# Mathematical Model for Movie Shooting Time Planning

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**Abstract:** In the 21st century, with rapid development of science and technology, people's degree of preference and popularity for movies have gradually increased. But making a movie is not easy. When making a movie, you need to consider various factors, such as actors, venues, equipment, etc.. These are very important parts of filming process. This article establishes a movie schedule model to generate a shooting schedule with the shortest total time based on known information of scenes, actors, and props [1]. In this paper, several types of constraint optimization algorithms are established, which can calculate movie shooting total time quickly and accurately. And it proposes a framework for movie shooting time planning algorithm based on time constraint set, establishes optimization problems of taking shooting time as optimization variable, and takes constraints and simultaneous arrival target as optimization goal. In addition, the simulation results verify accuracy and effectiveness of proposed algorithm. According to simulation test of data, the program running time is short, and the relationship expression between calculation time and quantity increasing is estimated. It verifies the proposed algorithm has high calculation efficiency, and the input variables of algorithm have no constraint requirements. Therefore, in promoting personnel scheduling aspect, the algorithm has a broad application prospect [2].

## 1. Problem Restatement

Chinese film industry is in a booming stage, with a total box-office of more than 60 billion yuan in 2018. Movie shooting is a complex project, which consists of multiple stages, and each of stage has to deal with its own tasks. For example, an important task in preparation stage is to arrange shooting schedule. This task not only involves complex coordination and communication, also includes resource planning. It is necessary to consider actors' schedules, shooting locations, props and shooting time and other factors while minimizing shooting time. While mathematical modeling is an effective tool to solve such problems. Suppose you are the head of a consulting company and are in contact with a movie shooting team. In order to prove you have the ability to solve this shooting schedule, please provide a solution and design test cases to verify the effectiveness and robustness of this solution.

Please collect relevant information and complete the following three questions

Question 1: Please establish a model arranging photography schedule, and the following constraints must be met:

① Actor schedule;

② Each scene needs to shoot the corresponding time;

③Some scenes need to wait for the pre-production to be completed;

④Some scenes require special props (such as helicopters), but this prop is only available in a certain time;

⑤ Other constraints that you think need to be met.

Question 2: If a constraint is deleted and rescheduled in Question 1, rescheduling may shorten shooting schedule. And the constraint with the most schedule shortened is called key constraint. The shooting team wanted to know the key constraints in order to further shorten schedule after coordination.

Question 3: During shooting process, unexpected situations may occur, if an actor is ill, and unable to participate in shooting for a period of time. At this time, the subsequent shooting schedule needs to be adjusted. Please design a model, and adjust subsequent shooting schedule according to emergency situation based on the schedule generated by model in question 1.

## 2. Model Assumptions and Symbol Description

### 2.1 Basic Assumptions

1) Assume that the actors' schedules are known and periodic over a long period of time. This assumption is set for the purpose of calculating schedule, and it does not indicate that actors have participated in shooting for a long time.

2) Suppose the appearance of specific elements required by scene is periodic.

3) Assume that the actors' schedule is in days, this is a realistic assumption, and makes it easier to arrange shooting schedule.

4) Suppose that when we discuss the arrangement of camera lens, we only consider the natures of lens and impacts on adjacent lens. This is due to the complexity of considering effects of multiple shots on one shot, and it has small impact on results.

5) If the scene changes during shots converting, we do not consider setting time, because in another scene the setting can be considered to be arranged before shooting.

6) Only the main actors' schedules need to be considered, and other actors' schedules can be adjusted according to movie shooting time. As the supporting actors are job seekers, they will adjust their schedules to suit movie shooting time.

### 2.2 Symbol Description

In order to simplify analysis of problem and number processing, the following symbolic provisions are made:

| | |
|---|---|
| $T$ | Total shooting time |
| $C_i$ | Scene name |
| $t_{C_i}$ | Each scene takes time |
| $Y_i$ | Actor name |
| $T_{Y_i}$ | Each actor's shooting cycles |
| $D_i$ | Necessary elements for each scene |
| $T_{D_i}$ | The appearing period of necessary elements for each scene |
| $f_{Y_i}(T)$ | The intermittent function of the $i$ actor's shooting time |
| $Q_{C_i}$ | Preparation time of scene $i$ |
| $f_{D_i}(T)$ | The time function of necessary element in scene $i$ |
| $T_{C_i}$ | The appearing cycle of each scene |
| $v_{C_i}$ | Each scene can shooting time per cycle |
| $\eta_{C_i}$ | Occupancy of each scene |

## 3. Problem Analysis

### 3.1 Problem One

In the first problem, the restrictions 1, 2, and 3 can be classified as a restriction on shooting time of a certain lens, which are referred to as schedule limit. For the fourth constraint, we consider it in two parts. one hand, it can be understood that some outside scenes may only be allowed to shoot at a certain time, and this limit is classified as a schedule limit. On the other hand, it can also be understood that the ideal shooting time is fixed in a certain scene. We divide shooting in each scene into shots, and the ideal shooting time of each shots is fixed.

