Towards a lightweight standard search language

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Goals

- Define a **search language** for MiniZinc
- **Lightweight:** Balance expressiveness with ease of implementation
- Basis for discussion and (eventually) wide adoption

Why custom search?

- Standard labeling sometimes not good enough
- Exploit **problem structure**
  - problem decomposition
- Combine **search procedures**
  - restarts, warm starts, backdoors, portfolios...

Why standard language?

- **Compare** different solvers and searches
- **Exchange** models (e.g. CSPLib)
- **Communicate** search strategies (e.g. papers)

- **Fix good names**
  (independent of adoption as a standard!)

Approach

- **Not:** fully programmable search (too complex)
- Language for **combining** predefined search strategies
- Library of **search templates** that define the strategies

Simple labeling

Template:

variables

```
{int,bool,set}_search(vars,varsel,domsplit)
```

variable selection

domain splitting

```
varsel ≡
input_order, random_order, {min,max}_{lb,ub},
{min,max}_dom_size,
{min,max}_dom_size_weighted_degree, ...
```

```
domsplit ≡
{assign,exclude}_{lb,ub}, bisect_{low,high},
{assign,exclude}_impact_{min,max}, ...
```

Limit Strategies

limit_search(*measure*,*limit*,*search*)

fails, nodes, solutions,
time, discrepancies

once(*search*) ≡ limit(solutions,1,*search*)

lds(*d*,*search*) ≡ limit(discrepancies,*d*,*search*)

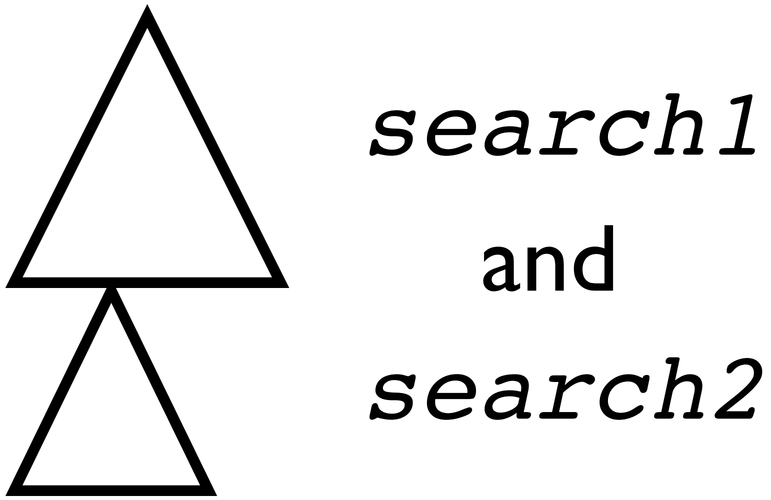
restart_geometric(*inc*,*init*,*measure*,*search*)

restart_luby(*init*,*max*,*measure*,*search*)

Composition

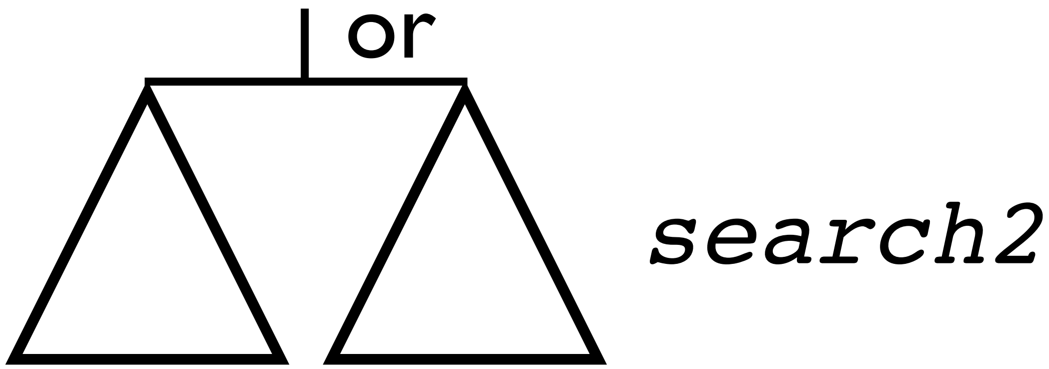
Sequential search:

```
seq_search([search1,...,searchN])
```



Parallel search:

```
par_search([search1,...,searchN])
```



Example: Job Shop

```
constraint
    forall(i in 1..size) (
        forall(j in 1..size-1) (s[i,j]+d[i,j] <= s[i,j+1])
    /\  s[i,size] + d[i,size] <= end
    /\  forall(j,k in 1..size where j < k) (
            no_overlap(s[j,i], d[j,i], s[k,i], d[k,i])
        )
    );

solve ::search minimize end;
```

Search annotation

Example: Job Shop

Simple dom/wdeg search:

```
search ≡ int_search(s,
                    min_dom_size_weighted_degree,
                    bisect_low)
```

Find first solution with LDS, then prove optimality with IBS:

```
search ≡ par_search([
    lds(3, int_search(s,min_lb,assign_lb)),
    int_search(s, max_impact, assign_impact_min)])
```

