

Constraint Programming-TP1



Jinling XING
1915481

March 1, 2018

1 Model

1.1 First Model

```
%-----%
% TP1---LNH match schedule
%-----%
include "globals.mzn";
%-----
% variables

int: nbTeams; %the number of teams
set of int: teams = 1..nbTeams;
int: num_games = nbTeams*(nbTeams-1) div 2; %the total number of games will be n*(n-1)/2
set of int: games = 1..num_games;

set of int: homeaway = 1..2; %the game will be held at home or away home

%in each game, we decided the game is held at home or away home
array[teams, teams] of var homeaway: pv;

int: nbRounds = nbTeams-1;
int: num_rounds = nbTeams-1; %n-1 rounds compactly
set of int: rounds = 1..num_rounds;

array[teams, rounds] of var games: game; %the scheduled games

%-----
% constraints

% a team cannot play against itself
constraint forall (i in teams, r in rounds) (game[i,r] != i::bounds);

%any team plays one game each round
constraint forall (i in teams) (all_different ([game[i,r] | r in rounds] )::bounds);
constraint forall (r in rounds) (all_different ([game[i,r] | i in teams]::bounds);

%each team plays against each other exactly once
constraint forall (i in teams, r in rounds) (game[game[i,r],r] = i::bounds);

%heldplace[i,r] = 1 or 2, rely on team i plays at home or awayhome in round r
array[teams, rounds] of var homeaway: heldplace;

%heldplace[i,r] = 1, in the meanwhile, pv[i,j]=1, j=game[i,r]
constraint forall (i in teams, r in rounds) (heldplace[i,r] = pv[i,game[i,r]]::bounds);
```

```

% Each team can not play more than three consecutive home games and no more than three away.
int: index_rounds = nbRounds-3; %n-1 rounds compactly
set of int: index = 1..index_rounds;

%???
%constraint forall(i in teams) (
%
%      (sliding_sum(5,7,4,[heldplace[i,r] | r in index])));
constraint
  forall(i in teams) (
    forall (r in index)(
      sum([heldplace[i,r+j] | j in 0..3]) >= 5
      /\
      sum([heldplace[i,r+j] | j in 0..3]) <=7::bounds)
    );
%-----
solve satisfy;
output[show(game[i,r])++ "("++show(heldplace[i,r])++ ")"+
  if r==nbTeams-1 then "\n" else "" endif
  | i in teams, r in rounds] ++ ["\n"];

```

1.2 Second Model

```

%-----
% TP1---LNH match schedule
%-----
include "globals.mzn";
%-----
% variables

int: nbTeams; %the number of teams
set of int: teams = 1..nbTeams;
int: num_games = nbTeams*(nbTeams-1) div 2; %the total number of games will be n*(n-1)/2
set of int: games = 1..num_games;
%the game will be held at home or away home
set of int: homeaway = 1..2;
%in each game, we decided the game is held at home or away home
array[teams, teams] of var homeaway: pv;

int: nbRounds = nbTeams -1;
int: num_rounds = nbTeams-1; %n-1 rounds compactly
set of int: rounds = 1..num_rounds;

array[teams,rounds] of var games: game; %the scheduled games
%-----
% constraints

% a team cannot play against itself
constraint forall (i in teams, r in rounds) (game[i,r] != i::bounds);

%any team plays one game each round, replace all_different
constraint forall (i,j in teams where i<j) (
  forall (r in rounds ) (game[i,r]!=game[j,r])::domain);

constraint forall (r1,r2 in rounds where r1<r2) (
  forall (i in teams ) (game[i,r1]!=game[i,r2])::domain);

%each team palys against each other exactly once
constraint forall (i in teams, r in rounds) (game[game[i,r],r] = i::domain);

```

```

%heldplace[i,r] = 1 or 2, rely on team i plays at home or awayhome in round r
array[teams,rounds] of var homeaway: heldplace;

%heldplace[i,r] = 1, in the meanwhile, pv[i,j]=1, j=game[i,r]
constraint forall (i in teams, r in rounds) (heldplace[i,r] = pv[i,game[i,r]]::domain);

% Each team can not play more than three consecutive home games and no more than three away.
% the DFA (for regular)
int: n_states = 7;
int: input_max = 2;
int: initial_state = 1;
set of int: accepting_states = 1..7;
%transition function
array[1..n_states, 1..input_max] of int: transition_fn =
  array2d(1..n_states, 1..input_max,
    [
      % home(1),away(2)
      2,3,
      4,3,
      2,5,
      6,3,
      2,7,
      0,3,
      2,0
    ]
  );

constraint
  forall(i in teams) (
    regular(heldplace[i,r] | r in rounds, n_states, input_max, transition_fn,
      initial_state, accepting_states)::bounds);
%-----
solve satisfy;

output[show(game[i,r])++ "("++show(heldplace[i,r])++ ")"+
  if r==nbTeams-1 then "\n" else "" endif
  | i in teams, r in rounds] ++ ["\n"];

