International Journal of Electrical and Electronics Engineers
Vol. No. 10, Issue No. 01, Jan-June 2018
ISSN (O) 2321-2055
ISSN (P) 2321-2047

N-D SEARCH ALGORITHM FOR THE AUTONOMOUS SURFACE VEHICLE FROM THE SHIP OFFSET PATH

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ABSTRACT

The foreign ships that are parked in the ocean carry out many illegal activities like carrying radioactive materials etc. These activities need to be mapped by remotely monitoring the foreign ship using autonomous surface vehicle (ASV) which will move without human assistance around the ship carrying a sensor. Given the remote path to be followed by ASV, ASV placed at any random point has to find the closest point on the pre-determined remote path and then follow the path. This paper addresses the issue of finding closest point on the pre-determined remote path of any random shape. We also discuss the advantages of the method mentioned in the paper.

Keywords: *autonomous surface vehicle, remote monitoring, offset perimeter, N-D search method*

I. INTRODUCTION

The foreign ships that are parked in the ocean carry out many illegal activities like carrying radioactive materials etc. These activities need to be mapped by remotely monitoring the foreign ship using autonomous surface vehicle (ASV) which will move without human assistance around the ship carrying a sensor. Given the remote path to be followed by ASV, ASV placed at any random point has to find the closest point on the pre-determined remote path and then follow the path (See Fig 1)

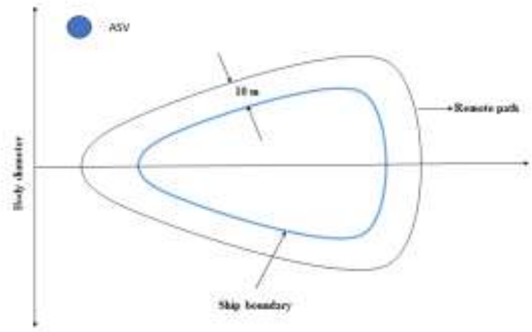

Fig 1 Random position of ASV w.r.t. the random path

In the ocean, where the ship co-ordinates are known, the remote path was generated with an offset of 10 meters from the ship boundary. Thus the remote curve is known to us. The ASV position is obtained with the help of GPS. The real question is to now find out the nearest point on the remote curve and reach to the point. If the ASV is to take any randomly detected point on the remote path, there is a possibility that the ASV may crash onto the ship thus leading to the complete failure of the mission.

The issue of nearest point finding method has received considerable critical attention. From the considerable amount of literature available on the nearest point finding algorithm, mentioned below are some of the control methods to carry out path designing:

As per the model mentioned in this paper [1], given a curve C and a point p, to find a point on C nearest to p or farthest from p, assuming a pre-determined bound on the speed of the curve, the answer can be estimated up to an additive error of ε using $O(1/\varepsilon)$ samples. However, many instances can be solved with substantially less number of samples. Results in this paper give asymptotically tight bounds on the absolute-error nearest-point-on-curve and farthest- point-on-curve problems in the adaptive framework. It is seen that there are almost tight bounds in the relative-error setting.

In this paper [2], a new fast iterative algorithm for support vector machine (SVM) classifier design is discussed. The problem of computing the nearest point between two convex polytopes is addressed. The study of the suitability of two classical nearest point algorithms, due to Gilbert, and Mitchell et al, ideas from both these algorithms are combined and modified to derive the proposed fast algorithm. For problems which require classification violations to be allowed, the violations are quadratically penalized and an idea due to Cortes and Vapnik and Frieß is used to convert it into a problem in which the classification violations are absent.

The authors [3] have presented an accurate method to compute the minimum distance between a point and the curve called as an elliptical torus. This is called the orthogonal projection problem. The idea is to transform a geometric problem into finding the unique real solution of a quartic equation. This equation needs to be fit for orthogonal projection of a point onto the elliptical torus. This proposed method proved to be an accurate method for the orthogonal projection problem of how to compute the minimum distance between a point and the elliptical torus for any kind of positions. But the authors did not concentrate more on developing a method to compute the minimum distance between a point and a general completely central symmetrical surface.

This paper [4] presented an accurate and also an efficient method for computation of the closest point on parametric curves. This problem is firstly formulated in terms of solution of a polynomial equation expressed in Bernstein basis, and then based on subdivision relying on the convex hull property of Bézier curve and the recursive bintree decomposition on the parameter domain, an ideal solution method is proposed. The computation of closest point is shown to be equivalent to the geometrically intuitive intersection of a curve with the parameter line. Finally, by comparing the distances between the test point and the candidate points, the closest point is found.

Despite their computational efficiency, the drawbacks like complexity in calculations of the methods surveyed above lead to their failure to achieve the challenge faced by us. Thus the method proposed in this paper solves the problem using minimum computations thus improving efficiency in terms of time and is described in section II.The simulations of these methods are done in MATLAB.

