CRT-AI Constraint Week 2024 - Programming Challenge

Helmut Simonis

August 19, 2024

Abstract

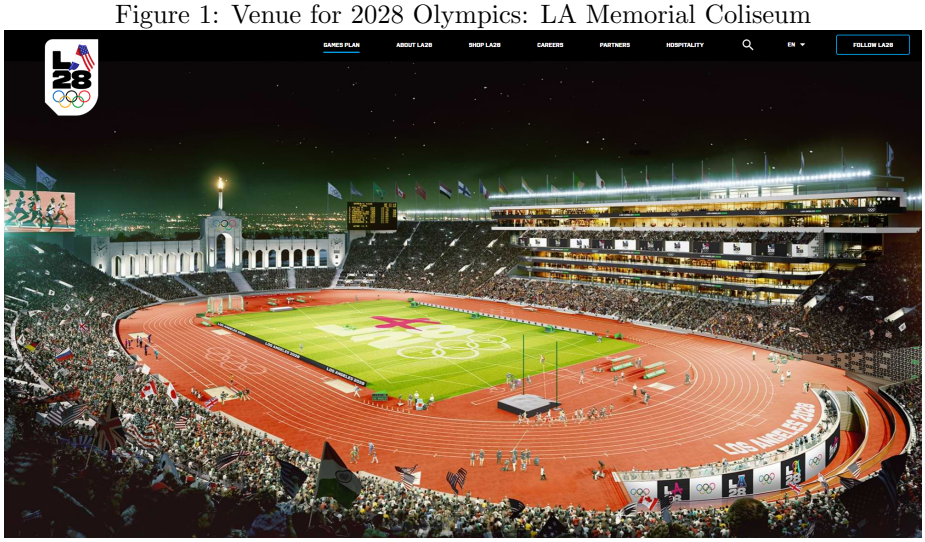
This document describes the Challenge Problem for the CRT-AI Constraint Week 2024, the annual training course for Irish PhD students in AI held at UCC in Cork. The challenge will be presented in steps, the initial problem will be presented on Monday, with possible extensions being presented on Tuesday, Wednesday, and Thursday. Following the recent Olympic games in Paris, this year's challenge will be to schedule the Athletics events at the Olympic games in Los Angeles in 2028.

1 Introduction

The Olympic Summer games re-occur every four years, and host events of many sports disciplines. After the recent games in Paris, the planning is now focused on the 2028 games in Los Angeles. Scheduling all events of the games is a massive challenge, we will here concentrate on one, still quite challenging, sub-problem, the scheduling of the Athletics discipline. This covers 48 events, all but five will be hosted in the Los Angeles Memorial Coliseum (see Figure 1), which was already used in the Olympic games of 1932 and 1984.

5 events removed from the total events

Figure 1: Venue for 2028 Olympics: LA Memorial Coliseum



Phases need to be in order: qualification round --> semi-finals --> finals

Each athletics event consists of one or more activities, which must be scheduled in a specific sequence. This can be for example a qualification round, followed by semi-finals and then finals, at which point the winner is determined. Some events, like the Men's Decathlon, or the Women's Heptathlon, consist of even more activities, where the athletes compete in different event types. The order of these activities is given by a stage number, with smaller value stating earlier execution.

Table 1: Sample Activities

Nr	Event	Stage Nr	Phase	Resource	Athletes	Final	Dur (min)
1	4 x 400m Relay Mixed	1	Round1	Track	64	0	16
2	4 x 400m Relay Mixed	2	Final	Track	32	1	4
3	Men's 10,000m	1	Final	Track	27	1	30
4	Men's 100m	1	PreliminaryRound	Track	46	0	25
5	Men's 100m	2	Round1	Track	72	0	49
6	Men's 100m	3	SemiFinal	Track	27	0	17
7	Men's 100m	4	Final	Track	8	1	1
8	Men's 110m Hurdles	1	Round1	Track	40	0	33
9	Men's 110m Hurdles	2	Repechage	Track	21	0	17
10	Men's 110m Hurdles	3	SemiFinal	Track	24	0	17
11	Men's 110m Hurdles	4	Final	Track	8	1	1
...							
114	Women's Heptathlon	1	Run100mHurdles	Track	23	0	17
115	Women's Heptathlon	2	HighJump	High Jump	23	0	104
116	Women's Heptathlon	3	ShotPut	Shot Put	23	0	42
117	Women's Heptathlon	4	Run200m	Track	23	0	17
118	Women's Heptathlon	5	LongJump	Long Jump	22	0	42
119	Women's Heptathlon	6	JavelinThrow	Long Throws	11	0	42
120	Women's Heptathlon	7	JavelinThrow	Long Throws	11	0	42
121	Women's Heptathlon	8	Run800m	Track	21	1	23
122	Women's High Jump	1	Qualification	High Jump	32	0	130
123	Women's High Jump	2	Final	High Jump	13	1	105
124	Women's Javelin Throw	1	Qualification	Long Throws	16	0	56
125	Women's Javelin Throw	2	Qualification	Long Throws	16	0	56
126	Women's Javelin Throw	3	Final	Long Throws	12	1	78
...							

Table 1 shows some examples of all activities to be scheduled, the table lists sequential number, the event, a stage number, the name of the phase of the event, the resource used, the expected number of participants, an indicator if that activity is a final, and the actual duration of this phase. The full list of all activities is given in the data file. Note that we have excluded five Athletics road events that are not placed in the stadium, and that are scheduled independently.

