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Adaptive case reasoning based aircraft carrier formation POL consumption prediction

Qin Hualong*, Guo Jikun, Sun Wangzhou, Fan Rong and Li Bixin

Logistical Engineering University, Chongqing, China

ABSTRACT

Based on collection and statistics of the aircraft carrier formation combat subjects exercise data, this paper introduces in case reasoning technology and service frequency adaptive calculation to endow weight to feature attribute, forming an intelligent POL consumption prediction method based on adaptive case reasoning. Considering the complex problems in the consumption prediction process such as uncertain concept, dynamic scene, diverse characterization and irregular cases, the aircraft carrier formation POL support case library has been structured and the current prediction problem has been solved by reuse or update of aircraft carrier formation POL consumption prediction source case, which effectively remedies the prediction defect by standard coefficient prediction method. It has been proved by practices to be a feasible and intelligent prediction method of good expandability, transportability and self-learning capability.

Key words: Adaptive case reasoning; aircraft carrier formation; POL consumption prediction

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INTRODUCTION

Aircraft carrier formation is the maritime military strength group composed of aircraft carrier, concomitant combat naval ships and supportive ships. It relies on carrier plane as main attacking force, including aerial defense, naval ship defense, submarine defense and sea beach offensive capability as a whole, which is currently the most powerful combat force on maritime battlefield[1][2]. Under new circumstances, to scientifically understand the aircraft carrier formation POL support demands and decide the orientation of aircraft carrier formation POL support system building is the urgent request to adapt to aircraft carrier formation construction and development.

The adaptive case reasoning based aircraft carrier formation POL consumption prediction takes case reasoning technology as basic guideline, which calculates and selects the most similar case through matching calculation between case source in the system and case to be studied, and also performs prediction on target case by case knowledge[3]. The method is featured with weighting the feature attributes by frequency adaptive calculation to make the feature attributes always in a dynamic correction and updating process, showing typical self adaptive character. After reasoning on huge amount of samples, it could form a relatively stable feature attribute weight, and weighting process of experts in the field will be more objective and stable. In the case reasoning process, case refers to the typical event already happened and recorded. The aircraft carrier formation POL consumption case refers to typical event recorded during aircraft carrier platform sea trial, training, operation, or carrier plane training, or training and implementing mission of naval ships from other formation; source case refers to typical event set in system database after long time accumulation; while target case is the problem to be predicted[4] [5].

The adaptive case reasoning based aircraft carrier formation POL consumption prediction solves the current prediction problems by reusing or updating plans and cases for previous surface naval formation POL consumption prediction [6]. It is of good expandability, transportability and self-learning capability to well work on complex prediction problems with uncertain concept, dynamic scene, diverse characterization and irregular case [7].

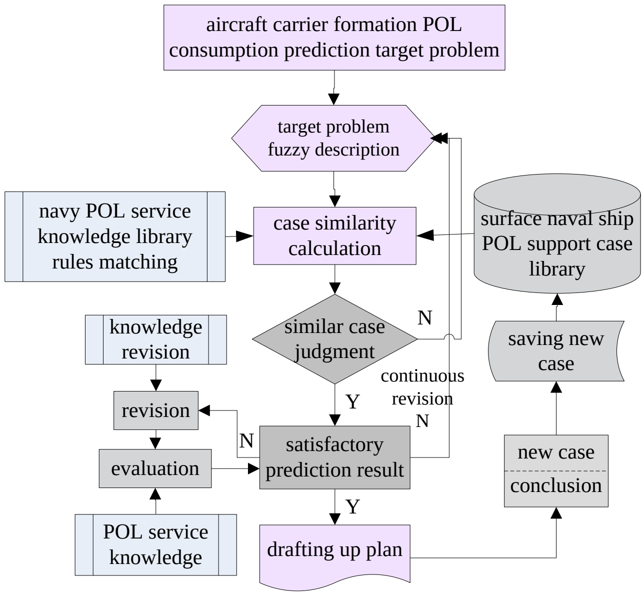


Fig.1 Process for adaptive case reasoning based aircraft carrier formation POL consumption prediction

1 FEATURE ATTRIBUTE BASED AIRCRAFT CARRIER FORMATION POL CONSUMPTION PREDICTION KNOWLEDGE BRIEFING

A lot of relevant information is required for aircraft carrier formation POL consumption prediction, such as the formation scale, operation pattern, operation time, etc., which is often shown in text. For the adaptive case reasoning method to better identify these texts, it shows the text core content in the form of attribute feature and structures the case library[8].

