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Agent system in control of ship movement

Keywords

decision support system, e-navigation, ship passing, route planning, modeling of sea navigation environment

Abstract

The problem of determining the optimal passing route of the ship between its current position and a remote destination point including the navigation situation occurring during moving along the route has been a subject of many papers and so far has not been definitely solved. In order to determine an optimal and safe route of the ship and its control along it, the author suggests application of an agent system. In the presented agent system three goals are accomplished. The first relies on data acquisition about current navigation situation around the ship and on analysis of possible collision risk. Second target – so far not present in anti-collision systems – relies on automatic negotiations between ships that operate in the same water region or between the coast stations in order to determine the potential area thru which a passing route could have been set. The third one connected to determining the passing route and its autocorrecting depending on current navigation situation.

1. Introduction

Sea transport is an unavoidable part of the world economy system. One can also say that driving the ship is an integral part of its operation no matter of its application (trade ship or naval). Based on the subject literature one may conclude that controlling the ship movements covers the operations that are completely irrelevant in terms of their similarity, connected to planning the ship passing route, controlling it between particular turning points, avoiding collision – setting anti-collision maneuvering, control and supervision of ships in the water regions with intensive movement. Depending on the applied methods and techniques the problem of ship control on the sea has been discussed in different ways and so far has not been definitely solved. The problem of optimal ship control can be brought to a task in which a globally optimal solution is searched for, which determines a safe passing route avoiding the navigation obstacles – other ships or restricted areas (lands, shoals, regions with difficult atmospheric conditions, regions excluded from navigation etc). For such a task, a solution compromising between the set route deviation costs or from the shortest way to accomplish a target and avoiding the navigation limits is searched for. For a problem defined as above in order to set an optimal passing route of the ship and its control along it is suggested to apply an agent system accomplishing three basic goals: data acquisition about current navigation situation around the ship and on analysis of possible collision risk; automatic negotiations between ships that operate in the same water region or between the coast stations in order to determine the potential maneuvering; determining of passing route and its autocorrecting depending on current navigation situation.

2. Agent system structure

General definition of the agent system states that it is a system that consists of a certain number of collaborating agents in order to solve a given problem. Their actions must be characterized by ability of performing individual actions without the intervention of the operator: ability of information exchanging with the operator and other agents or processes and by ability of detection and reaction to changes occurring in the environment [7]. In order for successful collaboration of the agents they must use interaction patterns. One of the three interaction patterns next to cooperation and coordination is negotiation i.e. attempt at obtaining a compromise accepted by all involved parties in case of a conflict.

In regard to a task of navigation on seas the statistics of sea accidents substantiate that the passing routes of a ship are not always determined correctly which is proven by sea collisions. The laws of International Sea Route are not always correctly interpreted and used by the navigators. In the light of the above it is suggested to use an agent system with a structure shown in *Figure 1*, whose particular system platforms could have been placed on different ship or coastal station.

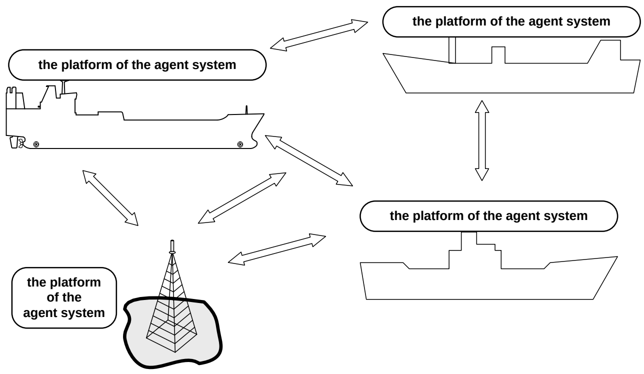


Figure 1. Simplified agent system structure.

Within a single platform of the agent system installed on any ship or coastal station the agents operate. The structure of a single platform of an agent system is shown on *Figure 2*.

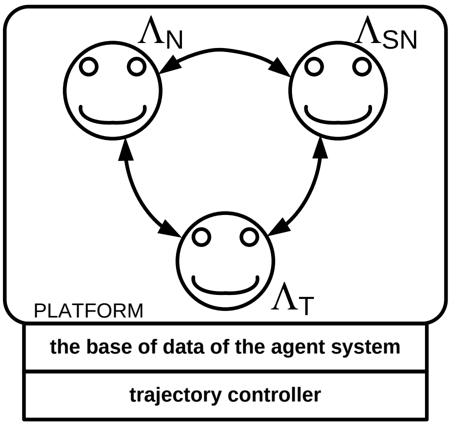


Figure 2. Simplified structure of a platform placed on elective ship or coastal station in agent system.

