

Method and Device for Determining and Representing
Possible Target Parameters

The invention relates to a method for determining and
5 displaying possible target parameters that are
determined by the directionally selective reception of
sound waves of the type mentioned in the preamble of
claim 1, as well as a corresponding device according to
the preamble of claim 9.

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Conventionally, sound waves of target noise emitted by
a target, e.g. a surface ship or a submarine, are
received by a carrier vehicle, such as e.g. a surface
ship or a submarine, using a sonar receiving system,
15 and the bearing angle to said target is measured in
order to determine target parameters such as target
course, target speed and target range of said target.
Assuming a uniform target motion, i.e. the target is
moving with constant course and constant speed, a
20 target position is estimated from the measured bearing
angles taking into account the known position of the
carrier vehicle and an estimated bearing angle
associated with said estimated position is calculated.

25 Methods for determining the target parameters are known
from DE 101 29 726 A1 and DE 103 52 738 A1. Here the
difference between measured and estimated bearing
angles is minimized over a plurality of processing
cycles using an iterative computing process. When the
30 difference falls below an error limit, the underlying
estimated position is recognized as a target position
whose parameters then also provide the target
parameters being sought.

35 Depending on the method used the target parameters are
optimized according to a predetermined optimizing
criterion. The target parameters obtained thus relate
to a solution optimized according to said optimizing

criterion that converges earlier or later with the actual correct solution.

5 However, said known methods determine only one solution that is given to an operator of the sonar receiving system. This is the best solution in each case, but how likely it is that the optimized solution is also the correct solution cannot be known.

10 DE 10 2008 030 053 A1 shows another method for determining target parameters that determines a quality indicator for each target parameter for the supposed best solution, i.e. the solution optimized according to a predetermined optimization criterion, wherein the
15 distribution of said quality indicator of each target parameter gives information about the reliability of the optimized solution.

20 For displaying the solution, the entire solution space is displayed in two-dimensional or three-dimensional diagrams on a separate display for each target parameter, i.e. the quality measure is respectively plotted against all assumed target courses, target ranges and/or target speeds.

25 Said method has the disadvantage, however, that the additional display means and a plurality of individual diagrams could overload the operator of a sonar receiving system.

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The object of the invention is to provide a simplified display of possible target parameters, which also displays the reliability of the possible target
35 parameters.

The invention solves this problem with a method according to claim 1 and with a device according to claim 9.

5 According to the conventional method described above for determining the solution optimized according to a predetermined optimizing criterion for target parameters, especially a target range, a target course and/or a target speed, target tracks are calculated for
10 a plurality of possible solutions for the target parameters to be determined. Said target tracks start on a first locating beam corresponding to a first measured bearing angle and end on a last locating beam corresponding to the last measured bearing angle, being
15 always respectively the first and last locating beams of a related series of measured bearing angles. Thus the target tracks have an associated initial range, especially a starting range, to the target, which lies on a first locating beam, and an associated final
20 range, especially an actual range that lies on a last locating beam used to determine the target parameters.

An associated quality indicator, especially a quality measure or an inverse quality measure or an inverse
25 quality measure normalized to 1, is calculated for each target track from assumed bearing angles and the measured bearing angles. This is a quality indicator indicating the quality of the target track, which gives the degree of agreement between the assumed target
30 track and the actual target track. There is a respective different distribution of the quality indicator for the different possible target parameters associated with a target track, because the quality indicator is different for the individual target
35 tracks. There are also quality indicators for the optimized solution obtained from the optimization method in said target parameter-dependent distributions. The target parameters obtained, such as

the target range, the target course and the target speed, are associated with said solution that is optimized according to the optimization method used. Said solution is updated during each processing cycle
5 with each new bearing angle measurement and in general is continuously improved.

The quality indicator is preferably specified by means of a quality measure that is calculated from the sum of
10 the, especially weighted, squares of the differences for the assumed bearing angle along the target track and the associated measured bearing angle. Here the quality measure is given by the following formula:

$$Q(i,j) = \sum_{k=1}^n W_k \cdot [B_{meas,k} - B_{est(i,j),k}]^2$$

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Here $Q(i, j)$ refers to the quality measure for an assumed target track $Z(i, j)$ with an initial range $R_0(i, j)$ associated with the starting point of the
20 target track and with a distance to the end point of the target track $R_n(j)$. The index k runs from 1 through n , wherein n indicates the number of measured bearing angles $B_{meas, k}$ or assumed bearing angles $B_{est, k}$ along the target track. W_k refers to weighting factors that
25 correspond e.g. to the inverse standard deviation of the measured bearing angle $B_{meas, k}$ determined during pre-filtering. $B_{est(i,j), k}$ refers to the assumed bearing angle of the k th locating beam for the target track $Z(i, j)$.

