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by

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PASSIVE POSITIONING TECHNIQUE OF SLOW SPEED RECONNAISSANCE PLATFORM

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ABSTRACT

Citing an example of ship-borne reconnaissance equipment, a study is conducted of the slow speed single station passive positioning technique in measuring only the bearing angle. With a series of measures such as filtering and screening the original reconnaissance data, adjusting the weighted information volume, and controlling the algorithmic trend, passive positioning of targets has been achieved, satisfying the fundamental conditions. With computer simulation, the positioning effect is quite satisfactory.

Key words: Electronic reconnaissance, Passive positioning, Execution with algorithm

I. Technical Features

Generally, a slow speed reconnaissance platform involves a ship-borne or vehicle-borne reconnaissance platform. The features of slower moving speed and lower platform location decide the characteristics of the reconnaissance target and data. In conjunction with engineering practice, the article cites an example of a ship-borne reconnaissance platform to study the passive positioning technique of a single slow speed station.

The ship-borne reconnaissance equipment and platform have the following characteristics:

-- The platform speed is between 3.68 and 30.96 km/h, and the typical speed is 9.2 km/h;

-- The lowest accuracy of the reconnaissance bearing angle is 3° (r.m.s.);

-- Only the bearing angle is measured, with no information on the pitch angle;

-- Variation of the reconnaissance bearing angle is less than 45°;

-- Information on the bearing angle is provided every three seconds; and

-- The reconnaissance distance of the ground target is affected by the platform altitude, which is generally lower than 200 km.

The above-mentioned concrete features determine the features of the passive positioning technique of a slow speed single station. In other words, with respect to a stationary or relatively slow speed target in single station multiple point passive positioning, the positioning results include information of longitude and latitude of the target.

II. Execution of Algorithm

Since the slow speed reconnaissance platform has the features of short reconnaissance base line, greater error in direction measurement, and short time interval of reconnaissance, it is difficult to be effective for a single traditional passive positioning technique. By citing an example of a stationary target with a distance of 40 km, when the ship-borne platform moving speed is 30 km/h, the maximum variation of the real bearing angle is only 0.036° within 3 seconds. This is negligible compared to the error for direction measurement of 3°. Thus, it is not allowed to directly apply each set of original reconnaissance data to passive positioning filtration; otherwise, the result will be harmful. Computer simulation results also prove this point. However, with respect to the slow speed reconnaissance platform, each set of original reconnaissance data is very valuable. If only those original reconnaissance data sets with bearing angle variation greater than the error discrimination rate are applied to the passive positioning infiltration, then the useful reconnaissance data will be limited. Thus, the positioning efficiency must be low and the reliability very low when including the direction meassuring error of 3° (r.m.s). Therefore, processing the original reconnaissance data is very important with respect to passive positioning of a slow speed single station reconnaissance platform.

2.1 Preprocessing of the original reconnaissance data

Ship-borne reconnaissance equipment can provide 20 sets of original reconnaissance data every minute. In the situation of target distance at 40 km and platform speed of 30 km/h, the maximum variation of the real reconnaissance bearing angle is 0.717°. It is assumed that the measurement error of the bearing angle is subject to $N(0, \sigma_0)$. We assume that the data of the i-th set of the original reconnaissance data is (λ_i, ϕ_i, P_i) within a minute. In the data set, λ_i and ϕ_i are, respectively, longtitude and latitude of the reconnaissance vessel at the moment when P_i is the reconnaissance bearing angle; then the reconnaissance bearing angle of the particular minute is:

$$P \triangleq (\sum_{i=1}^{20} P_i)/20$$

When $P \geq P_i$, the reconnaissance data set of the particular minute is $(\lambda_{20}, \phi_{20}, P)$.

When $P < P_1$, the reconnaissance data set at the minute is (λ_i, ϕ_i, P).

As revealed using computer simulation, the post-processing reconnaissance data set has some improvement over the original reconnaissance data set with respect to error in direction measurement, thus creating conditions for executing precise positioning for later passive positioning filtration. Moreover, the contradiction in terms of smaller variation between data volume and bearing angle is settled.