```

2 Result and Analysis

For Dataset LNH8a-8e

I tested the bounds level and domain level of LNH8a-8e for model 1 and model 2. At different consistency level, schedule plans are same on different dataset. The running time of model 1 is smaller than model 2 in many cases. The nodes of bounds level is smaller than domain level in many cases, the running time of different consistency didn't show a significant difference. In this dataset the failure is few. The detailed information is on table 1:


Table 1: Result of LNH8a-8e at bound and domain level

dataset	model	consistency level	runtime(ms)	nodes	failures
8a	1	bound	4.521	26	4
		domain	4.463	20	1
	2	bounds	5.131	15	0
		domain	22.896	15	0
8b	1	bound	4.458	20	2
		domain	4.858	16	0
	2	bound	5.549	19	2
		domain	27.376	19	2
8c	1	bound	4.193	18	0
		domain	4.421	16	0
	2	bound	20.686	15	0
		domain	5.712	15	0
8d	1	bound	4.530	25	4
		domain	4.562	14	0
	2	bound	51.360	14	0
		domain	6.669	14	0
8e	1	bound	4.293	15	0
		domain	4.524	15	0
	2	bound	8.372	16	0
		domain	5.547	16	0

For Dataset LNH14a-14e

When I checked the results of model 1, the results are different between different consistency level. The domain level performed better than the bounds level, the runtime, node, failures are smaller. For model 2, we can find the node and failures are same at domain and bounds level, but the domain runtime always bigger than bounds level. The detailed information is on table 2:

Table 2: Result of LNH14a-14e at bound and domain level

dataset	model	consistency level	runtime(ms)	nodes	failures
14a	1	bound	88.995	1252	1046
		domain	11.364	69	5
	2	bounds	786.689	15169	7555
		domain	951.577	15169	7555
14b	1	bound	82.285	1674	805
		domain	41.725	446	191
	2	bound	21.908	220	86
		domain	22.367	220	86
14c	1	bound	68.162	885	413
		domain	19.634	123	32
	2	bound	1404.646	22228	11086
		domain	1616.221	22228	11086
14d	1	bound	UNSATISFIABLE		
		domain	UNSATISFIABLE		
	2	bound	UNSATISFIABLE		
		domain	UNSATISFIABLE		
14e	1	bound	151.236	4078	2008
		domain	12.142	66	3
	2	bound	46.358	735	337
		domain	47.738	735	337

For Dataset LNH20a-20e

Most of the results exceeded the 10 minutes time limit, it shown as abort on table 3. For model 1, The domain level performed better than the bounds level, it can give us results within the time limit.


For model 2  can find the node and failures are same at domain and bounds level, but the domain runtime always bigger than bounds level, which is the same situation as LNH14a-14e. The detailed information is on table 1:



Table 3: Result of LNH20a-20e at bound and domain level

dataset	model	consistency level	runtime(ms)	nodes	failures
20a	1	bound	ABORT		
		domain	8045.028	43440	21651
	2	bounds	780931.688	5380081	2689970
		domain	ABORT		
20b	1	bound	ABORT		
		domain	32.182	178	11
	2	bound	1561.529	18190	9023
		domain	1928.789	18190	9023
20c	1	bound	415.624	4626	2236
		domain	262735.946	2015371	1007613
	2	bound	99.752	869	367
		domain	109.832	869	367
20d	1	bound	ABORT		
		domain	33.609	167	11
	2	bound	7314.259	125210	62530
		domain	8664.429	125210	62530
20e	1	bound	ABORT		
		domain	ABORT		
	2	bound	1181.740	13698	6780
		domain	1533.158	13698	6780