30 For determining the quality indicator, moreover, the calculation of the above-mentioned quality measure can be adapted according to support values for carrying out the optimizing process when using said support values, which promote the convergence of the optimizing
35 process. The formula for the quality measure when using support values for the range is then:

$$Q_{(i,j)} = \sum_{k=1}^n W_k \cdot [B_{meas,k} - B_{est(i,j),k}]^2 + W_R (R_{sub} - R_{n(i,j)})^2$$

Here $R_n(i, j)$ refers to the range at time t_n of the target track $Z(i, j)$ and W_R refers to a weighting factor.

The invention is, however, not limited to taking into account range support values. Rather, it is possible to take into account other support values, such as e.g. speed and course support values, during the calculation of the quality measure. Furthermore, a radial speed and a transmission frequency can be used as other support values. The simultaneous use of a plurality of different support values is also conceivable.

Likewise, any other measure that can be calculated from the above-mentioned quality measure, e.g. by means of forming a logarithm, forming a root, squaring, exponentiation, etc., can be used as a quality indicator.

Alternatively, the quality indicator can also be calculated from the sum of the, especially weighted, squares of the differences of measured bearing angles and assumed bearing angles, which is multiplied by the smallest of said sums of all assumed target tracks. In other words instead of the quality measure $Q(i, j)$ according to the above-mentioned formula, the inverse quality measure normalized to the interval between 0 and 1, i.e. to $[0, 1]$, is used. In other words $Q(i, j)$ is replaced here by $Q_{inv}(i, j) = \min(Q)/Q(i, j)$.

Using the distribution of the quality indicator an operator of the sonar receiving system obtains information about the reliability of the output optimized solution. In order to reduce the load on the operator, according to the invention the possible

target parameters in a solution space are displayed graphically and/or numerically on a display device, especially on a position display, using a solution space module.

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For this purpose the invention comprises a calculation unit, in which advantageously a future target position of the target is determined in advance for a specified future point in time for all target tracks or for a plurality of target tracks, wherein said future target position is determined from the target parameters associated with the respective target track, especially the target course and the target speed, for a predetermined time interval. The invention is, however, not limited to future points in time for determining the target positions. Rather, such target positions can also be determined using target parameters that were determined for past bearing measurements. The advantage of the determination according to the invention of the future target positions is that the operator is provided with an indication of which possible solutions the current bearings allow and especially how reliable the best solution is.

25 A display unit determines a future expected area from the future target positions determined by the calculation unit together with the quality indicators associated with the respective target tracks. Furthermore, the display unit is used to graphically and/or numerically display the future expected area on a display device.

Another calculation unit determines a range solution space from all target tracks or from a plurality of target tracks. Said range solution space has an initial range to the target associated with the respective target track to be displayed, a final range to the target and the associated quality indicators of said

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ranges and thus indicates the possible solutions for the target range.

5 A solution space module subsequently determines a solution space for displaying the possible target parameters, wherein said solution space contains the future expected area, the range solution space and/or the best target track. The solution space module is used to graphically and/or numerically display the
10 solution space on a display device, especially in the form of a PPI display (Plan Position Indicator display).

The advantage of the invention is to simplify the
15 operation of the sonar system for an operator by graphically displaying the target parameters to be determined with an optimized best solution directly in a single solution space or in a single display together with the associated quality indicators, preferably in
20 the usual position display.

According to another embodiment of the invention, only those target tracks are taken into account for determining the solution space whose associated quality
25 indicators, especially quality measures or inverted and/or normalized quality measures, have exceeded a predetermined threshold value, because only said target tracks are potentially relevant as a solution. In order to reduce the load on the operator of the sonar
30 receiving system, advantageously the solution space is further broken down using the quality indicator. If e.g. the quality measures are color coded according to different threshold values, then uncertainties in the determination of the target parameters can be directly
35 read out of the display of the solution space. However, it must be noted here that the worst solutions are displayed first and the best solutions last in order to avoid the good solutions with a quality measure

indicating higher quality being subsequently partially masked by the poor solutions having low quality, e.g. in a PPI diagram.

