Dynamic task assignment method based on NSGA-II algorithm in command and control field

Yichao He*, Xun Wang, Zhiqiang Jiao and Jieyong Zhang
Information and Navigation College, Air Force Engineering University, Xi’an, 710077, China

* Corresponding author: 996422701@qq.com

Abstract. In order to improve the adaptability of command and control organizations to complex operational environments and effectively solve the unexpected events that may be encountered in the operation of C2 organizations, this paper studies the dynamic task assignment of C2 organizations and proposes multi-objective tasks assignment method based on NSGA-II algorithm. Firstly, two kinds of emergencies such as platform damage and task increase in the course of combat are analyzed, and the mathematical expression method is given. Secondly, a multi-objective optimization model aiming at maximizing task completion quality and minimizing plan adjustment cost is constructed. And the adaptive NSGA-II algorithm is designed to solve the model. Finally, the simulation experiment shows that the constructed model can effectively deal with the above-mentioned emergencies, and the designed algorithm can obtain the better Pareto frontier and realize the dynamic task assignment.

1. Introduction
Command and Command (C2) organization [1-3] dynamic task assignment of platform resources refers to the real-time optimization and adjustment of the platform task assignment scheme for pre-war planning in military operations according to the dynamic changes of the battlefield environment [4-7]. Studying the dynamic task assignment method of C2 organization is beneficial to improve the agility of the organization and ensure that the C2 organization can respond correctly to emergencies on the battlefield and efficiently complete the operational mission [8,9]. In literature [10], the dynamic task assignment problem of battlefield re-sources is studied, and the hybrid greedy algorithm is proposed. However, it only considers the satisfaction of task resources and lacks the analysis of dynamic task assignment cost. In literature [11], the dynamic task assignment of the battle repair equipment in combat is carried out, and the mathematical model with three influencing factors as the optimization target is proposed. However, its analysis of the diversity of sudden tasks is insufficient, and the design method is generally not adaptable. In literature [12], the problem of resource uncertainty in the implementation of military mission plan increases the anti-interference ability of the plan by increasing the resource buffer and time buffer, but it sacrifices the resource cost and time cost, and does not fully utilize the inherent platform resource capability.
In order to ensure the adaptability of the operational plan to the uncertain battlefield environment, C2 organizations generally ensure the satisfaction of mission requirements by appropriately increasing the redundancy of operational resources [13]. The more abundant the resources are, the stronger the
robustness of the mission plan, and the stronger the anti-interference ability to sudden uncertainty events. However, in a fierce combat environment, it is difficult for any combat force to maintain the absolute superiority of operational resources. Therefore, researching dynamic task assignment under limited resources is of great significance to improve organizational agility.

The dynamic task assignment of platform resources distinguishes the initial assignment scheme. In modelling, it must consider the degree of satisfaction of the tasks and the adjustment range of the mission plan. The mathematical models constructed in the past tend to weight the two, but the optimization model of constructing a single target is the mandatory unification of different dimensional optimization objectives. The subjectivity of weighted summation is too strong, and its rationality is difficult to verify. Therefore, based on the multi-objective optimization theory [14], this paper studies the dynamic task assignment of C2 organizational platform resources, analyzes the optimization objectives and constraints of the platform task assignment process, constructs a multi-objective optimization model that maximizes task completion quality and minimizes planned adjustment costs, and design a model solving method based on NSGA-II algorithm.

2. Basic concept

The C2 organization is a mission-oriented military organization formed by the combination of various operational relationships around the operational units of the battlefield. The task assignment of the C2 organization is a key issue for the organization to use its own platform for combat mission processing. The main elements involved in the task assignment process include: combat missions, operational platforms, and resource capabilities.

**Definition 1** Resource (R) refers to the inseparable basic unit of the C2 organization's operational process, and is a quantitative description of the size of the combat platform resource type. Different combat missions will generate different resource capability requirements. Generally, each platform has one or more resource capabilities, and the task execution process is a match between platform resource capabilities and task resource requirements.

