Performance Evaluation of Aerospace Service Network Based on Entropy Weight Set-Pair-Analysis

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Abstract. The Aerospace Service Network (ASN) provides communication of voices, video, data. Its performance is the key to satellite launching. In order to comprehensive assessment of Aerospace Service Network’s performance, this paper presented evaluation index based on network analysis data and calculated index weight by entropy method. Furthermore, a network performance evaluation model based on interval number Set-Pair-Analysis is established. The analysis and comparison showed that this model is objective and effective, and it provides decision support for network maintenance.

1 Introduction

In recent years, with the development of equipment informatization becoming better, more and more equipment were putted on Aerospace Service Network (ASN). The type of interactive transmission information becomes variety, such as Language dispatching system, video picture, real time data etc. ASN operation type, data scale and transmission requirement change heavily. Therefore, the difficulty and the amount of network maintenance increases heavily, network maintainers are not sure whether network performance meets the requirement.

Entire operation quality in some direction at ASN objectively & quantitatively can’t be evaluated by using traditional end to end time-delay test method. Therefore, it becomes the most urgent problem that should be solved which establishing a kind of ASN performance evaluation system & method, then realizes complex evaluation of ASN. This paper establishes a kind of network evaluation system and method in ASN and presents computation method of indexes in system. In the end, it confirms correctness and practicability of the evaluation system and method in actual mission data.

2 Index system

At present, Network Communication Post can get part quantified link data of each direction through monitor software. This paper constructs index system based on the quantified data. Network performance’s chief index follows below:

1) Network transmission maximum time delay: PING test amount of data package from communication monitor point, maximum time delay among all returned data package.
2) Network transmission minimum time delay: PING test amount of data package from communication monitor point, minimum time delay among all returned data package.

3) Network transmission average time delay: PING test amount of data package from communication monitor point, minimum time delay among all returned data package.

4) Network transmission time delay variation: PING test amount of data package from communication monitor point, minimum time delay among all returned data package.

5) Package loss rate: PING test amount of data package from communication monitor point, Do not receive returned package proportion of all returned data package.

Analysis every relevance and membership of evaluation index, then construct structure model of network safety risk evaluation. Using resolution method, resolve evaluation system and establish systematic evaluation index system. As shown in the figure 1:

![Network performance chart](image)

**Figure 1.** Systematic evaluation index system.

### 3 Weight computation

After index system established, different index have different influence to software guarantee, therefore, it needs to compute index weight. Index weight mainly serves for computing maximum time delay, minimum time delay, average time delay, time delay variation index weight below time delay index.

Using entropy weight set computes index weight, basic thought is that confirm objective weight according to index variability. Generally speaking, some index information entropy \( E_j \) becomes smaller, it indicates that index value variability becoming larger. While more information it provides, more effect it makes in complex evaluation, hence, its weight is heavier. On the contrary, some index information entropy \( E_j \) is larger, it indicates that index value variability becoming smaller. While less information it provides, less effect it makes in complex evaluation, hence, its weight is lighter.

Computing process as follows, based on some actual mission for example:

Setting in evaluation system with \( m \) index and \( n \) evaluation object, original evaluation matrix \( R_{m,n} \), computing process details as below:

1. Since 4 index data are negative index, dealing them with standardization based on formula below:

   \[
   R'_{ij} = \frac{\max(R_j) - R_{ij}}{\max(R_j) - \min(R_j)} \quad (1)
   \]

2. Compute index information entropy.

   \[
   E_j = -\ln(n)^{-1} \sum_{i=1}^{n} P_{ij} \ln P_{ij} \quad (2)
   \]
Including below: \( P_{ij} = \frac{R_{ij}'}{\sum_{i=1}^{n} R_{ij}'} \), if \( P_{ij} = 0 \), then defines \( \lim_{P_{ij} \to 0} P_{ij} \ln P_{ij} = 0 \).

(3) The results of computing each index information entropy are \( E_1, E_2 \ldots \ldots E_n \) based on information entropy computing formula. Then, each index weights are:

\[
W_i = \frac{1-E_j}{n-\sum E_j} (i = 1,2 \ldots \ldots n)
\]

Take some actual mission data in 1st plane for example to compute results. As shown in the table 1. Computing weight is weight = (0.28158, 0.28181, 0.28188, 0.15473).

