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Planning the Amusing Hengelo Festival

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1 Introduction

The Amusing Hengelo festival [1] is an annual musical event in which around 4000 singers participate. These singers belong to one or more of the approximate 100 choirs which usually give two performances: one on a stage outside and one on a stage inside. This leads to the first part of the planning problem: assign the choirs to times and stages such that the requirements are met and the preferences are respected as good as possible. The second part of the planning problem is scheduling the volunteers that supervise the stages. This supervision is needed to look after the equipment on the stages and to assist when problems occur.

The planning problem gets complicated because of the interrelations between the main objects, choirs and volunteers, that we try to plan. We give a more detailed description in the next sections.

2 Planning the choirs

2.1 Stages and Choirs

The Amusing Hengelo festival takes place on the first or second Saturday in June. The festival on June 6, 2015 will be the tenth festival. The public performances of the choirs between 11 AM and 5 PM form the central part of

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the festival. Each performance takes 30 minutes allowing 12 performances on a stage. The stages and choirs have certain properties that have their influence on the planning.

More specific, a stage has the following properties:

- The *public opening time* and *closing time*. These are the times between which performances on the stage can take place.
- A *location* either *indoor* or *outdoor*. Most choirs give exactly one indoor and one outdoor performance.
- A *capacity*, the maximum number of singers that fit on the stage.
- An *equipment level*, ranging from A (no equipment) to E (full electronic equipment with piano). There are rules which higher equipped stages can replace the lower equipped stages.
- The *allowed styles*. Some stages are dedicated to choirs of certain styles, for example in the main church only religious and gospel choirs are allowed.
- A *quality*. Some stages are less attractive than others; it should be avoided the choirs are planned twice on a less attractive stage.

For the planning problem a choir is described by

- The *arrival time* and *departure time*. The performances of the choir should lie between these two times.
- The number of requested *indoor* and *outdoor* performances. The sum is at most 2.
- A *size*, the registered number of singers.
- A *required equipment level*, ranging from A to E. The performances should take place on stages providing the required equipment level.
- The *style*, like 'pop', 'religious', 'barber shop'.

The properties 'capacity', 'equipment level' and 'allowed styles' of the stage versus the properties 'size', 'required equipment level' and 'style' lead to a compatibility matrix for the stage-choir pairs. It is possible to adjust this compatibility matrix by special stage-choir relations, for example to allow a choir of size 41 on a stage with capacity 40.

2.2 Additional requirements

The problem above gets complicated because of choir members and directors (together called 'musicians') that are member of more than one choir; in the datasets there are around 40 of these musicians. Clearly the planning should be such that these persons are not planned double at any time. Moreover it is required that two performances of a musician at consecutive times should be on the same stage ('travel time constraint').

For the planning of the choirs we have the following requirements (H - hard, must be respected) and requests (S - soft, respect as much as possible).

- (H) The performances can only be scheduled on stages that the compatibility matrix allows.

- (H) The time of a performance of a choir on a stage must respect the time windows of the choir and the stage.
- (H) The performances of a choir can not be at consecutive times, neither at times more than three hours apart.
- (S) The number of requested indoor and outdoor performances should be respected.
- (S) The time between two performances should be as close as possible to the preferred time (two hours) between performances.
- (S) A stage of lower quality should be assigned to a choir at most once.
- (S) To retain the audience, stages should be planned without idle times: once a stage has a performance, it should have performances at all the time till the last performance.

Our main objective is to plan the number of requested performances for each choir. Secondary we try to reach good quality choir schedules, as specified by the soft contraints above. At the same time we try to avoid idle times for stages.

3 Planning the volunteers

Most stages cannot be left unattended. This means that we need someone to look after the stage, even if there is no performance. The festival has a list of around 50 volunteers that are willing to do this. The planning of volunteers is aligned with the performances, i.e. in blocks of 30 minutes. All blocks together assigned to a volunteer we call a *shift*.

Unfortunately the planning of the volunteers is not independent of the planning of choirs, because the volunteers are in around 20 % of the cases member of a choir. Like the musicians in Section 2.2 we must avoid double planning of volunteers at any time, and moreover the travel time constraint (planned at consecutive times implies same stage) should hold. A volunteer has the following properties that are important for the planning.

- (H) The *experience*. The first volunteer at a stage should be an experienced volunteer.
- (H) The *arrival time* and *departure time*. The shift of a volunteer should lie between these two times.
- (H) The *maximum shift length*. The shift assigned should not be longer than this maximum.
- (H) The *break rule*. If a shift is longer than 3 hours, there should be a break of one hour after at most 2.5 hours.
- (H) After the break the volunteer must be planned to a different stage.
- (S) If a volunteer is planned to two stages or more, preferable one of the stages is an inside stage, and another one is an outside stage.
- (H/S) Volunteers can have preferences around stages and choirs.

The main objective here is to plan at all times the required number of volunteers to the stages. Secondary we try to reach good quality volunteer schedules, as specified by the soft contraints above.

4 Typology

Although the problem has some interaction it seems convenient to solve it in two phases: planning the choirs and planning the volunteers once the choirs are fixed. Clearly both problems belong to the area of timetabling, [5], and we can try to categorize these two separate problems. The planning of choirs resembles school timetabling problems, see [3]. In fact the problem could be modeled in the XHSTT framework for high school timetabling problems, see [4]. The requested performance are the events to schedule, and the stages are the rooms to be used. The resources attached to an event (the choir and its musicians) should be scheduled without clashes, and we have some preferences on the rooms to use, and the time between the events of the same choir.

