

Prudent Ship Pilotage Using Trial Maneuver

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Abstract

Trial Maneuver is a graphical simulation facility provided by the Advanced Tactical Display (ATD) system which helps the ship operator to visualize the future positions of all the tracked targets relative to the own ship based on the changing position of own ship. Thus it helps in effective and safe maneuvering of the ship by avoiding collisions.

Key Words: Trial Maneuver, ship pilotage, ATD.

I INTRODUCTION

The Advanced Tactical Display (ATD) system receives and processes data from onboard ship sensors and displays an unambiguous tactical picture on a Dual Multi Function Console (DMFC). ATD provides facilities for surface surveillance, navigation, helicopter control, electronic chart feature and other mission critical warfare functions and assists the ship staff in the decision making process. The ATD system is designed primarily for small modern warships. Ship data as well as tracked target data is presented on the display. ATD is interfaced with four RADAR systems and has a Video Extractor and Tracker (VEXT) which generates surface and air targets.

Trial Maneuver is one of the Automatic Radar Plotting Aid (ARPA) features implemented in ATD system and is used in navigation for collision avoidance. Trial Maneuver simulates the effect of an own ship maneuver on all tracked targets with or without time delay. While Trial Maneuver is switched ON, actual target tracking continues in the background without any interruption.

The Trial Maneuver feature has been designed and developed indigenously at Bharat Electronics, Bangalore and integrated with the ATD system. This paper presents the brief description of Trial Maneuver simulation and also explains about its implementation.

II TRIAL MANEUVER

Trial maneuver feature has been designed for both true mode and relative mode of the ship Plan Position Indicator (PPI) display. In true mode, actual position of the own ship is displayed with its actual speed. Targets are also displayed with their actual velocity vectors in the true mode. In relative mode the own ship position is always at the center of PPI and targets are displayed with their relative velocity vectors. Using Trial Maneuver the operator can vary the speed, course and simulation time(delay) of the own ship and see at what course and speed the ship needs to be steered in order to avoid collision with the surrounding targets/vessels. To predict a potential close-quarters situation, we make use of Closest Point of Approach (CPA) and Time to Closest Point of Approach (TCPA) concepts.

1 CPA and TCPA

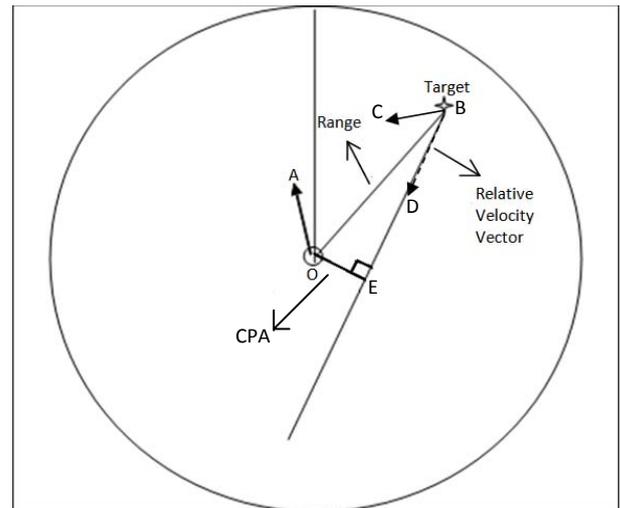


Figure 1 PPI showing CPA and TCPA

In the above figure, O represents the own ship and B represents a target. OA represents the own ship velocity vector. BC represents the target's true velocity vector. BD is the relative velocity vector of target B w.r.t. the own ship and is extended further in its direction. The perpendicular distance OE represents the closest point of approach between the own ship and the target B. The time taken for both the ships to come to their closest point of approach is called TCPA. These are the prime parameters in determining potential collision situations.

