

2015 IM²C Problem

Movie Scheduling

Team 2015004

Summary

Arranging a movie's shooting schedule can mean a lot of hard work. Different actors and actresses have their own schedules, various resources need to be booked, and special restrictions of some scenes must be considered. In order to offer a satisfactory solution, we have developed a model capable of finding possible schedules and selecting several better schedules based on our clients' preferences. We have also provided solutions that help our clients adjust their plan if an accident happens, as well as helping them identify the most important constraints that would most greatly affect their schedule if varied.

In the first part of our model, we search the possible shooting schedules according to the information that our clients provided, which may include the available time periods of each actor, specific sites and special resources. We sort out the various available dates by scenes, and using a 0-1 matrix to represent the availability of each scene on each of possible shooting dates. We then use the backtracking method, which is commonly used in solving constraint satisfaction problems and combinatorial search, to find arrangements that satisfy each scene's availability dates. Moreover, in order to further shorten the running time of our program, we pre-arranged the order of scenes, so that the scenes with the strictest restrictions would be considered first, enabling the program using the backtracking method to find more results more quickly.

In the second part of our model, we consider other special restrictions requested (for example, the required order of some scenes) and the general preference of our clients. We filter the solutions drawn from the previous part (which could be up to 10000 solutions), by first deleting the deficient solutions based on special restrictions, and then arraying the remaining solutions from the best to the worst. Our model can calculate the total shooting schedule length, the frequency of location changes, and required number of studios in a solution. And along with the average cost to rent a studio, the intended frequency of flexible day, the total budget, and traffic budget of our clients, we can assess the general appropriateness¹ and some characteristics of a schedule, based on which we array the solutions and provide 11 top schedules to our clients. The solutions include 5 overall best solutions, 2 solutions with least number of location changes, 2 solutions with least number of studios², and 2 solutions with least number of shooting days.

Extending our model, we provide ways to adjust an original schedule to various accidents. When our clients provide us with information of the original schedule they selected, accidents occurred and new restrictions, we can return a new schedule with feasible adjustments. These adjustments are achieved by running the program with the new data while leaving intact the scenes that have already happened or that are not expected to change. In this way, the computational complexity would be greatly reduced and the new schedule would involve as few changes as possible.

Lastly, we can also evaluate the most important constraints for our clients by calculating the differences in average characteristic value of top solutions before and after a constraint is changed. Having access to such information, our clients would be able to pay more attention to those important constraints and prevent major delays of their original shooting schedule.

¹We use the characteristic value to evaluate the appropriateness of a solution. For further explanation, please see 2.2, where we explain in detail how we calculate the characteristic value of a solution.

² Different settings cannot be constructed or shooting simultaneously at the same studio, so more than one studio may be required.

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1. Problem interpretation

1.1 Problem restatement

As one of the major types of popular entertainment, motion picture has become a fast-growing industry. The constant demand for new excellent films makes effective filmmaking an important job. Therefore, it is necessary for every producer to develop a good filming schedule within certain constraints, such as the availability dates of stars and specific resources. We hope to use mathematical models to come up with this optimal schedule.

1.2 Assumptions and Justifications

- 1) The filming schedule has a limited time span whose starting point and ending point are both reachable.
- 2) The filming schedule must conform to the following restrictions, which are inflexible and cannot be violated:
 - i. The availability dates of some stars.
 - ii. The availability dates of specific sites.
 - iii. The availability dates for specific resources.
 - iv. The time required to construct and film on a list of sets.
 - v. Some scenes cannot be shot until after certain computer generated content is defined and other physical items are constructed.
 - vi. Some scenes cannot be shot until other scenes are finished. For example, if a set is finally destroyed, all other scenes related to this set are supposed to be shot before it happens.
 - vii. Extra time is needed for redoing some shots if they turn out to be inadequate after editing and review.
 - viii. Extra time is needed for making up some delay or changes.
 - ix. During the filming process, the director might decide to add some new scenes, which will influence the schedule.
- 3) The schedule breaks down time into days for further allocation.
 - Filming schedules always choose "Day" as their unit, which is pretty reasonable. First, it is small enough, because most scenes require one or several days to be shot. Second, it is still flexible, because in every single day small delays can be compensated by working overtime, and night shoots can be compensated by more rests in the daytime.
- 4) Several scenes cannot be shot at the same time.
 - Every time a scene is shot, the director must be present.
- 5) The construction of sets does not interfere with the filming process.
 - Workers can build the sets themselves without being monitored by the director.

