

CRT-AI Constraint Week 2024 - Programming Challenge

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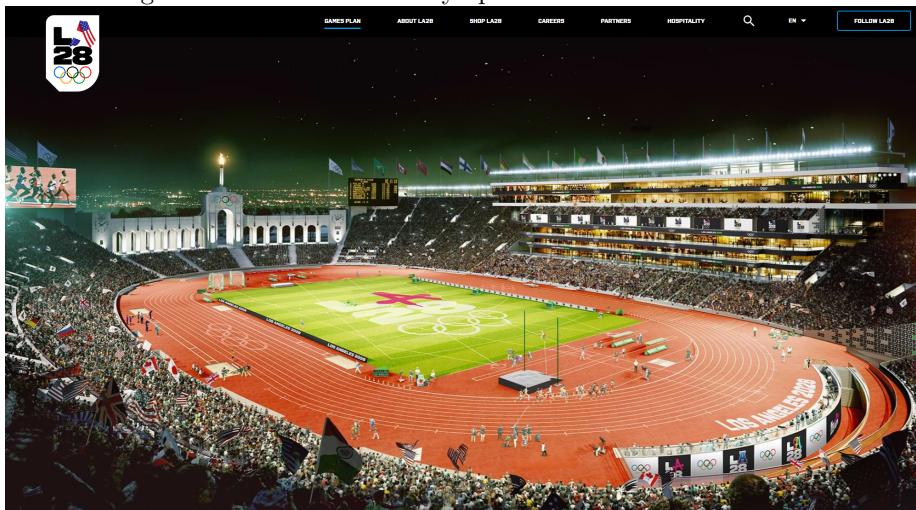
Abstract

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, subproblem, 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.

Figure 1: Venue for 2028 Olympics: LA Memorial Coliseum



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		Resource	Athletes	Final	Dur (min)
		Nr	Phase				
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 sessions¹. 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

¹The 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

July 2028	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
	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 one heat.

