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Intelligence is the development direction of command and control (C2) system. To some extent, intelligence technology can reduce the workload of human, but meanwhile may cause the reduction of situation awareness and other problems. In order to adequately exert the decision advantages of commander and automation, we need to do decision allocation between them during the design process of C2 system. Through decision allocation of C2 system, we can think there forms a cooperative relationship between commander and automation. This relationship is manifested in the different levels of automation (LOAs) of C2 system. In this paper, we firstly propose the decision allocation step of C2 system, and then we integrate the decision-making advantages of human and automation with uncertain linguistic multiple attribute decision making (ULMADM) method and determine the optimal automation level of C2 system.

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Decision allocation of C2 system based on ULMADM

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***Abstract*—Intelligence is the development direction of command and control (C2) system. To some extent, intelligence technology can reduce the workload of human, but meanwhile may cause the reduction of situation awareness and other problems.**

In order to adequately exert the decision advantages of commander and automation, we need to do decision allocation between them during the design process of C2 system. Through decision allocation of C2 system, we can think there forms a cooperative relationship between commander and automation. This relationship is manifested in the different levels of automation (LOAs) of C2 system. In this paper, we firstly propose the decision allocation step of C2 system, and then we integrate the decision-making advantages of human and automation with uncertain linguistic multiple attribute decision making (ULMADM) method and determine the optimal automation level of C2 system.

Keywords-command and control system, decision allocation, levels of automation, Uncertain Linguistic Multiple Attribute Decision Making (ULMADM).

I. INTRODUCTION

Decision allocation is the decision-making function allocation of human/machine intelligent system[1]. With the technology development of computer, artificial intelligence and automation, the autonomous level of intelligent system is continuously growing. According the environment information, they can take optimal action after decision-making. Function allocation of decision layer has become an important research aspect of human/machine system. In the command and control (C2) field, decision allocation reasonably allocates the decision-making function of command and control system between commander and automation.

Nowadays intelligence technology is broadly used in the C2 fields. To some extent, this can reduce the workload of human, but meanwhile may cause the reduction of situation awareness and other problems[2]. On the other hand, decision-making is partially optimized with the improvement of computing capability and the progress of decision-making algorithm, but there are still some questions, which may hard to solve or need long computation time. Heuristic methods can not always provide satisfying solutions for these problems[3,4,5,6].

Facing this situation, we can allocate the decision-making function of C2 system between human and machine and make decision in appropriate automation level. In this way, human participates in the decision-making process, and the decision-making advantages of human, like intuition, experience and initiative, and the advantages of machine, like computation speed and accuracy, are combined together and they complement each other. Cooperative decision-making can produce better result than singly decision-making. It can not only make the commander maintain better situation awareness and reduce workload and operation mistake, but also take full use of the automation's operation advantage, and finish the combat mission with high efficiency[7].

Through decision allocation of C2 system between human and machine, we can think there forms a cooperative relationship between commander and automation. This relationship is manifested in the different levels of automation (LOAs) of C2 system. In this paper, we firstly propose the decision allocation step of C2 system, and then we integrate the decision-making advantages of human and automation with uncertain linguistic multiple attribute decision making (ULMADM) method and determine the optimal automation level of C2 system.

II. DECISION ALLOCATION STEP OF C2 SYSTEM

The basic principle of decision allocation is as follows: using system analysis method and classifying the decision-making functions according to the properties and importance at the basis of function definition of system and subsystems, and then determining a certain function is allocated to human or automation to produce the best performance. Decision allocation is an iterative and continuous decision-making process and it closely contacts with all aspects of system design process.

In accordance with the above principle, decision allocation flow of manned/unmanned aerial vehicle formation C2 system mainly includes the following steps:

(1) Analysis and decomposition of decision-making function

Function analysis includes the process of determination, description and decomposition of system functions. Before the operation of manned/unmanned aerial vehicle formation, we should give out the definition of C2 system and subsystem with system analysis method on the basis of specific operation background, objective and intelligence information, and conduct a detailed analysis on its function, and then give out a comprehensive decision-making function list of C2 system.