5 With another preferred embodiment of the invention, from the target parameters associated with the target tracks vectors are determined whose end points as future target positions represent the future expected area. The starting points of said vectors lie within
10 the range solution space, preferably on the first or last locating beam, and the directions and lengths of the vectors are determined using the possible solutions for the target course and the target speed. This advantageously enables the display of future target
15 positions as a future expected area within the solution space, wherein said display is carried out pointwise or directionally oriented, especially as an arrow with arrowheads.

20 According to one preferred embodiment of the invention, from the target parameters associated with the best target track a vector is determined that is graphically displayed in the solution space, especially as an arrow with an arrowhead. Preferably, said vector is visually
25 highlighted, e.g. in a different color, so that advantageously an operator can immediately be aware of the best solution.

In another preferred embodiment of the invention,
30 boundary trajectories of the target parameters to be determined are determined and displayed as additional lines within the solution space for a better representation of the solution space. This has the advantage that any uncertainties in the solution,
35 especially for the target course and the target speed, can be better illustrated.

The display of said boundary trajectories preferably takes place only if the distribution of the quality indicators of the individual target parameters has not fallen below a predetermined width, i.e. the reliability of the optimized solution is low, because otherwise the display of the solution space is confusing.

Advantageously, the boundary trajectories can optionally be manually or automatically shown or hidden as required on exceeding and/or falling below predefined threshold values for the respective extreme values for the target course, target range and/or target speed.

According to another preferred embodiment of the invention, the respective extreme values for the target course, target range and/or target speed are output numerically in addition to a graphical display of the solution space. This has the advantage of showing the reliability of the individual target parameters, especially for a target course and a target speed, even for cases in which the corresponding display of the solution space does not allow the associated reliability of the optimized solution to be accurately detected.

In another preferred embodiment of the invention, a potential reciprocal course solution is determined by means of a reciprocal course calculation unit. For this purpose the value of the target course associated with the best target track is determined in order to calculate therefrom a corresponding reciprocal course and a reciprocal course area spanning the reciprocal course. Subsequently a target track giving the best reciprocal course solution, which lies within the reciprocal course area, and a vector associated with said target track are determined, wherein the vector is

recognizably displayed graphically and/or numerically in the solution space, e.g. by displaying it in a different color.

- 5 Preferably, even when determining reciprocal course solutions only those target tracks are taken into account whose quality indicators, especially the inverse quality measures and/or quality measures normalized to 1, have exceeded a predetermined
10 threshold value.

For smaller starting position angles between the submarine itself and the target, especially a starting position angle of e.g. 0° , conventional methods for
15 determining the solution optimized according to a predetermined optimizing criterion for target parameters cannot give a reliable indication for long as to whether the target is approaching or departing. The incoming course and its reciprocal course thus
20 exist as potential solutions. A corresponding display of said reciprocal course advantageously illustrates said potential reciprocal course situation to the operator.

25 Another embodiment of the invention graphically and/or numerically illustrates the future target positions for a plurality of the possible target tracks within the future expected area in the solution space, especially as arrowheads, for the case in which there is a
30 potential reciprocal course solution. By the display of many approaching and departing solutions the uncertainties of a reciprocal course situation are advantageously visually displayed to an operator.

35 Another embodiment of the invention shows the determination of an additional reciprocal course area for the case in which a best reciprocal course solution exists. The additional reciprocal course area is

thereby smaller or narrower than the previously determined reciprocal course area.

Preferably, the target positions of the future expected area are displayed graphically in the solution space, especially as arrowheads and/or numerically, for the case in which the best solution from the previously determined reciprocal course area also exists in the slightly narrower additional reciprocal course area.

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In another embodiment of the invention the display of the solution space is updated during each processing cycle of a series of successive processing cycles. According to the conventional method described above, the solution determined as the respective best solution converges earlier or later with the actual correct solution. In order to show this the display of the solution space is advantageously continually updated, so that both the range solution space and also the future expected area are increasingly limited.

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Other preferred embodiments arise from the dependent claims and from the exemplary embodiments according to the invention explained in detail using the accompanying figures. In the figures:

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Fig. 1 shows a schematic display of a possible scenario with n locating beams from a waterborne vehicle to a target,

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Fig. 2 shows a schematic display of two locating beams with a plurality of possible target tracks,

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Fig. 3 shows a block diagram for explaining the method,

Figs. 4A-D show the schematic display of the solution space for different processing cycles,

5 Fig. 5 shows a schematic display of a solution space with additional boundary trajectories,

10 Fig. 6 shows a schematic display of a possible scenario with n locating beams from a waterborne vehicle to a target for a starting position angle of 0 degrees and

15 Fig. 7 shows the schematic display of the solution space for the above-mentioned reciprocal course situation.

20 On board a waterborne vehicle, especially a submarine, there is at least one arrangement with a plurality of waterborne sound receivers of a sonar receiving system.

