Square Placement Variants
An example of search tree analysis

H. Simonis
COSYTEC SA
Overview

- Problem
- Different Strategies
- Search tree views
- Search tree comparison
- Failure causes
Problem

- Place 21 squares in square area
- Perfect placement problem
Program

run(X,Y):-
    data(Nr, Data, W, H),
    create_vars(Data, X, Y, Rectangles, W, H, Vars),
    cumulative(X, Data, unused, unused, H, W, [H, 0, 1]),
    cumulative(Y, Data, unused, unused, W, H, [W, 0, 1]),
    diffn(Rectangles, unused, unused, [W, H]),
    labeling(Rectangles).

data(21, [50, 42, 37, 35, 33, 29, 27, 25, 24, 19, 18, 17, 16, 15, 11, 9, 8, 7, 6, 4, 2], 112, 112).

create_vars([], [], [], [], _,_, [], []).
create_vars([L|L1], [X|X1], [Y|Y1], [], [X,Y,L,L]|S1], W, H, [X, Y | XsYs]):-
    X :: 0..W,
    Y :: 0..H,
    create_vars(L1, X1, Y1, S1, W, H, XsYs).

labeling([]).
labeling([[X,Y,W,_,__]]):-
    indomain(X),
    indomain(Y).
labeling([[X,Y,W,_,__],[X1,Y1,W1,_,__]|R]):-
    indomain(X),
    indomain(Y),
    indomain(X1, max),
    indomain(Y1, max),
    labeling(R).
Different Strategies

◆ Constraint options
  - diffn only
  - +cumulative limit
    \[ \text{cumulative}(X, \text{Data}, \text{Data}, \text{unused}, \text{unused}, H, \text{unused}, \text{unused}) \]
  - +cumulative overall end
    \[ \text{cumulative}(X, \text{Data}, \text{Data}, \text{unused}, \text{unused}, H, W, \text{unused}) \]
  - + soft intermediate level
    \[ \text{cumulative}(X, \text{Data}, \text{Data}, \text{unused}, \text{unused}, H, W, [H, 0]) \]
  - + forced intermediate level
    \[ \text{cumulative}(X, \text{Data}, \text{Data}, \text{unused}, \text{unused}, H, W, [H, 0, 1]) \]
  - + saturation for cumulative
    ♦ change of cumulative
  - +re-execution of all methods at all times
    ♦ change of cumulative
Different Strategies (2)

- Search
  - indomain alternating min/max
    - n-ary choice
  - indomain1 alternating min/max
    - binary choice, select/remove value

indomain(X):-
  dom(X,L),
  member(X,L).

indomain1(X):-
  domain_info(X,Min,..),
  indomain1(X,Min).

indomain1(X,X).
indomain1(X,Min):-
  X #\= Min,
  indomain1(X).
Different Strategies (3)

- **Shaving**
  - test each variable to find which values are consistent with current state
  - enough: test next variable in static variable ordering
  - enough: shaving on min and max
  - pointless?
    - does not control variable selection
    - does not count as backtracking step

*Shaving for all values in domain*

```prolog
shaving(Variable,all):-
    dom(Variable,Values),
    findall(Variable,member(Variable,Values),[ValidValue|ValidValues]),
    NewVariable :: [ValidValue|ValidValues],
    Variable = NewVariable.
```
diffn only (initial part only)
cumulative limit+end
forced intermediate
saturation cumulative
all methods, all times
indomain1
shaving
Comparing two search methods

