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Geographically Distributed Exam Timetabling

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1 Introduction

Exam timetabling is a well-studied domain where a large number of student exams need to be scheduled in a short period of time, taking into account a number of constraints (Qu et al, 2009). These constraints may limit the number of exams in a day, or may spread exams evenly for any one student. The literature on exam timetabling mainly assumes that examinations take place at a fixed location (e.g. in a school, or in a university campus) (Gaspero and Schaerf, 2001), or different campuses of the same university (Kaplansky et al, 2004). However, some real-world problems exist that require the scheduling of exams based on the geographical distribution of students (henceforth called candidates or participants), in locations that are not a priori fixed. For example, a certifying organization may want to conduct certification tests in multiple cities as close as possible to all candidates, while taking into account room availability and costs, as well as the travel distance, availability and fees of the exam supervisors. It is therefore our belief that the literature on exam timetabling needs to be extended to cover such complex real-world geographically distributed scenarios. Here we present the problem of geographically distributed exam timetabling, which to the best of our knowledge has not been addressed in the literature.

A large number of candidates from different cities enroll for certification exams, such as for Cisco certificates or certificates for Microsoft products. Each candidate specifies his/her preferred exam location in a web-based platform. Depending on the number of participants, a date is chosen by the organizer (or planner) and suitable locations are selected, based on the location preferences of candidates. An exam can take place on multiple locations, but has to be carried out at the same time, which is determined based on room availability. Thereafter, an exam supervisor is selected for each room.

This problem has been identified by Televic Education[1], which intends to offer a tool that supports the human planner at certifying organizations in this challenging

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task. Here we introduce an approach for addressing the above problem, which will later become part of a decision support tool.

2 A decomposition approach

We decompose the geographically distributed exam timetabling problem and propose a 3-phase approach to address it, where assignments are solved sequentially – the output of each phase is used by the following one. The proposed approach first *finds locations* that minimize the travel distance of all participants, then determines the *schedules of exams* that minimize the room occupancy at that location in order to reduce the costs for the organization, and finally minimizes the cost for *hiring exam supervisors*. Below we elaborate on each phase in this optimization process.

Phase 1: Location assignment. To minimize the travel distance of all candidates, one needs to find the geographical center of all location preferences. As candidates can be located in multiple cities, finding multiple geographical centers can further reduce the distance to all participants, at the expense of higher organizational costs. The course organizer determines the maximum number of locations k over which each exam e can be spread and the required minimum number of participants p at any given location. The grouping of participants is performed with the help of k-means clustering, where the number of clusters for each exam is k. The initial centroid of each cluster is set as the location preference of one uniformly randomly selected candidate. In other words, each data point to be clustered represents the preferred location of one candidate on the map. At each iteration the clustering algorithm computes the closest centroid for each data point and then moves each centroid to the geographical center of all data points in that cluster. This process is repeated until the locations of all centroids do not change more than a small number ϵ between two iterations. Without loss of generality, we chose to use euclidean distances, instead of actual road distances. After determining the geographical center of each cluster, an exam location is selected that is the closest to each centroid. Clusters with less than the minimum number of participants p for an exam are re-assigned to the closest location that has p or more participants. Alternatively, several clusters with less than p participants can be joined. The final number of locations for each exam may be k or lower, since multiple centroids can be close to the same exam location, and because small clusters may be merged with larger ones.

A number of different solutions with comparable average travel distance can be generated, due to the stochastic nature of the clustering algorithm. While k-means optimizes for the average travel distance, additional fairness metrics and organizational preferences can be considered when deciding on the final assignment of locations. Examples of additional factors that can influence the choice of a solution are the maximum travel distance, the final number of locations per exam, and the use of any particular (un)desired locations.

Phase 2: Room assignment. Once locations are determined based on the above metrics, exams at each location need to be assigned to available rooms at that location, taking into account the size of the exam, its equipment requirements and the occupancy schedule of the room. Our approach also takes into account all typical constraints in examination timetabling, such as that a participant can only take one exam at a time, a given exam taking place in multiple locations has to be carried out at the same time (Kaplansky et al, 2004), etc. Each exam location may contain multiple rooms r of different capacity r_c, where in some rooms certain equipment q is present, e.g. computers, a projector, etc. Each exam e may require equipment e_q to be present in the room. Thus, exams that require equipment e_q may only be scheduled in rooms with equipment q. In contrast, exams with no equipment requirement can be scheduled in any room, regardless of the available equipment. As some rooms may be reserved for other activities or be otherwise unavailable at given time slots (e.g. due to maintenance), such unavailabilities need to be taken into account in the assignment process. We use a general purpose MILP solver to find an allocation of exams to rooms that minimizes the sum of capacities r_c of all rooms used for exams, given the above constraints. The intuition behind this objective is that larger rooms have higher reservation costs. Starting times of exams are also determined in the allocation process.

The MILP solver yields the optimal allocation of exams to rooms, or a near-optimal one, in case computation time exceeds some pre-defined threshold. Thereafter, exam location, room, date and time are fixed and can be communicated to all participants. Once exam times are fixed, one can still accommodate any late changes to room schedules. Assigning a set of exams with fixed starting times to a set of rooms draws parallels to the shift minimization personnel task scheduling problem (Krishnamoorthy et al, 2012). Approaches, such as that proposed in (Smet and Vanden Berghe, 2012), for solving the latter problem can be applied for minimizing the number of used rooms.

Phase 3: Supervisor assignment. Lastly, having the exam locations and schedules, an exam supervisor s is assigned to each exam. Among all supervisors available at the time of each exam, our approach selects those that minimize the weighted sum of the fees s_f of that supervisor and his/her distance s_d to that respective location, where s_f is being weighted 5 times more than s_d. In this way the organization will hire an affordable supervisor, located relatively close to the exam location.

3 Summary and outlook

Geographically distributed exam timetabling is a challenging task that some organizations are often confronted with. To address this problem, we introduced a 3-phase approach, which can be integrated in a decision support tool that guides the organizer at different stages of the planning process. Our approach integrates individual preferences of candidates, and adequately balances the cost-quality trade-off of solutions. Each generated solution can provide information to the planner on the overall cost of the allocation, i.e. room and supervisor costs, as well as the average and maximum travel distance of participants. These measures allow planners to compare the different solutions and select the one that best fits the objectives of the organization.

In the proposed approach we tackle the distributed exam timetabling problem a sequential manner. In the first phase locations are fixed that are close to all participants, then exams are assigned to rooms in those locations and finally supervisors are selected for each exam. In future work we will consider an iterative process where each assignment uses the output of the others, further optimizing the costs of the organization. For example, room assignment should be taken into account in the clustering algorithm; large exams can be split in several smaller rooms; the availability of supervisors should also be considered when determining the starting times of exams; etc. In addition, the parameter k, or the maximum number of locations per exam, can be automatically determined by generating solutions with different values for k and selecting the result with the best cost-quality trade-off, as defined by the organization.

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