1.1 Data

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

```
1 include "globals.mzn";
2
3 int:nrActivity;
4 int:nrEvents;
5 int:nrResources;
6 int:nrSessions;
7 int:sessionDuration;
8
9 type Activity = record(string:event,
10                         string:phase,
11                         string:resource,
12                         int:nr,
13                         int:duration,
14                         int:participants,
15                         int:finals,
16                         int:stageNr);
17
18 % data arrays
19 array[1..nrActivity] of Activity:activity;
20 array[1..nrResources] of string:resources;
21 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

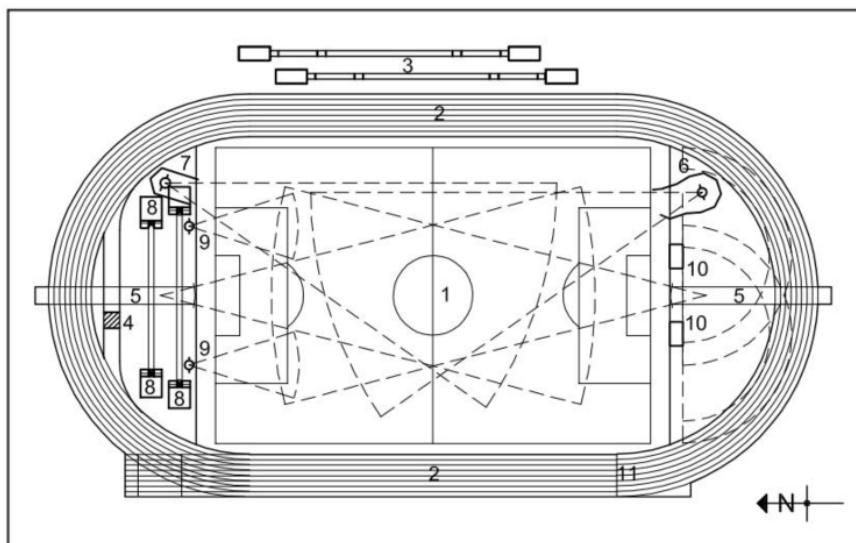


Figure 2.5a - Standard layout of competition facility

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

2 Tuesday

We asked the Olympic Committee and some track and field experts for feedback on the solutions produced so far. They stated several concerns:

- There are limited facilities in the stadium to accommodate the athletes of each session. The number of athlete participating in any one session should be limited to 250.
- The organizers want more control over the temporal ordering of the events. Instead of just expressing a precedence constraint, they want to state the required temporal relation between any two consecutive activities. Some activities must be scheduled in the same session, others should be in consecutive sessions. For longer competitions, the requirement may be that activities should be on consecutive days, or that there should be one or two rest days between races. No pair of activities should be more than three days apart, to avoid a loss of peak performance over multiple days without proper training facilities. The detailed data of the precedences are shown in Table 2, the data is contained in the data file `tuesday.json`.
- In Olympic games some athletes participate in more than one event, for example 400m Men's and 4x400m Men's relay. In order to facilitate this, the activities of such events should not be scheduled together in the same session. For the 2024 games, the events in Table 3 had athlete conflicts. Your schedule for 2028 should also respect these conflicts. The data are available in the file `tuesday.json`.

Table 2: Precedence Relations

Event	Before	After	Relation	Before Nr	After Nr
Athletics Women's Heptathlon	Run100mHurdles	HighJump	Same	114	115
Athletics Women's Heptathlon	HighJump	ShotPut	PreviousSession	115	116
Athletics Women's Heptathlon	ShotPut	Run200m	Same	116	117
Athletics Women's Heptathlon	Run200m	LongJump	PreviousSession	117	118
Athletics Women's Heptathlon	LongJump	JavelinThrow	Same	118	119
Athletics Women's Heptathlon	JavelinThrow	JavelinThrow	Same	119	120
Athletics Women's Heptathlon	JavelinThrow	Run800m	PreviousSession	120	121
Athletics Men's 200m	Round1	Repechage	PreviousSession	16	17
Athletics Men's 200m	Repechage	SemiFinal	Yesterday	17	18
Athletics Men's 200m	SemiFinal	Final	Yesterday	18	19
Athletics Men's Shot Put	Qualification	Final	Yesterday	67	68
Athletics Men's Javelin Throw	Qualification	Qualification	Same	60	61
Athletics Men's Javelin Throw	Qualification	Final	DayBeforeYesterday	61	62
Athletics Women's Triple Jump	Qualification	Final	Yesterday	133	134
Athletics Men's Triple Jump	Qualification	Final	DayBeforeYesterday	69	70
Athletics Women's 400m Hurdles	Round1	Repechage	Yesterday	98	99
Athletics Women's 400m Hurdles	Repechage	SemiFinal	Yesterday	99	100
Athletics Women's 400m Hurdles	SemiFinal	Final	DayBeforeYesterday	100	101
Athletics Women's 4 x 100m Relay	Round1	Final	Yesterday	90	91
Athletics Men's 110m Hurdles	Round1	Repechage	DayBeforeYesterday	8	9
Athletics Men's 110m Hurdles	Repechage	SemiFinal	Yesterday	9	10
Athletics Men's 110m Hurdles	SemiFinal	Final	Yesterday	10	11
Athletics Men's 400m	Round1	Repechage	PreviousSession	26	27
Athletics Men's 400m	Repechage	SemiFinal	Yesterday	27	28
Athletics Men's 400m	SemiFinal	Final	Yesterday	28	29
Athletics Men's Hammer Throw	Qualification	Qualification	Same	55	56
Athletics Men's Hammer Throw	Qualification	Final	DayBeforeYesterday	56	57
Athletics Women's 100m	PreliminaryRound	Round1	Same	72	73
Athletics Women's 100m	Round1	SemiFinal	Yesterday	73	74

Event	Before	After	Relation	Before Nr	After Nr
Athletics Women's 100m	SemiFinal	Final	Same	74	75
Athletics Men's 5000m	Round1	Final	ThreeDays	34	35
Athletics Women's Shot Put	Qualification	Final	Yesterday	131	132
Athletics Women's Javelin Throw	Qualification	Qualification	Same	124	125
Athletics Women's Javelin Throw	Qualification	Final	ThreeDays	125	126
Athletics Women's 4 x 400m Relay	Round1	Final	Yesterday	92	93
Athletics Men's High Jump	Qualification	Final	ThreeDays	58	59
Athletics Women's 800m	Round1	Repechage	PreviousSession	104	105
Athletics Women's 800m	Repechage	SemiFinal	Yesterday	105	106
Athletics Women's 800m	SemiFinal	Final	Yesterday	106	107
Athletics Women's Pole Vault	Qualification	Final	DayBeforeYesterday	129	130
Athletics Men's Decathlon	Run100m	LongJump	Same	40	41
Athletics Men's Decathlon	LongJump	ShotPut	Same	41	42
Athletics Men's Decathlon	ShotPut	HighJump	PreviousSession	42	43
Athletics Men's Decathlon	HighJump	Run400m	Same	43	44
Athletics Men's Decathlon	Run400m	Run110mHurdles	PreviousSession	44	45