- Often interested in comparison of two methods
- Difficult to achieve with two programs
  - two machines?
- Change search tree call
  OLD:
  \[
  \text{search\_start(Vars,}\text{labeling}(\text{Vars}))
  \]
  NEW:
  \[
  \text{search\_start(Vars,}\text{try}(\text{Vars}))
  \]

\[
\text{try}(\text{Vars}):- \\
\quad \text{\textit{once(labeling1(Vars)),}} \\
\quad \text{fail.}
\]
\[
\text{try}(\text{Vars}):- \\
\quad \text{\textit{once(labeling2(Vars)),}} \\
\quad \text{fail.}
\]
Compare indomain1 - indomain

first method: indomain1

second method: indomain
Compare cumulative - all methods, all times; indomain1

first method: all methods

second method: forced intermediate
### Backtracking count

<table>
<thead>
<tr>
<th>Methods</th>
<th>Backtrack</th>
<th>Time</th>
<th>Backtrack</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffn only</td>
<td>2975</td>
<td>22653</td>
<td>2993 (?)</td>
<td>18757</td>
</tr>
<tr>
<td>Cumulative limit</td>
<td>2261</td>
<td>21521</td>
<td>2259</td>
<td>17836</td>
</tr>
<tr>
<td>Cumulative limit+end</td>
<td>55</td>
<td>1292</td>
<td>48</td>
<td>1392</td>
</tr>
<tr>
<td>Cumulative intermediate</td>
<td>55</td>
<td>1272</td>
<td>48</td>
<td>1342</td>
</tr>
<tr>
<td>Forced intermediate</td>
<td>39</td>
<td>1402</td>
<td>35</td>
<td>1392</td>
</tr>
<tr>
<td>Saturation cumul</td>
<td>27</td>
<td>1072</td>
<td>21</td>
<td>961</td>
</tr>
<tr>
<td>All methods, all times</td>
<td>7</td>
<td>5197</td>
<td>7</td>
<td>5799</td>
</tr>
<tr>
<td>Shaving</td>
<td>3</td>
<td>6709</td>
<td>3</td>
<td>6911</td>
</tr>
</tbody>
</table>
## Failure Events

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Context</th>
<th>All methods</th>
<th>Cumul saturation</th>
<th>Force intermediary</th>
<th>Cumul limit+end</th>
<th>Diff only</th>
</tr>
</thead>
<tbody>
<tr>
<td>cumulative</td>
<td>avoid small hole before</td>
<td>295</td>
<td>108</td>
<td>104</td>
<td>104</td>
<td>0</td>
</tr>
<tr>
<td>cumulative</td>
<td>avoid small hole after</td>
<td>176</td>
<td>104</td>
<td>102</td>
<td>102</td>
<td>0</td>
</tr>
<tr>
<td>diffn</td>
<td>temoin overflow</td>
<td>54</td>
<td>104</td>
<td>183</td>
<td>191</td>
<td>29489</td>
</tr>
<tr>
<td>diffn</td>
<td>hole overflow</td>
<td>31</td>
<td>95</td>
<td>117</td>
<td>280</td>
<td>12133</td>
</tr>
<tr>
<td>cumulative</td>
<td>max intersect prune</td>
<td>30</td>
<td>35</td>
<td>32</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>cumulative</td>
<td>smallest high task prune</td>
<td>22</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>diffn</td>
<td>dom-arbitre</td>
<td>17</td>
<td>42</td>
<td>51</td>
<td>59</td>
<td>4871</td>
</tr>
<tr>
<td>cumulative</td>
<td>cant fill enough deepest hole</td>
<td>17</td>
<td>22</td>
<td>21</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>diffn</td>
<td>cum arbitre (fail k-conflict)</td>
<td>9</td>
<td>7</td>
<td>17</td>
<td>17</td>
<td>180</td>
</tr>
<tr>
<td>cumulative</td>
<td>oblig.part intersect</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>diffn</td>
<td>disj arbitre (fail)</td>
<td>5</td>
<td>15</td>
<td>12</td>
<td>13</td>
<td>249</td>
</tr>
<tr>
<td>diffn</td>
<td>cum arbitre (prune)</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>diffn</td>
<td>cum arbitre (fail)</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>12</td>
<td>182</td>
</tr>
<tr>
<td>cumulative</td>
<td>top of interval fail</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>cumulative</td>
<td>prune origin (global frontier)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>cumulative</td>
<td>residual high max cover fail</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
## Failure Events (2)

