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Application of EXCEL commonly used in navigation data processing

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Application of EXCEL commonly used in navigation data processing

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Abstract. Aiming at the problem of large amount of data calculation and collation in navigation work, several EXCEL data processing methods of commonly used nautical tables are presented based on the advantages of EXCEL with its flexible use, strong expansibility and easy storage. All the calculation processes involved in common nautical tables can be realized by manually inputting corresponding parameters through formula input and logical setting. This method not only reduces the amount of manual calculation, but also improves the accuracy and accuracy of data calculation and realizes the electronic storage of data, which is of great benefit to improve the efficiency of navigation.

1. Introduction

In the current navigation work, many navigation data acquisition and processing require manual plotting, measurement and collation of the navigator. For example, when calculating position errors, the navigator needs to plot the GPS position, inertial navigation position, and estimated position on the chart, and then take the azimuth and distance measurement, which is inefficient, and the error caused by human factors is large, and affects the accuracy. In order to solve these problems, computer software programming is often used, but it requires a certain programming language ability and numerical calculation basis, which is difficult for some navigators.

EXCEL software is simple to use, easy to master with its powerful data processing function. Using the calculation function of EXCEL itself to edit, modify and calculate functions, it can solve the calculation and processing of related data commonly used in the work of navigation, and can be stored electronically. It is especially suitable for all kinds of calculation work with large amount of data and strong repeatability in navigation.

Taking the data calculation and collation in the nautical plan table, the position error table, the calculation table of direction and direction vectors, the missile occupancy table as examples, this paper introduces in detail the specific application of EXCEL tool in the daily work of navigator and above, and demonstrates the simple, accurate, intuitive and easy-to-grasp characteristics of EXCEL in data processing, which is helpful to reduce the manual calculation of navigator and improve efficiency.

2. Application of EXCEL in navigation data processing

Excel is an office software independently developed by Microsoft. It has powerful data processing function, which can not only store and calculate ordinary data and generate various kinds of charts, but also enable users to quote formulas and functions, and customize formulas and functions to perform complex and tedious large-scale operations, especially various mutual references, formulas and numbers of worksheets and cells. The automatic filling and application of data are widely used in



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office, scientific research[1-2], engineering[3-5] and teaching fields[6-8], as well as the logical judgment and analysis of measurement data.

The specific application examples in this paper mainly include several kinds of navigational data which are commonly used in the daily work of the navigator, such as the data processing in Navigation Schedule, the position error table, the calculation table of the vector elements of course and direction, the missile occupancy table and the mine laying calculation table.

EXCEL data processing function formula, function and automatic calculation are mainly used in this paper. The so-called formula is the content of data calculation and processing for Excel worksheet designed by users, while the function is a special formula, that is, pre-defined, performing calculation, analysis and other special formulas for data processing tasks. Usually, functions have specific grammar and computational parameters. Excel software function library contains a large number of data processing functions, such as mathematical and trigonometric functions, statistical functions and so on.

Automated computing function refers to Excel can be extended by data and formulas of one or more cells. The automatic calculation function of Excel software is usually implemented in two ways: one is to expand the calculation according to the logical relationship of data between selected cells, such as cell A1 = 2, A2 = 3, select A1, A2 drag down the expansion calculation to get A3 = 4, A4 = 5: the other is to calculate according to the formula of selected cells, such as cell C1 = A1 + B1, select C1 drag down to fill. C2 = A2 + B2 can be obtained.

Firstly, according to the original data and computing needs, the overall table framework is designed in the empty Excel table. The first row and the first column are generally used as column names and serial numbers. Input the original data into the corresponding cell, and then input the calculation formula in the cell that needs to be calculated. Excel will automatically calculate the results according to the formula. The detailed design and calculation process are given below.

2.1. Navigation schedule

Navigation schedule is one of the most commonly used forms in navigation. When the latitude and longitude coordinates of two position points are given, the course and voyage between two points can be quickly calculated by using several functions of EXCEL. If the starting and ending points of each route are input, a complete chart of the voyage plan can be obtained, as is shown in Table 1.

Commonly used navigational knowledge and EXCEL functions are as follows:

2.1.1. Navigational knowledge

In the case of little difference in position error, there are the following relations between longitude difference and departure Dep on char

$$D\lambda = Dep / \cos\varphi \quad (\varphi \text{ is the latitude}) \quad (1)$$

2.1.2. Excel formula

SQRT (number): returns the positive square root.

POWER (number, power): returns the power of a given number. Number is the base. It can be any real number. Power is the exponent. The base is the power of the exponent.

RADIANS (angle): converts angle to radian.

DEGREES (angle): converts radian to degree.