2 Conventions Used in TM display

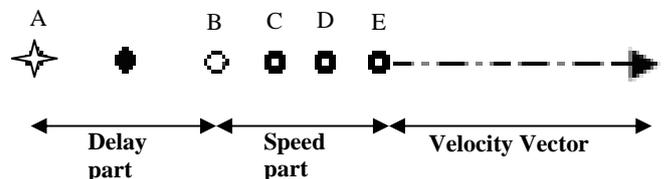


Figure 2 Trial Maneuver Display Conventions

The star shaped figure at point A represents the target/ ship center whichever the case may be. The points A, B, C, D and E represent the future positions of the target/own ship whichever the case may be. E represents the predicted final position of the target/own ship whichever the case may be. The distance AB represents the Delay part. The distance BE represents Speed part. The

distance BC is called Leg1. The distance CD is called Leg2. The distance DE is called Leg3. The line originating from E is the velocity vector. There are 2 legs for the target and 3 legs for own ship in the speed part Trial Maneuver representation.

III TRIAL MANEUVER IN TRUE MODE

In true mode of the PPI, the ship center moves in the direction of its course till 70% radius of the PPI and reverts back to 30% radius of the PPI and this cycle repeats. Hence in this mode we can visually see the position updation effect of the Trial Maneuver simulation on both the own ship as well as the tracked targets.

1 Trial Delay

Trial delay is the time for which the operator can view the Trial Maneuver simulation. This delay keeps decrementing with time till it reaches zero at which point the simulation comes to an end. Trial delay is operator configurable and its default value is 10 minutes. Trial delay is meant to provide the operator sufficient time to make a decision about the own ship maneuver. The trial delay value keeps decrementing as time elapses and hence the distance between A and B (from Figure 2) also decreases correspondingly. Finally when the trial delay becomes zero, the points A and B coincide with the target's current position itself.

2 Trial Speed

Trial speed is the probable future speed of the own ship and can be configured by the operator to a suitable value. The distance navigated by the ship with trial speed is represented by another set of points (C, D and E in Figure 2) which are placed beyond the dots which represent the trial delay. If the speed is increased, the distance between C, D and E also increases and viceversa. Trial speed can be varied and the corresponding effect on the target's future position can be observed in real time. The own ship's current Log/Speed will be the default value for Trial Speed when Trial Maneuver is first switched ON.

3 Trial Course

Trial course is the future predicted course of the own ship and can be configured by the operator to a suitable value. The trial course is represented by the angle in which C, D and E (from figure 2) are positioned beyond the delay points. A change in trial course of the own ship results in a change in the angle of C, D and E with respect to true north (which is at the 12 o'clock position). The velocity vector of the own ship also points at this new course whereas the angle of C, D and E of the targets as well as their vector heads remain unchanged in direction with change in trial course in true mode. The own ship's current Gyro/Course will be the default value for Trial Course when Trial Maneuver is first switched ON.

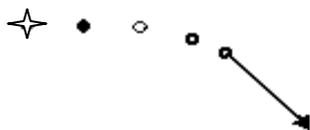


Figure 3 Effect of trial course on target vector emerging out from the predicted future position of the target.