The Λ_{SN} is a label of an agent whose task is to gather data about current navigation situation around the own ship and – based on it – analysis of collision risk. The second agent – labeled as Λ_T – is responsible for determining the passing route and its corrections in case collision risks. The task of the third agent – labeled as Λ_N – is to perform negotiations with other agents placed on system platforms of other ships operating on the particular water region which ensures the most advantageous passing route of the ship. The exchange of the data among agents takes into account such information as: course and the speed of the given ship and the planned next manoeuvre of the turn, information about the co-ordinate points of the turn of the route of passage (together with the destination place), type and the kind of the ship. In the case of the conflict of the sea road among ships, agents undertake negotiations with use of the games theory.

3. Determining of the passing route of the ship

In the agent system the role of determining of the passing route and its correction depending on the navigation situation belongs to Λ_T agent who uses multi-population competitive evolution algorithm. Its structure is shown on *Figure 3*.

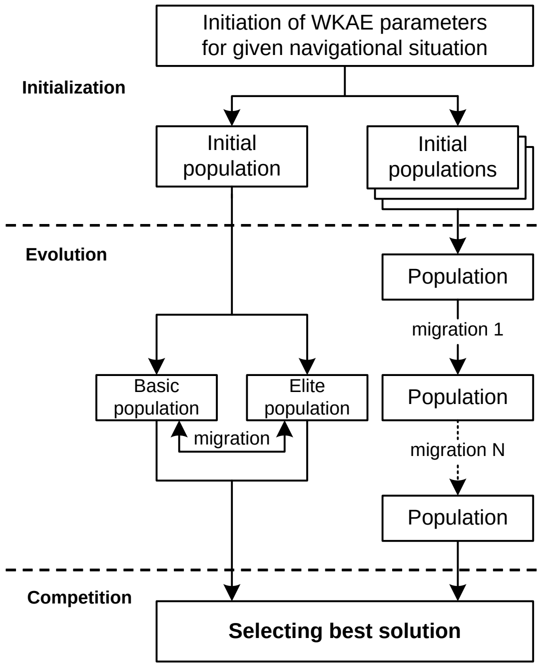


Figure 3. Structure of multi-population competitive evolution algorithm.

This algorithm is supposed to ensure the improvement of reliability and repeatability of obtained solution in relation to classic evolution algorithm. The MCEA consists of two competitive algorithm whose solutions obtained as a result of evolution compete with each other. The better solution in reflection to evaluation criterion is chosen. The first of competing algorithm has a typical structure of an evolution algorithm [1]. It is started repeatedly with passing on the solution from previous iteration to population processed in the subsequent run. The second evolution algorithm includes two populations in its structure: base and elite. The elite population consists of best adapted individuals from the initial population. The base population includes the rest of individuals (less adapted) from the start population. Both populations evolve independently, yet migration of specimen between them is possible.

The migration process is applicable to specimen from the base population with the value of adaptation higher than average adaptation of elite population. The value of migration delay and its period is selected experimentally. The base population is responsible for exploration of the area of problem solutions. The elite population exploits the surrounding of the best solutions obtained by the base population [5].

4. Navigation limits

The objects existing in the navigation environment in which the ship moves allow definition of limitations of a static and dynamic nature.

The static limits are: lands, shoals, fishery, water routes etc. theses limits are modeled by means of polygons in the same way as electronic maps are created (shaded regions in *Figures 4-7*). Water routes are represented by two channels in which the movements are allowed in direction only. In addition to water channels perpendicular rays blocking the passage outside of them.

The dynamic limits are other ships, icebergs and areas with unfavorable weather conditions which decrease the level of navigation safety. The dynamic limits are modeled by movable areas called domains with different shapes [3], [4].

The information about the parameters of navigation limits (radar system with ARPA, GPS AIS electronic maps, weather forecasts) are gathered by the agent labeled as Λ_{SN}.

In addition, the agent evaluating the navigation situation is responsible for analysis of the risk of the collision with one of the aforementioned limits. Gathered and processed data about the navigation environment together with information from agent Λ_N via negotiation with agents from other platforms is passed to agent Λ_T. In the evolution algorithm used by agent Λ_T the chromosome structure describes the passing route of the ship in a form of a broken line whose tips represent the coordinates of the turning points. Additionally, on particular sections of the route the velocity the ship should maintain is determined on the given section. The first turning point is the initial ship position and the last is its destination. The initial population specimens are created randomly (*Figure 4a*). In the consequence most of the routes - described by the specimen - contain loops or section injuring the static limits. Additionally there is a possibility of occurrence of fragments (turns too acute or sections too short) not feasible for the ship. In order to improve the efficiency of obtaining the solution by the MCEA the initial populations are subjected to preliminary processing.