Athletics Men's Decathlon	Run110mHurdles	DiscusThrow	Same	45	46
Athletics Men's Decathlon	DiscusThrow	DiscusThrow	Same	46	47
Athletics Men's Decathlon	DiscusThrow	PoleVault	Same	47	48
Athletics Men's Decathlon	PoleVault	JavelinThrow	PreviousSession	48	49
Athletics Men's Decathlon	JavelinThrow	JavelinThrow	Same	49	50
Athletics Men's Decathlon	JavelinThrow	Run1500m	Same	50	51
Athletics Men's 800m	Round1	Repechage	Yesterday	36	37
Athletics Men's 800m	Repechage	SemiFinal	Yesterday	37	38
Athletics Men's 800m	SemiFinal	Final	Yesterday	38	39
Athletics Men's 4 x 400m Relay	Round1	Final	Yesterday	24	25
Athletics Women's 400m	Round1	Repechage	Yesterday	94	95
Athletics Women's 400m	Repechage	SemiFinal	Yesterday	95	96
Athletics Women's 400m	SemiFinal	Final	DayBeforeYesterday	96	97
Athletics Men's 400m Hurdles	Round1	Repechage	Yesterday	30	31
Athletics Men's 400m Hurdles	Repechage	SemiFinal	Yesterday	31	32
Athletics Men's 400m Hurdles	SemiFinal	Final	DayBeforeYesterday	32	33
Athletics Men's Pole Vault	Qualification	Final	DayBeforeYesterday	65	66
Athletics Men's 100m	PreliminaryRound	Round1	Same	4	5
Athletics Men's 100m	Round1	SemiFinal	Yesterday	5	6
Athletics Men's 100m	SemiFinal	Final	Same	6	7
Athletics Women's Hammer Throw	Qualification	Qualification	Same	111	112
Athletics Women's Hammer Throw	Qualification	Final	DayBeforeYesterday	112	113
Athletics 4 x 400m Relay Mixed	Round1	Final	Yesterday	1	2
Athletics Women's Long Jump	Qualification	Final	DayBeforeYesterday	127	128
Athletics Women's Discus Throw	Qualification	Qualification	Same	108	109
Athletics Women's Discus Throw	Qualification	Final	ThreeDays	109	110
Athletics Women's 3000m Steeplechase	Round1	Final	DayBeforeYesterday	88	89
Athletics Women's High Jump	Qualification	Final	DayBeforeYesterday	122	123
Athletics Women's 1500m	Round1	Repechage	Yesterday	80	81
Athletics Women's 1500m	Repechage	SemiFinal	Yesterday	81	82
Athletics Women's 1500m	SemiFinal	Final	DayBeforeYesterday	82	83
Athletics Men's 1500m	Round1	Repechage	Yesterday	12	13
Athletics Men's 1500m	Repechage	SemiFinal	Yesterday	13	14
Athletics Men's 1500m	SemiFinal	Final	DayBeforeYesterday	14	15
Athletics Men's 4 x 100m Relay	Round1	Final	Yesterday	22	23
Athletics Women's 100m Hurdles	Round1	Repechage	Yesterday	76	77
Athletics Women's 100m Hurdles	Repechage	SemiFinal	Yesterday	77	78
Athletics Women's 100m Hurdles	SemiFinal	Final	Yesterday	78	79
Athletics Men's Long Jump	Qualification	Final	DayBeforeYesterday	63	64
Athletics Men's Discus Throw	Qualification	Qualification	Same	52	53
Athletics Men's Discus Throw	Qualification	Final	DayBeforeYesterday	53	54
Athletics Women's 5000m	Round1	Final	ThreeDays	102	103
Athletics Women's 200m	Round1	Repechage	Yesterday	84	85
Athletics Women's 200m	Repechage	SemiFinal	PreviousSession	85	86
Athletics Women's 200m	SemiFinal	Final	Yesterday	86	87
Athletics Men's 3000m Steeplechase	Round1	Final	DayBeforeYesterday	20	21

Table 3: Conflicts

Event1	Event2
Athletics 4 x 400m Relay Mixed	Athletics Women's 4 x 400m Relay
Athletics 4 x 400m Relay Mixed	Athletics Men's 4 x 400m Relay

Event1	Event2
Athletics 4 x 400m Relay Mixed	Athletics Women's 400m
Athletics 4 x 400m Relay Mixed	Athletics Men's 400m
Athletics 4 x 400m Relay Mixed	Athletics Women's 400m Hurdles
Athletics 4 x 400m Relay Mixed	Athletics Men's 4 x 100m Relay
Athletics 4 x 400m Relay Mixed	Athletics Men's 400m Hurdles
Athletics Men's 10,000m	Athletics Men's 5000m
Athletics Men's 100m	Athletics Men's 4 x 100m Relay
Athletics Men's 100m	Athletics Men's 200m
Athletics Men's 100m	Athletics Men's 4 x 400m Relay
Athletics Men's 1500m	Athletics Men's 5000m
Athletics Men's 1500m	Athletics Men's 800m
Athletics Men's 200m	Athletics Men's 4 x 100m Relay
Athletics Men's 200m	Athletics Men's 4 x 400m Relay
Athletics Men's 20km Race Walk	Athletics Marathon Race Walk Relay Mixed
Athletics Men's 4 x 100m Relay	Athletics Men's 4 x 400m Relay
Athletics Men's 400m	Athletics Men's 4 x 400m Relay
Athletics Men's 400m	Athletics Men's 200m
Athletics Men's 400m Hurdles	Athletics Men's 4 x 400m Relay
Athletics Women's 10,000m	Athletics Women's Marathon
Athletics Women's 100m	Athletics Women's 200m
Athletics Women's 100m	Athletics Women's 4 x 100m Relay
Athletics Women's 100m	Athletics Women's 100m Hurdles
Athletics Women's 1500m	Athletics Women's 10,000m
Athletics Women's 200m	Athletics Women's 4 x 100m Relay
Athletics Women's 200m	Athletics Women's 4 x 400m Relay
Athletics Women's 200m	Athletics Women's 400m
Athletics Women's 20km Race Walk	Athletics Marathon Race Walk Relay Mixed
Athletics Women's 3000m Steeplechase	Athletics Women's 10,000m
Athletics Women's 400m	Athletics Women's 4 x 400m Relay
Athletics Women's 400m Hurdles	Athletics Women's 4 x 400m Relay
Athletics Women's 5000m	Athletics Women's 10,000m
Athletics Women's 5000m	Athletics Women's 1500m
Athletics Women's 5000m	Athletics Women's 3000m Steeplechase
Athletics Women's 5000m	Athletics Women's Marathon
Athletics Women's 800m	Athletics Women's 4 x 400m Relay
Athletics Women's 800m	Athletics Women's 1500m
Athletics Women's Discus Throw	Athletics Women's Shot Put
Athletics Women's Triple Jump	Athletics Women's Long Jump
Athletics Women's Triple Jump	Athletics Women's 100m Hurdles

2.1 Data

The extended dataset is provided in the file `tuesday.json`. The MiniZinc data definitions to read the file are