2.2 Nonlinear least square method

As indicated by computer simulation, precise passive positioning can only be executed by applying the nonlinear least square method, due to limitations of reconnaissance time and error in direction measurement.

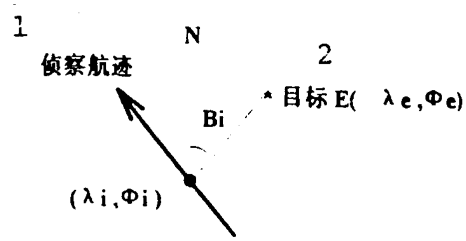

Fig. 1. Diagram showing reconnaissance direction measurement.

Key: 1-Reconnaissance navigation track; 2-Target

As shown in Fig. 1, the longitude and latitude of the target is (λ_i, ϕ_i). Based on the principle of triangulation, when the target and reconnaissance point are situated in east longitude and northern latitude, and the reconnaissance platform is situated at (λ_i, ϕ_i), the bearing angle of the target is:

$$\cos(B_i)=\frac{\varphi_r-\varphi_i}{\sqrt{(\varphi_r-\varphi_i)^2+(\lambda_r-\lambda_i)^2\cos^2\varphi_i}}$$

Then the measurement equation is:

$$\tilde{B}_i=\arccos\left\{\frac{\varphi_{r0}-\tilde{\varphi}_i}{\sqrt{(\varphi_{r0}-\tilde{\varphi}_i)^2+(\lambda_{r0}-\tilde{\lambda}_i)^2\cos^2\varphi_i}}\right\}$$
$$\triangleq F(\varphi_r,\lambda_r,\varphi_i,\lambda_i)$$

In the equation, λ_{r0} and ϕ_{r0} are, respectively, the estimated positions of the target.

We linearize the measurement equation, that is $\begin{cases} h_1 \triangleq \dfrac{\partial F}{\partial \lambda_r} \\ h_2 \triangleq \dfrac{\partial F}{\partial \varphi_r} \end{cases}$

Then, after the n-th reconnaissance, we obtain an n-dimension linear observation matrix

$$\underset{(n\times 1)}{\Delta Z} = \underset{(n\times 2)}{H} \cdot \underset{(2\times 1)}{\Delta X} + \underset{(n\times 1)}{N}$$

In the matrix:

$$H = \begin{bmatrix} h_{11} & h_{21} \\ \cdots\cdots\cdots & \\ h_{1i} & h_{2i} \\ \cdots\cdots\cdots & \\ h_{1n} & h_{2n} \end{bmatrix} \qquad \Delta Z = \begin{bmatrix} \tilde{B}_1 - F_1(\varphi_{ro}, \lambda_{ro}) \\ \cdots\cdots\cdots \\ \tilde{B}_i - F_i(\varphi_{ro}, \lambda_{ro}) \\ \cdots\cdots\cdots \\ \tilde{B}_n - F_n(\varphi_{ro}, \lambda_{ro}) \end{bmatrix}$$

Then we obtain the Markoff estimation of ΔX:

$$\Delta X = [\Delta\lambda_r \quad \Delta\varphi_r]^T$$

In the estimation,

$$\Delta X = (H^T \cdot R^{-1} \cdot H)^{-1} \cdot H^T \cdot R^{-1} \cdot \Delta Z$$

$$R = E[NN^T]$$

$$\begin{cases} \hat{\varphi}_r = \varphi_{ro} + \Delta\varphi_r \\ \hat{\lambda}_r = \lambda_{ro} + \Delta\lambda_r \end{cases}$$

2.3 Estimation of initial position of target

We assume that the longitude-latitude and direction measurement angle of two measurement points are

$$(\lambda_1, \varphi_1, P_1); (\lambda_2, \varphi_2, P_2)$$

The longitude and latitude of the target are (λ, φ_t).