**Definition 2** The platform (P) is the carrier of resource capability and the basic unit used by C2 organizations to perform combat missions. Different platforms may have different resource capabilities. The platform owned by the organization constitutes a platform set as $P = \{P_1, ..., P_j, ..., P_J\}$, and $J$ represents the number of platforms in the set. The resource capability vector is a basic attribute possessed by any platform $P_j$ in the set, and is denoted as $r = [r_{1j}, ..., r_{lj}, ..., r_{lJ}]$, where $r_{lj}$ represents the number of the $l$-th resource possessed by the platform $P_j$, and $L$ represents the type of resource that is available.

**Definition 3** Operational task (T) refers to the military action that is decomposed from the operational mission and needs to be completed by a platform with specific resource capabilities. It is the object that the organization needs to deal with. The set of combat missions can be written as $T = \{T_1, ..., T_i, ..., T_I\}$, where $I$ represents the number of tasks in the set. The resource requirement vector is a basic attribute possessed by any task $T_i$ in the set, and is expressed as $R_i = [R_{i1}, ..., R_{il}, ..., R_{iL}]$, where $R_i$ represents the number of requirements of the task $T_i$ for the $l$-th resource capability, and $L$ represents the processing. The type of resource capability required for this task.

**Definition 4** The task-platform assignment relationship is the correspondence between all platforms and all tasks based on the satisfaction of the resource requirements of the task. C2 organization's task-platform assignment relationship is represented as

$$y = \left\{ y_{ij} \right\}_{i,j}$$

(1)

where $i = 1, 2, ..., I$, $j = 1, 2, ..., J$, $y_{ij}$ represent the assignment relationship between the task $T_i$ and the platform $P_j$, and the assignment is as shown in the Eq.(2).

$$y_{ij} = \begin{cases} 
1, & \text{Platform } P_j \text{ executes } T_i \\
0, & \text{Platform } P_j \text{ does not execute } T_i
\end{cases}$$

(2)
3. Problem description and model construction

3.1. Problem description analysis
During the operation of C2 organization, due to the complexity and uncertainty of the operational environment, many uncertain events must occur on the battlefield. The dynamic assignment of operational resources for complex battlefield environments will be complicated by many factors. With the change of the battlefield situation, the distribution relationship between the platform and the task needs to be constantly adjusted. From a macro perspective, this is a real-time, continuous process; however, from a micro perspective, the changing operational situation is essentially a series of the chronological incident causes the dynamic adjustment of resources to be an event-driven, gradual, discrete process. Therefore, in order to facilitate the mathematical modelling of the complex process of resource dynamic task assignment, this paper first studies the dynamic task assignment problem under a single emergency event, and lays a theoretical foundation for re-source dynamic task assignment of more complex emergencies.

This essay only considers a few simple incidents. For example, the enemy suddenly adjusts its force deployment, the normal execution of bad weather blocking missions, and the loss of combat capability of some of our combat units. In the optimization of organizational modelling, several kinds of emergencies that may appear above can be summarized as two aspects. One type of emergency is the change of task, that is, the emergence of new sudden tasks or tasks in the battlefield. Change; another type of emergency is a change in the operational platform, that is, some platforms lose their mission execution ability without completing the task. The emergence of these two types of emergencies will result in the failure to achieve the minimum operational requirements for the completion of certain tasks, that is, the quality of mission completion is below the minimum threshold that needs to be achieved. This requires researching the C2 organization's dynamic task assignment method for emergencies to ensure the successful completion of the mission.

There are two main types of coping methods for C2 organizations in response to emergencies on the battlefield. One type is based on the idea of redundant backup. Before each campaign, it is guaranteed to have sufficient platform resources. When an emergency occurs, some of the reserved platforms are used for processing to ensure the smooth implementation of the overall original task assignment plan; It is based on the idea of adjustment and optimization, and the adjustment of the task execution relationship of the existing platform is used to ensure the smooth completion of all tasks. The first type of processing method can effectively deal with various emergencies. However, the actual combat action is often the assignment behaviour under resource constraints. In this case, the campaign decision makers are more inclined to play the performance of all platform resources instead of Used as a backup resource, therefore, the scope of application of the first type of method has limitations; the second type of method can handle some emergencies by improving organizational adaptability, and can provide a more optimized solution for combat operations under limited resources. However, this method can only deal with some local and limited emergencies. The limited resources limit the organization's ability to handle task changes to a certain extent. This paper focuses on the Resource Constrained Project Scheduling Problem (RCPSP), focusing on the C2 group optimization adjustment method belonging to the second category.