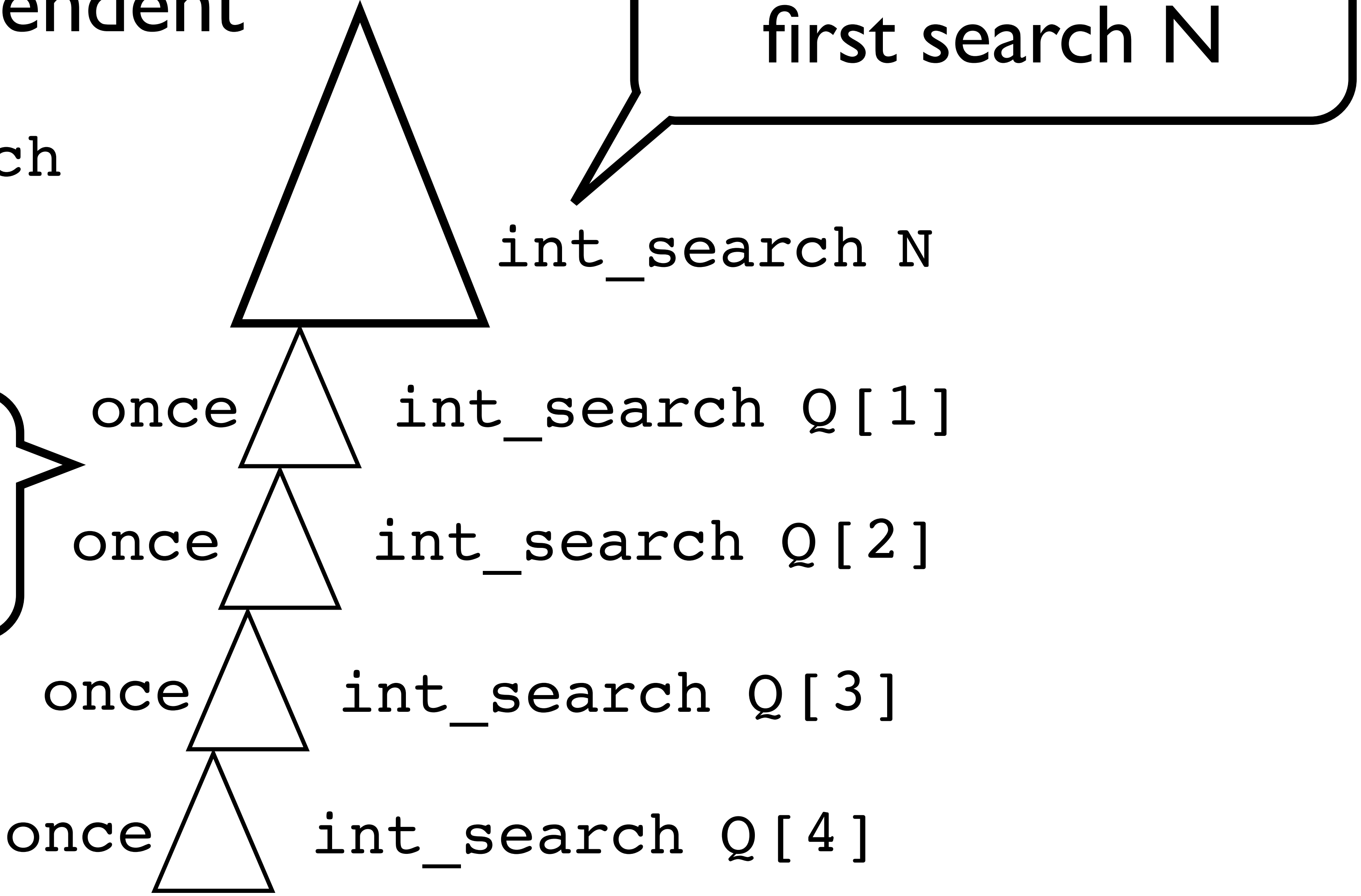
Example: Radiotherapy

```
var 0..Ints_sum: Beamtime;
var 0..m*n: K;
array[BTimes] of var 0..m*n: N;
array[Rows, Columns, BTimes] of var 0..m*n: Q;

constraint
     Beamtime = sum(b in BTimes) (b * N[b])
/\   K = sum(b in BTimes) (N[b])
/\   forall(i in Rows, j in Columns)
     ( Intensity[i,j] = sum([b * Q[i,j,b] | b in BTimes]) )
/\   forall(i in Rows, b in BTimes)
     ( ub_i(N[b], [Q[i,j,b] | j in Columns]) );

predicate ub_i(var int: N_b, array[int] of var int: L) =
   N_b >= L[1] + sum([ max(L[j] - L[j-1], 0) | j in 2..n ]);

solve ::search minimize (ub(K) + 1) * Beamtime + K;
```

Problem decomposition

Observation: after labeling the N, each row in the Q is independent

```
search ≡ seq_search
```


first search N

if one row fails, backtrack into N

Problem decomposition

Observation: after labeling the N, each row in the Q is independent

first search N

if one row fails, backtrack into N

```
search ≡
  seq_search(
    [int_search(N, min_dom                      ee,
                bisect_low)
    [once(int_search(
        [Q[i,j,b] | j in Cols, b in BTimes],
        max_activity, bisect_activity_min))
      | i in Rows])
```

Problem decomposition

Observation: after labeling the N, each row in the Q is independent

```
search ≡
  seq_search(
    [int_search(N, min_dom_size_weighted_degree,
                bisect_low)] ++
    [once(int_search(
        [Q[i,j,b] | j in Cols, b in BTimes],
        max_activity, bisect_activity_min))
      | i in Rows])
```

Implementation

- Two prototypes for FlatZinc/Gecode
  - code generator
  - C++ library
- Many templates implemented
- Generic approach, (hopefully) easy to adapt to other CP solvers

Future work

- Full implementation
- Define interaction with concurrent search
- Symmetry breaking?
- Shaving?
- Local search?

Conclusions

- Combinators and templates are expressive enough for useful, complex custom searches
- Proposed language can be implemented
- Useful as a standard:
  compare, exchange, communicate
  search strategies
- Independent of concrete modeling language:
  let's fix good names