1.1 Analysis on aircraft carrier formation POL consumption prediction case feature attributes

Tab.1 Aircraft carrier formation POL consumption prediction case attribute and valuing

Code	Feature attribute	Feature valuing	Feature value type
H1	Naval ship grouping	Formation, single ship (including carrier plane or not) etc.	UE
H2	Staff grouping	Naval ship formation staff strength (including that of pilot on carrier plane)	NP
H3	Operation pattern	Cruise, high seas operation, offshore defense, firepower attack, maritime blockage, aerial blockage, fishery protection & escort, electronic reconnaissance, safety defense, joint rehearsal, training, sea trial, etc.	UE
H4	POL consumption equipment (PCE) type	Aircraft carrier platform, destroyer, frigate, nuclear submarine, conventional power submarine, comprehensive supply ship, fighter, early warning aircraft, electronic fighter, antisubmarine helicopter, transport helicopter, etc.	UE
H5	PCE quantity	POL consumption equipment quantity of aircraft carrier formation	NP
H6	PCE working intensity	0.5-2 (step as 0.1)	OE
H7	Duration	Operation lasting time (h)	NP
H8	Sea condition	Calm-glassy, calm-rippled, smooth wavelet, moderate, rough, very rough, high, very high, phenomenal (level 1-9)	UE

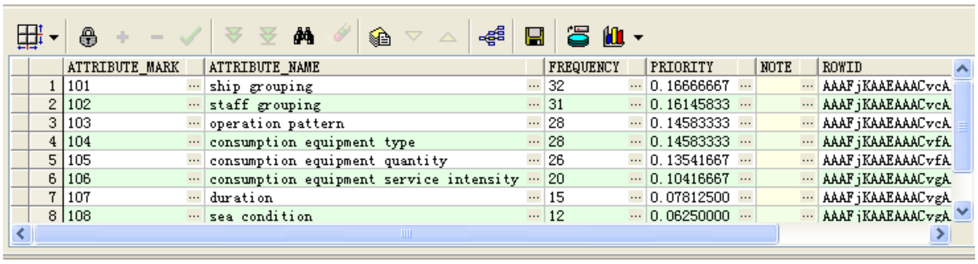
Tab.2 The aircraft carrier formation POL consumption case library structure diagram [9]

Y	H1	H2	H3	H4	H5	H6	H7	H8	Z
Y1	Single ship	1500	Sea trial	Aircraft carrier platform, fighter	1 ship/4 planes	1.5	12	Smooth wavelet	Consult
Y2	Single ship	1600	Cruise	Aircraft carrier platform, transport helicopter	1 ship/2 planes	1.0	7	Calm-rippled	Consult
Y3	Formation	2400	Training	Aircraft carrier platform, frigate, transport helicopter, antisubmarine helicopter	3 ships/6 planes	1.2	8	Moderate	Consult
Y4	Formation	2150	Sea trial	Aircraft carrier platform, destroyer, transport helicopter	2 ships/5 planes	1.5	15	Smooth wavelet	Consult

1.2 The aircraft carrier formation POL consumption case library structure

The aircraft carrier formation POL consumption case library structure is shown in tab. 2, where Y1, Y2, Y3, Y4 refers to aircraft carrier formation POL consumption source case, H1, H2, H3, H4, H5, H6, H7, H8 refers to case feature attribute respectively, Z refers to solution of all source cases[9], which is available by clicking consult.

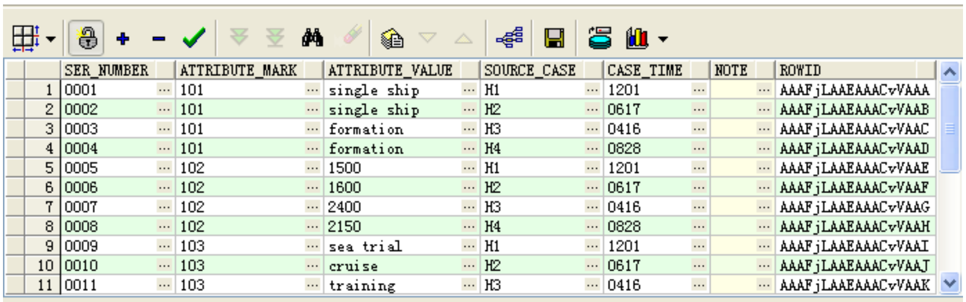
POL consumption case feature attributes consist of information such as feature mark, feature name, frequency and priority, etc. as in fig. 2. The frequency indicates feature attribute matching times during case reasoning process, and the case attribute importance changes with case reasoning times, shown as priority.