This can e.g. be a base of a cylinder in the bow of the waterborne vehicle and/or a linear antenna on each longitudinal side of the waterborne vehicle and/or a towed antenna behind the waterborne vehicle.

25 The sonar receiving system combines the reception signals of the waterborne sound sensors to form group signals with adjacent directional characteristics using a direction generator. For this purpose, the reception
30 signals of the sensors are summed according to their disposition with transition time and/or phase delays to form group signals.

35 Bearing angles are then associated with the group signals depending on the respective time delays, wherein the above-mentioned measured bearing angles to targets are determined from level variations of the group signals against the bearing angles.

Furthermore, such a sonar receiving system has an estimation filter for determining target parameters from the measured bearing angles to a target. During preferably constant travel of the waterborne vehicle along its path of motion, the so-called Eigen leg, bearing angles to the target from said waterborne vehicle are measured while the target is moving at constant speed from a first target position to a second target position.

Fig. 1 shows a possible scenario in which the waterborne vehicle with a sonar receiving system is traveling along a path of motion 6, also referred to as an Eigen leg, and is recording n bearings to a target that is moving from a first locating beam 8 via other locating beams to the n th locating beam 10 along a target track 12. The waterborne vehicle and the target thereby have a starting position angle 14 of approx. 45° at the start of the measurement.

Fig. 2 shows a schematic display of two locating beams 8, 10 with a plurality of possible target tracks. For determining target parameters, such as a target course C , a target range R and a target speed V , a plurality of positions 16 are selected on the first locating beam 8 and a plurality of positions 18 are selected on the last locating beam 10. Said positions correspond to starting positions or end positions of possible target tracks $Z(i, j)$, wherein index i refers to a position 16 on the first locating beam 8 and index j refers to a position 18 on the last locating beam 10. The first locating beam 8 and the last locating beam 10 are respectively the first and last locating beam used for determining the target parameter from a plurality of bearings. They are specified automatically or manually by operator intervention.

A quality indicator is determined for each of said possible target tracks $Z(i, j)$. Said quality indicator can e.g. be displayed in the form of a quality measure $Q(i, j)$ that is calculated from the differences between the measured bearing angles and the associated assumed bearing angles. The calculation preferably takes place according to the formula

$$Q(i, j) = \sum_{k=1}^n W_k \cdot [B_{meas, k} - B_{est(i, j), k}]^2$$

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Here $Q(i, j)$ refers to the quality measure for an assumed target track $Z(i, j)$. Index k runs here from 1 through n , wherein n gives the number of the bearing angle along the target track. W_k refers to weighting factors for weighting the measured bearing angle $B_{meas, k}$ according to its accuracy.

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However, the invention is not limited to the use of the above-mentioned formula for the calculation of the quality measures $Q(i, j)$. Rather, other methods for the calculation are conceivable, with which other data are taken into account, such as e.g. the measured frequency.

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Here it is also conceivable, instead of using the value of $Q(i, j)$ as a quality measure specified above, to use the inverse value of $Q(i, j)$ normalized to 1, i.e. $Q_{inv}(i, j)$. Preferably, for each target track $Z(i, j)$ a quality indicator is calculated, which specifies the quality with which the target track is considered as a possible solution for the target track being sought. The best calculated solution then occurs for the target track $Z(i, j)$ for which $Q_{inv}(i, j) = 1$.

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Fig. 3 shows a block diagram for explaining the method for determining and displaying possible target parameters. Initially the determined possible target

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tracks $Z(i, j)$ are transmitted together with the associated quality indicators to a threshold value detector 20. Said threshold value detector groups the target tracks $Z(i, j)$ according to the quality indicators such that a coding, especially a color coding, takes place based on different quality threshold values. Preferably only those target tracks $Z(i, j)$ are taken into account whose quality measures $Q_{inv}(i, j)$ have exceeded at least one predetermined threshold value, because only these represent the solution that may potentially be considered. Besides the quality indicator, each target track $Z(i, j)$ has an associated initial range R_0 , final range R_n , especially an actual range, course C and speed V , wherein R_0 represents an initial range related to the starting point of the target track on the first locating beam 8 and R_n represents a final range to the end point of the target track on the last locating beam 10.