Table 1. Xx mission test original data.

<table>
<thead>
<tr>
<th>Object</th>
<th>Maximum time delay</th>
<th>Minimum time delay</th>
<th>Average time delay</th>
<th>Time delay variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object[1]</td>
<td>2.378</td>
<td>1.144</td>
<td>1.692</td>
<td>1.234</td>
</tr>
<tr>
<td>Object[2]</td>
<td>0.432</td>
<td>0.340</td>
<td>0.396</td>
<td>0.092</td>
</tr>
<tr>
<td>Object[3]</td>
<td>0.754</td>
<td>0.406</td>
<td>0.458</td>
<td>0.348</td>
</tr>
<tr>
<td>Object[4]</td>
<td>0.641</td>
<td>0.414</td>
<td>0.524</td>
<td>0.227</td>
</tr>
<tr>
<td>Object[5]</td>
<td>6.250</td>
<td>0.342</td>
<td>0.993</td>
<td>5.908</td>
</tr>
<tr>
<td>Object[6]</td>
<td>1.753</td>
<td>1.525</td>
<td>1.666</td>
<td>0.228</td>
</tr>
<tr>
<td>Object[7]</td>
<td>1.002</td>
<td>0.945</td>
<td>0.971</td>
<td>0.057</td>
</tr>
<tr>
<td>Object[8]</td>
<td>4.086</td>
<td>0.797</td>
<td>1.167</td>
<td>3.289</td>
</tr>
<tr>
<td>Object[9]</td>
<td>0.855</td>
<td>0.798</td>
<td>0.813</td>
<td>0.057</td>
</tr>
<tr>
<td>Object[10]</td>
<td>6.220</td>
<td>0.821</td>
<td>1.538</td>
<td>5.399</td>
</tr>
<tr>
<td>Object[11]</td>
<td>1.105</td>
<td>1.026</td>
<td>1.061</td>
<td>0.079</td>
</tr>
<tr>
<td>Object[12]</td>
<td>12.491</td>
<td>11.666</td>
<td>11.925</td>
<td>0.825</td>
</tr>
<tr>
<td>Object[13]</td>
<td>11.968</td>
<td>11.723</td>
<td>11.877</td>
<td>0.245</td>
</tr>
<tr>
<td>Object[16]</td>
<td>60.062</td>
<td>59.799</td>
<td>59.922</td>
<td>0.263</td>
</tr>
<tr>
<td>Object[17]</td>
<td>70.831</td>
<td>70.162</td>
<td>70.379</td>
<td>0.669</td>
</tr>
<tr>
<td>Object[18]</td>
<td>70.355</td>
<td>70.033</td>
<td>70.119</td>
<td>0.322</td>
</tr>
<tr>
<td>Object[19]</td>
<td>79.905</td>
<td>79.632</td>
<td>79.752</td>
<td>0.273</td>
</tr>
<tr>
<td>Object[20]</td>
<td>35.485</td>
<td>35.151</td>
<td>35.293</td>
<td>0.334</td>
</tr>
<tr>
<td>Object[21]</td>
<td>59.358</td>
<td>58.626</td>
<td>58.810</td>
<td>0.732</td>
</tr>
</tbody>
</table>

4 Interval possibility degree Set-Pair-Analysis

4.1 Set-Pair-Analysis

Set-Pair-Analysis method is a kind of system theory on uncertainty analysis which is came up with by Mr. Keqin Zhao in our country. Set Pair is a pair that is consisted of two set which have some kind of relation between them. According to the definition of Set Pair, any two parts in system can be regarded as an example of set pair in some condition. Such
as, matter and energy, combination and decomposition, command and decision, and so on. Contents of Set Pair are all kinds of difference.

The kernel idea of Set-Pair-Analysis is that objective things between certainty and uncertainty relation are regarded as both uncertainty and certainty coexisting in a system to analyze and dispose. In specific analysis, certainty relation of two sets can be divided into “identity relation” and “difference relation”, meanwhile, uncertainty relation of two sets is a relation that is called “antagonism relation” different from “identity relation” and “difference relation”. For convenience, in these two set “identity”, “difference”, “antagonism” are short for “identity connection”, “difference connection”, “antagonism connection” respectively.