Dynamic task assignment based on adjustment optimization is different from the pre-warning task assignment plan. Dynamic assignment cannot simply re-plan the entire task due to the arrival of an emergency. This is because each operating platform is already established. Combat missions are targeted, and temporary changes to any one mission can bring hidden costs. The dynamic adjustment of resources should be based on ensuring that incidents can be handled, and the platform resources should be appropriately adjusted on the basis of changing the original task plan as much as possible. Therefore, for the dynamic task assignment problem, multi-objective optimization is of great significance. On the one hand, it maximizes the quality of all tasks, on the other hand, it minimizes the task adjustment cost of the platform. In addition, the Pareto frontier optimal solution set generated by
multi-objective optimization can provide decision makers with multiple choices when making decisions to solve current emergencies.

3.2. Mathematical description of an emergency

According to the above analysis of the problem, this paper mainly studies two types of emergencies, task change and platform change, which can be described as two scenarios: platform damage and task.

(1) Platform damage

Platform damage refers to the situation in which the combat platform cannot complete a given operational mission before the mission plan is executed. In the mathematical model, it shows that the number of task executions of a certain platform is 0. Assuming that the j-th platform is damaged and cannot perform tasks, the constraints in the mathematical model are as shown in equation (3).

\[ \sum_{i=1}^{I} y_{ij} = 0 \]  

(2) Task added

The addition of tasks refers to new emergent tasks that need to be dealt with during the battle. In the mathematical model, its essence is the change of task requirements, and the new constraints that reflect the task are shown in equation (4).

\[ R = \left( R_{i} \right)_{N \times L}, T \in T \bigcup T_{a} \]  

where \( T \) is the set of tasks which number are I to be executed, \( T_{a} = \left\{ T_{j+1}, \ldots, T_{j+n}, \ldots, T_{j+N} \right\} \) is a collection of new tasks, the resource demand vector is \( R_{a} = \left( R_{j} \right)_{N \times L} \), and \( R \) is the resource requirement vector of all tasks.

3.3. Measurement of dynamic task assignment in C2 organization

The measurement of task assignment is the basis for measuring the advantages and disadvantages of task assignment schemes. For C2 organization dynamic task assignment, the main considerations are two aspects. First, for the quality of task completion, maximizing the quality of task completion under the premise of ensuring that the quality of completion of all tasks reaches the minimum threshold. Second, for the cost of planning adjustment, minimize the original assignment while ensuring that all mission completion quality meets the requirements.

(1) Task completion quality

**Definition 5** The resource satisfaction degree is the ratio of the amount of the Class A resource provided by the platform assigned to the task \( Ti \) to the Class A resource requirement of the task \( Ti \) under the task-platform allocation relationship \( Y \), and the value is at most 1. The class A resource satisfaction degree of task \( Ti \) is as shown in equation (5).

\[ z_{i} = \min \left( \sum_{j=1}^{I} R_{ij} y_{ij} / R_{i}, 1 \right) \]  

**Definition 6** Task completion quality refers to the degree to which all resources that can be provided by a platform assigned to a task meet the requirements of all resources of the task. The quality of task completion is measured the degree of matching between the resource capacity of the platform allocated by the task and the capability requirement of the task resource. This task can only be effectively executed when the platform is able to provide all the resources needed for the task. Therefore, in the mathematical description, the task completion quality of the task \( Ti \) is defined as the geometric mean of the satisfaction degree of all the resources of the task \( Ti \), as shown in the formula (6). When the resource provided by the platform is 0, the quality of the task completion is 0. Therefore, this definition can effectively ensure that all resources required by the platform are provided to the task.

\[ QT_{i} = \left( \prod_{i \in R_{i}} z_{i} \right)^{1/|I|} \]
Where $R_i$, represents the set of resource types required for task $T_i$, and $\|R_i\|$ represents the number of resource types required for task $T_i$.

For the entire mission, the overall assignment goal is the weighted sum of the quality of all missions, as shown in equation (7):

$$QM = \sum_{i=1}^{I} o_i \cdot QT_i$$

(7)

Where $o_i$ is the weight of the $i$-th task, and its value depends on the preference of the decision maker. This paper takes the value as $o_i = 1/N$.