(2) Mandatory decision allocation

This step is the preliminary processing of decision allocation and its aim is to determine which function can be explicitly or mandatorily allocated to either human or automation. The functions processed include two types: one type is the functions obviously belong to the specialty of either human or automation, and the other type is the functions restricted by policies or regulations. We can judge only by some simple single rules of the rule set.

(3) Comprehensive assessment of human and machine decision-making advantages

As human and machine both are the syntheses of a number of capability, it is obviously unilateral to decide the ascription of a decision-making function by only a certain capability. We need to respectively integrate the capabilities of human and machine and give out more comprehensive assessment result. In this paper we will do the assessment with multiple attribute decision making (MADM) method based on uncertain extended weighted arithmetic averaging (UEWAA) operator.

(4) Determining the automation level range of decision-making function

The automation level classification method of human-machine system proposed by Paeasuraman has been widely used[8], as shown in table 1, and we will use this method in the paper.

TABLE I. AUTOMATION LEVEL

LOA	Description
1	System does not provide any assistance, and the operator must complete all the decisions and manipulation
2	System provides decision-making or action plan
3	System narrows scheme selection
4	System provides a proposal
5	Execute the plan if the operator agree
6	The scheme is allowed to be vetoed in the limited time before the implementation
7	Implement automatically unless it is necessary to notice man
8	Tell them if the operator want to know
9	Whether or not to inform man is decided by computer
10	System decides all the work and refuses man's intervention

Comprehensive assessment result indicates the effectiveness of human and machine to do the decision-making function[9]. We can use a complex number of decision space (the effectiveness of human is the real part and the effectiveness of machine is the imaginary part) to denote. As shown in Fig. 1, each region corresponds to different effectiveness. According to the region where the assessment result locates, we can determine the automation level range of every decision-making function.

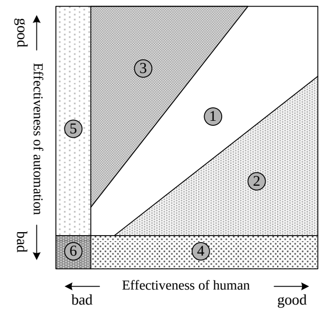

Figure 1. Comparison decision space of human/machine capability

(5) Determination the automation level of decision-making function

After we get the automation level range of decision-making function, we need to narrow the scope and determine the optimal automation level. Assessment criteria, like mental workload of operator, situation awareness, decision risk, system cost and so on, are used to assess different schemes[8,10]. A group decision making method combined with UEWAA operator and uncertain linguistic hybrid aggregation (ULHA) operator is used to determine the automation level.

III. DECISION ALLOCATION METHOD BASED ULMADM

A. *Basics of ULMADM*

From the above steps, we can see that decision allocation of C2 system is a typical MADM problem. Generally speaking, the experts can't evaluate the attribute value precisely. They just can use linguistic values to predict and evaluate relevant factors. The more general case is these linguistic values themselves are uncertain. For example, the expert think the commander's mental workload value is between common and higher in a decision allocation scheme. That value is a typical linguistic interval value. Facing this highly uncertain decision problem with the incomplete information, we use UEWAA and ULHA operators of the ULMADM method to solve.

Set $M=\{1,2,\cdots,m\}$, $N=\{1,2,\cdots,n\}$, $L=\{1,2,\cdots,\ l\}$, and set the linguistic assessment scale $S=\{s_\alpha \mid \alpha=-L,\cdots,L\}$. The number of terms in S is generally odd and S must meet the following conditions[11,12]:

If $\alpha>\beta$, then $s_\alpha>s_\beta$;

Negative operator $\operatorname{neg}(s_\alpha)=s_{-\alpha}$ exists.