The current plan for the 2028 games is to schedule the Athletics events at the start of the games, Figure 2 shows the available 16 sessions[1]. Activities can be either scheduled in the morning or evening session in the period of Saturday July 15th to Saturday July 22nd, after the opening ceremony on the 14th of July. Each session is four hours long.

As spectators buy tickets for each session individually, our aim is to spread the activities evenly over the available sessions, i.e. we aim to achieve a balanced schedule where every session has (as far as possible) the same number of activities. At this point we only care about the session in which an activity is scheduled, not the exact start and end times. The activities of one event must be scheduled in sequence, i.e. we cannot schedule an activity of some event with

[1]The Paris games scheduled Athletics at the end, while using the Stade de France for the Rugby Sevens competition at the beginning of the games.

a higher stage number in a session before another activity of that event with a lower stage number. It is possible to schedule multiple, consecutive activities of some event in the same session. Naturally, all activities must be scheduled, we are not allowed to skip some activities or events in the schedule.

Figure 2: Proposed Calendar of Athletics Event at Olympic Games 2028

	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
July 2028	14	15	16	17	18	19	20	21	22
Morning	-	1	3	5	7	9	11	13	15
Evening	-	2	4	6	8	10	12	12	16

The activities in the stadium each use some specific part of the track and field. The resource used is given in the activity table column `resource`. The following resources are defined:

- Track
- Long Jump
- High Jump
- Triple Jump
- Pole Vault
- Long Throws
- Shot Put

Each activity uses its resource exclusively, the total time used for any resource in each session must fit within the session length (240 minutes). This means for example that the total resource use for all track events in a session must be less than the session length. Note that some activities for an event internally consist of multiple heats, and their duration is given as the total time scheduled, not the length of on heat.

1.1 Data

The data is provided in the JSON file monday.json, which uses the following structure.

```
include "globals.mzn";

int:nrActivity;
int:nrEvents;
int:nrResources;
int:nrSessions;
int:sessionDuration;

type Activity = record(string:event,
              string:phase,
              string:resource,
              int:nr,
              int:duration,
              int:participants,
              int:finals,
              int:stageNr);

% data arrays
array[1..nrActivity] of Activity:activity;
array[1..nrResources] of string:resources;
array[1..nrEvents] of string:events;
```

There are some integer parameter values, two arrays of strings for the scheduled events and resources used, and an array of records called Activity. Each Activity contains the data describing one activity of an event, the values are either strings (event, phase, resource) or integers (nr, duration, participants, finals, stageNr). The duration is the length of the activity in minutes, participants is the number of athletes participating in the event, and finals is a 0/1 indicator to state if the activity is the final activity of the event. The activities of every event are consecutive in the array, arranged by increasing stage number.

Use the definition above to define the input data in your program. You can then for example refer to the event of activity i as `activity[i].event`.

1.2 Question

Please write a MiniZinc program that schedules all activities, based on the data file `monday.json`, which contains a JSON structure describing the instance. What are the variables, what are the constraints, and what (if any) is the objective?

1.3 Bonus Question

Only attempt this if you already have a solution for the initial problem!

In reality, the resource constraints are more complex. Figure 3 shows the standard stadium layout proposed by the IAAF (`https://worldathletics.org/`). Different events use different parts of the stadium, and each activity has

an assigned resource, which it uses exclusively. But activities that use different resources may also conflict. As an example, both shot put and discus throw use the main football pitch (Area 1 in Figure 3) field as the target and measuring area. It would be unsafe to schedule such events at the same time. On the other hand, these field events do not interfere with the track use, so we could schedule shot put or discus throw at the same time as a 100m event. Can you identify which resources will be in potential conflict? How does this affect the schedule?

Figure 3: Stadium Layout

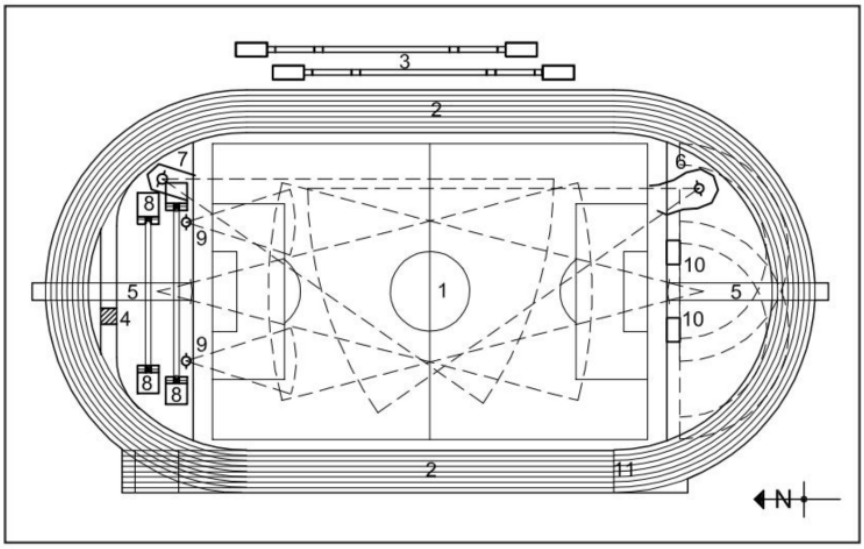


Figure 2.5a - Standard layout of competition facility

1 Footbal pitch
2 Standard Track
3 Long and Triple Jump facility
4 Water jump
5 Javelin Throw facility
6 Discus and Hammer Throw facility
7 Discus Throw facility
8 Pole Vault facility
9 Shot Put facility
10 High Jump facility
11 Finish line