(2) Platform adjustment cost

The platform adjustment cost refers to the cost that the combat platform needs to pay to abandon the execution of the original planned tasks and transfer other tasks. The adjustment cost information of each platform can be represented by the platform task transfer cost matrix, and the constructed transfer cost matrix is $C = \{c_{jnm}\}_{n,m,J,N}$, where $c_{jnm}$ represents the cost of the $j$-th platform from the execution of the $n$-th task to the execution of the $m$-th task, and $c_{jnm} \in [0,1]$.

**Definition 8** The platform task transfer matrix is a mathematical description that reflects the transfer of platform tasks. It is defined as $Prt = \{ptr_{jnm}\}_{n,m,J,N}$, when $ptr_{jnm} = 1$, it means that the $j$-th platform transfers from the execution of the $n$-th task to the execution of the $m$-th task, otherwise $ptr_{jnm} = 0$. Its calculation method is as shown in equation (8).

$$Prt = f(y, y^*)$$

(8)

Among them, $y$ is the original task assignment scheme, $y^*$ is the new task assignment scheme, and $f(*)$ is the functional relationship between the task assignment plan and the task assignment plans. The platform plan adjustment cost is the sum of the costs of all platform change tasks, as shown in equation (9).

$$Cost = \sum_{j=1}^{J} C_j \cdot Prt_j$$

(9)

Among them, $C_j$ is the adjustment cost vector of the $j$-th platform, and $Prt_j$ is the transfer vector of the $j$-th platform.

3.4. Mathematical model of dynamic assignment of C2 organization resources

3.4.1. Objective function of resource dynamic assignment optimization. According to the above definition of task assignment measure, the optimization goal of the resource dynamic assignment mathematical model is to maximize the quality of task completion and minimize the cost of planning adjustment. The two optimization goals constructed are as shown in equations (10) and (11).

$$\max QM = \sum_{i=1}^{I} o_i \cdot QT_i$$

(10)

$$\min Cost = \sum_{j=1}^{J} C_j \cdot Prt_j$$

(11)

3.4.2. Constraints for resource dynamic assignment optimization. Dynamic assignment of C2 organizational resources needs to consider resource satisfaction, platform task transfer, task completion quality, number of platforms for tasks, number of platform execution tasks, and emergencies.

(1) Resource satisfaction constraint
The resource satisfaction degree $z_d$ needs to satisfy the constraint of not more than 1, that is,

$$z_d = \min\left(\sum_{j=1}^{j} r_j y_{ij} / R_d, 1\right),$$

and the constraint conditions can be described as equations (12) and (13).

$$z_d \leq \sum_{j=1}^{j} r_j y_{ij} / R_d$$  \hspace{1cm} (12)

$$z_d \leq 1$$  \hspace{1cm} (13)

(2) Equality constraint of platform task transfer matrix
The platform task transfer matrix is obtained according to the original planned task plan $y^*$ and the adjusted plan $y$.

$$P_{tr} = f(y, y^*)$$  \hspace{1cm} (14)

(3) Incident constraint, that is, platform damage or task addition.

$$\sum_{j=1}^{j} y_{ij} = 0 \text{ or } R = (R_{ij})_{1 \leq i \leq T, 1 \leq j \leq T}, T_{i} \in T \cup T_{\text{add}}$$  \hspace{1cm} (15)

(4) Task completion quality constraint
The completion quality of each task must be greater than the minimum value of $QT_{\text{threshold}}$. Equation (16) is the constraint for the task completion quality, and equation (17) is the minimum constraint for the task completion quality.

$$QT = \left(\prod_{i=1}^{i} z_{i}\right)^{1/F-I}$$  \hspace{1cm} (16)

$$QT > QT_{\text{threshold}}$$  \hspace{1cm} (17)

(5) Number of platforms for tasks constraint
In order to maintain the balance of platform allocation, the number of platforms execute the same task is not greater than a certain value $con$, and each task requires at least one platform to execute, as shown in equation (18).

$$0 < \sum_{j=1}^{j} y_{ij} \leq con, y_{ij} \in Z$$  \hspace{1cm} (18)

(6) Platform execution task quantity constraint
This paper mainly deals with resource dynamic assignment problems of parallel tasks (the task execution time may coincide and there is no timing problem between tasks). Each platform executes at most one task in the same time period.

$$0 \leq \sum_{j=1}^{j} y_{ij} \leq 1, y_{ij} \in Z$$  \hspace{1cm} (19)

3.4.3. Mathematical model of dynamic task assignment. In summary, the mathematical model of the constructed dynamic task assignment is as shown in equation (19).
According to the above mathematical model, the C2 tissue resource dynamic assignment model belongs to the mixed integer nonlinear multi-objective optimization category. The difficulty lies in the solution of the Pareto Optimality of the multi-objective problem.