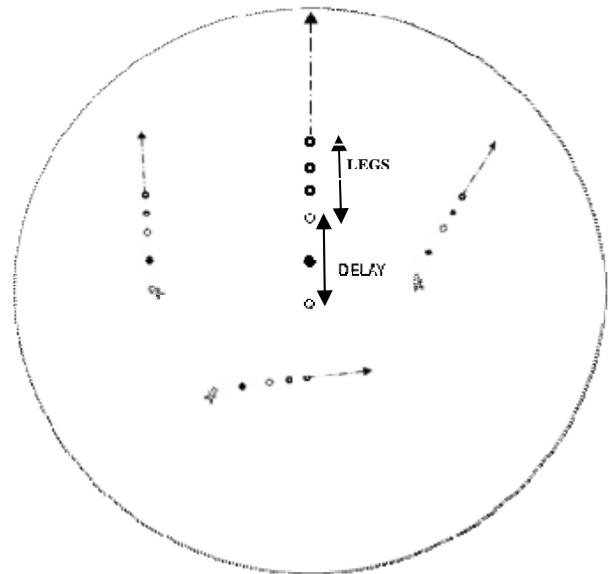


Figure 4 Trial Manoeuver in True mode

IV TRIAL MANOEUVRE IN RELATIVE MODE

In the relative mode of operation, since the own ship position is fixed at the center of the PPI, the delay part and speed part can be observed only for the targets and not for the own ship. Points for the delay part and speed part are not shown for the own ship in this mode. A vector originating from the center of the PPI represents the own ship trial speed and trial course. This vector's length corresponds to the trial speed and its direction corresponds to the trial course. In this mode, the course represented by the target vector is actually the relative course of that target w.r.t. own ship and the length of the target vector corresponds to its relative speed w.r.t the own ship.

1 Trial Delay

Trial delay is the time for which the operator can view the Trial Maneuver simulation. This delay keeps decrementing with time till it reaches zero at which point the simulation comes to an end. The trial delay can be adjusted by the operator as per the requirement. Trial delay is to provide the operator, sufficient time to make a decision about maneuver. The distance between A and B (from the figure 2) shows the relative distance traveled by the target (with its actual speed in its actual course) in the set delay time. Change in the delay time will correspondingly increase or decrease this distance.

2 Trial Speed

In relative mode, change in own ship's speed leads to a change in both the target's relative speed as well as its relative course. The effect can be seen on own ship velocity vector and target's velocity vector even without a change in the trial course. The own ship's current Log/Speed will be the default value for Trial Speed when Trial Maneuver is first switched ON.

3 Trial Course

Change in the trial course results in change in the direction of the own ship vector and also change in the direction of the speed part of the target correspondingly. The own ship's current Gyro/Course will be the default

value for Trial Course when Trial Maneuver is first switched ON.

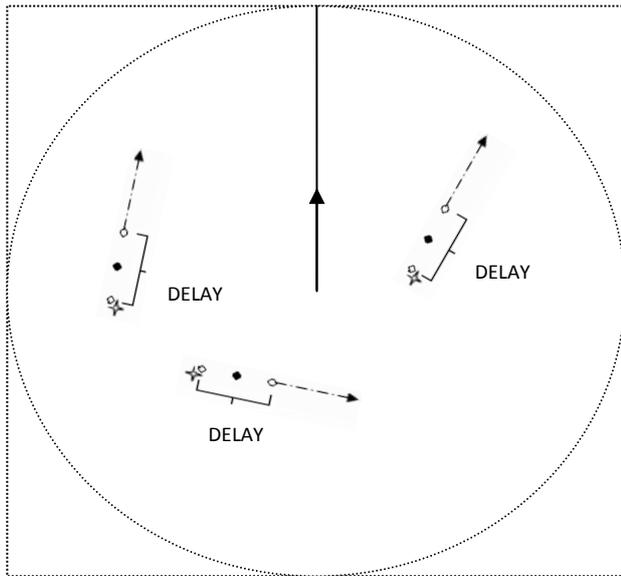


Figure 5 Trial Maneuver in Relative mode

V IMPLEMENTATION OF TRIAL MANEUVER

Firstly CPA and TCPA limits are set for the own ship by the ship operator. These values are carefully decided. When an automatically tracked target violates both the CPA and TCPA limits set for the own ship, then the collision warning alarm is raised. A red coloured triangle encompassing the target is displayed (to give a visual alarm indication to the ship operator) as long as the target violates the CPA and TCPA limits. Trial Maneuver is switched ON at this point in order to plan a course of action to avoid collision with the violating targets.

A menu on the GUI consisting of soft controls to vary the Trial Speed, Trial Course and Trial Delay pops up when TM is switched on.