IF(logical_test,value_if_true,value_if_false) is used to perform the judgment of true and false values, and returns different results according to the true and false values calculated by logic.

2.1.3. Establishment of navigation schedule and required function

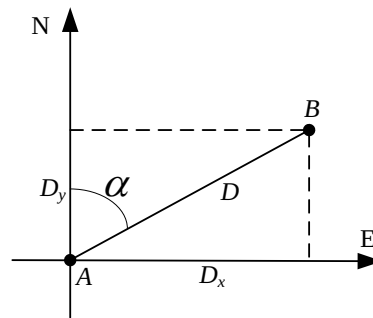


Figure 1.Heading table with distance between two points

A and B are any two points on the chart in figure 1, D is the distance between two points, α is the course, D_x is the component of D in the East and West direction, D_y is the latitude difference. According to Figure 1, we can get:

$$\begin{cases} D = \sqrt{D_x^2 + D_y^2} \\ \alpha = \arctan(D_x / D_y) \end{cases} \quad (2)$$

α in Formula (2) refers to the situation of heading in the northeast quadrant(0-90 degrees). In other cases, the positive and negative of D_x and D_y should be determined according to formula (3). Using the functions in formula (2) and EXCEL, an EXCEL-based nautical plan table can be made (as shown in Figure 2).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Navigation schedule													
1	Sequence number	Time	Integer of starting point Latitude	Fraction of starting point Latitude	Integer of starting point longitude	Fraction of starting point longitude	Integer of endpoint Latitude	Fraction of endpoint Latitude	Integer of endpoint longitude	Fraction of endpoint longitude	Latitude difference (cable)	Departure (cable)	Heading (degree)	distance (cable)
2														
3	1	0800	29	0.00	122	2.04	29	1.00	122	0.00	10	-17.825	299.297	20.436
4														

Figure 2.Navigation schedule

In navigation schedule, latitude and longitude are shown in two columns for input calculation. The specific calculation functions are as follows:

$$\text{Latitude difference } K3 = ((G3 - C3) \cdot 60 + H3 - D3) \cdot 10$$

$$\text{Departure } L3 = ((I3 - E3) \cdot 60 + J3 - F3) \cdot 10 \cdot \text{COS}(\text{RADIANS}(C3 + D3/60))$$

$$\text{distance } N3 = \text{SQRT}(\text{POWER}(K3, 2) + \text{POWER}(L3, 2))$$

$$\begin{aligned} \text{Heading } M3 &= \text{IF}(K3 < 0, \text{DEGREES}(\text{ATAN}(L3/K3)) + 180, \\ &\text{IF}(L3 < 0, \text{DEGREES}(\text{ATAN}(L3/K3)) + 360, \text{DEGREES}(\text{ATAN}(L3/K3))) \end{aligned} \quad (3)$$

2.2. Navigation Position Error Calculating Table

At present, navigational equipments such as GPS/GLONASS, Beidou and INS are usually equipped on warships. In navigation, it is necessary to compare the calculated ship position and the display positions of navigation equipments. The manual method is to plot the positions on the chart firstly and then measure the azimuth and distance between them. Using the EXCEL tool, the positions that need to be compared are entered into the EXCEL table and calculated using its functions, as shown in Figure 3. Comparing the two methods, the latter reduces the error of manual plotting and saves time.

In Figure 3, an example of calculating the estimated position error is given. The estimated distance error is as follows:

Navigation Position Error Calculating Table																												
	Integer of GPS Latitude	Fraction of GPS Latitude	Integer of GPS Longitude	Fraction of GPS Longitude	Integer of inertial navigation 1 Latitude	Fraction of inertial navigation 1 Latitude	Integer of inertial navigation 1 Longitude	Fraction of inertial navigation 1 Longitude	Integer of inertial navigation 2 Latitude	Fraction of inertial navigation 2 Latitude	Integer of inertial navigation 2 Longitude	Fraction of inertial navigation 2 Longitude	Integer of inertial navigation 3 Latitude	Fraction of inertial navigation 3 Latitude	Integer of inertial navigation 3 Longitude	Fraction of inertial navigation 3 Longitude	Integer of reckoning Latitude	Fraction of reckoning Latitude	Integer of reckoning Longitude	Fraction of reckoning Longitude	Error of inertial navigation on 1	Error of inertial navigation 2	Error of inertial navigation 3	Reckoning error (cable)	Bearing of reckoning error (degree)	Departure (cable)	Latitude difference (cable)	
1	29	15.2	125	45	29	14.7	125	45.3	29	14	125	41	29	14	125	31.1	29	11.3	125	42	0.55	3.8	14.1	4.8	36.0	2.83	3.9	
2	28	17.1	125	39	28	16.4	125	38.3	28	18	125	39	28	20	125	21.6	28	15.6	125	36.5	1.00	0.6	17.5	2.7	56.8	2.3	1.5	
3	27	19.6	125	42	27	19.1	125	42	27	18	125	39	27	27	125	34.9	27	19.4	125	35	0.51	3.2	10.2	6.3	88.2	6.33	0.2	
4	27	11.5	125	48	27	10.9	125	47.4	27	12	125	48	27	13	125	48.4	27	10.4	125	46.3	0.93	0.3	1.9	2	57	1.69	1.1	
5	26	44.2	125	45	26	43.9	125	44.3	26	44	125	43	26	44	125	43.3	26	37.3	125	40.8	0.40	1.2	1.2	7.7	26.3	3.42	6.9	
6	26	46.9	125	41	26	46.2	125	39.2	26	47	125	40	26	47	125	39.5	26	46.5	125	41	1.44	0.7	1.1	0.5	318.1	-0.4	0.4	
7	24	59.6	127	17	25	1.8	127	14.9	25	1.1	127	15	25	4.9	127	13.5	24	56.3	127	22.2	2.64	1.9	6	6.2	302.4	-5.2	3.3	
8	24	54.2	127	15	24	52.6	127	13.1	24	55	127	14	24	55	127	14.4	24	54.1	127	15.7	2.29	0.9	1.2	0.7	277.8	-0.7	0.1	
9	22	43.9	125	41	22	42.9	125	39.2	22	51	125	45	22	49	125	31.6	22	44.5	125	43.6	1.71	8.1	9.8	2.8	257.4	-2.7	-0.6	
10	22	44.6	125	35	22	44.9	125	32.8	22	44	125	34	22	45	125	34.5	22	44.3	125	35.9	1.79	0.5	0.5	1.2	285.1	-4.1	0.3	
11																												
12																												
13																												
14																												
15																												
16																												

Figure 3. Navigation position error calculating table

$$X3 = \text{SQRT}(\text{POWER}(\text{COS}(\text{RADIANS}(B3)) \cdot (T3 - D3) \cdot 60 + U3 - E3, 2) + \text{POWER}((R3 - B3) \cdot 60 + S3 - C3, 2)) \quad (4)$$

Estimate the error orientation:

$$Y3 = \text{IF}(AB3 < 0, \text{DEGERRS}(\text{ATAN}(AA3/AB3)) + 180, \text{IF}(AA3 < 0, \text{DEGERRS}(\text{ATAN}(AA3/AB3)) + 360, \text{DEGERRS}(\text{ATAN}(AA3/AB3)))) \quad (5)$$

This table can also be used to calculate the distance and azimuth to a certain position. For example, the longitude and latitude of an island can be input into this table during a long voyage, and the current position of the boat can be input during the voyage to calculate the distance and azimuth of the current boat from an island.

2.3. A mutual calculation table of heading, speed, direction and velocity

It is often necessary to reverse the flow direction (velocity) from the known track direction (speed) and course (speed of the main engine). The function of EXCEL tool can be used to complete data calculation conveniently. The ship's track direction, speed, course, main engine speed, flow direction and velocity constitute the vector triangle as shown in Figure 4, and the following relations on the X-axis and Y-axis respectively:

$$\begin{cases} V_x - V_{xx} = V_{sx} \\ V_y - V_{xy} = V_{sy} \end{cases} \quad (6)$$

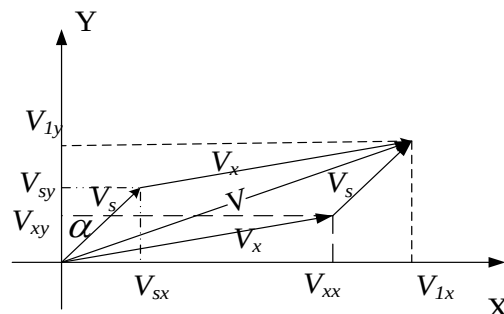


Figure 4. Diagram of the relationship among the factors of course, speed, direction and velocity. According to formula (6), the flow direction α and velocity V_s are obtained.

$$\begin{cases} V_s = \sqrt{V_{sx}^2 + V_{sy}^2} \\ \alpha = \arctan(V_{sx}/V_{sy}) \end{cases} \quad (7)$$

The format of the calculation table is shown in Figure 5.

Illustration: Similar to the method of finding the course in the nautical plan table, α in formula (7) refers to the flow direction between 0 and 90 degrees, and other situations V_{sx} and V_{sy} should be determined according to the positive and negative sum (see formula (8)).