3 Test Result

3.1 Dataset LNH20a-20e

Model 1: all of them are domain level

```
[jixin@l4714-04 tp1] $ mzn-gecode -s TP1_INF6101_1.mzn ./LNH/LNH20a.dzn
4(2)2(2)9(1)11(1)13(1)8(2)18(1)19(1)10(1)7(2)5(2)12(1)14(1)3(1)17(2)20(2)15(1)16(1)6(2)
8(2)1(1)18(1)10(2)9(1)16(1)4(2)13(1)17(2)15(2)6(1)20(1)11(1)19(2)7(2)14(2)12(1)3(2)5(1)
18(1)19(1)6(1)7(2)5(1)10(2)8(2)14(1)9(2)4(2)15(1)13(1)1(2)12(2)17(2)11(1)2(1)16(1)
1(1)17(2)10(1)9(2)7(1)6(1)2(1)5(2)13(2)3(1)14(2)19(1)20(1)15(2)16(2)12(2)18(1)11(1)8(1)
6(2)10(2)7(2)8(1)3(2)17(2)16(2)4(1)19(2)20(2)1(1)9(2)12(1)11(2)13(2)15(2)14(1)18(1)2(2)
5(1)8(1)3(2)20(2)10(1)4(2)19(1)12(1)7(2)14(2)2(2)16(1)15(1)9(1)11(2)18(2)17(1)13(1)1(1)
9(2)18(1)5(1)3(1)4(2)13(1)11(2)17(1)6(1)1(1)10(2)14(1)16(1)12(2)2(1)19(2)20(1)8(1)15(1)
2(1)6(2)11(1)5(2)14(2)1(1)3(1)9(1)20(2)12(2)19(2)10(1)18(1)17(2)15(2)16(2)13(1)7(2)4(2)
7(1)11(1)1(2)4(1)2(2)18(1)20(1)8(2)3(1)10(2)17(2)5(1)19(1)6(2)14(2)13(2)16(1)15(1)12(1)
13(1)5(1)4(2)2(1)6(2)3(1)15(1)16(1)1(2)9(1)7(1)8(2)17(1)14(2)20(2)11(2)19(1)12(1)18(1)
16(1)9(2)8(2)1(2)18(1)14(2)7(1)20(1)12(2)13(2)15(2)17(1)2(2)5(1)6(1)10(1)3(2)4(2)19(1)
19(1)16(1)17(1)18(2)15(2)20(2)14(1)6(2)11(1)8(1)13(1)1(2)5(2)7(1)3(1)4(1)2(2)10(2)9(2)
10(2)14(2)19(1)15(2)1(2)7(2)17(1)2(2)4(1)11(1)12(2)18(2)3(2)16(1)5(1)9(1)8(2)6(2)20(1)
20(1)13(1)15(2)16(1)8(1)11(1)12(2)3(2)18(1)6(1)4(1)7(2)1(2)10(1)9(1)2(1)5(2)19(1)17(1)
17(1)20(2)14(1)13(1)12(1)19(2)10(2)18(2)16(1)2(1)11(1)3(2)6(2)4(1)8(1)5(1)1(2)9(2)7(2)
11(2)12(2)20(1)14(2)17(2)2(2)5(1)10(2)15(2)19(2)18(1)6(2)7(2)13(2)4(1)8(1)9(2)1(2)3(2)
15(2)4(1)12(2)19(2)16(1)5(1)13(2)7(2)2(1)18(1)9(1)11(2)10(2)8(1)1(1)3(1)6(2)20(1)14(2)
3(2)7(2)2(2)12(1)11(2)9(2)1(2)15(1)14(2)17(2)16(2)13(1)8(2)20(2)19(2)6(1)4(2)5(2)10(2)
12(2)3(2)13(2)17(1)20(2)15(1)6(2)1(2)5(1)16(1)8(1)4(2)9(2)2(1)18(1)7(1)10(2)14(2)11(2)
14(2)15(1)16(2)6(1)19(1)12(1)9(2)11(2)8(1)5(1)3(1)2(2)4(2)18(1)10(1)1(1)7(2)17(2)13(2)
```

```
-----
%% runtime:      8.045 (8045.028 ms)
%% solvetime:    8.032 (8032.773 ms)
%% solutions:    1
```

```

%% variables:      760
%% propagators:    1439
%% propagations:   22967596
%% nodes:          43440
%% failures:       21651
%% restarts:       0
%% peak depth:     153