1 Trial delay calculation for own ship

Initial calculation is to predict own ship's position after 10 minutes (default trial delay time). For these calculations, the own ship actual parameters are taken. The distance 'Ds' traveled by own ship in 10 minutes is given by

$$Ds = \text{own_ship_speed} * 10/60 \text{ (per hour)} \quad (1)$$

Resolving this distance in X and Y components wrt actual own ship position and true north, we get

$$Ds_x = Ds * \text{Cos}(\text{OwnShipCourse}) \quad (2)$$

$$Ds_y = Ds * \text{Sin}(\text{OwnShipCourse}) \quad (3)$$

Ds_x and Ds_y give the point B (from Figure 2) for the own ship.

2 Trial delay calculation for target

Target's position after 10 minutes is calculated. For these calculations target's actual parameters are taken. Let the initial Range and Bearing of target from own ship be R and B.

Expressing R and B of the target in terms of X and Y components we get,

$$X = R \text{ Cos} (B) \quad (4)$$

$$Y = R \text{ Sin} (B) \quad (5)$$

The distance traveled by target in 10 Minutes is,

$$Dt = \text{target_speed} * 10/60 \text{ (per hour)} \quad (6)$$

Resolving this distance in X and Y components,

$$Dt_x = Dt * \text{Cos}(\text{target_course}) \quad (7)$$

$$Dt_y = Dt * \text{Sin}(\text{target_course}) \quad (8)$$

Target's extended position coordinates from equations (4),(5),(7) and (8) are

$$\text{New_x} = X + Dt_x \quad (9)$$

$$\text{New_y} = Y + Dt_y \quad (10)$$

New_x and New_y give the point B (from Figure 2) for the target. The trial delay value keeps decrementing till it reaches zero at which time the Trial Maneuver simulation comes to an end. Hence the above calculations are repeated as trial delay ticks down every second using the most recent values of target and own ship parameters.

3 Trial course and Trial speed calculations for own ship

The effect of varying the trial speed and trial course is shown by the position of the points C, D and E (from Figure 6).

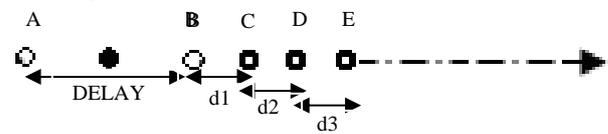


Figure 6 Speed part split into legs for own ship

In Figure 6, d1 is the distance between B and C, d2 is the distance between C and D and d3 is the distance between D and E. If both Trial Speed and Trial Course are changed, or if Trial Speed alone is changed, or if neither Trial Speed nor Trial Course are changed (i.e., if default values are taken), then the time factor 't' is given by

$$t = |ts - os|/A \text{ (in hours)} \quad (11)$$

where A = acceleration of own ship, ts = Trial Speed, os = own ship speed. If Trial Course alone is changed, the time factor 't' is given by

$$t = (dc / (\text{ROT} * 60)) \text{ (in hours)} \quad (12)$$

where (Rate Of Turn) ROT varies from one ship to another (unit is deg/min) and 'dc' is the difference in course given as

$$dc = (360 - \text{OwnShipCourse} + \text{TrialCourse}) \text{ modulo } 360 \quad (13)$$

If (dc > 180) then,

$$dc = -(360 - dc) \quad (14)$$

The difference in speed 'ds' is calculated as

$$ds = ts - os \quad (15)$$

From equations (11),(12) and (15) we get,

$$d1 = (os + (ds/3)) * (t/3) \quad (16)$$

$$d2 = (os + (2*ds/3)) * (t/3) \quad (17)$$

$$d3 = (os + ds) * (t/3) \quad (18)$$

Resolving distance d1 in X and Y components,

$$d1_x = d1 * \text{Cos}(\text{ownShipCourse} + dc/3) \quad (19)$$

$$d1_y = d1 * \text{Sin}(\text{ownShipCourse} + dc/3) \quad (20)$$

Therefore from equations (2),(3), (19) and (20), point C (in Figure 6) is given by

