\oplus\cdots\oplus r_n(s_n,u_n(s_n))\} \tag{2}$$

$$s\equiv s_k s_{i+1}=T_i(s_i,u_i(s_i)) \qquad i=k,k+1,\ldots,n$$

When initial state is s_1, system optimal strategy takes value as $f_1(s_1)$.

Dynamic planning is one of basic solutions to multistage decision process problems. Multistage decision process refers to that it can be divided into multiple mutual connected and mutual distinguishing stages according to problems specialty with time, space and other marks. In every stage, it gets one conclusion; let the whole process achieve best result. Therefore, every stage decision selection cannot be defined at random; it is up to present development state and future development situation here. After defining every stage decisions, it forms into a decision sequence, so that decides process activity route.

Sailing optimal dynamic path planning implementation steps and MATLAB optimal route simulation

Sailing optimal path planning's basic thought is utilizing dynamic planning, divides whole sailing process into a series of single stage problems, and then solve it one by one. Make optimal sailing route planning by adopting dynamic planning's order recurrence method[3]. After searching is over, it gets array BT_k all elements adding value that is earliest time spent on arriving at destination. Optimal route, it can get from every stage process optimal heading point array BP_k, starts from departing place P_0, connects every phase optimal nodes, till to objective point P_n, so that it gets optimal route.

By MATLAB software[4], it realizes sailing optimal route simulation test when riding upwind and wind angle is 45. According to relative books records, identification object movement membership function $Z(x, y)$ index λ and indicator function $EV_{k,j}$ index as well as τ_1, τ_2 and η are respectively: 0.7, 0.9, 0.1and -10.8. Other parameters as: wind speed $V_w = 4m/s$; ocean current flow speed $V_C = 0.4m/s$, flow direction $\gamma_C = -20^\circ$; sea wave direction $\varphi = 30^\circ$, wave height $h = 0.3m$; sail area $6m^2$; the shortest travel length $L = 200m$; course width $2W = 10m$; section $n = 20$.

When riding upwind, sailing optimal route planning figure and sailing route each node membership function values status respectively show in Figure 1 and Figure 2. When wind angle is 45°, sailing optimal route planning figure and route each node membership function values changes respectively show in Figure 3 and Figure 4.

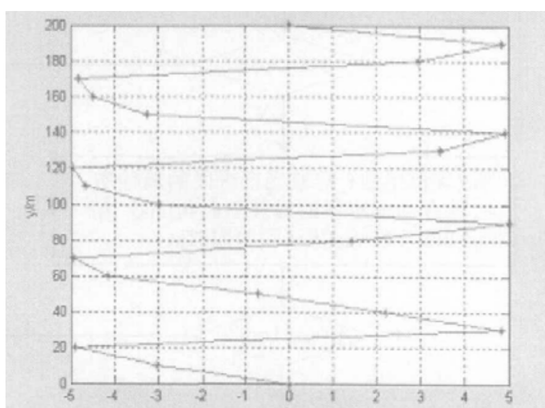

figure 1 : Optimal route schematic diagram when sailing wind-ward

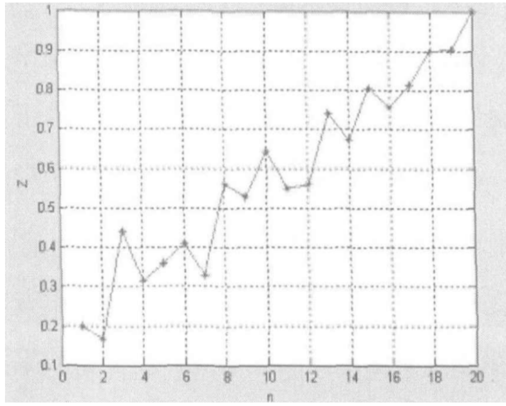

figure 2 : Optimal route corresponding membership functions values when riding upwind