```

1 include "globals.mzn";
2
3 int:nrActivity;
4 int:nrEvents;
5 int:nrResources;
6 int:nrSessions;
7 int:sessionDuration;
8 int:nrPrecedences;
9 int:nrConflicts;
10 int:nrAthletesPerSession;
11
12 type Activity = record(string:event,
13                         string:phase,
14                         string:resource,
15                         int:nr,
16                         int:duration,
```

```

17             int:participants,
18             int:finals,
19             int:stageNr);
20 type Precedence = record(string:temporalRelation,
21                         string:event,
22                         string:before,
23                         string:after,
24                         int:beforeNr,
25                         int:afterNr);
26 type Conflict = record(string:event1,
27                         string:event2);
28
29 % data arrays
30 array[1..nrActivity] of Activity:activity;
31 array[1..nrPrecedences] of Precedence:precedences;
32 array[1..nrConflicts] of Conflict:conflicts;
33 array[1..nrResources] of string:resources;
34 array[1..nrEvents] of string:events;

```

We have added integer parameters for the number of precedences, the number of events, and the number of athletes per session, and defined two new record types, *Precedence* for precedence structures, and *Conflicts* for conflicts between events. The temporal relations that can be expressed in the precedences are

Same The activities should be in the same session

PreviousSession The activities should be in consecutive sessions, the *before* activity should be in the session immediately before the session for activity *after*. The sessions do not have to be on the same day.

Yesterday The *before* activity should be in a session on the day before the session for activity *after*.

DayBeforeYesterday There should be one rest day between the activities.

ThreeDays There should be two rest days between the activities.