4. NSGA-II algorithm

The NSGA-II algorithm is a classical algorithm for solving multi-objective optimization problems, and it reduces the complexity of the non-inferior sorting genetic algorithm, has the advantages of fast running speed and good convergence of the solution set, and becomes the benchmark for the performance of other multi-objective optimization algorithms. However, the content of this paper is the hybrid integer optimization under strong constraints. The key to applying the NSGA-II algorithm is to deal with the constraints, in order to optimize the multi-objective problem of the algorithm. Therefore, based on the NSGA-II algorithm, the constraint processing is adaptively processed, and the mathematical optimization model under tight constraints is constrained and relaxed, and the NSGA-II algorithm is used to solve the problem.

The model constraints of this problem mainly include equality class constraints and inequality constraints. The difficulty of constraint processing lies in the processing of inequality constraints. The first, second and third class constraints belong to the equality constraints of the definition class, and the constraint on the optimization problem is not strong. Therefore, the core of constraint processing lays in the inequality constraints of categories 4, 5, and 6.

The fourth type of constraint guarantees that the quality of completion of each task meets the minimum requirements of operational requirements. It is very difficult to make the individual satisfy the above constraints by modifying the genetic operator. In this paper, the class constraint is added to the objective function in the manner of penalty function, which effectively reduces the difficulty of constraint processing. The penalty function can be designed to:

\[
G(z) = \sum_{i=1}^{n} \max \left( \rho (Q_{\text{threshold}} - Q_{T_i}), 0 \right)
\]

Where \( \rho \) represent penalty factor, used to punish individuals who violate the constraint.

After adding the penalty function to the objective function, the equivalent optimization problem can be got:

\[
\begin{align*}
\max QM &= \sum_{i=1}^{N} a_i \cdot Q_{T_i} \\
\min \text{Cost} &= \sum_{j=1}^{J} C_j \cdot P_{tr_j} \\
\end{align*}
\]

\[
\begin{align*}
z_i &= \sum_{j=1}^{J} y_{ij} \frac{R_{ij}}{R_i} \\
z_i &\leq 1 \\
P_{tr} &= f(y, y^*) \\
\sum_{i=1}^{I} y_{ij} &= 0 \text{ or } R = (R_i)_{i \in \{N_{ij} \}}, T_i \in T \cup T_{\text{add}} \\
Q_{T_i} &= \left( \prod_{i=1}^{I} z_{ij} \right)^{\frac{1}{I}} \\
Q_{T_i} &> Q_{\text{threshold}} \\
0 &< \sum_{j=1}^{J} y_{ij} \leq \text{const}, y_{ij} \in \mathbb{Z} \\
0 &\leq \sum_{i=1}^{I} y_{ij} \leq 1, y_{ij} \in \mathbb{Z}
\end{align*}
\]
\begin{equation}
\max QM = \sum_{i=1}^{N} \omega_i \cdot QT_i + G(z) \nonumber \\
\min \text{Cost} = \sum_{j=1}^{J} C_j \cdot Pr_j + G(z) \tag{22} \nonumber \\
G(z) = \sum_{i=1}^{N} \max \left( \rho (QT_{\text{threshold}} - QT_i), 0 \right) \nonumber \\
S.L. \quad QT_i = \left( \prod_{i \in R_i} z_i^{l} \right) \quad \text{if} \quad \mathbf{z} \in \mathcal{I} \nonumber \\
P_{\text{Tr}} = f(y, y^\#) \nonumber \\
\sum_{i=1}^{N} y_{ij} = 0 \quad \text{or} \quad R = \left( R_{ij} \right)_{i=1, N \times J}, \quad T_i \in T \cup T_{\text{all}} \nonumber 
\end{equation}

The fifth type and the sixth type of constraint are constraints on \( y \). This kind of constraint can be implemented by modifying the genetic operator, and will not be described here.

