Centre for
Data Analytics

Insight

MiniZinc Basics

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Licence

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`https://eclipseclp.org/ELearning/index.html`
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Part I

MiniZinc Basics

Objectives

- Understand MiniZinc IDE
- Bundled Solvers
- Basic Modelling in MiniZinc
- Some More Examples

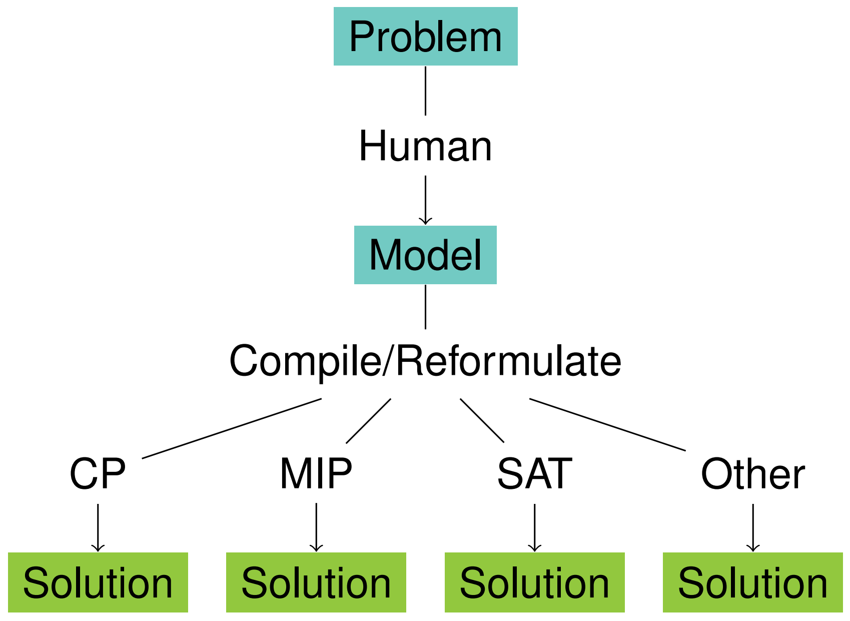
Outline

- MiniZinc Background
- IDE
- Elements of MiniZinc Programs
- Running Programs

MiniZinc

- Developed in the Australian NICTA project
- Maintained by Monash University
- Modelling tool with multiple back-end solvers
- Available from `https://www.minizinc.org/`

Framework Process



Bundled Solvers

- Chuffed
- Coin-BC
- Gecode
- Gecode Gist
- (Cplex)
- (Gurobi)

Chuffed

- Developed at Melbourne University/Monash
- Clause Learning FD Solver including SAT Reasoning
- Learns from failures
- Very successful in competitions

Coin-BC

- Open Source MIP Solver
- Initially Developed at IBM
- Completely different from techniques described here
- Moderate performance (non commercial)

Gecode

- Developed at KTH Stockholm
- Powerful C++ based solver
- Copying based solver design

Gecode Gist

- Extension of Gecode to interactive use
- Explore search tree interactively
- Visualization of search tree
- Useful to understand behaviour

Cplex/Gurobi

- Commercial MIP solvers
- Only interface bundled, needs installation on machine
- Two most successful MIP solvers at this time

Others

- Many solvers can be used as back-end to Minizinc
- Need manual installation
- Not all specific functionality may be available

Which to Choose?

- Difficult to state in general terms

Demo

Elements of MiniZinc

- Comments
- Parameters
- Variables
- Constraints
- Comprehensions
- Solve

Comments

```
% comments rest of line
/* comment here */
```

Parameter

```
int: n = 8;
int: n; % set somewhere else
int: nrDays = 4;
set of int: days = 1..nrDays;
set of int: games = {1,3,5,7};
array[days] of int: mat;
array[days] of int: mat = [1,2,3,4];
```

Variables

```
var 1..8:x;
array[days] of var games:y;
```

Constraints

```
constraint x != y;
constraint 4*y[1]+5*y[2] = z;
% operators =,!=,<,>,<=,>=
constraint alldifferent(y);
% annotations ::bounds ::domain

constraint forall(game in games)
  (pDay[game] = mapDay[x[game]]);
```

Defining Constraints

```
predicate exactly(array[int] of var int:x,
    int:count,int:value) =
  count = sum(i in index_set(x))(x[i] = value);
```

Comprehensions

```
constraint alldifferent([pDay[i]|i in team1Games]);

forall(i in days)(x[i] != v);
```

Solve

```
solve satisfy;
solve minimize(x);
solve maximize(x);
```

Solve annotations

- ::int_search(vars,var_selection,value_selection)
- input_order,first_fail,smallest,dom_w_deg
- indomain_min,indomain_median,
- indomain_random,indomain_split

