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Route Planning for Ships during Emergency Situations using Genetic Algorithm

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Abstract – During sea navigation, plotting an efficient route is highly essential. Simple target specific algorithms like Dijkstra Algorithm are generally used for this purpose. But these algorithm are not helpful during emergency situations when solutions are not optimal enough due to technical limitations.Thus, the authors propose the use of Genetic Algorithm(GA) in critical conditions to reach destination optimally or as closely as possible. GAs were proposed many times for sea navigation but are replaced with target specific algorithms due to delayed time in path-finding. This paper discusses the need of GA in emergency situations such as low fuel or ship damage (time constraint) where it can be used to find all possible paths by modifying the fitness function. The obstacles are plotted using ARPA system installed in the ship. The collective data is used to run simulations to find the optimal route. Once the optimal route is found, the ship can follow the course and will not exceed the constraints.

Index Terms – Emergency, Genetic Algorithm, Navigation, Optimal, Ships.

1. INTRODUCTION

Proper route planning is essential in ships as they face many obstacles and are prone to collisions. The literature [1] provide the concept of computer simulation to aid navigators to determine the safest path. Several algorithms are proposed to map the sea course During emergency situations, normal algorithms are not efficient enough to find the optimal solution and by Genetic Algorithm the problem is solved in a faster way. GAs can be run on simulations based on the obstacle data provided from the ARPA (Automatic Radar Plotting Aids) to find the best course without actually moving the ship. The technical constraints as of that situation like low fuel , or uncertain speed (due to damage or collision) can be used to modify the algorithm fitness function.

Recent technologies in the automation of ship navigation have helped the ship navigators select a collision-free path by using simulations. The data obtained from ARPA was used for this purpose. The simulations provide a possible anti-collision path. Genetic Algorithms were initially proposed for path-finding but were replaced with shortest-path or other general algorithms because GA takes a lot of time to process. But during emergency situations where time delay might not be a constraint, an optimal path must be calculated without wasting any resources. Thus, an algorithm that can solve any of these situations in a computer based simulation, to find possible optimal or near-optimal routes is essential. GA simulation is proposed by the authors to find a path among a large number of possible solutions, which, in such conditions , greatly assist the navigators in plotting the course.

The aim of this paper is to provide a simulation to ship navigation system that enables the use of Genetic Algorithm to find the optimal solution during emergency situations without the need of brute-forcing all possible paths manually.

A simple case [Fig. 1] can be observed where the source is a ship indicated on the left and the destination on the right. The ship has to reach the destination without colliding any obstacles. Multiple routes can be obtained and all paths lead to the destination. But to narrow down to the few solutions that are actually efficient, GA is used in paper. A computer based simulation in this case provides the information about which path is more efficient.

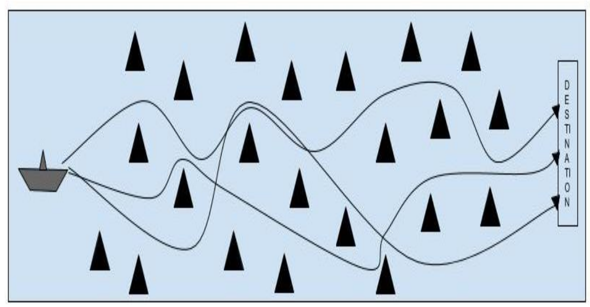

Figure 1. Destination with multiple paths

2. RELATED WORK

Many companies provide GPS system to navigate especially on the roads for vehicles, cyclists and pedestrians. Many works has been done in the field of navigation for ships, planes and vehicles.

As per navigating rules, genetic algorithm can be used for navigation in order to prevent obstacles[1]. ARPA is used to identify the obstacles. During emergency or even during normal times, assessment of impact risk and productivity of a way is taken in a cost function. To stay away from the exploring snags, the first course must be changed with the alter of head course. So keeping the course to promise her coving the offered course to the objective place on time is additionally generally

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essential. For this reason, the head bearing administrator is acquainted with the cost function and her course blunder is considered in closure quality of each chromosome[1].

For navigating without any damage, two different configurations can also be used for the navigation and propulsion system. The initially setup comprises of two established straight PID controllers (one for the route framework and the other for the impetus). In the second setup, a nonlinear Sliding Mode controller gives the route control and a PI directs the impetus[2].The above methods has been optimized using Genetic Algorithm.

