Script generated by TTT

Title: Seidl: Virtual Machines (03.06.2014)

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37 Clause Indexing

Observation:

Often, predicates are implemented by case distinction on the first argument.

$\Longrightarrow$ Inspecting the first argument, many alternatives can be excluded :-)

$\Longrightarrow$ Failure is earlier detected :-)

$\Longrightarrow$ Backtrack points are earlier removed. :-))

$\Longrightarrow$ Stack frames are earlier popped :-)))

Example:

The app-predicate:

$$\begin{array}{lll} \texttt{app}(X, Y, Z) & \leftarrow & X = [\,],\ Y = Z \\ \texttt{app}(X, Y, Z) & \leftarrow & X = [H|X'],\ Z = [H|Z'],\ \texttt{app}(X', Y, Z') \end{array}$$

- If the root constructor is $[\,]$, only the first clause is applicable.
- If the root constructor is $[|]$, only the second clause is applicable.
- Every other root constructor should fail !!
- Only if the first argument equals an unbound variable, both alternatives must be tried ;-)

Idea:

- Introduce separate try chains for every possible constructor.
- Inspect the root node of the first argument.
- Depending on the result, perform an indexed jump to the appropriate try chain.

Assume that the predicate p/k is defined by the sequence rr of clauses $r_1 \ldots r_m$.

Let tchains rr denote the sequence of try chains as built up for the root constructors occurring in unifications $X_1 = t$.

Example:

Consider again the app-predicate, and assume that the code for the two clauses start at addresses A_1 and A_2, respectively.

Then we obtain the following four try chains:

VAR:	setbtp	// variables	NIL:	jump A_1	// atom [ ]
	try A_1				
	delbtp		CONS:	jump A_2	// constructor [|]
	jump A_2				
			ELSE:	fail	// default

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The new instruction fail takes care of any constructor besides [ ] and [|] ...

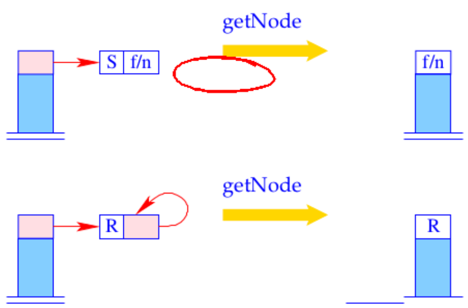
fail = `backtrack()`

It directly triggers backtracking :-)

Then we generate for a predicate p/k:

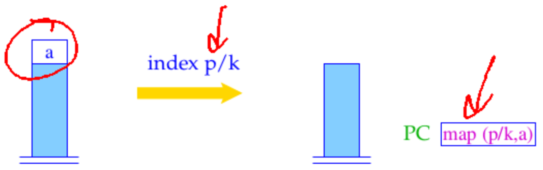
$$
\begin{array}{llll}
\text{code}_P\ rr & = & & \text{putref } 1 \\
 & & & \text{getNode} \quad \text{// extracts the root label} \\
 & & & \texttt{index } p/k \quad \text{// jumps to the try block} \\
 & & & \text{tchains } rr \\
 & & A_1: & \text{code}_C\ r_1 \\
 & & & \ldots \\
 & & A_m: & \text{code}_C\ r_m
\end{array}
$$

The instruction getNode returns "R" if the pointer on top of the stack points to an unbound variable. Otherwise, it returns the content of the heap object:




```
switch (H[S[SP]]) {
case (S, f/n):   S[SP] = f/n; break;
case (A,a):      S[SP] = a; break;
case (R,_) :     S[SP] = R;
}
```

The instruction index p/k performs an indexed jump to the appropriate try chain:



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SP– –;

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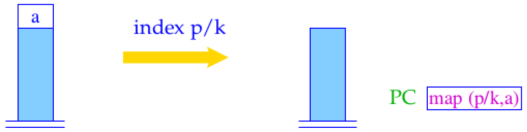

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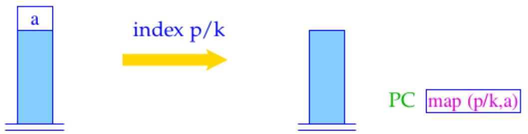

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38 Extension: The Cut Operator

Realistic Prolog additionally provides an operator "!" (cut) which explicitly allows to prune the search space of backtracking.