An expanded scale $\bar{S}=\{s_\alpha \mid \alpha\in[-q,q]\}$ is defined on the basis of original scale S and $q(q>L)$ is a sufficiently large natural number. If $\alpha\in\{-L,\cdots,L\}$, then s_α is a natural term. If $\alpha\notin\{-L,\cdots,L\}$, then s_α is an expanded term. The expanded scale still meets the upper conditions (1) and (2).

Definition 1 Assuming $\tilde{\mu}=[s_a,s_b]$, $s_a,s_b\in\bar{S}$. s_a and s_b are the lower and upper limits of $\tilde{\mu}$ respectively, so $\tilde{\mu}$ is called an uncertain linguistic variable.

Assuming $\tilde{S}$ is a set of all the uncertain linguistic variables. The algorithms of uncertain linguistic variable can be seen in reference [13].

Definition 2[13] Assuming $\tilde{\mu}=[s_a, s_b]$, $\tilde{\upsilon}=[s_c, s_d]\in\tilde{S}$, and $l_{ab}=b-a$, $l_{cd}=d-c$. The possible degree when $\tilde{\mu}\ge\tilde{\upsilon}$ is defined as

$$p(\tilde{\mu}\ge\tilde{\upsilon})=\max\left\{1-\max\left(\frac{d-a}{l_{ab}+l_{cd}},0\right),0\right\} \quad (1)$$

Definition 3[13] Assuming UEWAA: $\tilde{S}^n\to\tilde{S}$, if

$$\text{UEWAA}_{\boldsymbol{\omega}}(\tilde{\mu}_1,\tilde{\mu}_2,\cdots,\tilde{\mu}_n)=\omega_1\tilde{\mu}_1\oplus\omega_2\tilde{\mu}_2\oplus\cdots\oplus\omega_n\tilde{\mu}_n \quad (2)$$

where $\boldsymbol{\omega}=(\omega_1,\omega_2,\cdots,\omega_n)$ is a weight vector of the uncertain linguistic variable $\tilde{\mu}_i (i\in N)$, and $\omega_j\in[0,1]$ $(j\in N)$, $\sum_{j=1}^{n}\omega_j=1$. The function UEWAA is called an uncertain extended weighted arithmetic averaging (UEWAA) operator.

Definition 4[13] Assuming ULHA: $\tilde{S}^n\to\tilde{S}$, if

$$\text{ULHA}_{\boldsymbol{\omega},\boldsymbol{w}}(\tilde{\mu}_1,\tilde{\mu}_2,\cdots,\tilde{\mu}_n)=w_1\tilde{\upsilon}_1\oplus w_2\tilde{\upsilon}_2\oplus\cdots\oplus w_n\tilde{\upsilon}_n \quad (3)$$

where $\boldsymbol{w}=(w_1,w_2,\cdots,w_n)$ is a weight vector related to ULHA, $w_j\in[0,1]$ $(j\in N)$, $\sum_{j=1}^{n}w_j=1$. $\tilde{\upsilon}_j$ is the jth larger element of the weighted uncertain linguistic variable group $(\tilde{\mu}'_1,\tilde{\mu}'_2,\cdots,\tilde{\mu}'_n)$ $(\tilde{\mu}'_i=n\omega_i\tilde{\mu}_i, i\in N)$. Here, $\boldsymbol{\omega}=(\omega_1,\omega_2,\cdots,\omega_n)$ is a weight vector of an uncertain linguistic variable group $(\tilde{\mu}_1,\tilde{\mu}_2,\cdots,\tilde{\mu}_n)$, $\omega_j\in[0,1]$ $(j\in N)$, $\sum_{j=1}^{n}\omega_j=1$, and n is a balance factor. The function ULHA is called an uncertain linguistic hybrid aggregation (ULHA) operator.