For problem 1, first of all, it finds periodic function of each scene, and then sorts the periodic function according to occupancy rate from low to high (lower occupancy rate indicates that more constraints need to be met, and has priority to shoot). Under these constraints, we expect to establish a mathematical model, and provide reasonable shooting schedules for movie.

### 3.2 Problem Two

For problem 2: using the given data, assuming constraint conditions 1, 3 and 4 as the key constraint conditions, a new periodic function can be obtained for each scene. And then using mathematical model given in problem one calculates the results, the key constraints can be obtained by comparing results.

### 3.3 Question Three

For problem 3: First, suppose that actor $Y_i$ in $C_i$ scene has an ill during shooting process and cannot participate in shooting for a period of time. According to existing mathematical model, we can obtain the shooting order. And the shooting can be performed normally before $C_i$ scene. After time of $t$, due to actor $Y_i$ is ill during shooting process, the actor can't participate in shooting for a period of time. We can get a new shooting interruption function in scene $C_i$. From time $t$, it needs to re-order occupancy rate of each scene and re-determine shooting sequence. According to mathematical model of problem 1, it can obtain optimal shooting schedule.

## 4. Model Establishment and Solution

### 4.1 Problem -- Solution

We assume that there are k scenes in n scenes, which requires necessary elements. Assuming that in a certain period of time, we can shoot both scenes with non-special elements and special elements scenes. We will give priority to shooting scenes with special elements. That is, we give priority to shooting scenes with more constraints.

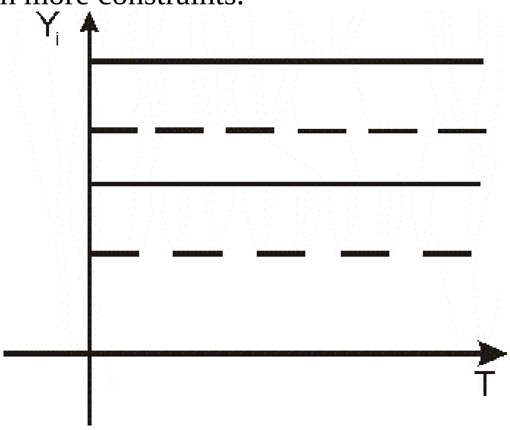


Figure 4.1.1

As shown in functional image $f_{Y_i}(T)$ of Figure 4.1.1, the solid line indicates that the actor can shoot throughout the process, while the dashed line indicates that the actor shoots intermittently, and shooting time is periodic.

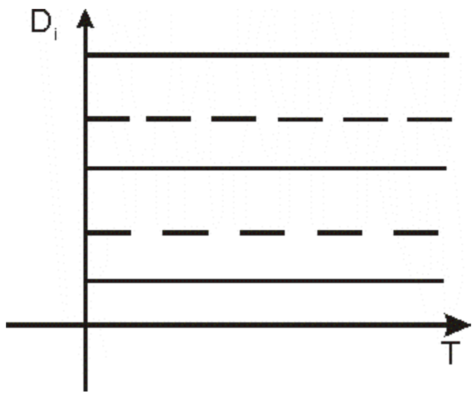


Figure 4.1.2

As shown in function image $f_{D_i}(T)$ in Figure 4.1.2, the solid line indicates that this scene can be taken at any time, while the dashed line indicates that this scene requires special elements and is periodic, such as day and night.

**4.1.1 Algorithm flow**

According to the above mathematical representation, we get a flowchart, as shown in Figure **4.1.1.1 below:**