Example:

$$\begin{array}{lll} \mathsf{branch}(X,Y) & \leftarrow & \mathsf{p}(X), !, \mathsf{q}_1(X,Y) \\ \mathsf{branch}(X,Y) & \leftarrow & \mathsf{q}_2(X,Y) \end{array}$$

Once the queries before the cut have succeeded, the choice is committed:

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The Basic Idea:

- We restore the oldBP from our current stack frame;
- We pop all stack frames on top of the local variables.

Accordingly, we translate the cut into the sequence:

```
prune
pushenv m
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where m is the number of (still used) local variables of the clause.

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We obtain:

setbtp	A:	$\boxed{\text{pushenv 2}}$	C:	prune	lastmark	B:	pushenv 2
try A		mark C		pushenv 2	putref 1		putref 2
delbtp		putref 1			putref 2		putref 2
jump B		call p/1			lastcall $q_1/2$ 2		move 2 2
							jump $q_2/2$

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In fact, an optimized translation even yields here:

```
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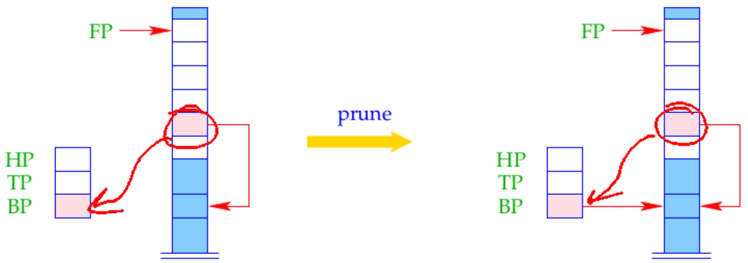
try A         mark C          pushenv 2   putref 2         putref 1
delbtp        putref 1                    move 2 2         putref 2
jump B        call p/1                    jump q1/2        move 2 2
                                                           jump q2/2
```


The new instruction prune simply restores the backtrack pointer:



BP = BPold;

Problem:

If a clause is single, then (at least so far ;-) we have not stored the old BP inside the stack frame :-(

$\Longrightarrow$

For the cut to work also with single-clause predicates or try chains of length 1, we insert an extra instruction setcut before the clausal code (or the jump):

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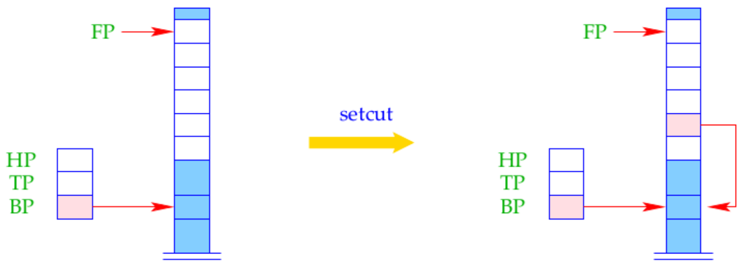
The instruction setcut just stores the current value of BP:



BPold = BP;

The Final Example: Negation by Failure

The predicate notP should succeed whenever p fails (and vice versa :-)

$$\text{notP}(X) \leftarrow \text{p}(X), !, \text{fail}$$
$$\text{notP}(X) \leftarrow$$

where the goal fail never succeeds. Then we obtain for notP :