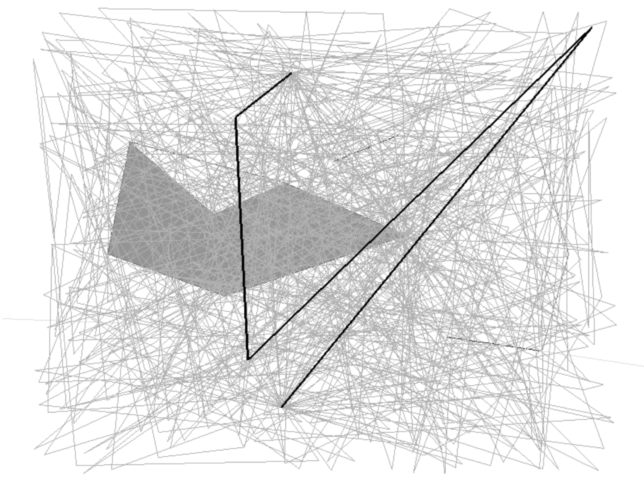


Figure 4. Preliminary processing - initial population created randomly.

The first step in the preliminary processing is removing the loops in the passing paths by the repair operator (*Figure 5*).

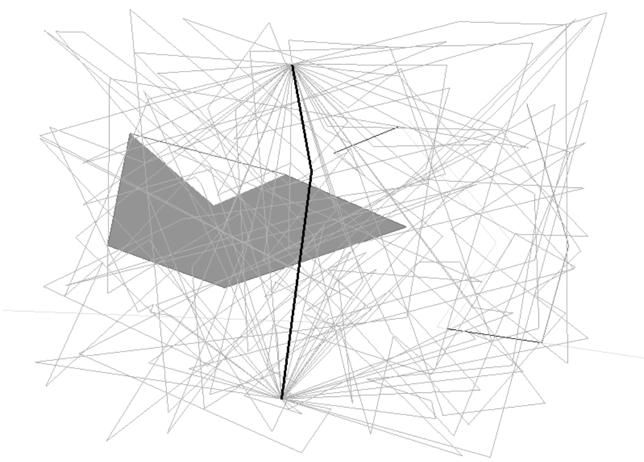


Figure 5. Preliminary processing - population of passing routes after loop removal.

The next modification of the genetic material is smoothing of routes included in the initial population (*Figure 6*).

Avoiding the static limits is accomplished by setting additional turning points in the adopted safe distance from the limit (*Figure 7*). Subjecting the initial population to operation of repair operators improves the quality of genetic material used in further part of calculations.

General principle of the evolution algorithm operation is based on repetitive processing of population of solutions with the use of genetic operators such as crossing and mutation.

Specialized versions of operators improving algorithm efficiency have been used.

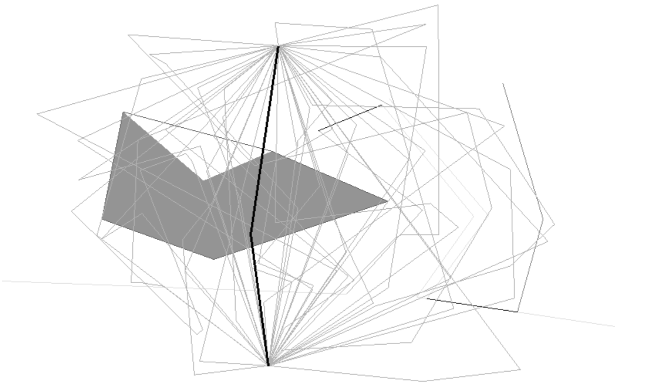


Figure 6. Preliminary processing - population of passing routes after smoothing process.

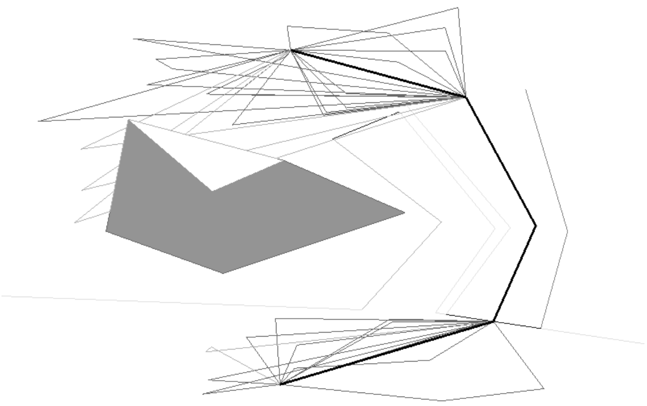
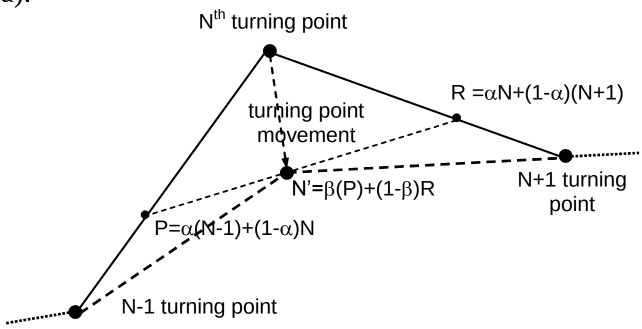


Figure 7. Preliminary processing - population of routes after repair in order to avoid static limits.