Seq_search Example

```
solve ::seq_search([
    int_search(x,smallest,indomain_split),
    int_search(y,first_fail,indomain_split)])
    minimize objective;
```

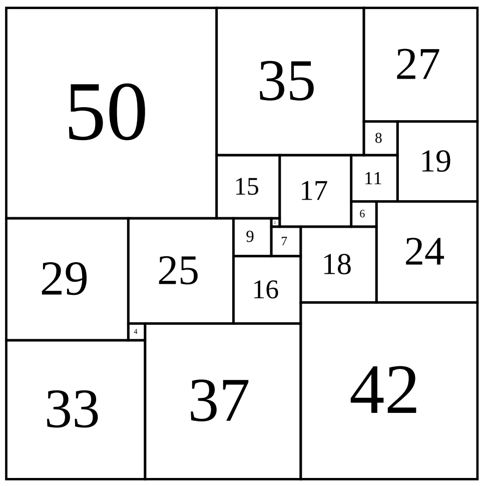
Priority_search Example

```
include “chuffed.mzn”;
solve ::priority_search(x,
       [int_search([x[i],y[i]],
        input_order,indomain_min)| i in T],
        smallest,complete)
    minimize objective;
```

Square Placement

- Consider a set of square rectangles of different sizes
- Pack them into an enclosing square
- Total surface of squares to pack is equal to the available area
- Perfect problem: no subset forms rectangle
- Famous combinatorial problem, difficult to solve by hand
- `http://www.squaring.net/sq/ss/spss/spss.html`
- Link to William Tutte (Breaking the Lorenz machine code in WW II)
- Solved in 1978 by A.J.W. Duijvestijn

Original Solution



21 : 112A AJD 1978

Data

```
S = 1..21;
size =  [2,4,6,7,8,9,11,15,16,17,
         18,19,24,25,27,29,33,35,37,42,50];
box = 112;
```

Square Packing Program (I)

```
include "globals.mzn";
set of int: S;
array[S] of int:size;
int: box;
include "squares.dzn";

array[S] of var 0..box:x;
array[S] of var 0..box:y;
```

Square Packing Program (II)

```
constraint forall (i in S)
    (x[i]+size[i]<=box);
constraint forall (i in S)
    (y[i]+size[i]<=box);
constraint diffn(x,y,size,size);
constraint cumulative(x,size,size,box);
constraint cumulative(y,size,size,box);

solve satisfy;
```

Solved with Chuffed

```
Running squares.mzn
x = array1d(1..21, [60, 33, 60, 53, 77, 53, 66, 62,
  37, 60, 42, 66, 42, 37, 85, 33, 0, 77, 0, 0, 62]);
y = array1d(1..21, [47, 79, 24, 42, 19, 49, 19, 47,
  42, 30, 24, 0, 0, 58, 0, 83, 79, 27, 42, 0, 62]);
-------
Finished in 4s 364msec
```

Job Shop Scheduling

- Schedule a number of jobs
- Each job consists of a number of tasks
- Each task has a duration and must run on one specific machine
- Tasks of a job must be executed in sequence
- A machine can only work on one task as a time

History

- 10x10 instance proposed by Fisher& Thompson
- Also known as 10x10 Muth & Thompson instance (1963)
- Stayed as open problem for 25 years
- Solved by Carlier and Pinson in 1989

Job Shop Data (I)

```
nrJobs= 6;
nrRes= 6;
taskUse= [|
   2, 0, 1, 3, 5, 4|
   1, 2, 4, 5, 0, 3|
   2, 3, 5, 0, 1, 4|
   1, 0, 2, 3, 4, 5|
   2, 1, 4, 5, 0, 3|
   1, 3, 5, 0, 4, 2 |];
taskDuration= [|
   1, 3, 6, 7, 3, 6|
   8, 5, 10, 10, 10, 4|
   5, 4, 8, 9, 1, 7|
   5, 5, 5, 3, 8, 9|
   9, 3, 5, 4,3, 1|
   3, 3, 9, 10, 4, 1 |];
```

Job Shop Data (II)