II. N-D SEARCH METHOD EXPLANATION

The Given the co-ordinates of points along the developed remote path which are 10m away from the ship boundary, the central question of the paper asks how the ASV will identify its closest point to the remote. To find the nearest point, the methods like nearest neighbor search and N-D (nearest distance) search were of interest to us. We chose N-D (nearest distance) search for its simplicity in the implementation.

The remote curve also known as an offset curve was derived based on cubic spline method and was given by:

$$S(x) = A + Bx + Cx^2 + Dx^3 \qquad (1)$$

where A, B, C and D are the coefficients of the polynomial

Thus for every x, there was a corresponding S value which constituted the remote co-ordinates that could be denoted by y.

The N-D search algorithm to find the closest point on the curve for the ASV to start its mission is mentioned below:

Step1: Known are the N points (x_1, y_1), the distance of ASV co-ordinates (x_2, y_2) in inertial frame [8] from each of the points on the remote path is calculated.

The Pythagoras Theorem to derive a formula for finding the distance between two points (ASV co-ordinate and the point on the curve) in 2D space.

Let $P = (x_1, y_1)$ and $Q = (x_2, y_2)$ be two points on the Cartesian plane (See Fig 2)

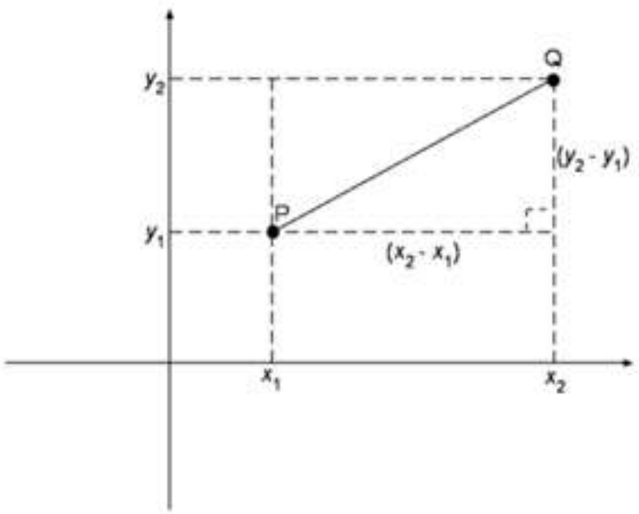

Fig 1 Distance between the two points

Then from the Pythagoras Theorem, the distance between P and Q is derived to be

$$PQ = \sqrt{((x_2 - x_1)^2 + (y_2 - y_1)^2)} \quad (2)$$

Step 2: from the set of distances calculated at each point, the minimum of the distance is calculated by comparing all the calculated distances. Thus the nearest point is achieved.

Step 3: using the heading controller of the ASV, the yaw angle is calculated [9]. Based on the turning radius of the ASV, ASV travels to the nearest point and completes the pre-defined mission given to the ASV controller.

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III. SIMULATIONS

The simulation of this method was conducted using the following parameters mentioned below (See Table I).

TABLE I. PARAMETER SPECIFICATION

Parameter	Value	Description
a	80 m	Full length of the vessel
d	20 m	Maximum hull diameter
n	2	Exponential coefficient
u	1.2 m/s	Forward speed of ASV

The ship profile is generated using a myring hull [9] profile given by

$$R(x) = \frac{1}{2} * d * \left[1 - \left[\frac{x-a}{a}\right]^2\right]^{\frac{1}{n}} \qquad (2)$$

IV. RESULTS

In Fig 3, the path marked in red shows the ship boundary and the blue path denotes the remote path to be followed by ASV.