The NSGA-II algorithm flow is shown in Figure 1. The algorithm is used to solve the equivalent optimization problem and the platform resource dynamic assignment scheme is obtained.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{flowchart.png}
\caption{Flow chart of NSGA-II algorithm.}
\end{figure}

5. Simulation
The effectiveness of the proposed algorithm is verified by taking the operational assumptions mentioned in [15] and [16] as examples. There are 10 tasks in a certain area to be completed, and the required resource types are 12 types. There are 12 types and 21 combat platforms to perform tasks in the area. The resource requirements of each task are shown in Table 1, and each platform has The resource capabilities are shown in Table 2. Regardless of geographical factors, the pre-allocation of tasks and platforms according to the supply and demand relationship of resources is shown in Table 3.
### Table 1. Resource requirements for tasks.

| Task                  | C2  | STR | AW | BMD | CM  | SUW | USW | MIW | ISR(A) | ISR(S) | ISR(G) | BDA |
|-----------------------|-----|-----|----|-----|-----|-----|-----|-----|--------|--------|--------|-----|
| AEW                   | 5   | 0   | 5  | 0   | 0   | 0   | 0   | 5   | 0      | 0      | 0      |     |
| TAMD GREEN            | 5   | 0   | 12 | 14  | 10  | 0   | 0   | 12  | 0      | 4      | 0      |     |
| TAMD BLUE             | 3   | 0   | 8  | 8   | 7   | 0   | 0   | 6   | 0      | 4      | 0      |     |
| SURF SURV Area A     | 2   | 0   | 0  | 0   | 0   | 0   | 0   | 5   | 0      | 0      | 0      |     |
| MIW                   | 2   | 0   | 0  | 0   | 0   | 0   | 5   | 0   | 4      | 0      | 0      |     |
| DEF vs. CDCM Attack  | 2   | 0   | 0  | 0   | 8   | 10  | 6   | 5   | 0      | 5      | 0      |     |
| Attack Air Bases      | 2   | 5   | 5  | 0   | 0   | 0   | 0   | 5   | 2      | 3      | 0      |     |
| Attack C2 Nodes       | 2   | 6   | 0  | 0   | 0   | 0   | 0   | 0   | 0      | 0      | 5      |     |
| Attack IADS           | 2   | 8   | 5  | 0   | 0   | 0   | 0   | 0   | 0      | 0      | 5      |     |
| Attack MSL Bases      | 2   | 7   | 0  | 0   | 0   | 0   | 0   | 5   | 0      | 7      | 0      |     |

### Table 2. Resource capabilities of platforms.

| Task      | Quantity | C2  | STR | A   | W   | BM  | D   | CM  | SUW | USW | MIW | ISR(A) | ISR(S) | ISR(G) | BDA |
|-----------|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------|--------|--------|-----|
| CVN       | 1        | 5   | 6   | 5   | 0   | 2   | 5   | 2   | 1   | 5   | 5     | 5      | 2      | 5   |
| CG        | 2        | 3   | 5   | 8   | 7   | 6   | 4   | 3   | 3   | 7   | 5     | 0      | 0      |     |
| DDG       | 3        | 2   | 5   | 8   | 7   | 6   | 4   | 3   | 3   | 6   | 4     | 0      | 0      |     |
| SSN       | 2        | 0   | 3   | 0   | 0   | 0   | 5   | 4   | 2   | 1   | 3     | 1      | 0      |     |
| P3        | 3        | 1   | 0   | 0   | 0   | 0   | 6   | 2   | 0   | 0   | 6     | 0      | 3      |     |
| MH53      | 1        | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 4   | 0     | 0      | 0      |     |
| AWACS     | 2        | 5   | 0   | 5   | 0   | 0   | 0   | 0   | 0   | 8   | 3     | 1      | 0      |     |
| JSTAR     | 1        | 3   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1     | 6      | 3      |     |
| U2        | 1        | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 3     | 2      | 4      | 3   |
| RJ        | 1        | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 4   | 3     | 3      | 2      |     |
| UAV       | 3        | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1     | 5      | 5      |     |
| AEF       | 1        | 5   | 7   | 5   | 0   | 0   | 1   | 0   | 0   | 4   | 1     | 3      | 3      |     |