<table>
<thead>
<tr>
<th>cumulative</th>
<th>Cant reach intermediate level</th>
<th>0</th>
<th>7</th>
<th>7</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>cumulative</td>
<td>Cum arbitre (fail)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Diffn</td>
<td>overlapping</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>9</td>
<td>243</td>
</tr>
<tr>
<td>diffn</td>
<td>Disj arbitre (before-after)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cumulative</td>
<td>First interval fail</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>diffn</td>
<td>Eval earliest end</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>359</td>
</tr>
<tr>
<td>diffn</td>
<td>Min ori prune</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>217</td>
</tr>
<tr>
<td>diffn</td>
<td>Hole include big size</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>diffn</td>
<td>Disj arbitre fail (marge)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>diffn</td>
<td>Max ori prune</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>diffn</td>
<td>Hole overflow2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>diffn</td>
<td>Disj partititon</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>673</td>
<td>563</td>
<td>680</td>
<td>829</td>
<td>47943</td>
</tr>
</tbody>
</table>

Not shown for shaving, as shaving failures can not be separated.
Newprop tool

<table>
<thead>
<tr>
<th>Type</th>
<th>Pred</th>
<th>Aggregate Type</th>
<th>Count</th>
<th>Context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>122</td>
<td>cum arbire (fail)</td>
<td>1</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>130</td>
<td>cum arbire (fail k-conflict)</td>
<td>1</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>122</td>
<td>prune origin (2 adjacent)</td>
<td>2</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>148</td>
<td>prune origin (global runner)</td>
<td>2</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>218</td>
<td>residual high max cover fail</td>
<td>2</td>
</tr>
<tr>
<td>Fail</td>
<td>diff</td>
<td>119</td>
<td>cum arbire (prune)</td>
<td>4</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>218</td>
<td>obig part intersect</td>
<td>5</td>
</tr>
<tr>
<td>Fail</td>
<td>diff</td>
<td>110</td>
<td>disc arbire (fail)</td>
<td>8</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>37</td>
<td>top of interval fail</td>
<td>8</td>
</tr>
<tr>
<td>Fail</td>
<td>diff</td>
<td>119</td>
<td>cum arbire (fail k-conflict)</td>
<td>10</td>
</tr>
<tr>
<td>Fail</td>
<td>diff</td>
<td>13</td>
<td>cum arbire (fail)</td>
<td>11</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>1</td>
<td>smallest high task prune</td>
<td>18</td>
</tr>
<tr>
<td>Fail</td>
<td>diff</td>
<td>22</td>
<td>cant fill enough deepest hole</td>
<td>29</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>118</td>
<td>deep arbire</td>
<td>22</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>118</td>
<td>max intersect prune</td>
<td>29</td>
</tr>
<tr>
<td>Fail</td>
<td>diff</td>
<td>128</td>
<td>hole overflow</td>
<td>58</td>
</tr>
<tr>
<td>Fail</td>
<td>diff</td>
<td>43</td>
<td>terror overflow</td>
<td>89</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>1</td>
<td>avoid small hole after</td>
<td>175</td>
</tr>
<tr>
<td>Fail</td>
<td>cumulative</td>
<td>1</td>
<td>avoid small hole before</td>
<td>228</td>
</tr>
</tbody>
</table>

- **Type of event**: The type of event that occurs in the system.
- **Constraint name**: The name of the constraint associated with the event.
- **Constraint number**: The number of the constraint.
- **Context**: The context in which the event occurs.
- **Count of events**: The count of how many times the event occurs.
Conclusion

- Example of problem analysis with search tree tool
- Comparison of strategies inside tool
- Backtracking count vs failure count
- Failure events
  - variety of methods
  - change of methods with small change of programs
- Newprop tool
  - listing of all propagation events
  - aggregation
  - internal use only
  - for tool developer
- Significant improvement of program by small modification