	ATTRIBUTE_MARK	ATTRIBUTE_NAME	FREQUENCY	PRIORITY	NOTE	ROWID
1	101	ship grouping	32	0.16666667		AAAFjKAAEAAACvcA
2	102	staff grouping	31	0.16145833		AAAFjKAAEAAACvcA
3	103	operation pattern	28	0.14583333		AAAFjKAAEAAACvcA
4	104	consumption equipment type	28	0.14583333		AAAFjKAAEAAACvfA
5	105	consumption equipment quantity	26	0.13541667		AAAFjKAAEAAACvfA
6	106	consumption equipment service intensity	20	0.10416667		AAAFjKAAEAAACvgA
7	107	duration	15	0.07812500		AAAFjKAAEAAACvgA
8	108	sea condition	12	0.06250000		AAAFjKAAEAAACvgA

Fig.2 Aircraft carrier formation POL consumption case feature attribute diagram

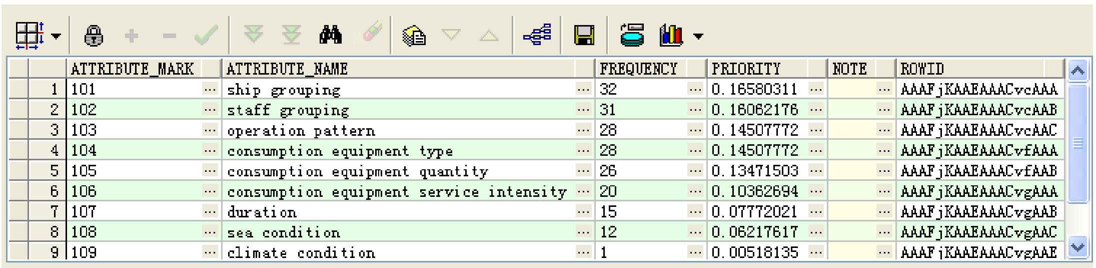
The aircraft carrier POL consumption case attribute information is composed of attribute mark, attribute value, source case and case reasoning time, etc., as in fig. 3.



	SER_NUMBER	ATTRIBUTE_MARK	ATTRIBUTE_VALUE	SOURCE_CASE	CASE_TIME	NOTE	ROWID
1	0001	101	single ship	H1	1201		AAAFjLAAEAAACvVAAA
2	0002	101	single ship	H2	0617		AAAFjLAAEAAACvVAAB
3	0003	101	formation	H3	0416		AAAFjLAAEAAACvVAAC
4	0004	101	formation	H4	0828		AAAFjLAAEAAACvVAAD
5	0005	102	1500	H1	1201		AAAFjLAAEAAACvVAAE
6	0006	102	1600	H2	0617		AAAFjLAAEAAACvVAAF
7	0007	102	2400	H3	0416		AAAFjLAAEAAACvVAAG
8	0008	102	2150	H4	0828		AAAFjLAAEAAACvVAAH
9	0009	103	sea trial	H1	1201		AAAFjLAAEAAACvVAAI
10	0010	103	cruise	H2	0617		AAAFjLAAEAAACvVAAJ
11	0011	103	training	H3	0416		AAAFjLAAEAAACvVAAK

Fig.3 Aircraft carrier formation POL consumption case attribute information diagram

1.3 Self-learning of aircraft carrier formation POL consumption case feature attribute
(1) Increment of case feature attribute
In the process of feature attribute matching between the aircraft carrier formation POL consumption target case and source case, for the new feature attribute in target case, such as new climate condition attribute in fig. 4, system will add the new attribute into case library feature attribute set, realizing enlargement and update for aircraft carrier formation POL consumption case library feature attribute.