$$[(Ds_x + d1_x), (Ds_y + d1_y)]$$

Resolving distance d2 in X and Y components,

$$d2_x = d2 * \text{Cos}(\text{ownShipCourse} + (dc*2/3)) \quad (21)$$

$$d2_y = d2 * \text{Sin}(\text{ownShipCourse} + (dc*2/3)) \quad (22)$$

Therefore from equations (2),(3),(19),(20),(21) and (22), point D (in Figure 6) is given by

$$[(Ds_x + d1_x + d2_x), (Ds_y + d1_y + d2_y)]$$

Resolving distance d3 in X and Y components,

$$d3_x=d3* \text{Cos}(\text{ownShipCourse} + (dc)) \quad (23)$$

$$d3_y=d3* \text{Sin}(\text{ownShipCourse} + (dc)) \quad (24)$$

Therefore from equations (2),(3),(19),(20),(21),(22),(23) and (24), point E (in Figure 6) is given by

$$[(Ds_x + d1_x + d2_x + d3_x), (Ds_y + d1_y + d2_y + d3_y)]$$

4 Trial course and Trial speed calculations for target

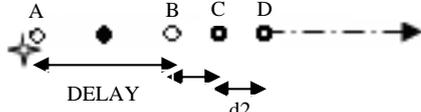


Figure 7 Speed part split into legs for target

Only two legs d1 and d2 are implemented for targets. Equations (11), (12), (13), (14) and (15) remain same for the purpose of the following calculations.

Speed of target while travelling from point B to C (from Figure 7) is

$$fLeg1\text{Speed} = os + (ds/2) \quad (25)$$

Speed of target while travelling from point C to D (from Figure 7) is

$$fLeg2\text{Speed} = os + ds \quad (26)$$

Course of target while travelling from point B to C (from Figure 7) is

$$fLeg1\text{Course} = (360 + \text{OwnShipCourse} + dc/3) \text{ modulo } 360 \quad (27)$$

Course of target while travelling from point C to D (from Figure 7) is

$$fLeg2\text{Course} = \text{TrialCourse} \quad (28)$$

Therefore from equations (11), (12), (25) and (26),

$$d1 = fLeg1\text{Speed} * t/2 \quad (30)$$

$$d2 = fLeg2\text{Speed} * t/2 \quad (31)$$

Resolving distance d1 in X and Y components,

$$Td1_x = \text{Leg1Dist} * \text{Cos}(fLeg1\text{Course}) \quad (32)$$

$$Td1_y = \text{Leg1Dist} * \text{Sin}(fLeg1\text{Course}) \quad (33)$$

Resolving distance d2 in X and Y components,

$$Td2_x = \text{Leg2Dist} * \text{Cos}(fLeg2\text{Course}) \quad (34)$$

$$Td2_y = \text{Leg2Dist} * \text{Sin}(fLeg2\text{Course}) \quad (35)$$

Therefore point C (in Figure 7) is given by

$$[(\text{New_x} + Td1_x), (\text{New_y} + Td1_y)]$$

Therefore point D (in Figure 7) is given by

$$[(\text{New_x} + Td1_x + Td2_x), (\text{New_y} + Td1_y + Td2_y)]$$

Once the final positions of the target are so obtained, CPA and TCPA of target final position w.r.t. own ship is calculated to check for violation. The red triangle drawn encompassing the target persists as long as such a violation exists.

The velocity vectors are straight lines drawn at the predicted final position of the target or the own ship whichever the case may be. The length of the velocity vector depends on the Trial Speed and the direction of the vector depends on the Trial Course.

The above calculations hold good for any PPI mode except for the fact that true speeds and true courses (for own ship and targets) are to be considered while implementing Trial Maneuver for True Mode and relative speeds and relative courses (for own ship and targets) are to be considered while implementing Trial Maneuver for Relative Modes of PPI.

Trial manoeuvre algorithm is indigenously designed and developed at BEL, Bangalore and it has been implemented in Indian naval project ATD (Advanced Tactical Display). ROT (Rate of turn) of the own ship is taken into consideration in this algorithm for smooth projection of own ship path and relative paths of tracks.