B. Automation level range of decision allocation

Assuming that X is a decision-making function set to be allocated, and H and M are the sets of the capability advantages of human and machine respectively. The weight factors of them are $\boldsymbol{\omega}=(\omega_1,\omega_2,\cdots,\omega_m)$ and $\boldsymbol{\xi}=(\xi_1,\xi_2,\cdots,\xi_l)$, and $\omega_j\ge 0$ $(j\in M)$, $\sum_{j=1}^{m}\omega_j=1$, $\xi_j\ge 0\,(j\in L)$, $\sum_{j=1}^{l}\xi_j=1$. The steps of the method to determine the automation level range based on UEWAA factor are as follows:

Step 1: The decision makers give out the uncertain linguistic assessment values of the influence degree $\tilde{r}_{ij}$ and $\tilde{q}_{ij}$ respectively, which are the capability advantages of man and machine $h_j\in H$ and $m_j\in M$, treat the undistributed decision-making function $x_i\in X$ ($i\in N$), and the assessment matrixes are obtained $\tilde{\boldsymbol{R}}=(\tilde{r}_{ij})_{n\times m}$ R** and $\tilde{\boldsymbol{Q}}=(\tilde{q}_{ij})_{n\times l}$, and $\tilde{r}_{ij},\tilde{q}_{ij}\in\tilde{S}$.

Step 2: Aggregate the linguistic assessment values in the ith line of assessment matrices $\tilde{\boldsymbol{R}}$ and $\tilde{\boldsymbol{Q}}$ respectively by UEWAA operator, and then obtain the comprehensive evaluation results $\tilde{y}_i(\boldsymbol{\omega})$ and $\tilde{z}_i(\boldsymbol{\xi})$ $(i\in N)$ which the capabilities of man and machine treat undistributed function $x_i\in X$.

Step 3: Calculate the possible degree $p_i=p(\tilde{y}_i(\boldsymbol{\omega})\ge\tilde{z}_i(\boldsymbol{\xi}))\,(i\in N)$ between comprehensive evaluation results $\tilde{y}_i(\boldsymbol{\omega})$ and $\tilde{z}_i(\boldsymbol{\xi})$ $(i\in N)$, and then obtain a possible degree vector $\boldsymbol{P}=\{p_1,p_2,\cdots,p_n\}$, $0\le p_i\le 1$.

Step 4: According to the possibility p_i, the automation level range A of function $x_i\in X$ can be established. The concrete rules are described as follows:

$$\begin{cases} floor((1-p_i)\times 10)-1\le A\le floor((1-p_i)\times 10)+1 \\ A\in\{1,2,\cdots,10\}\end{cases} \quad (4)$$

Note that $floor(x)$ is a Gauss integral function.

C. Automation level of decision allocation

After the automation level range of decision allocation has been established, several different schemes to decision allocation are given. Generally, in order to reduce the experts' subjective deviation, different schemes are usually graded by several evaluation experts in accordance with the assessment criteria. A group decision making method combined with UEWAA operator and ULHA operator is used to determine the automation level of decision allocation in this paper. The concrete steps are described as follows:

Step 1: Assume that X, U and D are respectively the scheme set, the assessment criteria set and the expert set. The weight vector of assessment criteria is $\boldsymbol{\omega}=(\omega_1,\omega_2,\cdots,\omega_m)$, $\omega_j\ge 0$ $(j\in M)$, $\sum_{j=1}^{m}\omega_j=1$. The weight vector of expert is $\boldsymbol{\lambda}=(\lambda_1,\lambda_2,\cdots,\lambda_t)$, $\lambda_k\ge 0\,(k=1,2,\cdots,t)$, $\sum_{k=1}^{t}\lambda_k=1$. The expert $d_k\in D$ gives out the assessment value $\tilde{r}_{ij}^{(k)}$ of the scheme $x_i\in X$ under the assessment criteria $u_j\in U$, and then we obtained the evaluation matrix $\tilde{\boldsymbol{R}}_k=(\tilde{r}_{ij}^{(k)})_{n\times m}$, and $\tilde{r}_{ij}^{(k)}\in\tilde{S}$.