	ATTRIBUTE_MARK	ATTRIBUTE_NAME	FREQUENCY	PRIORITY	NOTE	ROWID
1	101	ship grouping	32	0.16580311		AAAFjKAAEAAACvcAAA
2	102	staff grouping	31	0.16062176		AAAFjKAAEAAACvcAAB
3	103	operation pattern	28	0.14507772		AAAFjKAAEAAACvcAAC
4	104	consumption equipment type	28	0.14507772		AAAFjKAAEAAACvfAAA
5	105	consumption equipment quantity	26	0.13471503		AAAFjKAAEAAACvfAAB
6	106	consumption equipment service intensity	20	0.10362694		AAAFjKAAEAAACvgAAA
7	107	duration	15	0.07772021		AAAFjKAAEAAACvgAAB
8	108	sea condition	12	0.06217617		AAAFjKAAEAAACvgAAC
9	109	climate condition	1	0.00518135		AAAFjKAAEAAACvgAAE

Fig.4 Aircraft carrier formation POL consumption case feature attribute increment

(2) Deletion of case feature attribute
When the feature attribute in aircraft carrier formation POL consumption case library is not activated and used successively for more than design threshold value Q, system will regard it as redundancy feature and delete it. For example, in fig. 5, H2 staff grouping feature attribute is not used for more than initial threshold value 20, i.e. $X_{H2} = 21 > Q$, system will delete H2 feature attribute, whose vacancy will be filled by successive feature attribute in turn[10] [11].

	ATTRIBUTE_MARK	ATTRIBUTE_NAME	FREQUENCY	PRIORITY	NOTE	ROWID
1	101	ship grouping	55	0.15542522		AAAFjKAAEAAACvcAAA
2	103	operation pattern	48	0.14076246		AAAFjKAAEAAACvcAAB
3	104	consumption equipment type	46	0.13489736		AAAFjKAAEAAACvcAAC
4	105	consumption equipment quantity	46	0.13489736		AAAFjKAAEAAACvfAAA
5	106	consumption equipment service intensity	41	0.13471503		AAAFjKAAEAAACvgAAA
6	107	duration	39	0.12023460		AAAFjKAAEAAACvgAAB
7	108	sea condition	36	0.10557184		AAAFjKAAEAAACvgAAC
8	109	climate condition	32	0.09384164		AAAFjKAAEAAACvgAAE

Fig.5 Aircraft carrier formation POL consumption case feature attribute deletion

(3) Sort of case feature attribute

The important and secondary feature attribute can exchange according to service frequency of aircraft carrier formation POL consumption case feature attribute, i.e. realizing adaptive sorting of case feature attribute[12] [13].

To arrange aircraft carrier formation POL consumption case feature attribute weight α according to service frequency in descending order:

$$\alpha_{A1} \geq \alpha_{A2} \geq \cdots \geq \alpha_{An},$$

Satisfying

$$\sum_{i=1}^{n} \alpha_{Ai} = 1.$$

Initial sort of aircraft carrier formation POL consumption case feature attribute can be determined by experts in navy POL service, and then conduct self-learning according to service frequency variation of feature attribute in case reasoning process. As shown in fig. 6, case feature attribute H2, staff grouping service frequency is 42, other 6 feature attributes service frequency such as H3 operation pattern and H4 POL consumption equipment type is 62, 60, 60, 57, 54 and 43 respectively; aircraft carrier formation POL consumption feature attribute is rearranged, feature attribute from H3 to H8 sort is from 2 to 7, feature attribute H2 staff grouping sort is 8. When service frequency of aircraft carrier formation POL consumption case feature attribute is identical, case library keeps original sorting.

	ATTRIBUTE_MARK	ATTRIBUTE_NAME	FREQUENCY	PRIORITY	NOTE	ROWID
1	101	ship grouping	66	0.13636364		AAAFjKAAEAAACvcAAA
2	103	operation pattern	62	0.12809917		AAAFjKAAEAAACvcAAB
3	104	consumption equipment type	60	0.12396694		AAAFjKAAEAAACvcAAC
4	105	consumption equipment quantity	60	0.12396694		AAAFjKAAEAAACvfAAA
5	106	consumption equipment service intensity	57	0.11776860		AAAFjKAAEAAACvgAAA
6	107	duration	54	0.11157024		AAAFjKAAEAAACvgAAB
7	108	sea condition	43	0.08884297		AAAFjKAAEAAACvgAAC
8	102	staff grouping	42	0.08677686		AAAFjKAAEAAACvgAAD
9	109	climate condition	40	0.08264462		AAAFjKAAEAAACvgAAE

Fig.6 POL consumption prediction case feature attributes sorting

(4) Case feature attribute optimizing process

Aircraft carrier POL consumption case feature attribute optimizing process is shown in fig. 7:

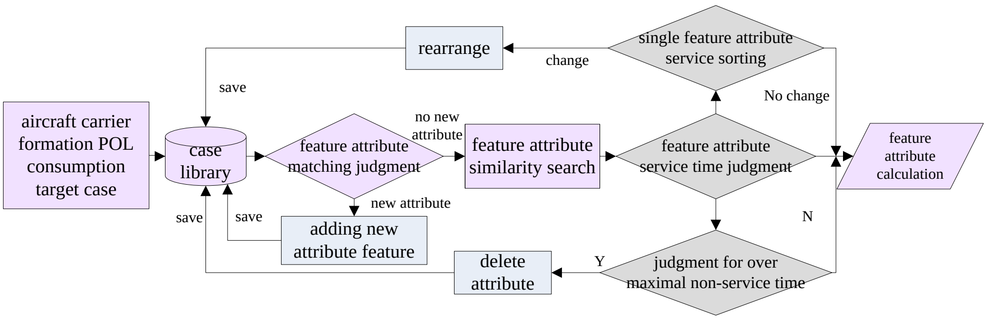


Fig.7 Aircraft carrier POL consumption case feature attribute optimizing process

2 SEARCH AND MATCHING OF AIRCRAFT CARRIER FORMATION POL CONSUMPTION CASE
Set the matching threshold value, orderly search and calculate matching degree between source cases in case library and target case according to aircraft carrier formation POL consumption case feature attribute importance level, and output the searching case satisfying demands of threshold value.

2.1 Feature attribute similarity calculation
The feature attribute similarity is calculated by variable weight Euclidean distance in the system [14], assuming POL consumption prediction target case is Y, some specific source case is Y_i, its weighted Euclidean distance is:

$$D_i^{(\alpha)} = D^{(\alpha)}(Y, Y_i) = \left[\sum_{r=1}^{n} \alpha_r^2 \left(x_r - x_{ir}\right)^2\right]^{\frac{1}{2}} = \left[\sum_{r=1}^{n} \alpha_r^2 x_r^2\right]^{\frac{1}{2}} \quad (1)$$

Where, α is feature attribute weight, i.e. frequency adaptive calculation result, satisfying $\sum_{r=1}^{n} x_r = 1$, x_r is the r^th^ case feature of target case, x_{ir} is the r^th^ feature attribute of source case, $x_r - x_{ir}$ is the distance between target case and source case on the r^th^ feature attribute.

Assume $x_r - x_{ir}$ is d_i, d_i is then regarded as a mapping from $F_i \times F_i$ to $(0, \infty)$, F_i is codomain of the i^th^ feature. This mapping is of the following properties:

When b and c is real number, then $d_i(b,c) = |b-c|$; when B and C is interval, $d_i(b,c) = \max|b-c|$ and $b \in B$, $c \in C$; when *b* and *c* is symbol, $d_i(b,c) = \begin{cases} 1, & b \neq c \\ 0, & b = c \end{cases}$

Distance between target case Y and source case Y_i is:

$$D_i^{(\alpha)} = \left[\sum_{r=1}^{n} \alpha_r^2 d_r^2 (Y_r, Y_{ir})\right]^{\frac{1}{2}} \quad (2)$$

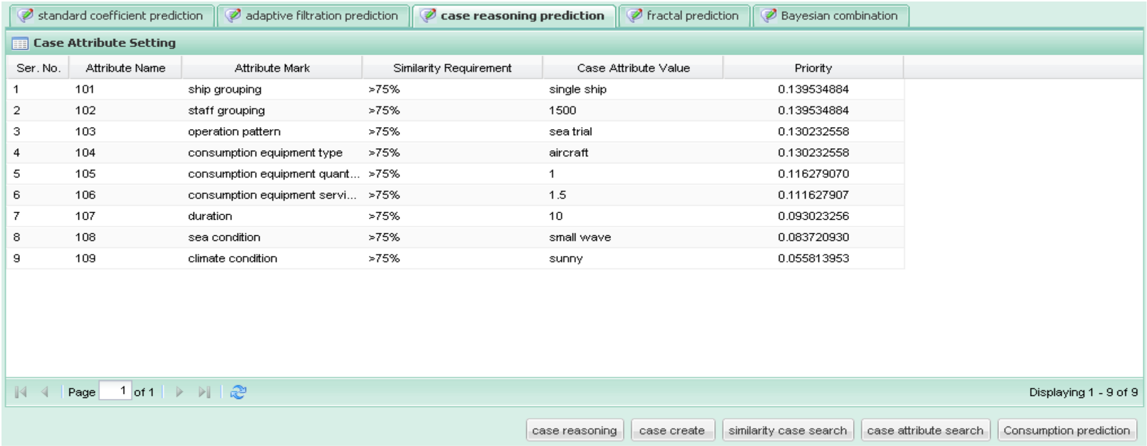
2.2 Case output
Weight of aircraft carrier formation POL consumption feature attribute is decided according to its service frequency, which indicates the importance degree of all feature attributes. For weighted Euclidean distance calculation, assume the maximal output distance is Dmax, system will output all cases that satisfy $Y_i < D\max$ as spare case [15]. Selection of solution is available according to Euclidean minimal distance or weighted average of spare cases.