### Table 3. Initial platform scheme.

| Task                  | Platform   | Task quality |
|-----------------------|------------|--------------|
| AEW                   | AWACS      | 100%         |
| TAMD GREEN            | CG         | DDG U2       | 100%         |
| TAMD BLUE             | DDG        | JSTAR        | 95.31%       |
| SURF SURV Area A     | 2×P3       | 100%         |
| MIW in Strait A      | P3         | MH53 AWACS   | 92.83%       |
| DEF vs. CDCM Attack  | CG         | 90.85%       |
| Attack Air Bases      | DDG        | UAV          | 100%         |
| Attack C2 Nodes       | UAV        | AEF          | 100%         |
| Attack IADS           | CVN        | 93.06%       |
| Attack MSL Bases      | 2×SSN      | RJ UAV       | 96.21%       |
In the case of the above task requirements, the C2 organization platform resource allocation plan with the highest task quality is shown in Table 3.

5.1. Simulation experiment of sudden platform damage
Assume that the RJ platform is unfortunately damaged in the above platform and cannot participate in the completion of the Attack MSL Bases task. According to the task requirements and the capabilities of the platform, when the RJ platform does not participate in the Attack MSL Bases task, the remaining platforms cannot be successfully executed due to the lack of C2 capabilities. In order to successfully complete the Attack MSL Bases task while ensuring the completion quality of other tasks, the initial allocation scheme is adjusted using the algorithm proposed in this paper. In the algorithm, the population size is set to 1000, the evolution algebra is set to 300, and the penalty factor is $\rho=10$. The Pareto frontier obtained by the improved NSGA-II algorithm is shown in figure 2. A solution is selected as the adjusted allocation scheme in the obtained Pareto frontier, as shown in Table 4.

![Figure 2. Pareto solution when a platform is damaged.](image)

**Table 4.** Platform scheme after adjustment

| Task             | Platform          | Task quality |
|------------------|-------------------|--------------|
| AEW              | AWAC S            | 100%         |
| TAMD GREEN       | CG DDG UAV        | 100%         |
| TAMD BLUE        | DDG UAV           | 89.08%       |
| SURF SURV Area   | P3 P3             | 100%         |
| MIW in Strait A  | MH53 AWAC S       | 84.34%       |
| DEF vs. CDCM Attack | CG               | 90.85%       |
| Attack Air Bases | DDG U2            | 100%         |
| Attack C2 Nodes  | P3 AEF            | 100%         |
| Attack IADS      | CVN               | 93.06%       |
| Attack MSL Bases | SSN JSTAR UV V    | 80.91%       |
5.2. Simulation experiment of sudden tasks

Assume that the new task SURF SURV Area B (same resource requirement as the SURF SURV task). Since
the initial allocation scheme has assigned tasks to all platforms, the new tasks cannot be completed. Here, the
initial allocation scheme is adjusted using the algorithm proposed in this paper (the settings of each
parameter in the algorithm are the same as in Section 4.1). The Pareto frontier obtained by the improved
NSGA-II algorithm is shown in figure 4. A solution is selected as the adjusted allocation scheme in the
obtained Pareto frontier, as shown in Table 5.

**Table 5.** Platform scheme after adjustment.

| Task                 | Platform | Task quality |
|----------------------|----------|--------------|
| AEW                  | AWAC     | 100%         |
| TAMD GREEN           | CG       | 71.84%       |
| TAMD BLUE            | DDG      | 89.08%       |
| SURF SURV Area A     | P3       | 100%         |
| MIW                  | DDG      | 100%         |
| DEF vs. CDCM Attack  | CG       | 90.85%       |

**Figure 3.** Quality comparisons before and after adjustment.

The QM and Cost corresponding to the allocation scheme are 93.83% and 0.0806, respectively. Figure 3 is
an effect diagram of the adjustment scheme. It can be seen from the figure that the Attack MSL Bases task
could not be executed after the adjustment of the scheme has a result of 0.8091. In addition, the quality
of completion of other tasks remained generally the same, although the completion of a small number of
tasks decreased slightly, but they were all within acceptable limits.
| Attack Air Bases | AEF | 100% |
|------------------|-----|------|
| Attack C2 Nodes  | DDG UAV | 94.10% |
| Attack IADS     | CVN P3 | 93.06% |
| Attack MSL Bases | SSN JSTA R 2×UAV | 80.91% |
| SURF SURV Area B | AWAC S | 77.45% |

**Figure 5.** Quality comparisons before and after adjustment.

The QM and Cost corresponding to the allocation scheme are 93.83% and 0.2380, respectively. Since the new task has a greater impact on the overall platform resource allocation plan, the adjustment cost is higher than the adjustment cost of the platform damage in case 1. Figure 5 is a comparison of the quality of the task completion before and after the adjustment. It can be seen from the figure that the quality of the task completion before and after the adjustment of the program remains unchanged, although the quality of the completion of a small number of tasks is slightly reduced. However, the SURF SURV Area B task that could not be worked was 77.45%.

