Ring Out the Bells

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1 Introduction

Campanology is the art or study of bell casting and ringing. For many people this is an interesting and fulfilling hobby. Every year in southern England a campanology event is held which aims to introduce beginners to the hobby as well as allowing more experienced campanologists the opportunity to learn new techniques and visit different church towers.

The event takes place over a four day period (Thursday – Sunday) in which participants are organized into teams for the duration of the event. Each team participates in 6 sessions of bell ringing during which participants are tutored by experienced campanologists with the aim that by the end of the weekend the team will be able to ring the bells independent of the tutors' instruction. Each of the six sessions are held in a different church towers. This gives each team exposure to aspects such as differing construction of towers, different bell weights, rope draught and tension etc.. allowing them to deepen their knowledge of the nuances involved in ringing bells in different settings.

Within bell ringing methods are rung on different numbers of bells e.g. double methods require 5 method bells and a cover bell; minor methods require 6 bells; triple methods require 7 method bells and a cover bell. Due to this not all church towers are suitable for certain styles of ringing.

This makes the scheduling of this event difficult as not only do considerations need to be made for the suitability of each church tower, but also, due to the dispersion of church towers among the region, minimal movement of the teams between each of their sessions would be preferred. Additionally on top of this, considerations could be made for issues such as local amenities, nearby accommodation, annoyance of local residents and access to the towers themselves.

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2 Background Research

The complex nature of bell ringing is highlighted in several research papers which explore the mathematics of the hobby [1, 2]. Reading these reinforces the need for accurate measurements by which the suitability of each bell tower may be judged. In regards to the timetabling aspect of the problem, generally this type of problem is regarded as a routing problem. However, beyond route finding there are many examples from literature and the real world that fit into the same group of problems [9]. Many approaches to the topic of timetabling have been presented ranging from simply guided heuristic searches [3] to complex meta heuristic methods such as tabu search [4, 5] and simulated annealing [6].

3 Methodology

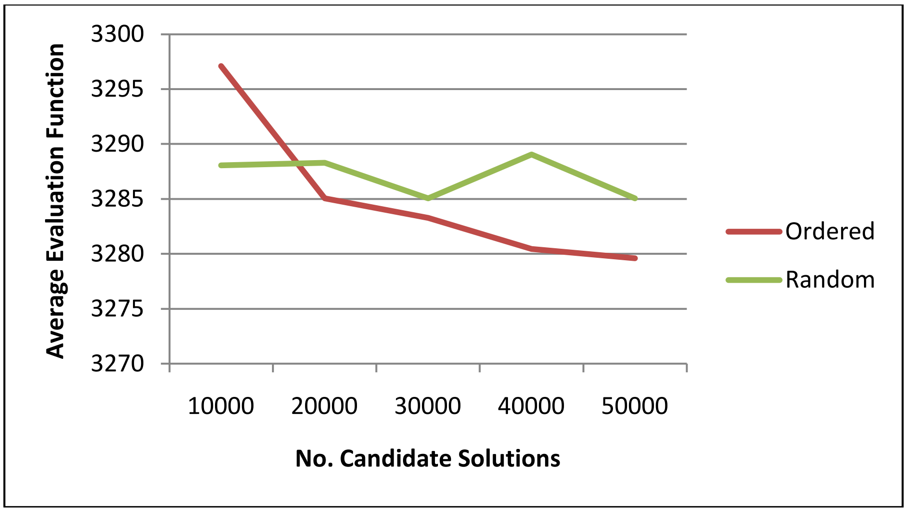
The initial approach to formulating a solution was to model this as a graph coloring problem. The generation of proposed solutions is guided through the use of an ordering heuristic that orders the teams based on the difficulty required in scheduling, such as a large number of team members or teams consisting entirely of beginners. Following the generation of a pool of feasible candidate solutions, an evaluation function is applied to each timetable. This provides an accurate representation to allow comparison between candidate solutions.

To enable quick and accurate calculation of the distances between bell towers, a distance matrix containing the road distance between each tower is pre-computed using Google Maps. The suitability of towers is calculated by comparing the rated skill level of the members of a team the weight of the bells in that tower.

The heuristic used in the evaluation function is comprised of a summation of statistical measures derived from the candidate solution. The aim of this evaluation function is to combine measures for both the suitability of the towers assigned to teams based on the ringing style that team specializes in and also to minimize the distance moved between sessions. Additionally the evaluation function aims to favor solutions that have an even spread of values across the entire candidate solution. The main downfall of a summation of values such as this is that if one value in the summation is abnormally high or low then it could disproportionately affect the entire value of the summation. To alleviate this issue each individual summation value is weighted in an attempt to ensure that each part of the summation carries equal value. These weights were calculated through analysis of approx. 1,000,000 feasible candidate solutions. Subsequently the evaluation function is as follows:

4 Results

For comparison the developed ordering heuristic was compared to a heuristic that generates random, feasible solutions. What was found was that on average, the greater the number of test solutions generated the better performing the ordered heuristic was as shown in the figure below.



It was also discovered that across all testing the ordered heuristic was approx 15% faster in generating the same amount of candidate solutions as the random heuristic.

This shows that it is possible to create an ordering heuristic that will effectively produce timetables that meet the needs of multiobjective problems. However, for this particular problem and implementation, the heuristic requires the production of many candidate solutions. In real world implementations this could prove problematic if the generation of the time table/schedule is time sensitive.

In regards to the best candidate solutions generated, the ordered heuristic 80% of cases and it produced the 5 of the top 10 candidate solutions 95% of the time. This shows the best solutions generated by the ordering heuristic are very much better than the average performance of the random heuristic.

5 Future Research Directions

This paper describes a real world model of a scheduling problem. The solution implemented currently generates good quality initial solutions and, even given the issues with weighted summations as a means to evaluate multiple objectives, still provides an effective way to select the best candidate solution.

Naturally the next obvious avenue for exploration would be that of meta-heuristic search methods in way of improving upon these initial solutions. Introduction of an improvement phase to the construction of candidate solutions may also allow us to reduce the time required in generation good quality workable solutions. Due to its success in other related areas, we intend to investigate the Great Deluge [7, 8] in this respect. A full implementation and results of both the construction and improvement phase will be presented at the conference.

Future directions of the research include a full multi-objective representation and comparison of the construction and improvement approaches with other related scheduling problems e.g. examination and course timetabling.

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