```

[jixin@l4714-04 tp1] \$ mzn-gecode -s TP1_INF6101_1.mzn ./LNH/LNH20b.dzn

```

4(1)18(1)11(2)9(2)8(2)5(1)6(2)7(1)16(2)10(2)19(2)17(1)13(1)15(2)12(2)20(2)14(1)2(2)3(2)
3(1)4(1)6(1)11(2)5(2)9(2)10(1)8(1)7(2)14(2)16(2)18(1)19(1)13(2)20(2)15(2)17(1)1(1)12(1)
2(2)7(1)8(1)12(1)4(2)6(2)9(1)20(1)5(2)18(2)14(2)19(1)17(1)16(2)13(2)11(2)15(1)10(1)1(1)
1(2)2(2)7(2)15(1)3(1)10(2)5(2)18(1)6(2)9(2)12(2)8(1)14(1)17(2)11(2)19(2)16(1)13(1)20(1)
15(1)8(2)9(1)10(1)2(1)1(2)4(1)6(1)3(1)16(2)17(2)12(1)11(1)14(2)18(2)13(2)20(1)19(1)7(1)
11(1)17(1)2(2)7(1)9(2)3(1)1(1)5(2)4(1)8(2)15(2)10(1)20(1)18(2)16(2)14(2)19(1)12(1)13(1)
13(1)3(2)4(1)6(2)10(2)8(1)16(1)1(2)2(1)20(2)9(1)14(2)18(1)19(2)15(2)17(2)12(1)11(2)5(2)
20(1)5(1)3(2)17(1)1(1)7(2)13(1)2(2)11(1)6(1)10(2)4(2)16(1)9(2)14(2)12(2)18(1)15(1)19(1)
17(1)13(1)5(2)1(1)6(1)2(1)3(2)15(1)10(1)4(1)7(2)20(1)12(1)8(1)19(2)18(2)11(1)14(1)16(1)
18(1)20(1)14(2)5(2)7(1)4(1)2(2)19(1)9(2)1(1)8(1)6(2)15(1)12(2)17(2)16(2)13(1)3(2)11(2)
6(2)19(1)1(1)2(1)12(2)13(2)14(2)17(1)8(2)15(2)18(2)16(1)5(2)20(2)4(1)3(1)9(2)7(1)10(1)
16(2)15(1)13(1)3(2)11(1)17(1)20(1)14(2)18(2)19(2)4(1)5(2)9(2)10(1)1(1)8(1)7(2)6(2)2(2)
7(2)9(2)12(2)14(1)18(2)11(1)8(2)16(1)19(2)17(2)20(2)15(1)1(2)2(1)3(1)5(1)10(2)4(2)6(2)
19(1)16(1)10(1)13(2)15(2)18(2)11(1)12(1)20(2)2(1)3(1)7(1)4(2)5(1)8(1)6(1)1(2)9(2)17(1)
5(2)12(2)16(1)4(2)14(1)20(2)19(1)9(2)17(2)11(1)6(1)13(2)10(2)1(1)7(1)2(1)3(2)8(2)18(2)
12(1)14(2)15(2)20(2)17(1)19(2)7(2)13(2)1(1)5(1)2(1)11(2)8(2)3(1)6(1)10(1)4(2)18(1)9(2)
9(2)6(2)19(1)8(2)16(2)12(2)18(1)11(2)15(1)13(1)5(1)1(2)3(2)4(1)10(1)7(1)2(2)20(1)14(2)
10(2)1(2)20(1)19(2)13(1)14(1)17(2)4(2)12(1)3(1)11(1)2(2)7(2)6(1)5(1)9(1)8(2)16(2)15(1)
14(2)11(2)17(2)18(1)20(2)16(1)15(2)10(2)13(1)12(1)1(1)3(2)2(2)7(1)9(1)4(1)6(2)5(2)8(2)
8(2)10(2)18(2)16(1)19(1)15(1)12(2)3(2)14(1)7(1)13(1)9(2)6(2)11(1)2(1)1(1)5(2)17(2)4(2)

```

```

%% runtime:        0.032 (32.182 ms)
%% solvetime:      0.019 (19.602 ms)
%% solutions:      1
%% variables:      760
%% propagators:    1439
%% propagations:   44652
%% nodes:          178
%% failures:       11
%% restarts:       0
%% peak depth:     159