The values 22 for the possible target parameters filtered according to the threshold values are transferred to a calculation unit 24 for determination of the future target positions 25, e.g. the target positions in 5 minutes' time. Vectors are calculated from the values for course C and speed V , especially course/speed vectors, whose end points represent possible future target positions 25. Using said determined future target positions 25 together with the quality indicators in a display unit 26 a future expected area is determined, which based on the filtered input values 22 can be displayed on a display device 27 color coded according to the threshold values. Thus e.g. that area of the future expected area whose associated target positions 25 have a quality Q_{inv} greater than an upper value is displayed in a first color, that area of the future expected area whose associated target positions 25 have a quality Q_{inv} below

another value is displayed in a second color and the area in between is displayed in a third color. The number of the color codes is, however, not limited to three, but can also adopt larger or smaller values.
5 Furthermore, a suitable coding can take place using gray stages or different patterns.

The values 22 for the initial range R_0 and the final range R_n of the filtered target tracks $Z(i, j)$ filtered
10 according to the threshold values in the threshold value detector 20 are passed to another calculation unit 28 together with the quality indicators. Using a first locating beam 8 used for determining the target parameters and using a last locating beam 10 used for
15 determining the target parameters, the possible target ranges of the initial range R_0 and the possible target ranges for the final range R_n are specified as the range solution space. Here too for better display of the range solution space a color coding can be implemented
20 depending on the respective quality indicator associated with the respective target range, in particular Q_{inv} . Furthermore a suitable coding is also possible here using gray stages or different patterns.

25 A target track calculation unit 30 determines a best target track Z_{best} with a quality measure $Q(i, j)$ or $Q_{inv}(i, j)$ indicating a maximum achievable quality from the filtered values 22, especially the potential possible target tracks $Z(i, j)$, using the quality
30 indicators. The best target track Z_{best} preferably lies where the quality measure Q is at a minimum or the inverted quality measure Q_{inv} normalized to 1 is approximately equal to 1.

35 A solution space module 32 determines a common solution space from the output data of the other calculation unit 28, the output data of the display unit 26 and the output data of the target track calculation unit 30;

the common solution space shows in a display, especially a PPI display, the future expected area, the range solution space and/or the best target track Z_{best} in a solution space on a display means. Displaying the
5 solution space is carried out here using at least one display signal to control a display device 27.

Figs. 4A-D show a schematic representation of the solution space of the scenario shown in Fig. 1 in a
10 position display. In addition to the solution space, the first locating beam 8 and the last locating beam 10 are shown in Figs. 4A-D. Possible target positions for the starting range R_0 are shown on the first locating beam 8 and possible target positions for the final
15 range R_n are shown on the last locating beam 10.

The possible target positions on the two locating beams 8, 10 are divided into different areas according to the grouping of the threshold value detector 20 depending
20 on their quality indicators. There is thus a range solution space 34 that shows the associated quality measure Q_{inv} for each assumed solution R_0 , R_n or each target track $Z(i, j)$ with a minimum quality measure. There is thus e.g. an area 36 of the range solution
25 space 34 with solutions of particularly high quality, an area 40 with a quality measure indicating a minimum quality and a medium area 38 in between. Preferably, the differentiation of the solutions with respect to their quality is highlighted using color in order to
30 display the solution space with the associated reliability to the operator even within his usual position display.

The determined future target positions 25 are provided
35 by the calculation 24 unit for displaying the future expected area 42. Areas can also be specified here using color according to the quality measures Q or Q_{inv} .

Finally, the best target track Z_{best} , which is transferred from the target track calculation unit 30 to the solution space module 32, is highlighted in the displayed solution space. This takes place by means of
5 a starting point 44 on the first locating beam 8 and an end point 46 on the last locating beam 10, wherein the points 44, 46 are graphically highlighted. The vector related to this target track Z_{best} is shown as an arrow with an arrowhead whose tip indicates the best future
10 target position 25 within the future expected area 42.

The display of the solution space according to Fig. 4A shows that the range solution space 34 and the future expected area 42 are still quite wide and the
15 optimization method for determining a best solution of the target parameters is still not correctly converged. Figs. 4B-D show the solution space following further process cycles or bearing measurements at later points in time during the optimizing process. The determined
20 best solution of the target parameters converges with the true solution as time increases, so that both the range solution space 34 and also the future expected area 42 are limited further.

25 The solution space illustrated in Fig. 4D shows the operator a best target track Z_{best} with a target position to be expected within the future expected area 42, which has a quality measure Q_{inv} indicating high reliability or high quality.