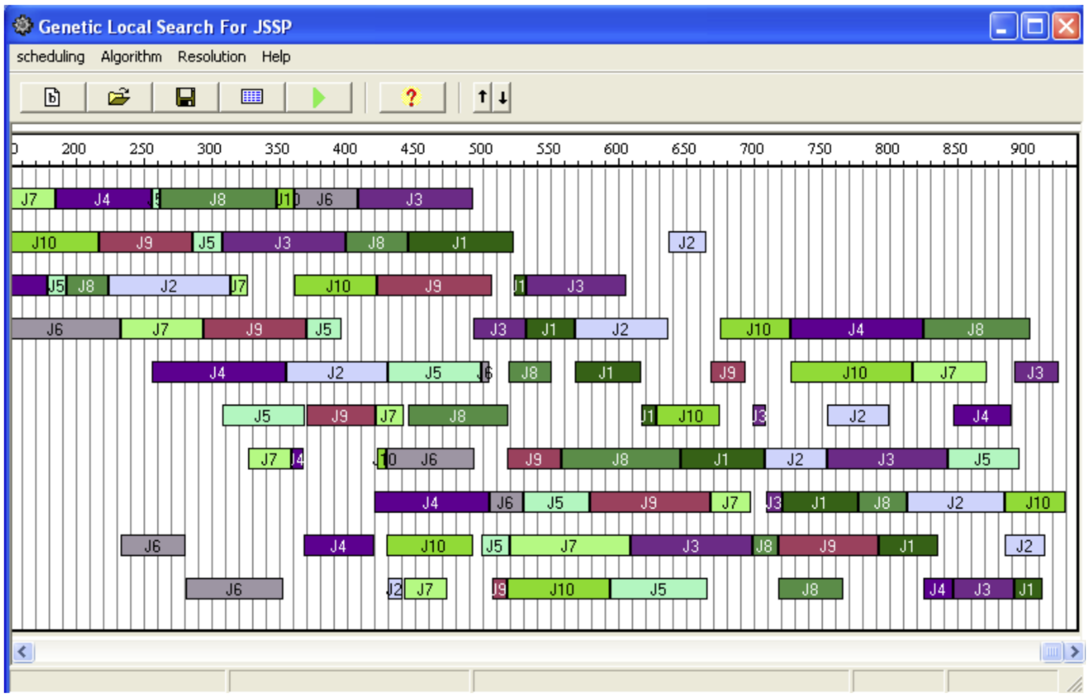
```
nrJobs= 10;
nrRes= 10;

taskUse= [|
0, 1, 2, 3, 4, 5, 6, 7, 8, 9|
0, 2, 4, 9, 3, 1, 6, 5, 7, 8|
1, 0, 3, 2, 8, 5, 7, 6, 9, 4|
1, 2, 0, 4, 6, 8, 7, 3, 9, 5|
2, 0, 1, 5, 3, 4, 8, 7, 9, 6|
2, 1, 5, 3, 8, 9, 0, 6, 4, 7|
1, 0, 3, 2, 6, 5, 9, 8, 7, 4|
2, 0, 1, 5, 4, 6, 8, 9, 7, 3|
0, 1, 3, 5, 2, 9, 6, 7, 4, 8|
1, 0, 2, 6, 8, 9, 5, 3, 4, 7 |];
```

Job Shop Data (III)

```
taskDuration= [|
29, 78,  9, 36, 49, 11, 62, 56, 44, 21|
43, 90, 75, 11, 69, 28, 46, 46, 72, 30|
91, 85, 39, 74, 90, 10, 12, 89, 45, 33|
81, 95, 71, 99,  9, 52, 85, 98, 22, 43|
14,  6, 22, 61, 26, 69, 21, 49, 72, 53|
84,  2, 52, 95, 48, 72, 47, 65,  6, 25|
46, 37, 61, 13, 32, 21, 32, 89, 30, 55|
31, 86, 46, 74, 32, 88, 19, 48, 36, 79|
76, 69, 76, 51, 85, 11, 40, 89, 26, 74|
85, 13, 61,  7, 64, 76, 47, 52, 90, 45 |];
```

Example Solution


Genetic Local Search For JSSP
scheduling Algorithm Resolution Help
200 250 300 350 400 450 500 550 600 650 700 750 800 850 900
J1 J2 J3 J4 J5 J6 J7 J8 J9 J10

screenshot from: A LOCAL SEARCH GENETIC ALGORITHM FOR THE JOB SHOP SCHEDULING PROBLEM Kebabla Mebarek, Mouss Leila Hayat and Mouss Nadia

Job-Shop Program (I)

```
include "globals.mzn";
int:nrJobs;
int:nrRes;

set of int: J=1..nrJobs;
set of int: R=1..nrRes;

array[J,R] of int:taskUse;
array[J,R] of int:taskDuration;
include "mt06.dzn";
int:ub =sum(j in J,r in R)(taskDuration[j,r]);

array[J,R] of var 0..ub:start;
var 0..ub:objective;
```

Job-Shop Program (II)

```
constraint forall(j in J)
    (objective >= start[j,nrRes]+
                  taskDuration[j,nrRes]);
constraint forall(j in J, r in 1..nrRes-1)
    (start[j,r+1] >= start[j,r]+
                     taskDuration[j,r]);
constraint forall (r in R)
(cumulative(
  [start[j,k]|j in J, k in R
    where taskUse[j,k]+1=r],
  [taskDuration[j,k]|j in J, k in R
    where taskUse[j,k]+1=r],
  [1|j in J, k in R
    where taskUse[j,k]+1=r],
  1)
);
```

Job-Shop Program (III)

```
solve minimize objective;
```