```

[jixin@l4714-04 tp1] \$ mzn-gecode -s TP1_INF6101_1.mzn ./LNH/LNH20c.dzn

```

17(1)9(1)11(1)4(2)7(1)3(1)8(2)5(1)16(2)10(1)13(2)2(2)14(1)15(2)20(2)12(2)19(1)18(1)6(1)
4(1)8(2)18(1)6(1)10(2)5(2)9(2)16(1)20(2)11(2)17(2)1(1)13(1)19(2)15(2)14(2)12(1)3(1)7(1)
12(1)13(1)9(2)7(2)6(1)1(2)10(2)4(1)15(2)14(2)20(2)18(1)11(1)8(2)17(2)19(2)16(1)2(2)5(2)
2(2)5(1)10(1)1(1)20(2)8(1)14(2)3(2)17(1)19(2)12(2)6(2)18(1)9(1)11(2)16(2)15(1)7(1)13(1)
18(1)4(2)7(1)20(2)19(2)2(1)16(2)1(2)14(2)9(1)15(2)10(2)17(1)12(2)13(2)11(2)8(1)6(1)3(1)
10(2)11(1)8(1)2(2)3(2)19(2)7(1)15(1)9(2)12(2)18(2)4(1)20(1)16(2)14(2)17(2)13(1)5(2)1(2)
9(2)10(2)5(2)3(1)1(2)12(2)6(2)19(1)8(2)20(2)11(2)15(1)16(1)14(2)18(2)13(2)17(1)4(2)2(2)
13(1)2(1)6(2)12(1)9(2)4(2)1(1)18(1)7(1)15(2)14(2)17(1)19(1)3(1)16(2)20(2)5(2)11(1)10(2)
7(1)1(2)3(1)11(1)8(1)20(2)2(1)13(1)6(1)5(2)16(2)14(1)12(1)4(2)19(2)15(2)18(1)10(2)17(1)
6(1)7(1)4(2)17(1)2(1)16(2)3(1)11(1)13(1)1(2)19(2)5(1)15(1)20(2)12(2)18(2)14(1)9(1)8(1)
16(1)6(2)1(2)9(2)17(1)13(1)15(1)10(2)19(2)2(1)7(1)12(1)3(2)18(2)4(1)5(1)20(1)8(2)14(2)
3(2)17(1)20(1)8(2)15(2)7(1)19(1)14(1)18(2)6(1)4(1)11(2)9(2)5(1)10(1)1(1)2(2)13(1)16(2)
8(2)3(2)15(1)16(2)14(2)11(2)20(1)9(2)10(2)18(2)1(1)19(1)2(2)17(2)5(1)7(1)6(2)12(2)4(2)
15(1)20(1)16(1)19(2)13(1)18(2)4(1)12(2)5(1)3(1)8(1)9(2)1(2)7(1)6(1)2(1)10(2)17(1)11(1)
14(2)16(1)13(2)18(2)12(1)17(1)11(2)6(2)3(1)8(1)5(1)7(2)10(2)1(1)2(1)9(1)4(2)20(1)19(1)
11(2)15(2)14(2)13(1)18(2)10(1)5(1)2(2)1(1)17(2)9(1)20(1)7(2)6(1)8(1)4(1)3(2)19(1)12(1)

```

1(2)12(2)19(1)10(2)11(2)15(2)18(1)20(1)4(2)16(1)2(1)8(2)5(2)13(1)3(1)6(1)7(2)14(2)9(2)
5(2)19(2)2(2)15(1)16(1)14(1)17(2)8(2)12(1)13(1)6(1)3(2)4(2)11(1)7(1)10(1)9(2)1(2)20(1)
20(1)18(1)17(2)14(1)5(1)6(1)12(2)7(2)11(1)4(1)10(1)13(2)8(2)2(1)9(1)3(1)1(2)16(2)15(2)
19(2)14(2)12(2)5(1)4(1)9(1)13(2)17(2)2(1)7(1)3(1)16(2)6(2)10(1)1(1)8(1)11(2)15(2)18(2)

```
-----
%% runtime:      4:22.735 (262735.946 ms)
%% solvetime:    4:22.723 (262723.638 ms)
%% solutions:    1
%% variables:    760
%% propagators:  1439
%% propagations: 829150766
%% nodes:        2015371
%% failures:     1007613
%% restarts:     0
%% peak depth:   168
```