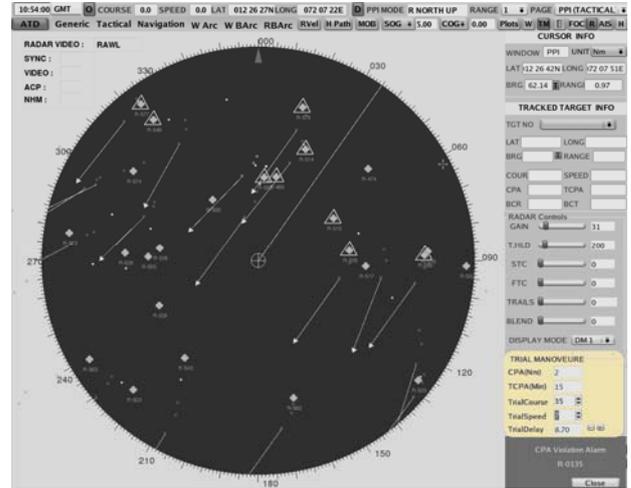


Figure 8 Screenshot of Trial Maneuver in Relative North up mode of PPI as implemented in project ATD

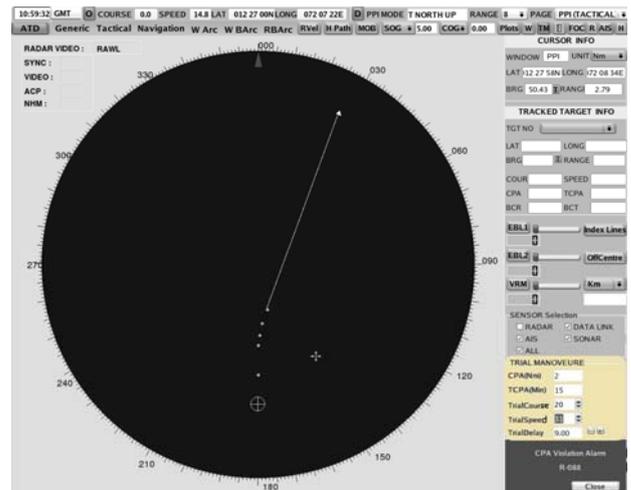


Figure 9 Screenshot of Trial Maneuver in True North up mode of PPI as implemented in project ATD

VI FEATURES OF TRIAL MANEUVER

- Trial manoeuvre indicates collision warning considering CPA, TCPA of targets with respect to ownship. When the TM feature is selected from the menu bar of the ATD display, it displays the vectors of all targets as well as the own ship. The targets which can cause collision in future are surrounded by red triangular symbol that keeps blinking so as to alert the operator.
- Trial manoeuvre predicts the future positions of own ship and tracks and displays the path taken by the targets and own ship to get to these future positions. Each path is broken into multiple legs in order to precisely depict the path.
- Trial manoeuvre functionality works in 5 different PPI modes to give the operator a better picture of the

maneuver. They are Relative North Up, Relative Head Up, Relative Course Up, True North Up, True Course Up modes.

During the TM simulation trial speed can be varied from 0 to 100 knots in intervals of 1knot, trial course can be varied from 0 to 360 degree in intervals of 5 degrees and trial delay can be varied from 0 to 60 minutes in intervals of 1 minute.

CONCLUSION

With the help of Trial Maneuver, the operator selects the required speed and course of ownship and observes the corresponding effect on the targets surrounding the own ship. TM effectiveness can be checked by observing:

- (a) *The true motion* of all relevant targets (to ensure early detection and identification of target manoeuvres).
- (b) *The relative motion* of all relevant targets to check for the fulfilment of the forecast nearest approach.

In any potential collision situation, particularly in restricted visibility, the interpretation of displayed radar information facilitates the determination and execution of action to avoid close-quarters situations.

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