Then, based on the cotangent law and sine law of the spherical triangle, we can obtain by calculation:

$$\lambda_t = \lambda_1 + arc\ tg\left(\frac{sinP_1}{ctgd_1 \cdot cos\varphi_1 - sin\varphi_1 \cdot cosP_1}\right)$$

$$\varphi_t = arc\ cos\left\{\frac{sin\ d_1}{sin(\lambda_2 - \lambda_1)} \cdot sinP_1\right\}$$

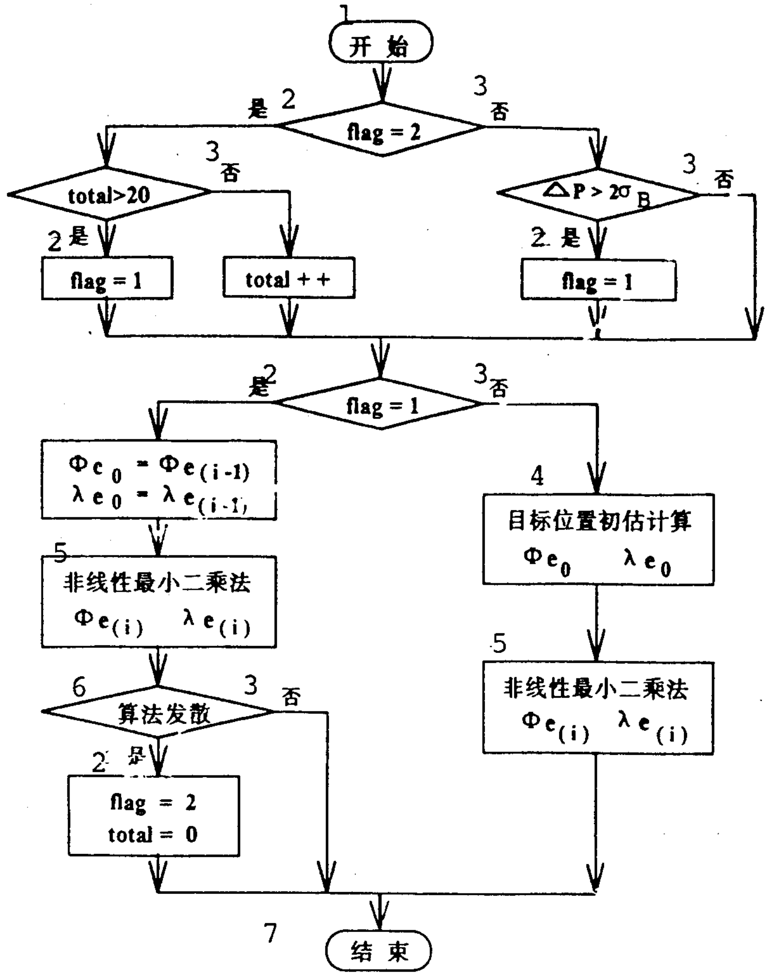

Fig. 2. Flow diagram of passive positioning of ship-borne reconnaissance.

Legend:

flag = 0	beginning of passive positioning algorithm;
flag = 1	Variation of reconnaissance angle greater than 2 B with recurrent operation;
flag = 2	Divergence in algorithm; and
total	Number of effective recordings after divergence in algorithm

Key: 1-Begin; 2-Yes; 3-No; 4-Initial estimated computation of target position; 5-Nonlinear least mean square method; 6-Divergence in algorithm; 7-End.

2.4 Flow chart of positioning

Figure 2 shows a ship-borne reconnaissanace passive positioning diagram.

III. Explanation on Computer Simulation and Results

Figure 3 shows a diagram of the relationship between the target position and the reconnaissance track. Refer to Table 1 for the results of the computer simulation. The moving speed of the simulation platform is 5 km/h; the reconnaissance precision of direction measurement is 3° (r.m.s); the time of reconnaissance is 120 minutes. The whole procedure applies the Visaul C 1.0 compilation in a Windows environment, while the database applies Microsoft FoxPro management software. The longest computing time of positioning for each target is less than 3 seconds, including the readout time for data.