Model 2: all of them are bounds level

```
[jixin@l4714-04 tp1] $ mzn-gecode -s TP1_INF6101_2.mzn ./LNH/LNH20a.dzn
3(1)13(1)2(2)11(1)7(2)12(1)8(2)17(2)6(2)19(1)15(1)9(1)4(2)14(1)10(1)16(1)5(2)18(1)20(2)
18(1)10(2)1(1)13(1)3(2)7(2)15(2)16(1)12(1)9(1)8(2)5(1)14(2)11(1)17(2)4(2)6(1)20(1)19(2)
1(2)15(1)14(1)9(2)2(1)6(1)10(2)13(1)4(2)7(2)5(1)16(1)20(2)8(2)19(1)11(1)12(2)17(2)18(1)
19(1)18(1)12(2)7(1)14(2)8(1)9(2)10(1)3(1)11(1)16(2)20(1)1(1)5(2)6(1)2(1)13(2)15(2)17(2)
7(2)9(2)6(2)12(1)13(2)15(2)17(2)8(1)20(2)18(1)3(2)2(2)10(2)4(1)11(2)19(2)1(1)14(1)16(2)
16(1)11(2)5(1)14(2)8(1)3(2)19(1)20(2)1(1)12(1)10(1)18(2)7(2)9(1)4(2)17(1)2(2)13(1)15(1)
5(1)16(1)18(1)4(2)1(1)2(1)13(1)11(2)17(1)3(1)20(1)10(2)6(1)19(2)8(1)15(1)9(2)12(2)14(1)
14(2)12(2)11(1)16(2)6(2)4(2)1(1)5(2)18(1)17(2)2(1)19(2)15(2)3(1)7(2)9(1)20(2)10(1)13(1)
17(2)5(1)20(1)3(1)10(2)19(1)4(1)14(2)16(1)2(2)18(1)1(2)13(2)6(2)15(1)8(2)7(1)11(1)12(1)
13(1)2(1)19(1)20(2)9(1)17(1)3(1)4(2)14(2)16(1)6(2)7(1)5(1)18(1)1(2)12(1)15(1)8(2)11(2)
12(2)6(1)8(2)1(2)19(1)13(2)20(1)7(1)15(2)4(2)14(2)17(1)16(1)2(2)5(1)3(2)18(1)9(2)10(1)
11(1)8(1)4(1)5(2)20(2)1(2)14(1)18(2)2(2)6(2)19(1)15(2)17(1)16(1)13(1)10(2)3(1)7(1)9(2)
10(2)1(2)16(1)2(2)5(1)11(1)7(2)3(2)19(1)20(1)17(1)14(2)9(1)15(2)12(2)18(2)4(1)6(2)8(2)
8(1)17(1)3(2)6(1)4(1)16(1)12(2)9(1)10(1)15(2)11(1)13(1)2(1)1(2)18(1)20(1)19(1)5(2)7(2)
20(2)3(2)17(1)18(2)16(1)5(1)2(1)19(2)11(1)14(1)1(2)12(1)8(1)13(1)9(2)7(2)10(2)4(1)6(2)
6(2)7(2)13(2)8(1)15(2)14(2)18(1)2(2)9(2)10(2)4(1)3(2)11(2)12(2)20(1)1(2)17(2)19(2)5(1)
9(1)14(2)15(2)19(2)18(1)10(2)5(1)1(1)7(2)8(1)13(2)11(2)12(2)20(1)2(1)6(2)16(1)3(1)4(1)
2(2)4(2)7(2)15(1)17(2)20(2)16(2)12(1)8(2)5(2)9(2)6(1)19(2)10(2)14(2)13(1)11(2)1(2)3(2)
4(2)20(2)10(2)17(1)11(2)9(2)6(2)15(1)13(2)1(2)12(2)8(1)18(1)7(1)3(2)5(1)14(2)16(1)2(1)
15(1)19(1)9(2)10(1)12(1)18(1)11(2)6(1)5(1)13(2)7(2)4(2)3(1)17(2)16(2)14(2)8(1)2(2)1(1)
```

```
-----
%% runtime:      13:00.932 (780932.688 ms)
%% solvetime:    13:00.897 (780897.977 ms)
%% solutions:    1