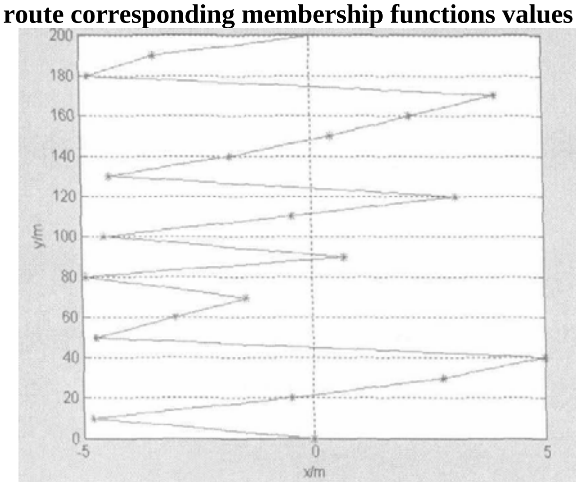

figure 3 : Sailing optimal route diagram when wind angle is 45°

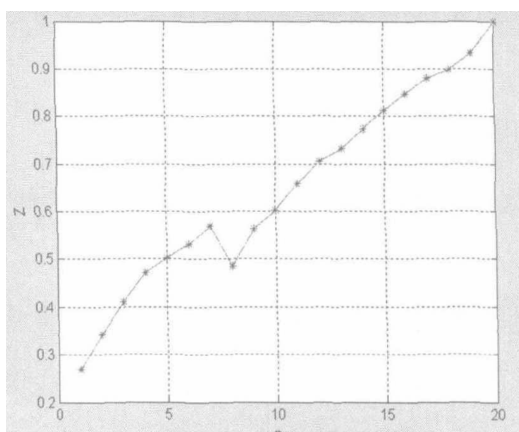

figure 4 : Optimal route corresponding member functions values when wind angle is 45°

As Figure 2 show, sailboat during sailing process, when y axis deviated distance increases as well as ε angle increases, membership functions values will reduce accordingly, and it increases with gradually approximating to objective point, when arriving at objective point, its value is 1. The searching method, algorithm is relative simple, and easily to engineering realization. But in every stage partial searching, it still exists searching direction classification quantity problems, if partial searching branch is too little, it is prone to miss good searching point, let searching result cannot arrive at best; on the contrary, if searching branch is too much, then searching speed slows down and calculation efficiency reduces. To solve the problem, we propose the thought of implanting dynamic planning into partial searching, utilize evolutionary planning global searching optimization so as to improve dynamic planning partial searching efficiency, convergence speed and accuracy ability.

OPTIMIZATION MODEL ESTABLISHMENT AND SOLUTION

Evolutionary planning theory basic principle

Evolutionary planning work flow is similar to other evolutionary algorithm, similarly it goes through initial population, mutation, calculating individual fitness, selecting, composing into new group, and then repeatedly iteration, evolves generation by generation, till it arrives at optimal solution[5].

For continuous parameters optimization problems, it has:

$$\min f : S \to R \tag{3}$$

Among them, f is fitness function, $s = \prod_{i=1}^{n} [a_i, b_i]$ is searching space, here $a_i < b_i, i = 1,2,\cdots,n$

Solve continuous parameters optimization problems' evolutionary planning algorithm process is as following:

Set algorithm iteration times $t = 1$;

Randomly generating scale as m initial population $P(0) = \{(x_1, \sigma_1),(x_2, \sigma_2),\cdots,(x_1, \sigma_1)\}$;

Calculate every individual fitness value $f(x_i)$;

Mutation operator:To $P(t-1)$ every parent individual (x_i, σ_i), according to (4)and (5), it averagely generate a sub individual $\left(x_i', \sigma_i'\right)$.

$$x_i' = x_i + \sigma_i' \cdot N(0,1) \tag{4}$$

$$\sigma_i' = \sigma_i + \exp(\tau' \cdot N(0,1) + \tau \cdot N(0,1)) \tag{5}$$

Among them, $N(0,1)$ is random number that conforms to standard normalization distribution, τ and τ' are given external parameters, considering multiple factors, and then let $\tau = \left(\sqrt{2\sqrt{n}}\right)^{-1}$, $\tau' = \left(\sqrt{2n}\right)^{-1}$.