Theoretical—At oceanic route, fabricating a viable course accept a few troubles. At the point when the issue zone is huge, seaway is mind boggling and as indicated by common reasons it differs in time, strict course fabricating techniques might be incapable on the grounds that they require excessive time[1,2]. So considering these facts and ensuring the avoidance of such circumstances, Genetic Algorithm is ideally proposed. At times, ships are not ready to explore amid crisis circumstances which brings about mischances and death toll also.

Genetic Algorithm will be connected keeping in mind the end goal to encourage the boats/vessels explore immediately when a crisis happens and assist them with reaching their coveted goal by utilizing the most limited course accessible amid such sort of circumstances.

3. PORPOSED MODELLING

The proposed model discusses the following aspects to achieve the implementation of this simulation and experimental demonstration:

- Software
- Obstacle Plotting
- Initialization of the Population
- Selection
- Reproduction
- Fitness Function
- GA During Critical Conditions

3.1. Software

Processing Programming Language is used in this paper to perform the demonstrative simulations. It is an IDE with graphical library built specifically for digital arts, visual design and media art etc. Its main goal is to provide a platform for non-coders and amateurs to learn and visualize the basics of computer programming and designing. Processing is powered with Java programming language and also is integrated with additional mathematical functions and optimal classes. It also has a graphical user interface for simplifying the compilation and execution stage.

The simulation contains a source and the destination which can be a fixed point or a moving point. The coordinates from the ARPA gives the navigator a idea about where the obstacles are. This data can be transferred to array-list of the code, which maps the obstacles required for further operations. Once the destination and provided obstacles have been plotted, the process for finding the optimal path begins. The simulation uses a smaller time frame for demo purpose. A small population of species are released for 300ms to find the route. As their life-cycle ends, they iterate to next generation using two genetic methods

- ●Crossover
- ●Mutation

All the species that couldn't reach the destination are terminated and it is decided by selecting through the fitness function. The Figure 2 provides the layout of the simulation where the objective of the program is to reach the destination by plotting a path while avoiding the obstacles.

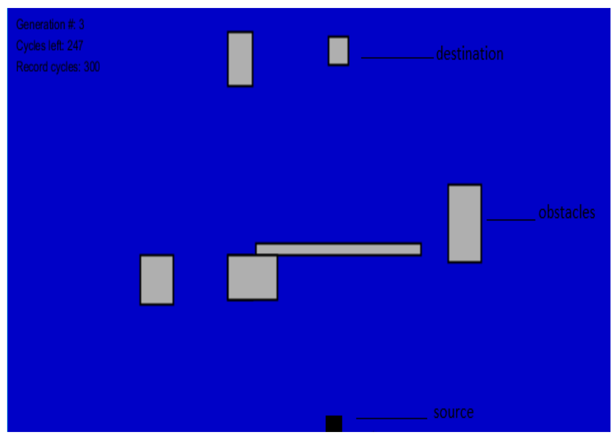

Figure 2. Environment of the simulation

Genetic algorithm follows the following operations that are mentioned below and the Figure 3 gives the idea of the steps involved. When one species reaches the destination, other species keep searching for other solutions. Thus, the longer the simulations runs the more efficient solution is found.

3.2. Obstacle Plotting

The function for obstacles is used for both plotting the obstructions on the course that the ship needs to avoid and also to mark the destination.. The coordinates of the actual obstacles can be simulated in the program using the vector functions and polygons. The Arraylist holds the dimensions of each and every obstacle. This creates a virtual map of the existing naval course. The code snippet below describes the mapping of the obstacles [Figure 4].