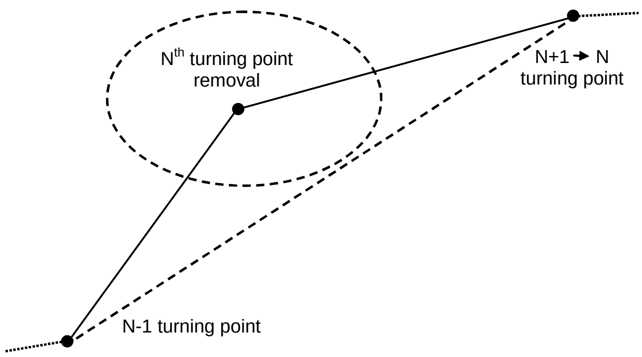
Operation of three versions of mutation operator depends on the angle between the sections connected to the discussed turning point. With high value of the angle the gene is removed under the condition that the new passing route will not injure the navigation limits (*Figure 8a*). For medium value of the angle random move of the tip towards the direction causing smoothing of the route (*Figure 8b*), operation is done under the condition that the trajectory remains safe. Adding a turning point occurs in case of acute angles between the sections (*Figure 8c*), the angle tip is moved to randomly chosen position on the angle arm, operator is applied under the condition that the introduced modification will not cause injuring the limits.
The remaining operators are the operators of repair used in preliminary processing and:

- global mutation which randomly moves the turning point, but the change is possible in the whole allowable range on the condition of not injuring the limits,
- speed mutation modifying the speed on randomly chosen section of the trajectory, which may allow avoiding contact with dynamic limits,
- crossing, using the genetic material from two parental trajectories it creates the progenies. The parents' cutting points are chosen randomly from the cutting points which do not cause injuries of the limits in the progenies. Next the specimen swap their cut fragments creating the offspring.

a).



b).



c).

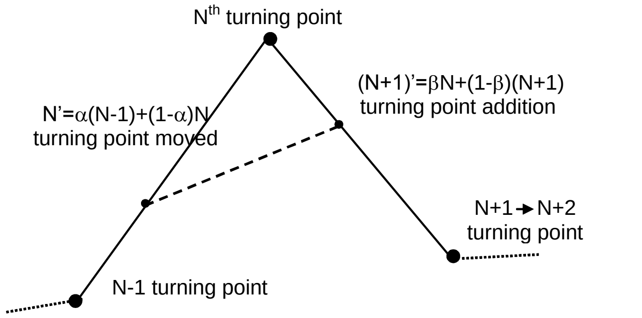


Figure 8. Operation of mutation operators depends on the value of the angle between the sections of the route: a) turning point movement, b) turning point removal, c) turning point addition.

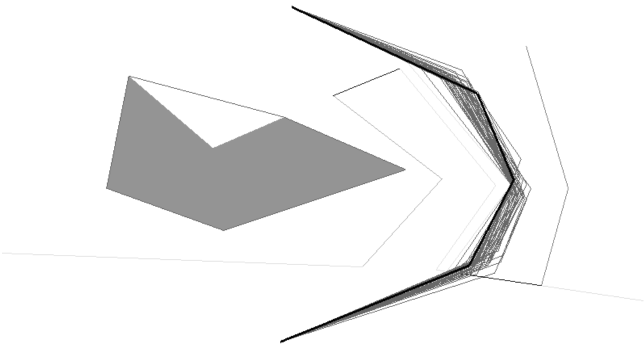


Figure 9. View of population after 300 generations (use of remaining genetic operators).

The passing route parameters obtained from operation of Λ_T agent are forwarded via agent system database to trajectory controller. Applied trajectory controller presented in references [2], [4], [6] determines the control process for real ship trajectory based on determined passing route and including the dynamics of own ship and current weather perturbations affecting the ship body such as wind, sea current, and waves.

5. Conclusion

Practical application of the agent system is aimed at easing the work of the navigator whose duty is to perform calculations pertaining determining the passing route of the ship and to maintain the route of the ship in connection to hydro-meteorological perturbations affecting it. The main feature of the system will be reflected in safe and automatic control of the ship in case of collision-likely situations. You should underline that algorithm which finds the optimal solution not only in static conditions, i.e. when all constraints are fixed. The qualification of the optimum route of the passage is possible for navigational situations with limitations of a static and dynamic nature. To great extent the system may contribute to higher safety level on seas and to limitation of operation costs of the ship.

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