Step 2: Aggregate the uncertain assessment information in the ith line of evaluation matrix $\tilde{\boldsymbol{R}}_k$ by UEWAA operator, and then get the comprehensive property assessment value $\tilde{z}_i^{(k)}(\boldsymbol{\omega})\,(i\in N,$ $k=1,2,\cdots,t)$ of the allocation scheme x_i given by decision makers d_k.

Step 3: Aggregate the comprehensive property assessment values $\tilde{z}_i^{(k)}(\boldsymbol{\omega})(k=1,2,\cdots,t)$ of scheme x_i given by t decision makers with ULHA operator, and then acquire the group comprehensive property assessment value $\tilde{z}_i(\boldsymbol{\lambda},\boldsymbol{w}')$ $(i\in N)$ of the allocation scheme x_i.

Step 4: Calculate the possible degree $p_{ij}=p(\tilde{z}_i(\boldsymbol{\lambda},\boldsymbol{w}')\geq\tilde{z}_j(\boldsymbol{\lambda},\boldsymbol{w}'))\,(i,\,j\in N)$ of the comprehensive attribute values $\tilde{z}_i(\boldsymbol{\lambda},\boldsymbol{w}')$ $(i\in N)$ between each scheme and establish the possible degree matrix $\boldsymbol{P}=(p_{ij})_{n\times n}$.

Step 5: Calculate the priority vector $\boldsymbol{v}=(v_1,v_2,\cdots,v_n)$ of the possible degree matrix $\boldsymbol{P}$, and rank the schemes according to the component size of $\boldsymbol{v}$, and then get a optimal solution. Note that

$$v_i=\frac{1}{n(n-1)}\left(\sum_{j=1}^{n}p_{ij}+\frac{n}{2}-1\right),\quad i\in N\,. \tag{5}$$

IV. EXAMPLE AND ANALYSIS

We will take decision allocation of Targets Clustering (TC), one of the functions of C2 system, as an example to analyze the upper decision allocation method.

A. Automation level range of TC

Define the sets of capability advantages of human and machine respectively as $H=\{h_1,h_2,h_3,h_4,h_5,h_6,h_7,h_8\}$ and $M=\{m_1,m_2,m_3,m_4,\ m_5,m_6,m_7,m_8\}$. The meaning of each element is shown in Table 2.

TABLE II. SETS OF CAPABILITY ADVANTAGES OF HUMAN AND MACHINE[14,15]

H	M
h_1-Experiential learning capability	m_1-Data management capability
h_2-Inductive Reasoning capability	m_2-Combinatorial problems handling capability
h_3-Pattern recognition capability	m_3-Continuously working capability
h_4-Visual perception capability	m_4-Multi-tasking capability
h_5-Fuzzy information processing capability	m_5-Fast computing capability
h_6-Spatial reasoning capability	m_6-Complex mathematical calculation capability
h_7-Creativity	m_7-Accurate calculation capability
h_8-Uncertain event processing capability	m_8-Simple repetition of the decision-making capability

Analytic hierarchy process (AHP) is used to determine the weight coefficient of each element in the two sets. The weight vectors of elements in the set H and M are $\boldsymbol{\omega}=(0.287,0.106,0.081,0.142,0.119,0.019,0.193,\ 0.053)$ and $\boldsymbol{\xi}=(0.163,0.097,0.228,0.126,0.154,0.106,\ 0.062,0.064)$.

Establish the linguistic assessment scale $S=\{s_\alpha\,|\,\alpha=-5,\cdots,5\}$ = {minimum, very small, small, comparatively small, a little small, normal, a little large, comparatively large, large, very large, maximum}.

