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Application of Minimum Subordinative Degree on Choice of Key Defense Site in Battle

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Abstract: In this study, a solution to the choice of key defense site in battle is proposed by analyzing a series of simulated topographic factor data based on the model of Minimum Subordinative Degree (MSD). The key topographic factors to the choice of defense site are intervisibility rate, fire-control distance, number of highland and road within the attack range, gradient of defense site and the difference of elevation. In the situation that we do not have enough factor data mentioned above, the optimal defense site is picked out by our model using the theory of MSD and lagrange.

Key words: Topographic factor, minimum subordinative degree, lagrange theory

INTRODUCTION

Commanders will have a complex consideration when they choose a key defense site. Many decisive factors will make effect on the result of a battle while the topographic factor play an important role. The topographic factors consist of the intervisibility rate, fire-control distance, number of visible highland and road, gradient and the difference of elevation (Luo and Tang, 2008). Of course, other factors are also significant like the tactics data of four highlands (highland A, B, C and D) is simulated in next part, which the optimal one will be finally picked out by the theory of MSD.

MODEL HYPOTHESES

We can define in the following a set of reasonable conditions and hypotheses that belong to a battle:

- The effects of weather, vegetation and soil to the battle are ignored
- The battle in this study especially refers to the war on land
- The independent factor obeys the law of normal distribution

DATA AND THE MSD MODEL

Data and description: The data and description is shown in Table 1.

MSD MODEL AND RESULT

MSD model: From the data in Table 1, the factor set contains 5 effect factors and 4 highlands A, B, C and D make up the solution set X. The weighing vector is $(\omega_1, \omega_2, \ldots, \omega_m)$ where ω_i is the weighing of each effect factor. $T = (\alpha_{ij})_{n\times m}$ is the decision matrix and $R = (r_{ij})_{n\times m}$ is the standard matrix where row vectors of R $(r_{i1}, r_{i2}, \ldots, r_{im})$ is correspond to solution set. According to the standard matrix R, $x^+ = (1, 1, \ldots, 1)$ is defined as positive solution and $x^- = (0, 0, \ldots, 0)$ is the negative solution. Obviously, the solution x_i which is nearest to the positive one is the optimal. So the error is defined as following:

$$e_i^+(\omega) = \sum_{j=1}^{m} |1 - r_{ij}|\omega_j = \sum_{j=1}^{m} |1 - r_{ij}|\omega_j, \quad i \in N$$

Our target is to pick out the solution x_i with the least error $e_i^+(\omega)$, therefore a multi-target decision model is built below (Xu, 2004):

$$\begin{cases} \min e^+(\omega) = (e_1^+(\omega), e_2^+(\omega), \ldots, e_n^+(\omega)) \\ \text{s.t.}\, \omega \in \Phi \end{cases} \tag{1}$$

Due to the weight of each solution in the solution set, (1) can be transfer to the single-target decision model in (Eq. 2):

$$\begin{cases} \min e^+(\omega) = \sum_{i=1}^{n} e_i^+(\omega) \\ \text{s.t.}\, \omega \in \Phi \end{cases} \tag{2}$$

Table 1: Data and description

	Highland			
Factor	A	B	C	D
Intervisibility rate	0.6568	0.5185	0.578	0.5072
Fire-control distance	1258.3	892.4	1039.1	760.7
Number of highland and road within the attack range	4	2	3	4
Gradient	23	15.3	15.3	22
Difference of elevation	76	70	72.5	91.6

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Then:

$$\begin{cases} \min e^{+}(\omega) = n - \sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}\omega_j \\ s.t.\omega \in \Phi \end{cases} \quad (3)$$

Where:

$$\omega^{+} = (\omega_1^{+}, \omega_2^{+}, ..., \omega_m^{+})$$

Order the result $e_i^{+}(\omega^{+})(i \in N)$ from small to large and the minimum value is the optimal solution.