3 REVISION AND STUDY OF AIRCRAFT CARRIER FORMATION POL CONSUMPTION CASE
When system completes case search and matching, and output case satisfies weighted Euclidean distance, if the result in output case satisfies current case demands, then the expected goal is therefore realized. If there is no case output under maximal distance D_{max}, there should be methods such as case substitution, shift, or combination adjustment to revise source case so as to adapt to target problem demands.

Save target cases with new information and feature attribute to case library, delete those of big approximation with source case. Expanding knowledge and reducing information redundancy of case library is to reduce cost of case search and enhance case prediction efficiency.

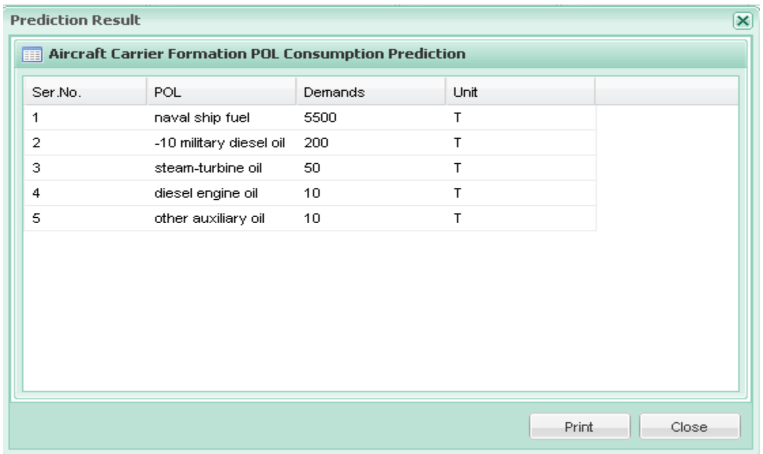
4 REAL CASE OF AIRCRAFT CARRIER FORMATION POL CONSUMPTION PREDICTION

Aircraft carrier formation POL consumption prediction by adaptive case reasoning method:



Ser. No.	Attribute Name	Attribute Mark	Similarity Requirement	Case Attribute Value	Priority
1	101	ship grouping	>75%	single ship	0.139534884
2	102	staff grouping	>75%	1500	0.139534884
3	103	operation pattern	>75%	sea trial	0.130232558
4	104	consumption equipment type	>75%	aircraft	0.130232558
5	105	consumption equipment quant...	>75%	1	0.116279070
6	106	consumption equipment servi...	>75%	1.5	0.111627907
7	107	duration	>75%	10	0.093023256
8	108	sea condition	>75%	small wave	0.083720930
9	109	climate condition	>75%	sunny	0.055813953

Fig.8 Aircraft carrier formation POL consumption prediction based on adaptive case reasoning



Ser.No.	POL	Demands	Unit
1	naval ship fuel	5500	T
2	-10 military diesel oil	200	T
3	steam-turbine oil	50	T
4	diesel engine oil	10	T
5	other auxiliary oil	10	T

Fig.9 Result of aircraft carrier formation POL consumption prediction based on adaptive case reasoning

Judging from prediction result, the predicted POL consumption for aircraft carrier platform over 10 days by adaptive case reasoning method is 5,500 tons of naval ship fuel, 200 tons of military diesel oil, 70 tons of auxiliary oil such as steam-turbine oil, which is of 5.3% error compared with actual consumption summation 5,480 tons, therefore, the method is deemed practical and feasible.

CONCLUSION

Adaptive based case reasoning aircraft carrier formation POL consumption prediction method endows weight to feature attribute by adaptive calculation of frequency, and realizes current prediction solution by reuse and update of previous similar POL consumption prediction plan and case. The method can directly transfer POL support knowledge fragment that is difficult to sum up the rules, so as to make acquisition of POL support information easier; inputting case matching required critical parameters could realize solution of target problem, simplify POL consumption prediction process, enhance prediction efficiency, acquire new case method for self-learning, and the predicted result is highly reliable and easily acceptable. Therefore, adaptive case reasoning POL consumption prediction method is feasible with fine prediction effect.

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