The experts evaluate the influence (contribution) degree on TC function by each element of the capability advantages of human and machine and get the results of the evaluation as follows:

$\tilde{\boldsymbol{R}}=([s_2,s_3],[s_0,s_2],[s_3,s_4],[s_1,s_3],[s_0,s_2],[s_2,s_3],[s_{-2},$ $s_0],[s_0,s_2])$,

$\tilde{\boldsymbol{Q}}=([s_0,s_2],[s_2,s_4],[s_0,s_1],[s_2,s_3],[s_2,s_4],[s_3,s_4],[s_1,$ $s_3],[s_{-3},s_{-1}])$。

We use UEWAA operator to aggregate the evaluation results $\tilde{\boldsymbol{R}}$ and $\tilde{\boldsymbol{Q}}$, and then obtain the comprehensive evaluation results $\tilde{y}(\boldsymbol{\omega})=$ $[s_{1.138},s_{2.224}]$ and $\tilde{z}(\xi)=$ $[s_{0.942},s_{2.482}]$.

The possible degree of $\tilde{y}(\boldsymbol{\omega})\geq\tilde{z}(\xi)$ is $p(\tilde{y}(\boldsymbol{\omega})\geq\tilde{z}(\xi))=0.538$. According to Eq. (4), we can get the automation level range of TC function is $3\leq A\leq 5$.

B. Automation level of TC

After determined the automation level range of TC function, we can get three different allocation schemes. Assume $X=\{x_3,x_4,x_5\}$ is the set of allocation schemes about TC function, and x_i means that the automation level of the scheme x_i is $i(i=3,4,5)$. Allocation assessment criteria set is $U=\{u_1,\ u_2,u_3,u_4,u_5\}$. The elements of U are corresponding to five main evaluation criteria of decision allocation: u_1—mental workload, u_2—situation awareness, u_3—reliability, u_4—decision-making risk, u_5—system cost. We can get the attribute weight vector $\boldsymbol{\omega}=(0.351,0.227,0.284,0.037,0.074)$ with AHP method. The set of decision-maker $D=\{d_1,d_2,d_3\}$, and d_i is the ith decision-maker, $i=1,2,3$. The weight vector of D is $\boldsymbol{\lambda}=(0.33,0.33,0.34)$.The three decision-makers give out the uncertain linguistic evaluation matrices in Tables 3-5 according to the linguistic assessment scale S. $S=\{s_\alpha\,|\,\alpha=-5,\cdots,5\}=$ {Worst, very bad, bad, comparatively bad, a little bad, normal, a little good, comparatively good, good, very good, best}.

TABLE III. DECISION MATRIX $\tilde{\boldsymbol{R}}_1$

	u_1	u_2	u_3	u_4	u_5
x_3	$[s_0, s_2]$	$[s_3, s_4]$	$[s_{-2}, s_0]$	$[s_2, s_4]$	$[s_2, s_3]$
x_4	$[s_0, s_3]$	$[s_0, s_2]$	$[s_3, s_5]$	$[s_1, s_4]$	$[s_2, s_4]$
x_5	$[s_1, s_3]$	$[s_2, s_4]$	$[s_2, s_4]$	$[s_1, s_3]$	$[s_0, s_1]$

TABLE IV. DECISION MATRIX $\tilde{\boldsymbol{R}}_2$

	u_1	u_2	u_3	u_4	u_5
x_3	$[s_{-1}, s_0]$	$[s_2, s_3]$	$[s_{-1}, s_1]$	$[s_2, s_3]$	$[s_1, s_2]$
x_4	$[s_0, s_1]$	$[s_0, s_2]$	$[s_2, s_3]$	$[s_1, s_2]$	$[s_2, s_3]$
x_5	$[s_0, s_2]$	$[s_0, s_1]$	$[s_1, s_2]$	$[s_1, s_3]$	$[s_0, s_1]$

TABLE V. DECISION MATRIX $\tilde{\boldsymbol{R}}_3$

	u_1	u_2	u_3	u_4	u_5
x_3	$[s_1, s_2]$	$[s_3, s_4]$	$[s_2, s_3]$	$[s_1, s_2]$	$[s_2, s_3]$
x_4	$[s_2, s_4]$	$[s_0, s_1]$	$[s_3, s_4]$	$[s_2, s_4]$	$[s_1, s_2]$
x_5	$[s_{-1}, s_1]$	$[s_2, s_3]$	$[s_{-1}, s_1]$	$[s_3, s_4]$	$[s_1, s_3]$