	A	B	C	D	E	F	G	H	I
1	Calculation between heading and flow								
2	Time	Heading	Main engine	Track	Speed	Flow direction	Flow speed	X axis	Y axis
3	0800	120	2	120	3	147.73	0.59	0.32	-0.5
4	0930	56	0.67	9.5	0.7	305.67	0.54	-0.44	0.32
5	1000	56	4	53	4.9	39.98	0.93	0.59	0.71

Figure 5. Tables for calculating the factors of course, speed, direction and velocity

In Figure 5, the difference between heading (host speed) and track (speed) on X axis and Y axis is calculated according to formula (6), and then the flow direction (velocity) is calculated according to formula (7). Similarly, heading and engine speed can also be calculated according to flow direction (velocity) and track direction (speed). The specific calculation functions are as follows:

$$\begin{aligned} \text{X axis } H3 &= E3 * \sin(\text{RADIANS}(D3)) - C3 * \sin(\text{RADIANS}(B3)) \\ \text{Y axis } I3 &= E3 * \cos(\text{RADIANS}(D3)) - C3 * \cos(\text{RADIANS}(B3)) \\ \text{Flow speed } G3 &= \text{SQRT}(\text{POWER}(H3,2) + \text{POWER}(I3,2)) \\ \text{Flow direction } F3 &= \text{IF}(I3 < 0, \text{DEGREES}(\text{ATAN}(H3/I3)) + 180, \text{IF}(H3 < 0, \\ &\quad \text{DEGREES}(\text{ATAN}(H3/I3)) + 360, \text{DEGREES}(\text{ATAN}(H3/I3)))) \end{aligned} \quad (8)$$

2.4. Missile Occupancy Table

In practice, when a certain type of ship launches a certain type of missile during drilling, there are stricter requirements for the occupancy maneuver of the ship, especially in the last few minutes, the specific course and speed must be guaranteed.

Therefore, there are certain requirements for the position of the ship within a certain time before the launch time T. In order to ensure the accuracy of position and reduce the time of manual plotting and measuring position, the position of launching point can be input into EXCEL table, and the position of the last few minutes can be calculated more conveniently by using EXCEL function. The calculation table is designed as shown in Figure 6.

	A	B	C	D	E	F	G	H	I	J	K
1	Table of missile occupation										
2	Time	Flow direction	Flow speed	Heading	Speed	Integer of Latitude	Fraction of Latitude	Integer of longitude	Fraction of longitude	Latitude component	Longitude component in X axis
3	T	186.00	0.00	56	6.00	27	51.000	122	6.000	3.36	5.626
4	T-6	186.00	0.00	56	6.00	27	50.665	122	5.437	50.66	5.437
5	T-10	186.00	0.00	56	6.00	27	50.441	122	5.062	50.44	5.062
6	T-15	186.00	0.00	56	6.00	27	50.161	122	4.594	50.16	4.594
7	T-20	186.00	0.00	56	6.00	27	49.882	122	4.125	49.88	4.125
8	T-30	186.00	0.00	56	6.00	27	49.322	122	3.187	49.32	3.187
9	T-40	186.00	0.00	56	6.00	27	48.763	122	2.250	48.76	2.250
10	T-50	186.00	0.00	56	6.00	27	48.204	122	1.312	48.20	1.312
11	T-60	186.00	0.00	56	6.00	27	47.645	122	0.374	47.64	0.374
12	T-90	186.00	0.00	56	6.00	27	45.967	122	57.561	45.97	-2.438

Figure 6. Table of missile occupation

Referring to the method of back-thrust flow elements, the data in Figure 6 are calculated. Firstly, according to the relationship between the direction of launch time (T), the velocity (set to zero, i.e. no flow counting) and the heading and the speed of the main engine, the sum of the components of the two in the X-axis and Y-axis (i.e. the latitude component of the Y-axis) is obtained (i.e. the range of the X-axis and Y-axis).

Then the position of the time before the last few minutes (T-N) is calculated. In the last few minutes, the heading is 056.0 degrees (assumed heading, according to actual setting), the speed is 6 knots (assumed speed, according to actual setting); and then the position of the remaining time is deduced according to the position of the T-N time in the track direction of 056.0 degrees, and the speed is 6 knots (also calculated in the X axis and Y axis respectively). The specific calculation formula is similar to the previous one and will not be further elaborated.

3. Conclusion

Based on the powerful function calculation function of EXCEL tool, this paper presents several data processing methods of EXCEL tables commonly used in navigation. This method can simplify the long-term work, effectively improve the speed and accuracy of data calculation, and the processed data are easier to be preserved for a long time. Several data processing methods mentioned in this paper have been tested in practice, and the effect is good. This method can be popularized and implemented in navigation work, so as to improve the level of computer use of navigation cadres and promote the development of navigation work better and faster.

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