%% variables:    760
%% propagators:  7810
%% propagations: 749379693
%% nodes:        5380081
%% failures:     2689970
%% restarts:     0
%% peak depth:   153
```

```
[jixin@l4714-04 tp1] $ mzn-gecode -s TP1_INF6101_2.mzn ./LNH/LNH20b.dzn
16(2)7(1)13(1)15(2)9(2)17(1)3(2)10(2)11(2)5(1)6(2)4(1)8(2)12(2)2(2)14(1)19(2)18(1)20(2)
17(1)18(1)3(1)9(2)14(2)4(1)11(2)8(1)12(1)15(2)5(2)10(1)7(2)6(1)1(1)13(2)16(2)20(2)19(1)
11(2)10(1)2(2)5(2)7(1)6(2)1(1)13(2)19(1)16(2)14(2)15(1)9(1)8(1)4(2)12(1)20(1)17(1)18(2)
7(2)20(1)5(2)19(2)18(1)2(2)14(1)9(2)13(1)12(2)8(1)1(2)11(2)10(2)3(1)6(2)15(1)16(1)17(2)
```



```

19(1)8(2)4(1)3(1)10(1)18(2)9(1)7(1)6(1)1(2)2(1)12(1)20(1)13(2)11(1)17(2)14(2)15(1)16(2)
12(1)17(1)11(1)16(2)8(2)3(1)7(1)20(1)5(2)19(1)1(1)9(2)18(2)2(2)10(1)4(1)13(1)14(2)15(2)
4(1)1(2)9(1)10(2)3(2)16(1)6(2)5(2)18(1)17(2)20(2)8(1)2(1)15(2)19(2)11(2)12(1)13(1)14(2)
9(2)5(1)10(2)18(1)6(1)14(2)17(1)2(2)15(1)20(1)4(2)7(2)1(1)3(2)16(1)19(1)11(1)12(2)13(1)
8(1)14(1)7(2)2(1)1(1)15(1)5(2)4(1)16(1)10(1)19(2)6(1)3(2)17(1)13(1)20(1)18(2)11(1)12(1)
14(2)3(2)8(1)7(1)5(2)13(1)16(2)1(1)20(1)9(2)15(1)2(2)12(2)4(1)6(2)18(1)17(2)19(1)11(2)
3(1)16(1)6(2)13(2)15(2)19(1)2(1)12(2)1(1)14(2)18(2)17(1)4(1)20(2)5(2)7(1)8(2)9(2)10(1)
6(2)15(1)19(2)17(1)16(2)20(1)18(2)11(1)2(2)4(1)13(1)5(2)10(1)1(1)14(2)3(2)7(2)8(1)9(2)
15(1)19(2)1(2)11(1)17(2)10(2)20(2)3(1)4(2)18(2)12(2)14(1)16(1)5(1)9(2)2(1)6(2)7(2)8(2)
10(1)9(2)16(1)20(2)2(1)8(1)4(2)18(2)17(1)11(1)3(1)13(2)15(2)19(1)12(1)1(2)5(1)6(1)7(1)
13(2)12(2)18(2)1(1)11(1)9(2)19(1)17(2)8(2)2(1)10(2)3(2)14(1)7(1)20(2)16(1)4(2)5(2)6(1)
1(1)11(2)14(2)6(1)12(1)7(2)10(1)19(2)9(2)3(1)17(1)20(2)13(2)18(1)8(2)15(2)2(1)4(2)5(1)
2(2)6(2)20(1)12(2)13(1)1(2)8(2)15(1)14(2)7(1)16(2)11(2)19(1)9(2)18(1)5(1)10(1)3(2)4(1)
20(1)2(2)15(1)8(2)4(2)5(1)12(1)14(1)7(2)13(1)11(1)19(2)6(1)16(2)17(2)10(2)9(1)1(2)3(1)
5(2)13(1)12(1)4(1)20(2)11(2)15(2)16(1)3(2)6(2)9(1)18(1)17(2)14(2)7(1)8(2)1(1)10(2)2(2)
18(2)4(2)17(2)14(1)19(1)12(2)13(1)6(2)10(2)8(2)7(1)16(1)5(2)11(1)15(1)9(2)3(2)2(1)1(1)