**6. Conclusion**

Aiming at the problem of dynamic assignment of C2 organizational resources, firstly, the basic process of organizational dynamic assignment is analyzed, and a multi-objective optimization model based on maximizing task completion quality and minimizing platform adjustment cost is constructed. The improved NSGA-II algorithm is used to solve this problem. The mixed integer nonlinear programming problem is solved. The simulation results show that the obtained Pareto front can provide decision makers with multiple adjustment plans, which can effectively overcome the adverse effects of emergencies on mission planning and improve the adaptability of C2 organizational task assignment.

**7. References**

[1] Crawford A B. Command and control [J]. IEEE Transactions on Aerospace & Electronic Systems, 2008, 1(3):254-258.

[2] Salas E, Burke C S, Samman S N. Understanding command and control teams operating in complex environments [J]. Information Knowledge Systems Management, 2001, 2(4): 311-323.

[3] Li N, Huai W, Wang S. The solution of target assignment problem in command and control decision-making behaviour simulation [J]. Enterprise Information Systems, 2017, 11(7): 1059-1077.

[4] Kaempf G L, Klein G, Thordsen M L, et al. Decision making in complex naval command-and-control environments[J]. Human Factors, 1996, 38(2):220-231.

[5] Abello M B, Bui L T, Michalewicz Z. An adaptive approach for solving dynamic assignment with time-varying number of tasks—Part II[C]/ Evolutionary Computation. IEEE, 2011:1711-1718.

[6] Turner J, Meng Q, Schaefer G, et al. Distributed task reassignment with time constraints for the optimization of total task allocations in a multirobot system.[J]. IEEE Transactions on Cybernetics, 2017, PP(99):1-15.

[7] Xu X, Hao J, Yu L, et al. Fuzzy Optimal allocation model for task-resource assignment problem in collaborative logistics network[J]. IEEE Transactions on Fuzzy Systems, 2018, PP(99):1-1.
[8] Shi W, Feng Y, Huang S. A novel nested assignment algorithm for agile command and control organization [J]. DEStech Transactions on Engineering and Technology Research, 2017.

[9] Zhao M, He H Z, Yue S H, et al. Agility of C2 system [J]. Fire Control & Command Control, 2016, 41(9):1-5.

[10] Yu S, Yao P, Zhang S, et al. Dynamic battlefield task assignment model and algorithm with interval parameters [J]. Systems Engineering-Theory & Practice, 2017, 37(4):1080-1088.

[11] Chen W L, Chen C L, Chen K Z, et al. Dynamic assignment of battlefield rush-repair tasks under uncertainty in offensive operation [J]. Acta Armamentarii, 2017, 38(5):1011-1019.

[12] Zhang Y, Chen C, Liu Z, et al. Method for modeling and solving military mission planning with uncertain resource availability [J]. Journal of National University of Defense Technology, 2013, 35(3):30-35.

[13] Sun Y. Research on design and evaluation method for agile command and control organization [D]. Xi’an: Air Force Engineering University, 2017.

[14] Maghsoudlou H, Afshar-Nadjafi B, Niaki S T A. A multi-objective invasive weeds optimization algorithm for solving multi-skill multi-mode resource constrained project assignment problem [J]. Computers & Chemical Engineering, 2016, 88(C):157-169.

[15] Han X, Mandal S, Pattipati K R, et al. An optimization-based distributed planning algorithm: a blackboard-based collaborative framework [J]. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 2014, 44(6): 673-686.

[16] Han X, Mishra M, Mandal S, et al. Optimization-based decision support software for a team-in-the-loop experiment: multilevel asset allocation [J]. IEEE Transactions on Systems, Man, and Cybernetics: System, 2014, 44(8): 1098-1112.