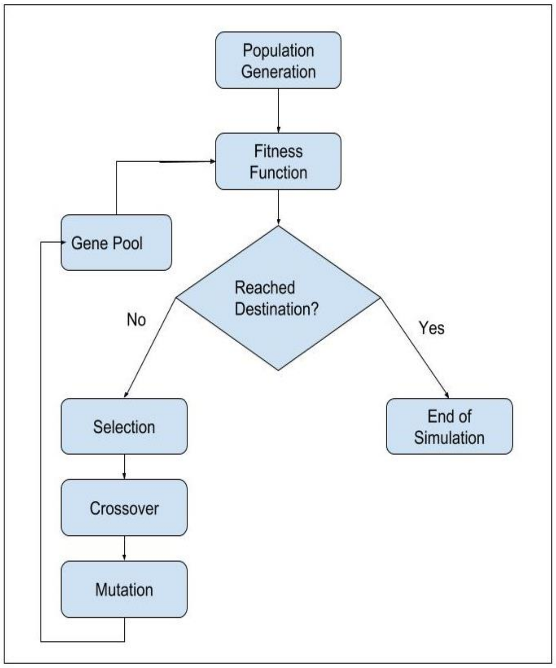

Figure 3. GA flowchart

```
  // Create the obstacle course
  obstacles = new ArrayList<Obstacle>();
  obstacles.add(new Obstacle(300, height/2, width-600, 10));
  obstacles.add(new Obstacle(width/4,460,60,height-80));
  obstacles.add(new Obstacle(width/3,20,30,height/9+2));
  obstacles.add(new Obstacle(width/3,height-height/2+10,30,height/10-2));
  obstacles.add(new Obstacle(width/3,height-height/2+10,60,height/10-2));
  obstacles.add(new Obstacle(width/5,height-height/2+10,40,height/10+2));
  obstacles.add(new Obstacle(2*width/3,height/2-height/8,40,height/6));
}
```

Figure 4. Obstacles Plotting

3.3. Initialization of the Population

First a population of ‘n’ species are created and each species has a randomly generated DNA function that is changed every generation using genetic operations. The population generates new species by iterating the generation and selecting new species after crossover and mutation. The DNA class contains the actual parameters of individual species. The speed of ship, its dimensions, its fuel supply and other constraints are utilized for alter the DNA class to optimize the results accordingly.

3.4. Selection

The selection process is done by evaluating the fitness or success of each species among the population and building a mating pool for next generation iteration. All the species that passed the fitness function (i.e not hitting the obstacle) are gathered into the mating-pool. The parents are selected from the pool and are morphed into new children by using crossover and mutation operators.

3.5. Reproduction

The reproduction process involves the selection of two relatively fit parents from the mating pool. First, The parents(or the ship path) is cropped into a new path using Crossover function[Fig. 4]. Later, the mutation function[Fig. 5] is used for mutating the DNA for minute path deviation. The new child is added to a new population and the generation is iterated. The next generation has species that are crossed over and mutated from the previous generation and process continues till destination is reached.

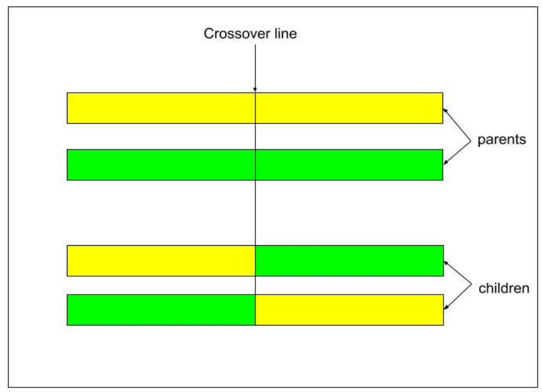

Figure 5. Crossover of selected parents

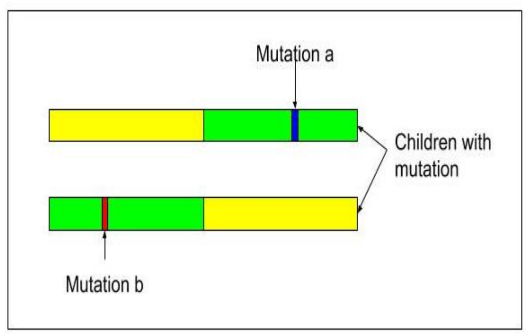

Figure 6. Mutation after crossover

3.6. Fitness Function

The selection of species for next iteration is greatly determined by the fitness function of the program. The goal of the ship or the species is to reach the target. The fitness of such species depends on how close it has reached the destination. Thus, as the species goes closer to the destination, it’s fitness gets higher. Inversely, if the species is far from the destination, it’s fitness is less. The fitness is calculated and used as a parameter to select the next iteration of species

The flowchart [Fig. 7] specifies the step by step proposal of this paper. With the help of the simulation software the navigator can guide the ship in a more effective way.