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Another possibility for displaying the uncertainties of the solution space or the associated target parameters is the display of additional lines as so-called boundary trajectories.

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Fig. 5 shows a schematic display of a solution space with additionally plotted boundary trajectories. The boundary trajectories are specified in a boundary

trajectory module 50 according to Fig. 3 using the target parameters to be determined and are transferred to the solution space module 32. The values 22 for the possible target parameters filtered according to the threshold values in the threshold value detector 20 are transferred to the boundary trajectory module 50. From these solutions for R_0 , R_n , C and V , extreme values 48, especially $R_{\min}$, $R_{\max}$, $R_{n\min}$, $R_{n\max}$, $C_{\min}$, $C_{\max}$ and $V_{\min}$, $V_{\max}$, are determined, from which the respective boundary trajectories are determined.

Fig. 5 shows the solution space of Fig. 4A with additional lines as boundary trajectories for the extreme values of the starting range, $R_{\min}$ and $R_{\max}$ 52, the boundary trajectories for the course, $C_{\min}$ and $C_{\max}$ 54 as well as the boundary trajectories for the speed, $V_{\min}$ and $V_{\max}$ 56, to better display the bandwidth of the different solutions.

Preferably, said boundary trajectories 52, 54, 56 are only displayed if the associated solution space is relatively broad, i.e. the difference between the maximum and minimum value of a target parameter exceeds a predetermined value.

Furthermore, the extreme values 48 of the target parameters determined in the boundary trajectory module 50 are additionally displayed numerically on the display means 27, because the position display does not allow the width of the solution space to be detected in every case.

Fig. 3 contains as a further embodiment of the invention a reciprocal course calculation unit 60 for promptly displaying possible reciprocal course situations to the operator.

Fig. 6 shows a schematic display of a possible scenario of a reciprocal course situation with n locating beams from a waterborne vehicle to a target. The waterborne vehicle is moving here along an Eigen leg 6 and recording n bearings to a target, which is approaching the waterborne vehicle on a target track 12 with a starting position angle of zero degrees.

The n bearings are in this case closely adjacent to each other on a position display according to Fig. 6. An applied optimization method does not distinguish with sufficient reliability whether the target is on an approaching or departing course. Both the approaching course C and also its reciprocal course $C + 180$ degrees are potential solutions.

Fig. 7 shows a schematic display of the solution space for the reciprocal course situation illustrated in Fig. 6. For determining the solution space, a best target track Z_{best} is first determined by means of the target track calculation unit 30 using the quality indicators and the associated course C_{best} is transferred to the reciprocal course calculation unit 60 according to the method illustrated in Fig. 3. The reciprocal course calculation unit 60 determines a reciprocal course from the best course C_{best} :

$$C_{gegen} = (C_{best} + 180) \bmod 360,$$

wherein the two courses C_{best} and C_{gegen} correspond to the approaching and departing course of the target.

Using the value for C_{gegen} , a reciprocal course area $G1$ is determined, which spans the course C_{gegen} within a predetermined angle X from both sides:

$$G1 = [C_{gegen} - X, C_{gegen} + X].$$

Subsequently, a best target track Z_{gegen} or a best reciprocal course solution is determined by means of the quality measure $Q(i, j)$ or $Q_{\text{inv}}(i, j)$ and lies within the reciprocal course area $G1$. From the best target track Z_{gegen} and the best target track Z_{best} a vector is determined for displaying said target tracks within the solution space. Hence Z_{best} and Z_{gegen} can be displayed together in the solution space, especially being distinguishable by color or in another way.

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In order to further illustrate the reciprocal course situation, in Fig. 7 the future target positions are illustrated as arrowheads of the vectors determined from the associated target tracks $Z(i, j)$. Said display according to Fig. 7 illustrates a plurality of possible solutions with an approaching and departing course. The arrowheads represent the future expected area 42, which is divided into two areas in this case.

20 If there is no longer a reciprocal course solution following further processing cycles of the optimizing process, then as explained above only the best solution Z_{best} is shown in the solution space, especially as an arrow with an arrowhead.

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Because a display of the solution space with a plurality of arrowheads of the future target positions does not always appear advantageous, the invention contains as a further embodiment the determination of an additional reciprocal course area $G2$. The additional reciprocal course area is thereby determined as somewhat narrower with a smaller angle $Y < X$ about the previously determined reciprocal course C_{gegen} :

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$$G2 = [C_{\text{gegen}} - Y, C_{\text{gegen}} + Y].$$

Hence the solution space is only illustrated with a plurality of arrowheads for the future target positions

25 on the display device 27 if the determined best solution Z_{gegen} lies both within the reciprocal course area G1 and also within the additional reciprocal course area G2.