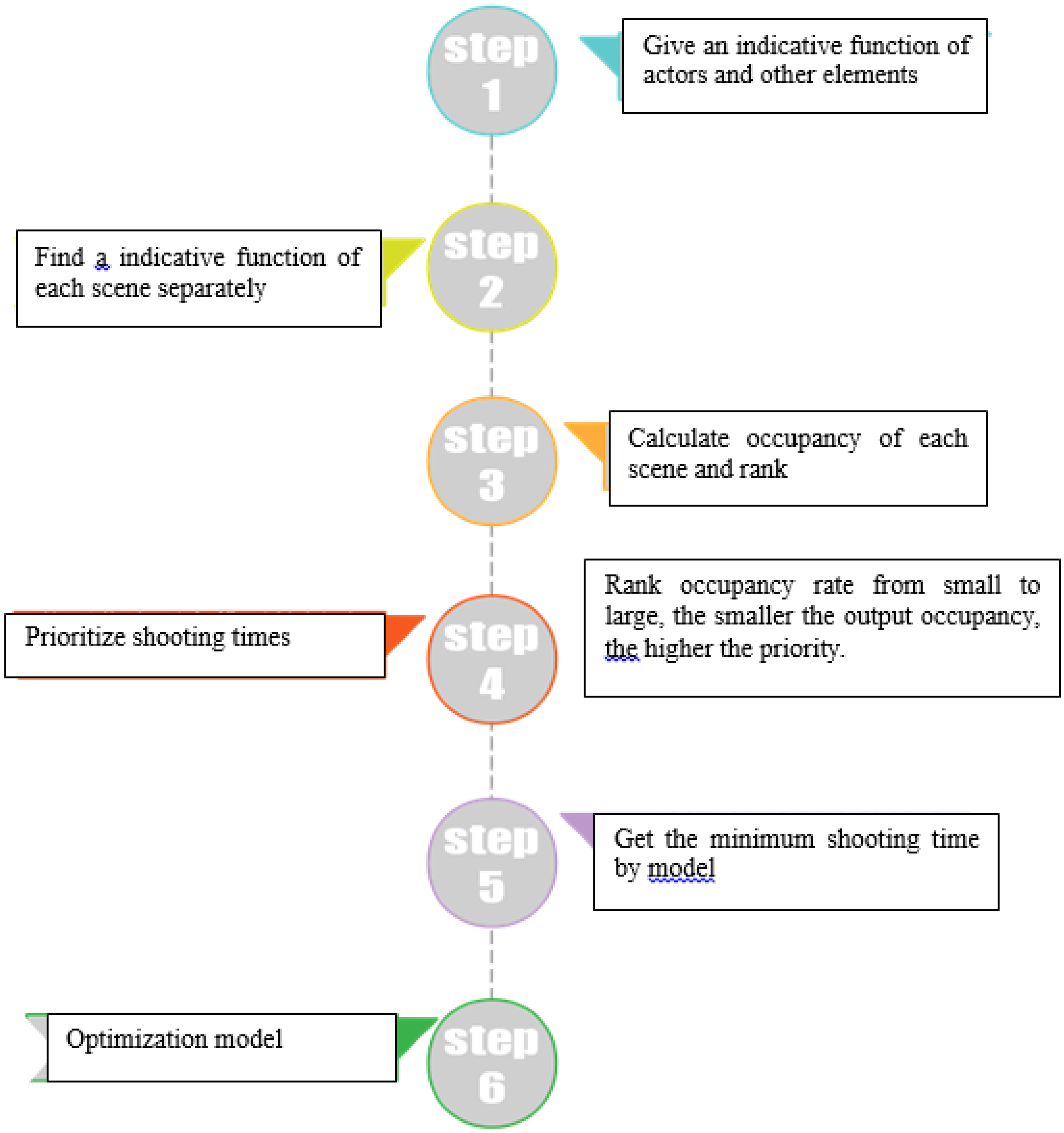


Figure 4.1.1.1

In this question, the strictest limit is schedule limit. We first discuss schedule limits, and the constructor $g_{Y_i}(t)$ satisfies:

$$g_{Y_i}(t)=\begin{cases}0 & \text{At time } t\text{, the actor } Y_i \text{ can not shoot.}\\ 1 & \text{At time } t\text{, the actor } Y_i \text{ can shoot.}\end{cases}$$

Representing actor $Y_i$ can participate in shooting at $t$ time. The constructor $a_{ij}$ satisfies:

$$a_{iY_i}(t)=\begin{cases}0 & \text{The actor } Y_i \text{ do not take lens } i\text{.}\\ 1 & \text{The actor } Y_i \text{ takes lens } i\text{.}\end{cases}$$

The constructor $h_{D_i}(t)$ satisfies:

$$h_{D_i}(t)=\begin{cases}0 & \text{At time } t\text{, the scene } D_i \text{ can not be shot.}\\ 1 & \text{At time } t\text{, the scene } D_i \text{ can be shot.}\end{cases}$$

From this, we can obtain a shooting time function of scene $C_i$:

$$f_{C_i}(t)=\prod_{\substack{Y_i, D_i \\ a_i Y_i=1}} g_{Y_i}(t)h_{D_i}(T)$$

Satisfies

$$f_{C_i}(t)=\begin{cases}0 & \text{In the scene } i\text{, it can not be shot.}\\ 1 & \text{In the scene } i\text{, it can be shot.}\end{cases}$$

$$g_{Y_i}(t)=\begin{cases}0 & \text{At time } t\text{, the actor } Y_i \text{ can not take lens } i\text{.}\\ 1 & \text{At time } t\text{, the actor } Y_i \text{ can takes lens } i\text{.}\end{cases}$$