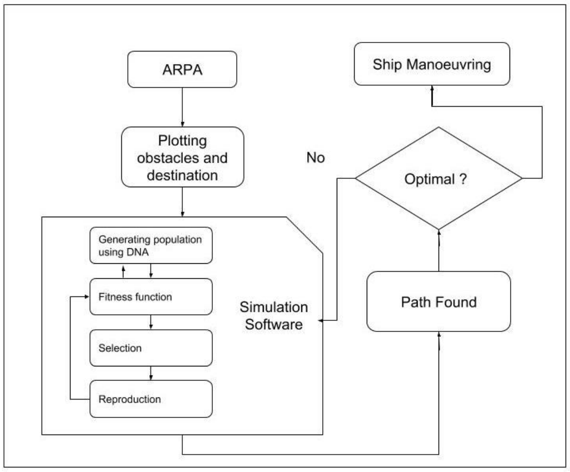

Figure 7. Route Planning Architecture

3.7. GA During Emergency Situations

During Emergency situations, such as low fuel or less time. The GA can be altered to optimize the results.

The size of the working field can be altered along with the life time of each simulation. This indicates the time duration taken for every ship route to reach the destination. The default time demonstrated in the simulation is 300ms. Similarly, if existing paths cannot reach the destination. All random possible paths can be traveled by increasing the mutation rate which is set to 0.01. The DNA function contains the configuration of the ship as in its size, maximum force, angles of rotation etc. The maximum force or current speed can be different due to any external damage. These alterations can be used as constraints to find optimal or near optimal path without the loss of fuel or any damage due to collision.

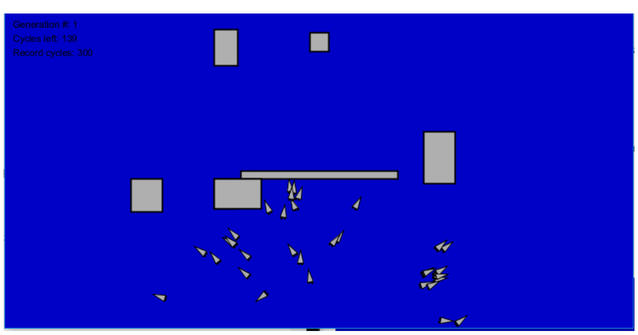

Figure 7. Starting of Simulation.

The path-finding simulations are observed over multiple generations and the images [Fig. 7] and [Fig. 8] are the snapshot of beginning and ending of the simulation. At the beginning the species randomly travel through all possible paths and after certain generations of crossover and mutation the destination is finally reached by learning the optimal path using this evolutionary algorithm.

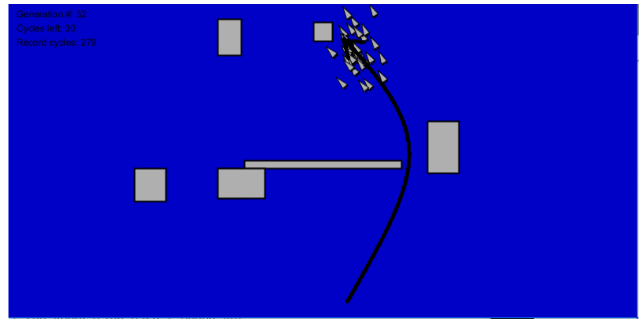

Figure 8. End of Simulation.

4. RESULTS AND DISCUSSIONS

The results can be summarized into two sections. They are as follows:

- At Constant Mutation Rate
- At Constant Lifetime

4.1. At Constant Mutation Rate

In favour to quicker demonstration, the simulation was made to run on a few obstacles [Fig. 7] and lifetime of each cycle is observed in milliseconds. This can be scaled up to actual parameters in real-time situations. The first table [Table 1] contains the time taken for the simulation to complete at various Lifetime. The lifetime indicates the minimum time the ship has to reach the destination (low fuel situation). As observed, the simulation takes lesser time when the ship has more time to spare and during less lifetime, the simulation time increases exponentially but by using GA, we are able to try all possible paths. The mutation rate is kept same throughout the trials. The time duration highlighted in bold indicates the shortest time taken for the simulation to complete, indicating that at 600ms lifetime, the ship has very less risk of running out of fuel before reaching the destination as it has plenty of time. At lesser lifetime, the simulating time is high, as it is difficult to find out a path that can reach the destination in less than 300ms.