(1) Identity relation, if two sets have some identical feature, it means the sets have identity relation.

(2) Difference relation, if two sets have some difference feature, it means the sets have difference relation.

(3) Antagonism relation, if two sets have some relation that is different from “identity relation” and “difference relation”, it is called “antagonism relation”.

Antagonism relation of two sets is a kind of uncertainty relation which is totally different from identity relation of two sets and difference relation of two sets, and meanwhile, has intimate relation with those above.

Identity, difference, antagonism relation degree expression is confirmed as follows: this method analysis set which is consisted with set A and set B based on question W. setting set pair has N features, among them include S common features by set A and set B, these two sets oppose in P features, and the reminded F=N-S-P features are not opposite and unified, which means property is uncertain. With not considering weight of each feature, it is called:

\[ S/N \text{ is called identical degree combined with set A and set B in problem W. It is recorded ‘a’ for short.} \]

\[ F/N \text{ is called diversity degree combined with set A and set B in problem W. It is recorded ‘b’ for short.} \]

\[ P/N \text{ is called opposite degree combined with set A and set B in problem W. It is recorded ‘c’ for short.} \]

Identical degree, diversity degree and opposite degree describe relation conditions of two sets from different angles, therefore it uses expression below to describe total relation conditions of two sets overall: \( u = a + bi + cj \). \( i \) is diversity degree mark which value is located between \([-1, 1]\]. \( J \) is opposite degree which value is -1. And \( a, b, c \) satisfy normalizing condition: \( a + b + c = 1 \).

### 4.2 Interval possibility degree

In result matrix, Identical degree is approximated degree between approximated result and theoretical result in \( u = a + bi + cj \). The premise of this method is assume that approximated result and theoretical result more closer and more better, and do not consider difference relation and antagonism relation in result matrix. In result, there is one-sidedness which result vector is not fully used well enough.

For fully using all information of final connection number, the best support plan should be get by comparing the result after converting the result vector of Set-Pair-Analysis into interval number The specific method is that converting connection number \( u = a + bi + cj \) into interval number \([u-, u+]\) according to formula, then expressing the worst situation of this project, among them \( u- \) is possible minimum of the connection number and the best situation of this project, among them \( u+ \) is possible maximum of the connection number.
$$u = a + bi + cj \gg [u^-, u^+] \lessgtr \begin{cases} u^- = a - c - b, i = -1, j = -1 \\ u^+ = a - c + b, i = 1, j = -1 \end{cases}$$ \hspace{1cm} (4)

For comparing interval number, concept of interval number possibility degree is introduced. Setting $$a = [a_-, a_+]$$ is a interval number. When $$a = a_+$$, a degenerates into a real number.

When a, b are both real number, $$p(a \geq b) = \begin{cases} 1 & a \geq b \\ 0 & a < b \end{cases}$$ is called possible degree of $$a \geq b$$.

When a, b are both interval numbers or have at least one interval number, setting $$a = [a_-, a_+]$$, $$b = [b_-, b_+]$$, setting $$l_a = a_+ - a_-$$, $$l_b = b_+ - b_-$$, then

$$p(a \geq b) = \frac{\max[0, l_a + l_b - \max(b^- - a^-, 0)]}{l_a + l_b}$$ \hspace{1cm} (5)

Formula (5) is called possible degree of $$a \geq b$$ and sequence of a, b is $$\frac{a \geq b}{p}$$. If there are two interval numbers, possible degree of $$a \geq b$$ is larger than possible degree of $$b \geq a$$, it means that result of interval number a is more excellent than result of interval number b.