First, we aggregate the linguistic assessment information of the ith line of evaluation matrix $\tilde{\boldsymbol{R}}_k$ with UEWAA operator, and then we get the comprehensive attribute assessment value $\tilde{z}_i^{(k)}(\boldsymbol{\omega})$ about the decision scheme x_i which the decision maker d_k gives out $(i=3,4,5,k=1,2,3)$:

$\tilde{z}_3^{(1)}(\boldsymbol{\omega})=[s_{0.335},s_{1.98}]$, $\tilde{z}_4^{(1)}(\boldsymbol{\omega})=[s_{1.037},s_{3.371}]$,

$\tilde{z}_5^{(1)}(\boldsymbol{\omega})=[s_{1.41}, s_{3.282}]$, $\tilde{z}_3^{(2)}(\boldsymbol{\omega})=[s_{-0.033}, s_{1.224}]$,

$\tilde{z}_4^{(2)}(\boldsymbol{\omega})=[s_{0.753}, s_{1.953}]$, $\tilde{z}_5^{(2)}(\boldsymbol{\omega})=[s_{0.321}, s_{1.682}]$,

$\tilde{z}_3^{(3)}(\boldsymbol{\omega})=[s_{1.785}, s_{2.758}]$, $\tilde{z}_4^{(3)}(\boldsymbol{\omega})=[s_{1.702}, s_{3.063}]$,

$\tilde{z}_5^{(3)}(\boldsymbol{\omega})=[s_{0.004}, s_{1.686}]$.

With the discrete normal distribution method, we can get the position weight vector $\boldsymbol{w}=(0.243, 0.514, 0.243)$ of ULHA operator[16,17], and then we obtain the group comprehensive attribute assessment value $\tilde{z}_i(\boldsymbol{\lambda}, \boldsymbol{w})\,(i=3,4,5)$ of decision allocation scheme x_i.

$\tilde{z}_3(\boldsymbol{\lambda}, \boldsymbol{w}) = [s_{0.403}, s_{1.324}]$,

$\tilde{z}_4(\boldsymbol{\lambda}, \boldsymbol{w}) = [s_{0.753}, s_{1.963}]$,

$\tilde{z}_5(\boldsymbol{\lambda}, \boldsymbol{w}) = [s_{0.336}, s_{1.375}]$.

With Equ.(1), we can build the probability matrix $\boldsymbol{P}$:

$$\boldsymbol{P}=\begin{bmatrix} 0.5 & 0.268 & 0.504 \\ 0.732 & 0.5 & 0.723 \\ 0.496 & 0.277 & 0.5 \end{bmatrix}.$$

And then we can draw the priority vector $\boldsymbol{v}$ of probability matrix $\boldsymbol{P}$:

$\boldsymbol{v}=(0.295, 0.409, 0.296)$.

Rank the order according to the component size of $\boldsymbol{v}$, and we get $x_4 \succ x_5 \succ x_3$. Thus the optimal scheme is x_4, that is to say, the automation level of TC takes 4 the most appropriate.

V. CONCLUSIONS

In the formation C2 system, it is the primary task of decision allocation to allocate the decision-making function between human and automation system. From the decision allocation process we can see that, only after full awareness of the mission requirements and the current development level of automated decision-making technology and after careful analysis of the characteristic of human and machine, the designer of C2 system can get the dialectical unity of commander and automation in the C2 system and choose optimal human-machine cooperative decision mode to achieve the objective of system. Decision allocation is not only a complicated but also an iterative process. With the increase of training level of commanders and the improvement of system automation and intelligent level, the decision allocation result needs to be adjusted accordingly.

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