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All the features mentioned in the above-mentioned figure description, in the claims and in the introduction to the description can be used both individually and also in any combination with each
10 other. The disclosure of the invention is thus not limited to the described or claimed combinations of features. Rather, all combinations of features are to be considered as disclosed.

Claims

1. A method for determining and displaying possible target parameters associated with a target, especially a target range (R), a target course (C) and/or a target speed (V), which are determined by directionally selective reception of sound waves emitted or transmitted by the target by using bearing angles measured by an arrangement of receivers of waterborne sound of a sonar receiving system and estimated bearing angles that are determined from estimated positions of the target, and a bearing angle difference between measured and estimated bearing angles is iteratively minimized and on reaching the minimum the estimated position of the target parameters provides an optimized solution for the display, and wherein during each processing cycle of a series of successive processing cycles for the possible solutions for the target parameters to be determined a plurality of different target tracks ($Z(i, j)$) and a respective quality indicator, especially a quality measure ($Q(i, j)$) or an inverse quality measure ($Q_{inv}(i, j)$) that may also be normalized to 1, are determined for each assumed target track, wherein a best target track (Z_{best}) giving a best solution is determined using the quality indicators associated with the target tracks ($Z(i, j)$),
- characterized in that
- a future target position (25) of the target for all or a plurality of target tracks ($Z(i, j)$) is determined from the target parameters associated with the respective target track, especially the target course (C) and the target speed (V), for a predetermined time interval,
- a future expected area (42) is determined from the future target positions (25) of the target and the

quality indicators associated with said target positions (25) and is displayed on a display device (27),

5 a range solution space (34) indicating the possible solutions for the target range (R) is determined from all or a plurality of target tracks ($Z(i, j)$) having an initial range (R_0) associated with the respective target track and a final range (R_n) with the associated quality indicator and

10 a solution space containing the possible target parameters having the future expected area (42), the range solution space (34) and/or the best target track (Z_{best}) is graphically and/or numerically displayed on the display device (27).

2. The method as claimed in claim 1, characterized in that

20 for determining the solution space only those target tracks ($Z(i, j)$) are taken into account whose associated quality indicator, especially the inverse and/or normalized quality measure ($Q_{inv}(i, j)$), has exceeded at least one predetermined threshold value.

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3. The method as claimed in claim 1 or 2, characterized in that

30 from the target parameters associated with the target tracks ($Z(i, j)$), vectors are determined whose end points represent the future expected area (42), wherein the starting points of the vectors lie within the range solution space (34) and the directions and lengths of the vectors are determined using the possible solutions for the target course (C) and target speed (V).

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4. The method as claimed in claim 3, characterized in that

from the target parameters associated with the best target track (Z_{best}) a vector is determined, which is graphically displayed in the solution space, especially as an arrow with an arrowhead.

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5. The method as claimed in any one of the preceding claims,
characterized in that

10 boundary trajectories (52, 54, 56) are determined from predetermined extreme values (48) of the target parameters to be determined and are shown as lines within the solution space for a better display of the solution space.

- 15 6. The method as claimed in any one of the preceding claims,
characterized in that

20 a potential reciprocal course solution is determined in addition to the best solution, wherein the determination comprises the following steps:

- 25 a) determining the value of the target course (C_{best}) associated with the best target track (Z_{best}),
- b) calculating a reciprocal course (C_{gegen}) as well as a reciprocal course area (G1) spanning the reciprocal course (C_{gegen}) from the determined value of the target course (C_{best}),
- 30 c) determining a target track (Z_{gegen}) within the reciprocal course area (G1) giving a best reciprocal course solution and a vector associated with said target track and
- 35 d) graphically and/or numerically displaying the vector of the target track (Z_{gegen}) of said best reciprocal course solution and/or the vector of the

target track (Z_{best}) within the solution space.