Especially, if the decider cannot provide and information of weighing, the single-target optimal model in the following is available (Li, 2003):

$$\begin{cases} \min F^{+}(\omega) = \sum_{1}^{n} f_i^{+}(\omega) \\ s.t.\omega_j \geq 0, j \in M, \sum_{j=1}^{m}\omega_j = 1 \end{cases}$$

$$f_i^{+}(\omega) = \sum_{j=1}^{m}(1 - r_{ij})\omega_j^2$$

is the error between solution x_i and the idea value.

Then, build lagrange function:

Where $f_i^{+}(\omega) = \sum_{j=1}^{m}(1 - r_{ij})\omega_j^2$ mean the:

$$L(\omega, \zeta) = \sum_{i=1}^{n}\sum_{j=1}^{m}(1 - r_{ij})\omega_j^2 + 2\zeta(\sum_{j=1}^{m}\omega_j - 1)$$

$$\begin{cases} \frac{\partial L}{\partial \omega_j} = 2\sum_{i=1}^{n}(1 - r_{ij})\omega_j + 2\zeta = 0, j \in M \\ \frac{\partial L}{\partial \zeta} = \sum_{j=1}^{m}\omega_j - 1 = 0 \end{cases}$$

and $\omega^{+} = (\omega_1^{+}, \omega_2^{+}, ..., \omega_m^{+})$ is the optimal solution:

$$\omega_j^{+} = [\sum_{j=1}^{m}(n - \sum_{i=1}^{n} r_{ij})^{-1}]^{-1}(n - \sum_{i=1}^{n} r_{ij})^{-1}, j \in M \quad (4)$$

Order the result $f_i^{+}(\omega)(i \in N)$ from small to large and the minimum value is the optimal solution.

Model solution: Evaluate the weighing values of each factor if they are unknown.

Replace the data in Table 1 with X and U, then the decision matrix A is shown in Table 2 as bellow:

The standard matrix R can be achieved by excel (Jiang and Xie, 2003) (Table 3).

According to Eq. 1, the $\omega^{+} = (\omega_1^{+}, \omega_2^{+}, ..., \omega_m^{+})$ is ω^{+} = (0.274433,0.057104, 0.204293, 0.214881, 0.249288).

Then: $f_i^{+}(\omega) = \sum_{j=1}^{m}(1 - r_{ij})\omega_j^2$ can be worked out:

- $f_1^{+}(\omega^{+}) = 0.012477$
- $f_2^{+}(\omega^{+}) = 0.06913$

Table 2: The decision matrix-A

	u_1	u_2	u_3	u_4	u_5
x_1	0.6568	1258.3	4	23.0	76.0
x_2	0.5185	892.4	2	15.3	70.0
x_3	0.5780	1039.1	3	15.3	72.5
x_4	0.5072	760.7	4	22.0	91.6

Table 3: The standard matrix-R

	u_1	u_2	u_3	u_4	u_5
x_1	1	0.419433	1	1	0.829694
x_2	0.789434	0.297467	0.5	0.665217	0.764192
x_3	0.880024	0.346367	0.75	0.665217	0.791485
x_4	0.772229	0.253567	1	0.956522	1

- $f_3^{+}(\omega^{+}) = 0.050017$
- $f_4^{+}(\omega^{+}) = 0.021596$

where, $f_1^{+}(\omega^{+}) < f_4^{+}(\omega^{+}) < f_3^{+}(\omega^{+}) < f_2^{+}(\omega^{+})$ is obvious.

So, the optimal highland is A, then D, C and B is the undesirable choice. Besides, weighing value of each factor is displayed in vector $\omega^{+} = (\omega_1^{+}, \omega_2^{+}, ..., \omega_m^{+})$.

ω^{+} = (0.274433, 0.057104, 0.204293, 0.214881, 0.249288).

CONCLUSION

In this study, we propose a model which can estimate weighing values of each factor in the case of not enough data and some key information. The result achieved by lagrange method makes positive effect when making decide.

But the weighing value can only order the solutions. Without a concrete case, the weighing values make no sense. In addition, the error of weighing value is significant when one factor make a overwhelming effect which is valuable to discuss deeply.

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