The above is a mathematical representation for the scene $C_i$. It uses $\eta_i$ representing scene occupancy of $f_{C_i}(t)$. While $\Delta T_{C_i}$ represents shooting total time in scene $C_i$ during time N.

$$\eta_i = \frac{\Delta T_{C_i}}{N}$$

$$N = \prod_i T\left(f_{C_i}\right)$$

Then, we hope to use these representations to write an algorithm, so as to determine appropriate movie shooting time. And the specific algorithm is shown in flow Figure 1:

### 4.1.2 Shooting Duration Calculation and Model Solving

Now, we consider total shooting time, and it consists of three parts, namely actual shooting time, shooting space, and special scenes require pre-production time. The actual shooting time and shooting space can be obtained through the above algorithm, and they are reflected in shooting schedule. And the special scenes require pre-production time.

Then we consider the situation in actual shooting, the actors' schedule is arranged in advance, and in this paper

We assume that the actor's schedule appears periodically.

Example 1. We assume that a movie needs 3 scenes, which is $C_1$, $C_2$ and $C_3$ respectively. And they all need to shoot 12 hours. There are 3 actors, they are $Y_1$, $Y_2$ and $Y_3$ respectively. The scene $C_1$ only needs actor $Y_1$, and scene $C_2$ needs actor $Y_1$ and actor $Y_2$, and scene $C_3$ needs actor $Y_2$ and actor $Y_3$.

The indicative function of $Y_1$ is $f_{Y_1}(T)=\begin{cases}0 & 12\le t-24n\le 24\\ 1 & 0\le t-24n\le 12\end{cases}\ n=0,1,2...$, as shown in Figure 4.1.2.1:

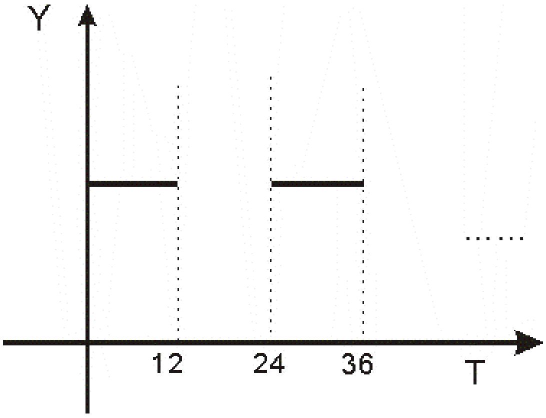


Figure 4.1.2.1

The indicative function of $Y_2$ is $f_{Y_2}(T)=\begin{cases}0 & 8\le t-24n\le 24\\ 1 & 0\le t-24n\le 8\end{cases}\ n=0,1,2...$, as shown in Figure 4.1.2.2:

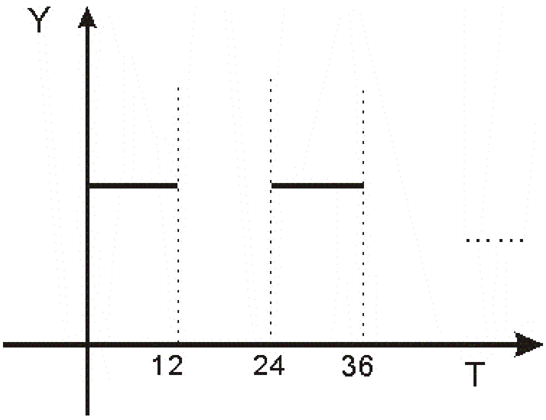


Figure 4.1.2.2

The indicative function of $Y_3$ is $f_{Y_1}(T)=\begin{cases}0 & 12\le t-24n\le 24\\ 1 & 0\le t-24n\le 12\end{cases}\ n=0,1,2...$, as shown in Figure 4.1.2.3:

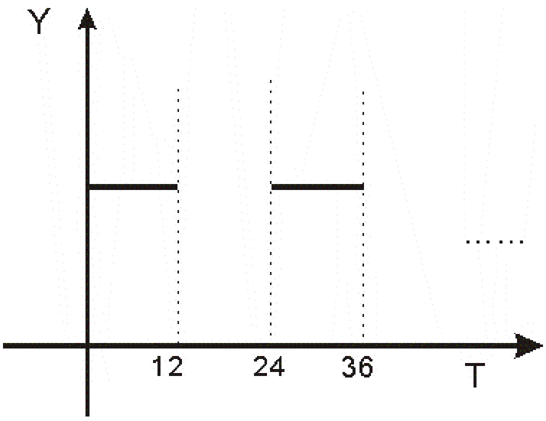


Figure 4.1.2.3

The indicative function of $D_1$ is $f_{D_1}(T)=1$, as shown in Figure 4.1.2.4:

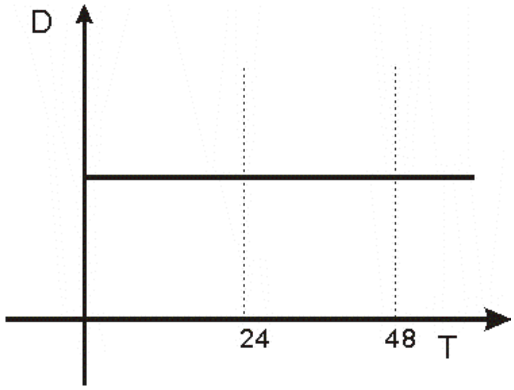


Figure 4.1.2.4

The indicative function of $D_2$ is $f_{d_2}(T)=1$, as shown in Figure 4.1.2.5:

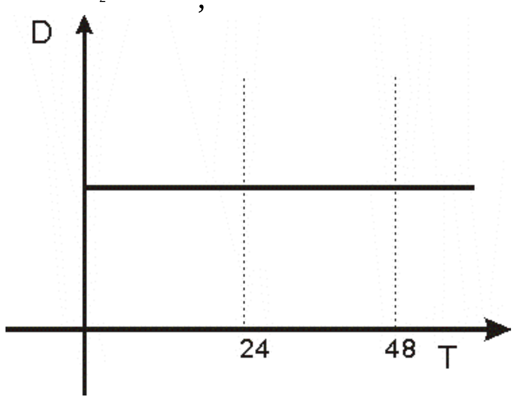


Figure 4.1.2.5

The indicative function of $D_3$ is $f_{D_3}(T)=\begin{cases}0 & 6\le t-24n\le 24\\ 1 & 0\le t-24n\le 6\end{cases}$ $n=0,1,2...$, as shown in Figure 4.1.2.6:

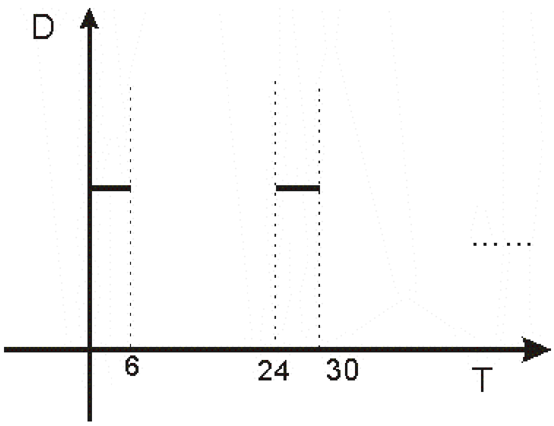


Figure 4.1.2.6

Therefore, we can obtain indicative functions of scene $C_1$,$C_2$ and $C_3$, showing in the following figure:

The indicative function of $C_1$ $f_{C_1}(T)=\begin{cases}0 & 12\le t-24n\le 24\\ 1 & 0\le t-24n\le 12\end{cases}$ $n=0,1,2...$, as shown in Figure 4.1.2.7:

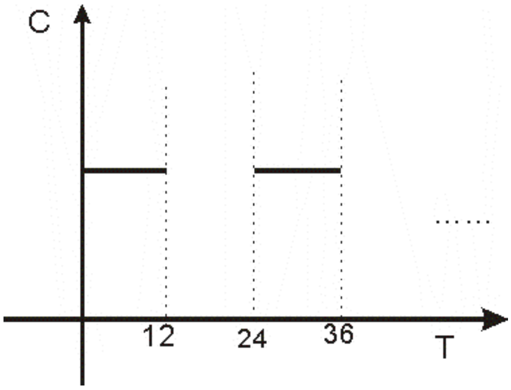


Figure 4.1.2.7

The indicative function of $C_2$ $f_{C_2}(T)=\begin{cases}0 & 8\le t-24n\le 24\\ 1 & 0\le t-24n\le 8\end{cases}$ $n=0,1,2...$, as shown in Figure 4.1.2.8:

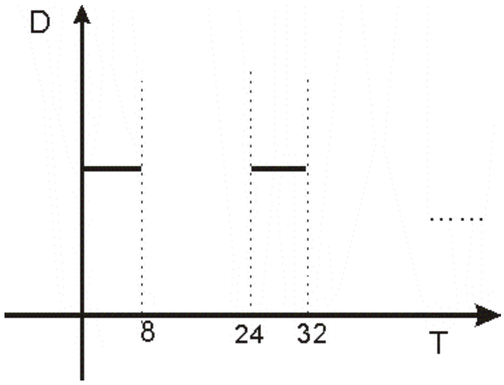


Figure 4.1.2.8

The indicative function of $C_3$ $f_{C_3}(T)=\begin{cases}0 & 6\le t-24n\le 24\\ 1 & 0\le t-24n\le 6\end{cases}$ $n=0,1,2...$, as shown in Figure 4.1.2.9:

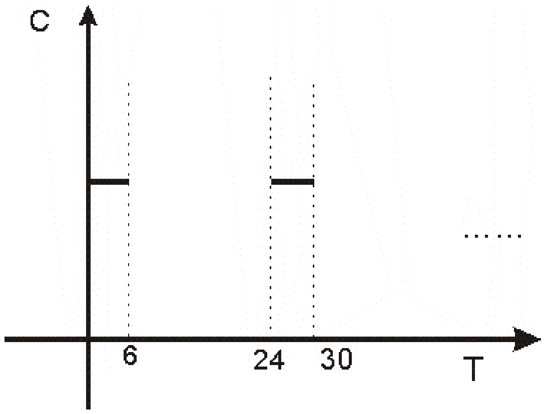


Figure 4.1.2.9

From $N=\prod_i T\left(f_{C_i}\right)$, it can get $N=24$; $\eta_i=\frac{\Delta T_{C_i}}{N}$, including $\zeta_1=\frac{1}{2}$, $\zeta_2=\frac{1}{3}$ , $\zeta_3=\frac{1}{4}$

If $\eta_1=\frac{1}{4}<\eta_2=\frac{1}{3}<\eta_3=\frac{1}{2}$ ,it should consider the smaller scene $\eta$ shooting firstly. And shooting order is the corresponding scene of $\eta_1,\eta_2,\eta_3$. According to the flow figure 4.1.1.1, it can get shooting discontinuous function of scene $\eta_1,\eta_2,\eta_3$, as shown in Figure 4.1.2.10, 4.1.2.11 and

4.1.2.12:

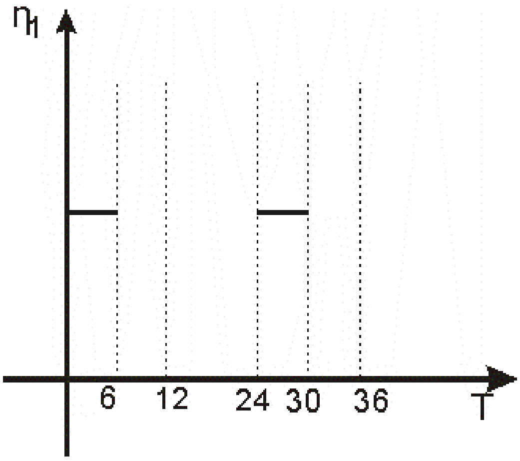


Figure 4.1.2.10

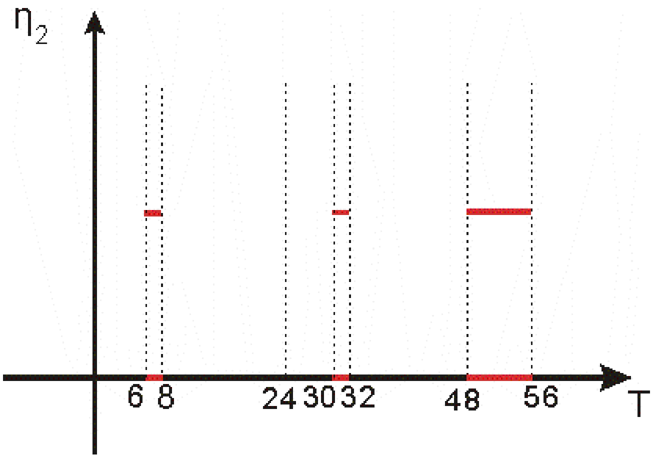


Figure 4.1.2.11

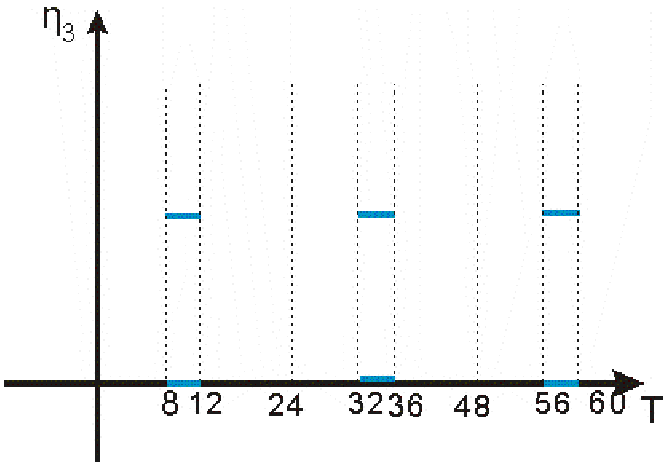


Figure 4.1.2.12

We assume that shooting preparation time required by $C_1$ is $Q_{C_1} = 6, Q_{C2} = 8, Q_{C_3} = 2$. And we guarantee that preparation time of each scene needs to be completed before formal shooting scene. Therefore, there is $x_{Q_{C_i}} < x_{K_{C_i}}$. It can get shooting schedule $\eta$ from the above mathematical model, as shown in Figure 4.1.2.12:

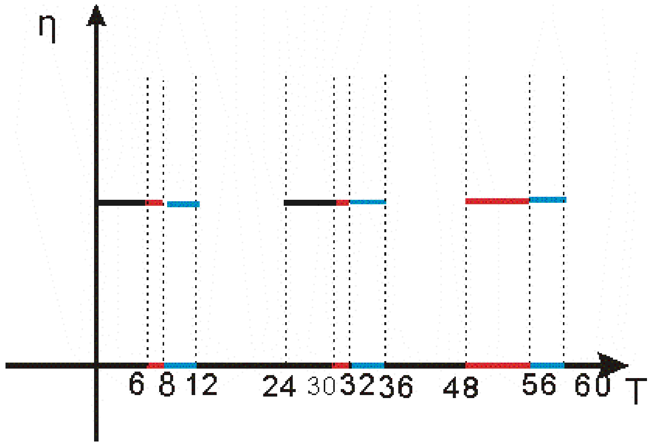


Figure 4.1.2.13

Therefore, we need to start shooting 8 hours in advance. So it's 68 hours in total

### 4.2 Problem Two

We calculate on the basis of example in question 1, assuming that constraints 1, 3 and 4 are the key constraints, we can obtain intermittent shooting of each scene, and then get shooting plan:

Firstly, assuming constraint 1 is a key constraint function, that is, the actor is ready to shoot at any time. At this time, the constraints are only props, thus, we can calculate the indicative function of each scene:

$$f_{C_1}(T)=1$$

$$f_{C_2}(T)=1$$

$$f_{C_3}(T)=\begin{cases}0 & 6\le t-24n\le 24\\ 1 & 0\le t-24n\le 6\end{cases}\quad n=0,1,2\ldots$$

The shooting schedule C can be obtained from mathematical model, as shown in Figure 4.1.2.12:

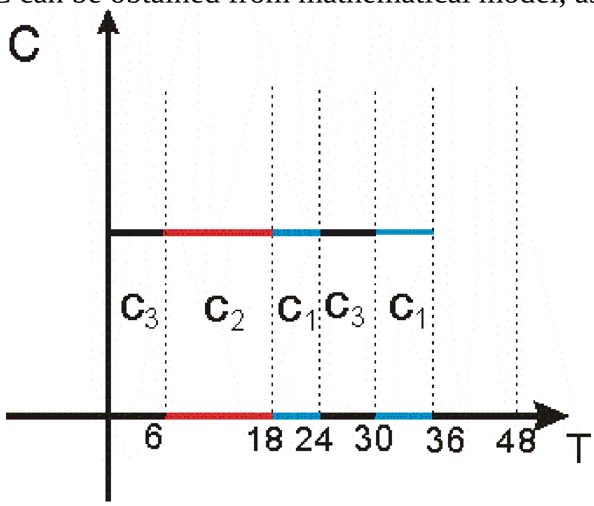


Figure 4.1.2.12

Therefore, we need 36 hours to complete formal shooting, and 44 hours to complete the entire shooting with preparation time.

Assuming constraint 4 is the key constraint function, namely, regardless of requirements of shooting props, we can get indicative function of each scene:

$$f_{C_1}(T)=\begin{cases}0 & 12\le t-24n\le 24 \quad n=0,1,2\ldots\\ 1 & 0\le t-24n\le 12\end{cases}$$

$$f_{C_2}(T)=\begin{cases}0 & 8\le t-24n\le 24 \\ 1 & 0\le t-24n\le 8\end{cases}\quad n=0,1,2...$$

$$f_{C_3}(T)=\begin{cases}0 & 8\le t-24n\le 24 \\ 1 & 0\le t-24n\le 8\end{cases}\quad n=0,1,2...$$

The shooting schedule C can be obtained from mathematical model, as shown in Figure 4.1.2.13:

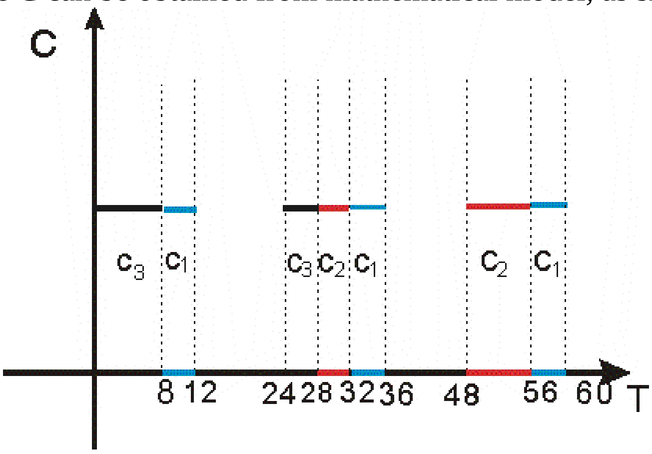


Figure 4.1.2.13

In this case, the minimum preparation time is 6 hours in advance, so the total time is 66 hours;

Assume constraint 3 is the key constraint, that is, there is no preparation time for the entire shooting process. Therefore, the entire shooting schedule is the same as result once removing preparation time, and it takes 60 hours. The shooting schedule is shown in Figure 4.1.2.14:

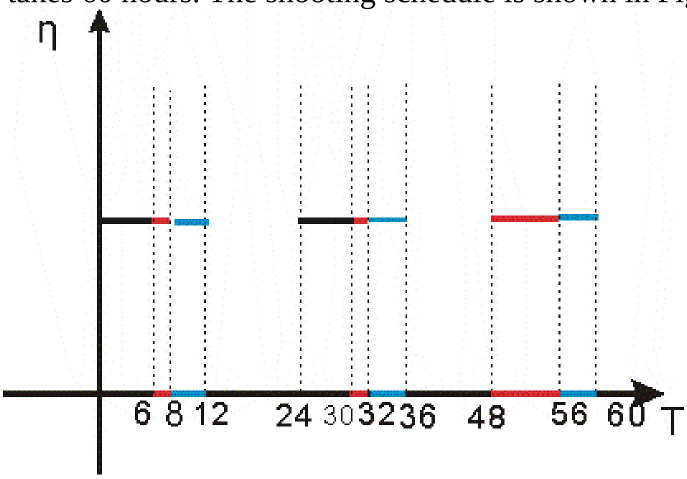


Figure 4.1.2.14

Comparing results of shooting time in the above three cases, we consider that the actor's schedule is the key constraint among three constraints.

### 4.3 Question Three

If burst time occurs on the basis of 1, that is, we can recalculate the indicative function of each scene and repeat previous process after we remove the scenes that have been shot.

## 5. Model Evaluation

### 5.1 Model advantages

1) The model of article pays more attention to data processing and storage methods, and it is presented in form of tables and graphics, which greatly improves query efficiency.

2) The dissertation gives a lot of graphics and analysis. They are intuitive and easy to understand,

but the reasoning is rigorous, and the results are accurate. The model is highly maneuverable and convenient to promotion and application.

3) Taking the lens as basic unit, it makes schedule more specific and clear.

4) By using greedy algorithm, it greatly reduces calculation complexity and saves time. It only takes six seconds to schedule a thousand shots, and allows schedules to be adjusted in real time.

5) The priority is used as a measure for selecting shots. On the one hand, it considers whether overall shooting can be completed, on the other hand, it minimizes overall shooting time.

6) The correlation coefficient is used to describe influence of various factors on shooting time in actual situation. It is considered comprehensively and has strong realistic relevance.

### 5.2 Model Shortcomings and Improvements

1) In the process of modeling and programming, the data used is only an approximation of real data, so the results may differ from actual situation.

2) Our model has many idealized assumptions, which are simple to consider relatively. They may not fully meet actual situation, and the values that cannot be calculated by model alone need to be obtained through experiments.

3) Due to limitation of time, external conditions and my computer programming level, this model has a limited scope of application. In future research, this model needs to be further improved and optimized.

4) The correlation coefficient contains a large number of coefficients given by experience, which may cause deviation in actual application process.

5) On selecting shots, the greedy algorithm has a great impact on overall planning. Some unexpected situations, such as stopping some shots, can greatly slow down the shooting process.

6) This model handles some unexpected situations poorly, for example, the shooting date will be prolonged a lot when an actor cannot shoot suddenly.

## 6. Promotion and Application

This model handles some unexpected situations poorly. For example, if an actor fails to shoot suddenly, the shooting date will be prolonged. For this, we can add a function to measure actor's schedule in priority, in this case, the actor will take shooting first, which can improve results effectively. At the same time, we think that we can consider more factors, which affects shooting time. For this, we can add more variables to correlation coefficient. Therefore, we can use AHP analytic hierarchy process [3] to describe the influence of various factors on shooting time quantitatively, so as to make model more realistic. For shots without actors (that is, environment shots), we can also set priority according to actual situation, and add it to shooting schedule.

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