Target Importance Ranking Method Based on Non-Return Mapping Analysis

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Abstract. The ranking of target importance is an important basis for target attack and defense decision-making. The decision-making idea of non-return fully took into account the dynamic changes of the target network, so that the decision makers can obtain the staged sequencing results according to the existing network structure of the target. The mapping analysis model simplifies the modeling process of complex target networks and enhances the efficiency of decision-making. Finally, the method is verified by analyzing the importance of each target individual in the target network system of Taiwan aviation station. The full text expresses each index quantity through interval numbers, making the result more reliable. The research results show that the method is simple and practical, close to reality, and has certain reference value for target attack and defense decision-making.

1. Introduction
The goal network is composed of multiple goals, which interact, correlate, coordinate and achieve certain functions together. The ranking of target importance is an important basis for target attack and defense decision-making.

Modern combat process is a very complicated process with high uncertainty. Many uncertain factors on the battlefield will bring large errors to the target importance ranking [1] The basic theories of target importance ranking include center of gravity effect theory, chain effect theory, bottleneck effect theory, troubler effect theory, hierarchical effect theory, and combination theory [2]. There are many commonly used target importance ranking methods. Wang Changchun and others put forward the theory of using complex networks [3] and Deng Zhihong and others [4] pointed out that the value of the target depends on the individual value of the target and the value of the target network. The two kinds of values of the target are merged together to form the final value of the target. Lei Ting and others [5] explore various constraints and relationships in the target importance ranking, and get an effective modeling method for target importance ranking. The difference between individuals of the target is not obvious in the complex network theory, the comprehensive value modeling method does not consider the dynamic changes of the target network sufficiently, and the multi-constraint and multi-correlation modeling method is complicated and the phased characteristics of the combat are not reflected in it.

The modeling method based on non-return mapping analysis proposed in this paper can effectively simplify the analysis process, take into account the dynamic changes of the target network and the characteristics of the different combat phases, and can provide certain decision support for the operational commanders.
2. Theoretical Basis

2.1. Description of Non-Return Decision-Making Theory
In order to rank the importance of the target network, it is often necessary to consider the connection between the targets. Sometimes, even the connection is more important than the inherent attribute of the target. Therefore, the basic idea of the non-return decision-making method is to fully consider the dynamic changes of the target network. After determining the most important target, the determination of the second important target is to make a new decision without removing the most important target, that is, not to put back the most important target in the original network structure, thus making the decision-making result closer to reality.

2.2. Description of Mapping Analysis Principle
When studying complex problems, it is sometimes difficult to directly study and express the complicated relationship between related individuals. Therefore, through mapping, problem A1 is transformed into A2 with corresponding and easy to consider through certain mapping rules, and a virtual research object will be established. B2 is obtained through studying the virtual object, and then according to certain rules, the research result is mapped to B1 of the research entity, thus achieving the purpose of simplifying the research process.

This paper studies the target network, maps the target to a virtual target, and obtains the ranking result of the importance of the target through the research of the virtual target. Among them, the thickness of the connection between the targets indicates the closeness of the connection between the targets.

![Figure 1. Non-return decision-making theory](image_url)

![Figure 2. Principle of virtual target mapping analysis](image_url)

3. Overall Planning and Design Implementation
Step 1 Construct a target network model. \( T_i \) represents target individuals in the network, and \( C_{ij} \) represents the association between target network individuals, using interval numbers to represent the values of related objects, and using the size of interval span to represent the size of uncertainty for information, the larger the span, the greater the uncertainty[6]. Among them,

\[
V_{Ti} = [a_l, a_u], V_{C_{ij}} = [a_l, a_u]
\] (1)
respectively represent the target value and the associated value between the targets \( i, j \).

**Figure 3.** Virtual target construction

**Figure 4.** Flow chart of objective importance ranking method based on non-return mapping analysis
Step 2 Construct virtual targets, and determine the scale coefficient of mapping the associated target to the virtual target. Among them, $T_{ci}, T_{cj}$ represent two target individuals linked to each other in the target network, $C_{ij}$ indicates the association between two related targets. Here, we discuss how much the individual values of the two interrelated targets are mapped onto the virtual targets. In order to simplify the calculation, each target value is evenly allocated to the relevant virtual targets. The mapping scale coefficient is:

$$k_{ci} = D_i^{-1}$$

Among them, $D_i$ is the number of targets associated with target $i$.