Calculate every sub individual fitness value $f(x_i)$. Select operator: Adopt q competition selection method that let all parent individuals and sub individuals compose a scale of $2m-1$ temporary group, to group every individual, select q piece of individuals from other $2m-1$ individual random and other probability to make comparison with others. Select most winning times m pieces of individuals from $2m-1$ pieces of individuals as next generation parent individual. If it meets algorithm termination, otherwise $t = t+1$, return to(4).

Optimal route searching algorithm based on evolutionary planning theory

Unrestraint heading decision comprehensive evaluation function is expressed as:

$$g_k = \tau_1 T_{k,j} + \tau_2 \eta Z(x_{k,j}, y_{k,j}) + r\left[\max\left\{0, -\left(M - \left|x_{k,j}\right|\right)\right\}^2\right] \quad (6)$$

Reference evolutionary planning algorithm basic steps, according to evolutionary planning theory optimal route searching algorithm flow, its algorithm designing key points are:

(1) Population initialization. Individual set is population, according to sailboat straight sailing game status, only considering course boundary conditions, select boundary constraint conditions satisfied feasible field distributed m pieces of individuals as initial population.

(2) Fitness function. According to formula (6), fitness function is sailing decision comprehensive evaluation functions.

(3) Mutation operator. Parent generation as initial population, evidence for every individual making mutation is adaptive mutation mechanism, everyone parent generation individual (x_i, σ_i) according to formula (4) and formula (5), it generates sub individual (x_i', σ_i').

(4)Select operator. m pieces of parent individuals will totally generate m pieces of sub individuals. Adopt random q competitive alternatives method, next generation population is the selected m pieces of individuals from parent generation and offspring total. Among them, parameter q is extremely important, to excellent individual favoritism, it will increase with q increasing, when $q = 2m$, selection becomes a definite alternative; on the contrary, the randomness increases with q decreasing. Due to selection process, it always keeps more excellent individual, so, new generation individual will more excellent than previous generation individuals, or it will not be worse than previous one at least. Therefore, the bigger q value is, its evolutionary advantage will become more remarkable. Considering randomness and maintaining optimal individual, selects $q = 0.8m$.

(5) Convergence judgment. In common cases, optional maximum iteration number is taken as convergence criterion, and to get global optimal solution plan, maximum iteration time is relative bigger, corresponding calculation time will be longer. In actual calculation, to define proper quantity iteration convergence criterion, so that it reduces calculation time.

(6) Searching over. Defined variable BT_k, BS_k, BH_k, BP_k, functions are remained, to meet objective, the k stage sailing spend time, optimal sail turning angle, optimal heading angle information and optimal heading point.

According to Figure 6 steps, after making searching, all elements added sum in gained array BT_k is the shortest time that possible to arrive at. The optimal sailing course can get from each stage optimal heading point array BP_k, it starts from departure place p_0, connects optimal nodes in each stage successively, till to objective point p_n then it will get optimal sailing route.

MATLAB applied optimal route simulation

By MATLAB software, it realizes sailing optimal sailing route planning when riding upwind and wind angle is -90°. According to relative books records, distinguish object sport membership function $Z(x, y)$ index $\lambda = 0.7$ and indicator function $EV_{k,j}$ index τ_1, τ_2 and η are respectively:0.7, 0.9, 0.1and -10.8. Other parameters are: wind speed $V_w = 5m/s$, wind direction θ is 0 degree; ocean current flow speed $V_C = 0.6m/s$, flow direction $\gamma_C = 30^\circ$; sea wave direction $\varphi = 45^\circ$, wave height $h = 0.4m$; sail area $10m^2$; the shortest travel length $L = 200m$; course width $2W = 10m$; section $n = 20$.

According to experiment demands, let $m = 15$, $q = 12$, iteration times $\max t = 100$, $\sigma_1 = 0.1$. When sailboat riding upwind, according to dynamic planning method and evolutionary planning method gained optimal sailing route, it reflects in Figure 5 and Figure 6. They all sail along zigzag, but adopt dynamic planning method, experienced time from sailing starting to ending is $90.76s$, and experienced time by adopting evolutionary planning method is $82.46s$.