```

```

-----
%% runtime:      1.561 (1561.529 ms)
%% solvetime:    1.527 (1527.401 ms)
%% solutions:    1
%% variables:    760
%% propagators:  7810
%% propagations: 1410149
%% nodes:        18190
%% failures:     9023
%% restarts:     0
%% peak depth:   152

```

```

[jixin@14714-04 tp1] $ mzn-gecode -s TP1_INF6101_2.mzn ./LNH/LNH20c.dzn
12(2)6(1)3(1)15(2)9(1)11(1)7(1)4(2)5(1)8(2)10(1)17(1)16(2)13(2)2(2)14(1)19(1)18(1)20(2)
3(1)8(2)7(1)14(2)6(1)17(2)9(2)11(2)13(1)4(1)15(2)10(2)18(1)12(1)1(1)5(2)16(1)20(2)19(2)
2(2)5(2)1(2)12(1)13(1)14(2)8(2)19(2)11(1)15(2)9(2)16(1)10(2)4(1)6(1)7(2)20(2)17(2)18(1)
5(1)13(1)10(1)11(2)19(2)6(2)18(1)1(1)7(1)2(2)14(2)12(2)8(1)3(2)20(2)9(1)15(1)16(2)17(1)
4(2)3(1)17(1)13(2)7(1)12(2)6(1)10(2)1(2)9(1)18(1)8(1)11(2)20(2)19(2)2(1)14(2)15(2)16(2)
16(2)1(2)13(1)18(2)2(2)4(1)5(2)8(1)10(2)17(2)7(1)19(2)9(2)11(1)3(2)20(1)12(2)14(2)15(1)
17(1)10(2)2(2)19(1)5(2)9(2)1(2)16(1)4(2)12(2)6(2)15(1)20(2)8(2)18(2)3(1)11(2)13(2)14(2)
11(1)2(1)14(2)9(2)18(1)15(2)3(1)6(2)16(2)1(1)20(2)5(2)4(2)7(1)13(1)17(1)10(2)19(1)12(1)
13(1)15(2)16(2)8(1)1(2)7(1)2(1)20(2)19(2)5(2)3(1)14(1)6(1)10(2)17(1)4(2)18(1)12(1)11(1)
14(1)7(1)4(2)20(2)17(1)19(2)15(1)5(1)6(1)18(2)1(2)2(1)3(1)9(1)16(2)12(2)8(1)11(1)13(1)
8(2)19(2)15(1)4(1)16(1)1(2)17(1)2(1)3(2)14(2)13(1)20(1)5(1)6(2)12(1)18(2)7(1)10(2)9(2)
1(1)17(1)20(1)3(2)14(1)5(1)13(1)18(2)15(2)7(1)16(2)4(1)19(1)2(2)11(2)10(1)6(1)9(2)8(2)
9(2)4(2)6(2)5(1)3(2)20(1)12(2)15(1)2(2)19(1)11(2)18(2)14(2)1(1)8(2)16(2)17(2)7(1)10(2)
10(2)16(1)8(1)2(1)12(2)3(1)20(1)17(1)18(2)11(1)4(1)9(2)13(1)19(2)15(1)1(2)5(1)6(1)7(1)
18(2)9(1)11(2)1(1)20(1)8(1)10(2)13(2)12(1)3(1)2(1)7(2)17(1)16(1)14(2)19(1)4(2)5(1)6(2)
6(1)14(2)9(1)17(2)11(2)18(2)19(1)7(2)8(1)20(1)12(1)3(2)1(1)15(2)10(1)13(1)2(2)4(1)5(1)
7(2)12(2)5(2)16(1)10(2)2(1)11(2)14(2)20(1)6(1)19(1)1(2)15(2)18(1)9(2)8(2)13(1)3(1)4(2)
15(1)20(1)19(2)6(1)8(2)16(1)4(2)12(1)14(1)10(1)5(2)13(1)2(2)17(2)7(1)11(1)9(2)1(2)3(2)
20(1)11(1)18(1)7(2)4(1)10(1)16(2)3(1)9(1)13(2)17(2)6(1)12(2)14(1)5(1)15(2)1(2)8(2)2(1)
19(2)18(2)12(2)10(1)15(2)13(2)14(2)9(1)17(2)16(2)8(1)11(2)7(1)5(1)4(1)6(2)3(1)2(1)1(1)

```

```

-----
%% runtime:      0.099 (99.752 ms)
%% solvetime:    0.065 (65.644 ms)
%% solutions:    1
%% variables:    760
%% propagators:  7810
%% propagations: 194006
%% nodes:        869

```

```
%% failures:      367
%% restarts:      0
%% peak depth:    142
```