Step 3 Determining virtual target value

Define the virtual target value as $V_N$. Its value function is $V_N = f(T_i, T_j, C_{ij})$. Determine the virtual target value through mapping rules. The expression is:

$$V_N = k_{ci}V_{Ti} + k_{cj}V_{Tj} + V_{Cij}$$

Step 4 Determine the system value of the goal.

$$VS_i = \sum V_{Ni}$$

Among them, $\sum V_{Ni}$ represents the sum of all virtual targets associated with the target $i$.

Note: when seeking the value of the target system, if there is an isolated target (This kind of situation usually occurs after several target individuals in the target network are destroyed), its system value is equal to the inherent value of the target, but not zero.

Step 5 According to the size of $VS_i$, determine the target importance ranking.

Step 6 According to the requirements of the task, judging whether the judgment of the secondary important target is needed or not, if so, carrying out a new round of target importance ranking according to the existing target network structure under the condition that the most important target is excluded.

4. Case Analysis

In order to further prove the effectiveness of this method, this paper finds out the distribution of Taiwan's air stations and the situation of their flights through consulting relevant data, and constructs the target network as shown in figure 4.

The inherent value of each aviation station and its connection value are directly given by the...
relevant experts according to the information of the intelligence department. And use interval numbers to express, in order to solve the errors caused by various reasons. At the same time, in order to ensure the unity of all dimensions, the centesimal system is used to assign values. The assignment situation is shown in table 1 and 2.

Table 1. Corresponding relation of each number and inherent value of target

| Sequence 1 | Air station | Value  | Sequence 2 | Air station | Value  |
|------------|-------------|--------|------------|-------------|--------|
| 1          | Bei gan     | [35,50]| 9          | Tai zhong   | [75,82]| 
| 2          | Nan gan     | [40,55]| 10         | Jia yi      | [38,50]| 
| 3          | Jin men     | [80,89]| 11         | Tai dong    | [35,45]| 
| 4          | Ma gong     | [70,82]| 12         | Lv dao      | [22,32]| 
| 5          | Wan gan     | [42,57]| 13         | Lan yu      | [37,42]| 
| 6          | Qi mei      | [67,76]| 14         | Hua lian    | [40,48]| 
| 7          | Tai nan     | [40,52]| 15         | Taipei International | [82,92]| 
| 8          | Gaoxiong    | [78,86]| 16         | Heng chun   | [35,45]| 

Table 2. The value of each link

| Joint edge sequence 1 | Value  | Joint edge sequence 2 | Value  | Joint edge sequence 3 | Value  | Joint edge sequence 4 | Value  |
|-----------------------|--------|-----------------------|--------|-----------------------|--------|-----------------------|--------|
| C1-15                 | [20,30]| C3-9                  | [57,68]| C4-9                  | [78,83]| C9-14                 | [49,56]| 
| C2-9                  | [40,55]| C3-10                 | [63,70]| C4-10                 | [65,78]| C11-12                | [20,30]| 
| C2-15                 | [45,52]| C3-15                 | [65,75]| C4-15                 | [63,70]| C11-13                | [20,30]| 
| C3-4                  | [69,82]| C4-6                  | [72,82]| C5-8                  | [20,30]| C11-15                | [25,35]| 
| C3-7                  | [65,70]| C4-7                  | [75,85]| C6-8                  | [68,75]| C14-15                | [38,50]| 
| C3-8                  | [60,70]| C4-8                  | [70,78]| C8-14                 | [48,58]| C15-16                | [20,30]| 

In order to ensure the comprehensiveness of the analysis results, it is necessary to fully consider the relationship between individuals in the target network, usually to conduct a complete two-two correlation analysis, then determine the constraint relationship and construct the virtual targets according to the task requirements, and then determine the value of the virtual target through the research on the virtual targets.