Simulation Time	Lifetime in millisecond
00:01:59:68 00:02:04:44	300
00:02:14:97 00:02:10:12	400
00:00:47:72 **00:00:32:00**	600

00:01:22:62 00:01:10:23	1000

Table 1. Simulation time during constant mutation rate.

4.2. At Constant Lifetime

The Table 2 contains the simulation time during constant lifetime of 600 ms. During situations when there are countless paths or solution to the destination, the only method of finding optimal path for the ship is by brute-forcing the actual path among all paths. If the path has lesser obstacles, then by upgrading the mutation rate, solution can be found even quicker. The mutation rate must be kept balanced with the lifecycle as higher mutation rate would cause random species to be created for every generation. This will explore all the map randomly but the species do not evolve efficiently after every generation. The Simulation time highlighted in bold indicates the fine use of mutation rate which can ease the complexity of search time. But once the rate goes higher , the search time increases exponentially.

Simulation Time	Mutation Rate
00:00:56:12 00:00:42:03	0.01
00:01:26:00 00:01:02:65	0.02
00:00:31:76 00:00:46:07	0.06
00:00:27:16 00:00:50:34	0.1

Table 2. Simulation time during constant Lifetime.

5. CONCLUSION

The paper, thus, provides the need for an evolutionary algorithm such as GA as an aid for naval navigation during critical conditions. Navigators, with the help of such simulations can plot more accurate and optimal paths without wasting ship resources. The demonstration proves the path-finding ability of GA using evolutionary methods. Grid containing more complex paths and obstacles with large number of solutions can be easily brute-forced with the help of GA as used in the simulation.

REFERENCES

[1] Xiao-ming Zing,Masanori Ito and Etsuro Shimizu-"Planning and keeping the safe course to avoid collision at sea with Genetic Algorithm."
[2] Eva Alfaro-Cid, Euan W. McGookin and David, J.Murray-Smith- "Genetic Algorithm Optimization of a supply ship propulsion and Navigation System."
[3] I.A.Yanchin,O.N.Petrov-" Parallel Genetic Algorithm for building a route for the vessel."
[4] Sanaa M. Alhalabi,Sokyna M. Al-Qatawneh,Dr. Venus W. Samawi - "Developing A Route Navigation System Using Genetic Algorithm.". New York: McGraw-Hill, 1964, pp. 15–64.
[5] Miha Kovacic,Joze Balic,Miran Brezocnik-"Genetic Algorithm Approach for Autonomous Vehicles."
[6] Hitoshi Kanoh Nobuaki Nakamura-"Route Guidance with Unspecified Staging Posts Using Genetic Algorithm for Car Navigation Systems."
[7] Jie Duan, Maoli Wang, Yan Jiang, Jingbo Zhao, Yongwei Tang-"A Compound Fuzzy Control Method for Agricultural Machinery Automation Navigation Based on Genetic Algorithm."
[8] Masaya Yoshikawa, Hidekazu Terai-"Car Navigation System based on Hybrid Genetic Algorithm."
[9] Vanja Brkljač, Ljiljana Brkić-"Navigating Pre-recorded Off-road Routes Using a Mobile Device."
[10] Colley B.A, Stockel C.T.- "Marine Traffic Flow and Collision Avoidance Computer Simulation."
[11] Lamb W.G.P.- "The Calculation of Marine Collision Risks."
[12] Smierzchalski R, "The Decision Support System toDesign the Safe Maneuver Avoiding Collision at Sea."
[13] Zha J. Wang P. and Wu Z.v.-"The Development of Ship Collision Avoidance Automation."
[14] Smierzchalski R- "Multi-Criterion Modeling the Collision Situation at Sea for Application in Decision Support."
[15] Hara K.- "On Shipboard Use of the Intelligent Ship Concept for Safe Navigation."