5. Computing instance analysis

Taking data in table 1 for example, all data is cost type index, which means the smaller data is the better it could be. Optimal solution of all project is the smallest value P and the worst solution is largest value G, so, $$P < x_i < G$$, setting interval $$[P, G]$$, the interval is divided into two equal parts, then the middle point is $$M = \frac{P + G}{2}$$, cost type index relation degree function can be calculated as follows:

Setting $$S_1 = |x_i - G|$$, $$S_2 = |x_i - M|$$, $$S_3 = |x_i - P|$$, $$S = S_1 + S_2 + S_3$$;

Then, relation degree, $$u = a + bi + cj = \frac{S_1}{S}i + \frac{S_2}{S}i + \frac{S_3}{S}j$$;

Result matrix of XX device can be calculated by using method above:

$$Y = \begin{bmatrix} 0.66113 & 0.32227 & 0.016595 \\ 0.6644 & 0.3288 & 0.006808 \\ 0.663 & 0.326 & 0.011007 \\ 0.61504 & 0.23008 & 0.15488 \end{bmatrix}$$

Weighted result matrix:

$$H = \text{weight}^T \cdot Y = 0.65545 + 0.31089i + 0.033658j$$

Similarly, as shown in the table 2, all weighted result matrix T are:

<table>
<thead>
<tr>
<th>Object</th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object[1]</td>
<td>0.65545</td>
<td>0.31089</td>
<td>0.033658</td>
</tr>
<tr>
<td>Object[2]</td>
<td>0.66646</td>
<td>0.33292</td>
<td>0.006808</td>
</tr>
<tr>
<td>Object[3]</td>
<td>0.66454</td>
<td>0.32909</td>
<td>0.006372</td>
</tr>
<tr>
<td>Object[4]</td>
<td>0.66532</td>
<td>0.33065</td>
<td>0.00403</td>
</tr>
<tr>
<td>Object[5]</td>
<td>0.55822</td>
<td>0.32275</td>
<td>0.11903</td>
</tr>
<tr>
<td>Object[6]</td>
<td>0.66263</td>
<td>0.32526</td>
<td>0.012106</td>
</tr>
<tr>
<td>Object[7]</td>
<td>0.66528</td>
<td>0.33056</td>
<td>0.004162</td>
</tr>
<tr>
<td>Object[8]</td>
<td>0.62538</td>
<td>0.28157</td>
<td>0.093045</td>
</tr>
<tr>
<td>Object[9]</td>
<td>0.66564</td>
<td>0.33128</td>
<td>0.003083</td>
</tr>
<tr>
<td>Object[10]</td>
<td>0.56696</td>
<td>0.31482</td>
<td>0.11822</td>
</tr>
</tbody>
</table>

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Identical degree comparison result as shown in the figure 2:

\begin{align*}
H_{AI} &= \frac{1}{n(n-1)} \left( \sum_{j=1}^{n} P_{ij} + \frac{n}{2} - 1 \right) \\
\end{align*}

(6)

Gets result vector:

\begin{table}[h]
\centering
\begin{tabular}{|l|c|}
\hline
Object & \text{Result} \\
\hline
Object[1] & 0.05511 \\
Object[2] & 0.050469 \\
Object[3] & 0.053048 \\
Object[4] & 0.052421 \\
Object[5] & 0.039837 \\
Object[6] & 0.053918 \\
Object[7] & 0.052472 \\
\hline
\end{tabular}
\caption{Result vector.}
\end{table}

Figure 2. Identical degree comparison.

Transforming matrix T into interval number as formula (4), comparing possibility degree between any two means as formula (5), comparison matrix can be gotten, this comparison matrix is fuzzy matrix of $P_{21x21}$. Using paper’s brief sorting formulas, gets:

\begin{align*}
H_{AI} &= \frac{1}{n(n-1)} \left( \sum_{j=1}^{n} P_{ij} + \frac{n}{2} - 1 \right) \\
\end{align*}

(6)

Gets result vector:

\begin{table}[h]
\centering
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Object[4] & 0.052421 \\
Object[5] & 0.039837 \\
Object[6] & 0.053918 \\
Object[7] & 0.052472 \\
\hline
\end{tabular}
\caption{Result vector.}
\end{table}
Comparative mapping as shown in the figure 3:

![Interval number comparison](image_url)

**Figure 3.** Interval number comparison.

Comparative two methods as shown in the figure 4:

![Comparison of the two methods](image_url)

**Figure 4.** Comparison of the two methods.
The results compared with identical degree analysis method are basically the same. However, it using all the analyzed information of connection number, compared with identical degree, is more precise and more effective.

References