According to the analysis method shown above, the values of each virtual target in this model are shown in table 3:

Table 3. The value of each virtual target

| Virtual target value | Virtual target Sequence 1 | Virtual target value | Virtual target Sequence 2 | Virtual target value | Virtual target Sequence 3 | Virtual target value | Virtual target Sequence 4 |
|----------------------|---------------------------|----------------------|---------------------------|----------------------|---------------------------|----------------------|---------------------------|
| N1-15                | [66.7,93.1]               | N3-9                 | [89.1,103.3]              | N4-9                 | [106.7,115.2]             | N9-14                | [81.1,92.5]               |
| N2-9                 | [78.8,103]                | N3-10                | [95.3,109.8]              | N4-10                | [94.0,114.7]              | N11-12               | [53.7,77.0]               |
| N2-15                | [76.7,92.6]               | N3-15                | [90.05,102.98]            | N4-15                | [84.7,94.9]              | N11-13               | [68.7,87.0]               |
| N3-4                 | [92.3,108.5]              | N4-6                 | [115.5,131.7]             | N5-8                 | [77.6,104.2]             | N11-15               | [48.4,65.1]               |
| N3-7                 | [98.3,110.8]              | N4-7                 | [105.0,122.7]             | N6-8                 | [117.1,130.2]            | N14-15               | [63.1,79.1]               |
| N3-8                 | [88.9,102.0]              | N4-8                 | [95.6,106.9]              | N8-14                | [76.9,91.2]              | N15-16               | [66.7,88.1]               |

After simplifying the study of the problem, the first step of virtual mapping theory has been completed. The second step is to remap the virtual target value to each target entity through certain mapping rules. Determine the system value of the target according to equation (4). It is shown in table 4:
Thus, the interval number of target system value is obtained. There are many methods for sorting interval numbers [7] based on the possibility function, this paper introduces boolean matrix [9] to sort interval numbers, and then obtains the index vector of interval number size. 

\[ \delta = (3, 9, 14, 15, 5, 6, 7, 13, 12, 8, 10, 3, 1, 10, 16, 2) \]

Wherein \( \rho \) takes 2.5. Therefore, the ranking results of target importance are as follows:

\[
T_{15} \prec T_4 \prec T_3 \prec T_8 \prec T_9 \prec T_{11,14} \prec T_2 \prec T_{10} \prec T_7 \prec T_6 \prec T_5 \prec T_{12,13} \prec T_{16} \prec T_{13}
\]

Then, further analyze the importance of the target. The secondary target is sorted under the condition that the most important target is excluded. At this point, the target system value interval number index vector is

\[ \delta' = (2, 3, 13, 15, 6, 9, 8, 14, 12, 10, 11, 5, 4, 7, 1) \]

Therefore, the ranking results of sub-important targets are as follows:

\[
T_4 \prec T_8 \prec T_3 \prec T_6 \prec T_{11} \prec T_{10} \prec T_7 \prec T_6 \prec T_5 \prec T_{12} \prec T_{13} \prec T_2 \prec T_1 \prec T_{16}
\]

It is easy to see that the dynamic changes of the target network have an important influence on the target attack and attack decision-making.

5. Conclusion
The target importance ranking method based on non-return mapping analysis can effectively reflect the dynamic changes of the target network and has an important role in the implementation decision of the target network under the dynamic changes. At the same time, mapping analysis effectively simplifies the analysis process and can provide certain support for the decision-making process of target attack and defense.

6. References
[1] Wang Zehui and Fang Yangwang. 2018 Effectiveness Evaluation Method of Air-combat Based on Bayesian Networks. Advances in aeronautical science and engineering. 9 35 - 42
[2] Qiu Chenglong and Shen Sheng 2004 the Model and Methods of Target Selection. Fire Control & Command Control 29 7- 9.
[3] Wang Changchun, Chen Junliang and Chen Chao. 2012 Modeling and simulation of combat systems paralysis based on complex network. Journal of system simulation 24 1491- 95
[4] Deng Zhihong 2009 Research on methods of target value analysisfor targeting of conventional missile operation(Changsha: National University of Defense Technology( in Chinese))
[5] Lei Ting, Zhu Cheng and Zhang Weiming 2014 Target selection under multi-constraint and multi-association conditions Fire Control & Command Control 39 9 - 12
[6] He Zhongxiong 1984 Fuzzy mathematics and its application. (Tian Jin: Tianjin science and technology publishing house) 76 - 94
[7] Sun Hairlong and Yao Weixing 2010 Comments on methods for ranking interval numbers Journal of systems engineering 25 18 - 26
[8] Xiao Jun, Zhang Yue and Fu Chuan 2011 Comparison Between Methods of Interval Number Ranking Based on Possibility Journal of Tianjin University 44 705 - 11
[9] Li Deqing, Han Guozhu, Zeng Wenyi and Yu Xianchuan 2016 Ranking method of interval numbers based on Boolean matrix Control and Decision 31 629 - 34