7. The method as claimed in claim 6,
5 characterized in that
for a plurality of the target tracks ($Z(i, j)$) the
future target positions (25) are graphically and/or
numerically highlighted within the future expected
area (42) in the solution space, especially as
10 arrowheads, for the case in which there is a
potential reciprocal course solution (C_{gegen}).
8. The method as claimed in claim 6,
characterized in that
15 an additional reciprocal course area ($G2$) is
determined for the case in which there is a best
reciprocal course solution (C_{gegen}), wherein the
additional reciprocal course area ($G2$) is smaller
than the previously determined reciprocal course
20 area ($G1$), and
for a plurality of the target tracks ($Z(i, j)$) the
future target positions (25) are highlighted
graphically and/or numerically within the future
expected area (42) in the solution space,
25 especially as arrowheads, for the case in which the
best reciprocal course solution (C_{gegen}) lies within
the additional reciprocal course area ($G2$).
9. A device for determining and displaying possible
30 target parameters associated with a target,
especially a target range, a target course and/or a
target speed, which can be determined by
directionally selective reception of sound waves
emitted or transmitted by the target by using
35 bearing angles measured by an arrangement of
receivers of waterborne sound of a sonar receiving
system and estimated bearing angles that are
determined from estimated positions of the target,

and a bearing angle difference between measured and estimated bearing angles is iteratively minimized and on reaching the minimum the estimated position provides the target parameters of an optimized solution for the display, and wherein during each processing cycle of a series of successive processing cycles of the possible solutions for the target parameters to be determined a plurality of different target tracks ($Z(i, j)$) and respective quality indicators, especially a quality measure ($Q(i, j)$) or an inverse and/or normalized quality measure ($Q_{inv}(i, j)$), can be determined for each assumed target track, wherein a best target track (Z_{best}) giving a best solution can be determined using the quality indicators associated with the target tracks ($Z(i, j)$), characterized by

a calculation unit (24) that is designed to determine, for all or a plurality of target tracks ($Z(i, j)$), a future target position (25) of the target for a predetermined time interval from the target parameters associated with the respective target track, especially the target course (C) and the target speed (V),

a display unit (26) that is designed to determine a future expected area (42) from the future target positions (25) determined by means of the calculation unit (24) and the quality indicators associated with said target positions (25) and to display said expected area (42) on a display device (27),

another calculation unit (28) that is designed to determine a range solution space (34) indicating the possible solutions for the target range (R) from all or a plurality of target tracks ($Z(i, j)$), the solution comprising an initial range (R_0) associated with the respective target track and a

final range (R_n) with the associated quality indicator and

a solution space module (32) that is designed to determine a solution space containing the possible target parameters, which comprises the future expected area (42), the range solution space (34) and/or the best target track (Z_{best}), and to display the same graphically and/or numerically on the display device (27).

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10. The device as claimed in claim 9, characterized by

15 a threshold value detector (20) for determining those target tracks ($Z(i, j)$) whose associated quality indicators, especially the inverse and/or normalized quality measure ($Q_{inv}(i, j)$), have exceeded at least one predetermined threshold value.

20 11. The device as claimed in either of the claims 9 through 10, characterized by

25 a means of generating vectors from the target parameters (C, R, V) associated with the target tracks ($Z(i, j)$), wherein the end points of the vectors represent the future expected area (42), the starting points of the vectors lie in the range solution space (34) and the directions and lengths of the vectors can be determined using the possible solutions for the target course (C) and the target speed (V).

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12. The device as claimed in any one of the claims 9 through 11,

characterized by

35 a means of generating a vector from the target parameters (C, R, V) associated with the best target track (Z_{best}) and

a means of graphically displaying said vector in the solution space, especially as an arrow with an arrowhead.

- 5 13. The device as claimed in any one of the claims 9 through 12,
characterized by
a boundary trajectory module (50) that is designed
to determine boundary trajectories (52, 54, 56) for
10 the target parameters (C, R, V) to be determined,
which can be represented within the solution space
as lines for a better display of the solution
space.
- 15 14. The device as claimed in any one of the claims 9 through 13,
characterized by
a reciprocal course calculation unit (60) for
determining and displaying a potential reciprocal
20 course solution that can be determined from a
reciprocal course (C_{gegen}) and a reciprocal course
area (G1) spanning the reciprocal course (C_{gegen}).
- 25 15. The device as claimed in claim 14, characterized in
that
the reciprocal course calculation unit (60) is
designed to determine an additional reciprocal
course area (G2) for the case in which a best
reciprocal course solution (Z_{gegen}) exists, wherein
30 the additional reciprocal course area (G2) is
smaller than the previously determined reciprocal
course area (G1) and
the solution space module (32) is designed to
graphically and/or numerically highlight the future
35 target positions (25) within the future expected
area (42) in the solution space for a plurality of
the target tracks ($Z(i, j)$) for the case in which

the best reciprocal course solution (Z_{gegen}) lies within the additional reciprocal course area (G2).

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