When sailboat is sailing at wind direction of -90°, respectively adopt two kinds of planning methods gained sailboat optimal sailing route, it reflects in Figure 7. Adopt dynamic planning method, experienced time from sailing starting to ending is $58.17s$; And experienced time by adopting evolutionary planning method is $41.26s$.

By the simulation test, it is clear under same environment parameters conditions, applies sailing optimal route dynamic planning method with evidence of evolutionary planning theory, the gained optimal route speeds shortest time, sailing is fastest and more effective, reasonable.

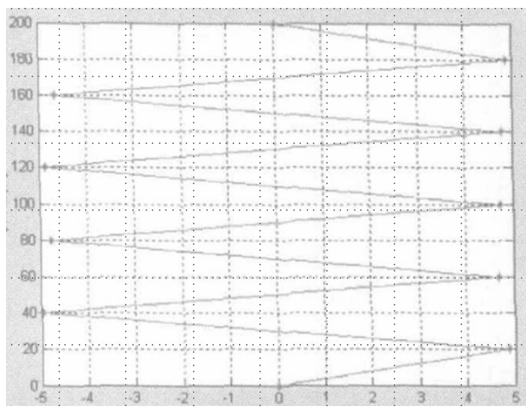

figure 5: Gained optimal route figure by applying dynamic planning method when riding up-wind

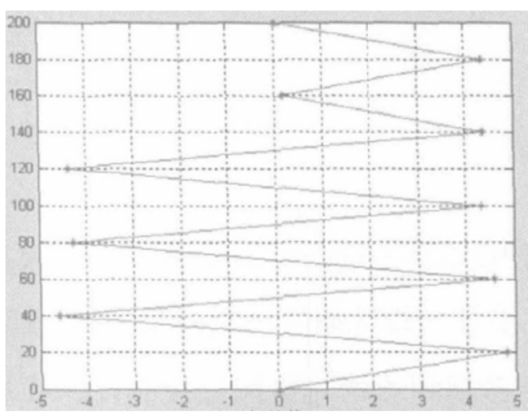

figure 6: Gained optimal route figure by evolutionary planning method when riding up-wind

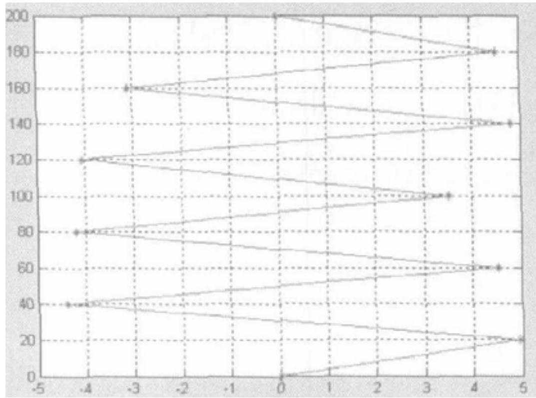

figure 7: Gained optimal route figure according to evolutionary planning method when sailing with left wind

CONCLUSION

In conclusions, it proceeds with optimal route planning method researching and searching in dynamic planning theory sail race. Furthermore, for dynamic planning slow partial searching efficiency, branch quantity difficulty defining status; it proposes sailboat straight sailing race optimal route planning method according to evolutionary planning theory. The method adopts penalty function method, effectively converts constraint heading decision comprehensive evaluation function into unrestraint non- linear function, and regards it as planning evidence. By function optimization ability and evolutionary planning global optimization searching, it improves dynamic planning accuracy and partial searching efficiency. Finally it adopts MATLAB software to make simulation test, so that make comparison analysis of the two route planning methods, the results effectively proves that sailboat sailing optimal route dynamic planning algorithm based on evolutionary planning theory has better practicality and scientificity. In modern society, it pays more and more attention to utilize modern information technology and automatically control way, to select optimal route considering Olympic Games period marine meteorology parameters and guide sailboat sailing and proceed with more scientific training.

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