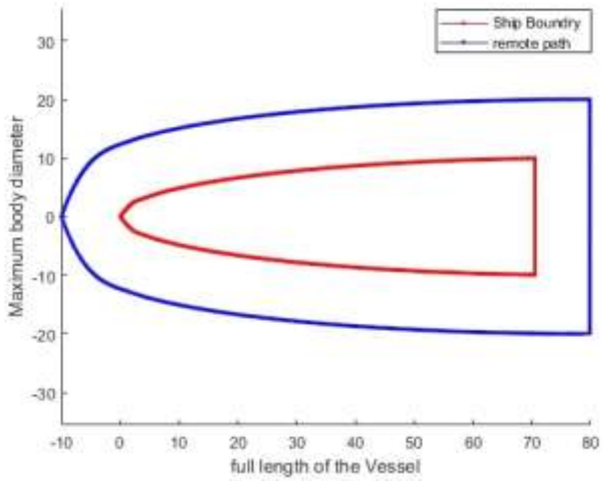

Figure 3 The Remote path around the Ship boundary

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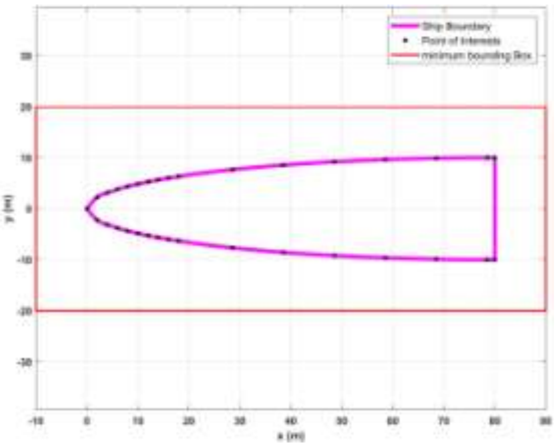

Below are the results of the simulation of ASV conducted in MATLAB considering different positions of the ASV (See Fig 4, 5 & 6).

4.1. ASV placed at (80,-30)

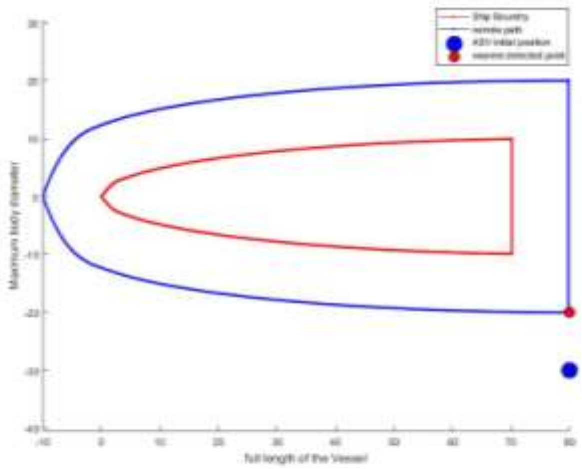

Figure 4 ASV placed at (80,-30)

4.2. ASV placed at (-20,0)

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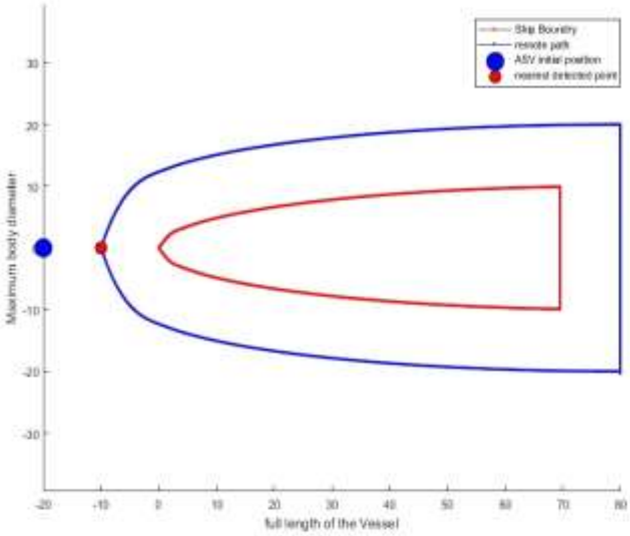

Figure 5 ASV placed at (-20,0)

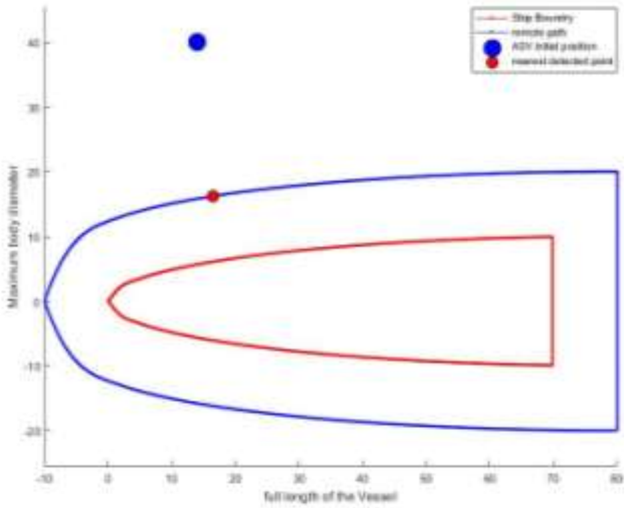

Figure 6 ASV placed at (14,40)

V. CONCLUSION

As can be seen from the output graphs, the N-D search algorithm correctly calculates and compares the distance from each point on the ship offset perimeter. It correctly gives the nearest point on the offset ship boundary by comparing the distance between any location co-ordinates of ASV and each of the offset coordinate. The co-ordinate of the nearest point is correctly achieved thus successfully keeping the ASV away from entering close to the parked ship initially. The advantage of this method is it serves the expected results with lesser complex computations although it may take comparatively longer time for its computations.

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