Planning the volunteers is slightly different in nature, and resemble call center rostering, see for example [2]. The demands are volunteer requirements for the stages, and we try to fulfill these requirements by assigning shifts to the volunteers. What is very specific here are the extra limitations on the availabilities of the volunteers.

5 Methods and results

For both planning problems we developed algorithms that we describe here. In view of the interrelations between the two parts, first the choirs are planned, and then the volunteers.

5.1 A capacity check

A check is implemented to get an a priori estimate whether the planning of choirs is possible or not, and, if not, to give an indication why not. We construct two networks in which a bipartite graph with arcs reflecting the (choir, stage)-compatibility matrix is the core. We consider two networks, as we can separate the inside and outside performances. To the bipartite graph we add a source node and a sink node. From the source to each choir-node we add an arc with capacity the number of requested inside, respectively, outside performances. Similarly we add an arc from each stage-node to the sink node, with capacity the number times the stage is open for performances. Essentially this network forgets about the timing of the performances; a maximum flow from source to sink is an upperbound for the maximum number of performances that can be planned inside, respectively, outside. The upperbound found here usually is reached by the algorithms described below.

5.2 Algorithms for planning the choirs

In the construction phase we first plan the musicians that belong to four or more choirs. These musicians are performing 8 of the 12 times, which in

combination with travel time constraint deserves special attention. In fact the most suitable inside stage and outside stage are selected, and the choirs of the musician are planned in two sequences (with a break) on these stages.

Once the most difficult musicians are planned (and fixed) we try to plan the remaining performances. Since the planning of inside performances is more tight, we first plan those, and after that all outside performances. The choirs are sorted by difficulty and planned to the most suitable stage one by one. We add some randomization in the order of choirs and stages, to be able to repeat this process several times.

In the practical cases the solution is not satisfactory even after several attempts of the construction above. For this reason we implemented several improving algorithms. The first algorithm selects the worst planned choir that is not tabu and finds the best time-stage combination for one of the requested performances of the choir. Then the choir is made tabu, indicating that it will not be considered for some time, and the search restarts.

Usually the tabu-search above will not assign all requested performances. Therefore in the next phase, we take a complementary point of view and consider the stages one by one, trying to improve the selected stage's planning; accordingly we consider the performances on the other stages fixed. For the selected stage we try to increase the total number of planned performances while reducing the idle times. For this we solve a matching problem in a bipartite graph. One side of the bipartite graph consists for the choirs that currently are planned on the stage together with the choirs that still can be planned on this stage, because the requested number of performances is not reached yet. On the other side of the bipartite graph are the times that this stage is available for performances. We add an edge from the choir-node to time-node, if the choir can be planned on the stage at this time, and add costs to the edges reflecting choir planning costs, and our wish to reduce the idle times of the stage. We solve the matching problem and keep on iterating over the stages as long as improvements are found.

5.3 Algorithm for planning the volunteers

Planning the volunteers turned out to be harder than planning the choirs. We developed several local search procedures, that unfortunately were not able to plan all required blocks. For this reason we decided to work in two phases: in the first phase we do local search, yielding a solution with a few percent of unplanned blocks. In the second phase we fix the most restricted volunteers to the shift as planned during the local search, and continue to formulate and solve an ILP model for the remaining volunteers. A direct model (without partial fixing) is also possible, but the time to obtain a solution with all blocks planned takes over 10 hours of computation time, even with a commercial solver. Fixing the easy volunteers reduces this to 10 or 15 minutes.

Year	Choirs	Stages	Volunteers
2012	114	20	51
2013	105	19	26
2014	93	18	46

Table 1 Main characterisitics of the data of 2012, 2013, and 2014

5.4 Results

We developed algorithms for both planning problems and tested them on the planning data of 2012, 2013, and 2014. The main characteristics of the data can be found in Table 1. It gives the number of registered choirs, number of stages, and number of known volunteers at the time of planning; the volunteer data in 2013 is not complete, since the planning was done by hand.

The algorithms for choir planning have been used in all these years, while the approach for volunteers planning was tested this year. The version of 2014 revealed that the choir planning is solved very satisfactory, but for volunteer planning more modeling is needed to describe the acceptable rosters for volunteers. The generated roster served as starting point for manual improvements, and thus already saved hours of work.

References

[1] Amusing Hengelo, http://amusing-hengelo.nl/?l=en.
[2] Ernst A, Jiang H, Krishnamoorthy M, Sier D (2004) Staff scheduling and rostering: A review of applications, methods and models. European Journal of Operational Research 153(1): pp. 3–27.
[3] Pillay N (2013) A survey of school timetabling research. Annals of Operations Research, doi: 10.1007/s10479-013-1321-8.
[4] Post G, Ahmadi S, Daskalaki S, Kingston J, Kyngas J, Nurmi C, Ranson D (2012) An XML format for benchmarks in high school timetabling. Annals of Operations Research 194(1): pp. 385–397.
[5] Schaerf A (1999) A survey of automated timetabling. Artificial Intelligence Review 13(2): pp. 87–127.