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- 6) If multiple schedules are available, the studio will consider the continuity of locations.
- Since the crews do not wish to move frequently, a small number of changes in filming locations is preferred.
- 7) Since we can rent several filming studios, it is possible to build different settings at the same time. However, renting more filming studios will increase the cost, so we hope that these constructions do not conflict with each other.
- 8) Although the crew may not work every day, we should pay for them as long as the shoot is not finished. Therefore, the whole time span is not likely to be too long.
- 9) To deal with problems of delays and reshoots, the filming crews usually have a “flexible day” for every two weeks. On this “flexible day”, they can shoot the scenes that were not completely finished before. Each day without a shooting plan can be seen as a flexible day.

1.3 The goal of modeling

According to the assumptions given above, the optimal schedule derived from our model is an arrangement that:

- satisfies all the inflexible restrictions in 2nd assumption;
- promises relatively less changes in locations;
- has relatively less conflicts in construction of different settings;
- has an appropriate time span;
- has enough flexible day for problems of delays and reshoots.

In this model, we attempt to find a schedule that can excel in all these criteria.

2 Model

2.1 Overview of the model

The whole model consists of two parts: “finding” solutions and “filtering” solutions. For each specific situation, our model first figures out all possible schedules, and then picks up the best ones among them. The model can also adjust previous schedules to deal with new accidents, such as delays in some aspects or changes in the availability of some assets.

2.2 Definition of variables

In order to build a reasonable model, we first introduced some variables:

$T_{\max}$: The maximum time length of filming schedule, which is the difference between the latest

date and the earliest date appearing in the input sheets. A movie cannot be finished if the span of shooting schedule is longer than T_{max} .

T_{min} : The minimum time length of filming schedule, which is the actual shooting time.

A_k : The personal schedule of actor k , which is a 0-1 array within the spread of T_{max} . A '0' as the n^{th} element means that the actor cannot work on the n^{th} day. Similarly, '1' means the actor can join shooting on that day.

B_l : The availability dates of site l . We can simply regard a site as an actor, because to accomplish a shooting task, we need both the actors and the sites available at the same time. If one element is unavailable, the shooting cannot be accomplished. Thus we describe B_l in the same way as that of A_k ; that is, a 0-1 array with the length of T_{max} . Additionally, we define $|B|$ as the number of sites.

C_m : The availability dates of setting m . Similar to sites, a setting can be treated just like an actor. We define $|C|$ as the number of the settings.

D_n : The availability dates of special resource n , such as a helicopter or a tank, which is only available at certain time intervals. Since resources also can be treated as actors, we use A_k to record D_n to simplify the model. We define $|A|$ as the total number of actors and special resources. (The reason why we do not combine B_l and C_m with A_k is that information about sites and settings are required for other calculations in the "filtering" process.)

N_o : A set that records the time required (a.k.a. time length) to film scene o and the elements (e.g. actors, special resources, and a site or a setting) involved. N_o cannot be an empty set; it has to contain at least one actor and one site or setting. Generally, its time length cannot be changed, which already contains a little flexible time for preparation and transportation. Moreover, we consider a scene the smallest part of shooting, which means that a scene cannot be divided. When all scenes are finished, the shooting task is done. We define $|N_o|$ as the time length of this scene, which is an element of the set.

Q_i : A sequence showing a specific arrangement of all N_o s. Q_i is a time plan for all scenes.

t_{N_o} : The number of possible ways to arrange scene o , regardless of arrangements of all other

scenes.

x_i : The actual shooting time length of Q_i .

A_k^* : An "Invisible actor" that has the same character as a real actor. We can use this idea to fulfill the special requirements, such as a specific scene that can be shot in several particular time intervals. This variable depends on requirements of the clients.

E_P : A special restriction P that Q_i must conform to. For example, the restriction that N_1 must be shot before N_2 are accomplished. This variable depends on requirements of the clients.

P : A value between 0 and 1 that measures the ability of a schedule to deal with delays and

reshoots. We define that in every $\frac{1}{P}$ days, one flexible day is used to compensate delays and reshoots. Small delays or quick reshoots, which need only a few hours, can be adjusted on the very day it occurs, so that the whole schedule will not be affected. If delays or reshoots cost a longer time, we can resort remaining scenes into a new schedule. So that only when delays and reshoots

need one day or several days, the flexible day in the $\frac{1}{P}$ days is needed. P is an average value, which satisfies $0 \leq P < 1$. This variable depends on requirements of the clients.

K_i : The number of changes in sites or settings (a.k.a. location changes) that occur in an arrangement Q_i .

K_0 : The least possible number of location changes.

L_i : The number of required filming studios.

y_i : The extra number of Q_i 's location changes. Since we want to avoid unnecessary location changes, the smaller y_i is, the better Q_i is.

z_i : The extra number of filming studios that are required. We say that the more filming studios are used, the more money is spent, and the less efficient the schedule is.

M_{budget} : Total budget of the movie, which is given by our client.

$M_{\text{total traffic}}$: Total traffic budget of the movie, which is also decided by our client.

$M_{\text{traffic per time}}$: The average cost of a location change, which is the money spent on travelling and