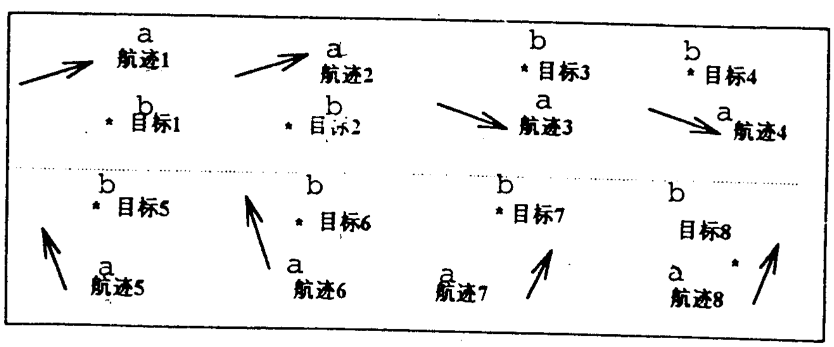

Fig. 3. Schematic diagram of target positions and reconnaissance navigation tracks.

Key: a-Navigation track; b-Target.

Referring to Fig. 3 and Table 1, we can see the following: under conditions of the variation of the reconnaissance bearing angle as greater than a time segment of $2\sigma_H$ with a steady algorithm, generally the positioning error is better than 5%. The greater the variation in the reconnaissance bearing angle, and the larger the times of effective reconnaissance recordings, the higher is the general positioning precision. The reason why the positioning precisions for targets number 4 and 6 are lower than the corresponding targets number 3 and 5 is the emergence of algorithm divergence, especially the fact that the algorithm of target number 4 has not completely stabilized.

Table 1. Results of Computer Simulation.

a 目标编号	b 目标真实经度	c 目标真实纬度	d 侦察时间(分)	e 有效侦察组数	f 目标估计位置经度	g 目标估计位置纬度	h 目标最近距离(km)	i 定位误差(km)	j 侦察角变化(度)	k 误差百分比%
1	122°	30°	120	113	122°1′47″	29°58′15″	135	4.33	8°24′	3.20
2	122°	30°	120	103	122°0′14″	29°59′28″	113	1.06	11°06′	0.93
3	122°	32°	120	110	122°0′56″	32°00′52″	135	2.21	7°12′	1.63
4	122°	32°	120	62	122°1′30″	32°16′09″	112	29.95	10°36′	26.78
5	123°	31°	120	110	123°0′32″	31°00′39″	130	1.48	6°59′	1.14
6	123°	31°	120	112	123°1′25″	31°00′14″	98	2.31	13°54′	2.37
7	121°	31°	120	109	121°1′13″	30°59′05″	116	2.59	10°18′	2.23
8	121°	31°	120	112	121°0′41″	30°59′56″	97	1.12	14°00′	1.15

The number of effective reconnaissance sets is the residual number of reconnaissance sets after removing points with greater errors.

Key: a-Target number; b-Real longitude of target; c-Real latitude of target; d-Reconnaissance time (minutes); e-Number of effective reconnaissance sets; f-Longitude of estimated target position; g-Latitude of estimated target position; h-Nearest distance (km) of target; i-Error (km) in positioning; j-Variation of reconnaissance angle (degrees); k-Percent error.

IV. Conclusions

With simulation proofs of multiple reconnaissance tracks and multiple targets, this positioning technique can execute passive positioning processing of a slow speed reconnaissance platform. In the case when the fundamental conditions are satisfied, for targets with measurement of only the bearing angle while the range of the target is within 200 km and the positioning error is less than 5%, this positioning technique can distinguish the motion attribute of the target to a certain extent. It is also worthwhile to mention that the software environment for executing this technique is very suitable for an information processing center capable of carrying out passive positioning processing of multiple targets in a multiple mission environment.

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