```
setbtp      A:  pushenv 1    C:  prune        B:  pushenv 1
try A           mark C           pushenv 1        popenv
delbtp          putref 1         fail
jump B          call p/1         popenv
```


39 Garbage Collection

- Both during execution of a MaMa- as well as a WiM-programs, it may happen that some objects can no longer be reached through references.
- Obviously, they cannot affect the further program execution. Therefore, these objects are called garbage.
- Their storage space should be freed and reused for the creation of other objects.

Warning:

The WiM provides some kind of heap de-allocation. This, however, only frees the storage of failed alternatives !!!

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Operation of a stop-and-copy-Collector:

- Division of the heap into two parts, the to-space and the from-space — which, after each collection flip their roles.
- Allocation with new in the current from-space.
- In case of memory exhaustion, call of the collector.

The Phases of the Collection:

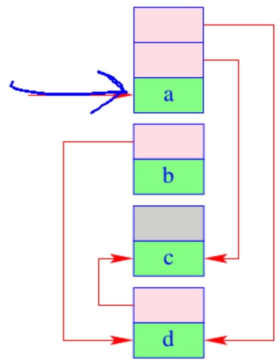
1. Marking of all reachable objects in the from-space.
2. Copying of all marked objects into the to-space.
3. Correction of references.
4. Exchange of from-space and to-space.

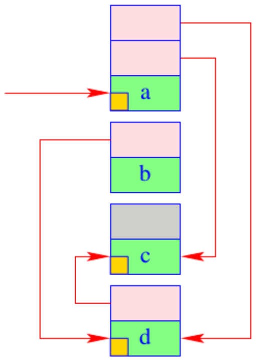
(1) Mark: Detection of live objects:

- all references in the stack point to live objects;
- every reference of a live object points to a live object.

$\Longrightarrow$

Graph Reachability





(2) Copy: Copying of all live objects from the current from-space into the current to-space. This means for every detected object:

- Copying the object;
- Storing a forward reference to the new place at the old place :-)

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all references of the copied objects point to the forward references in the from-space.

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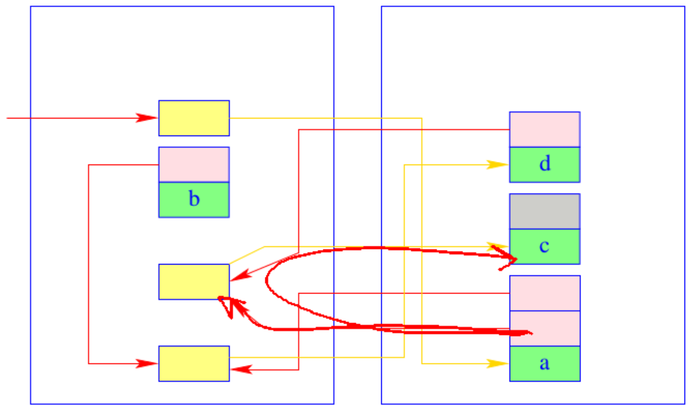
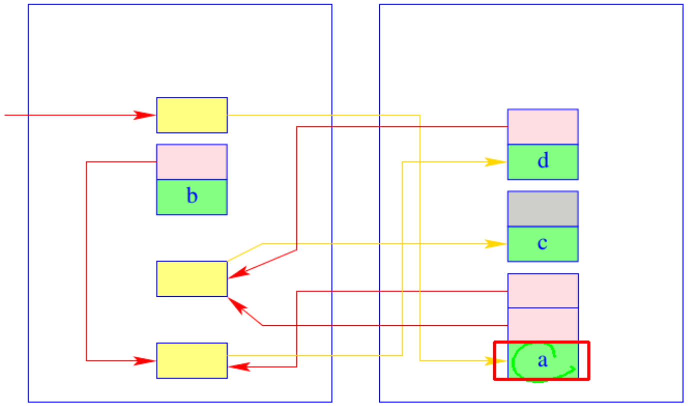
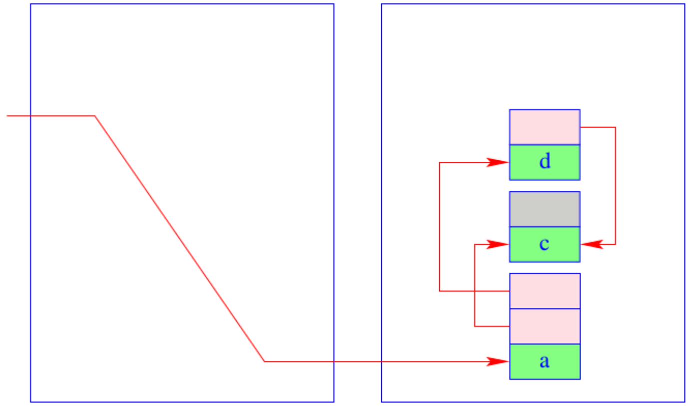
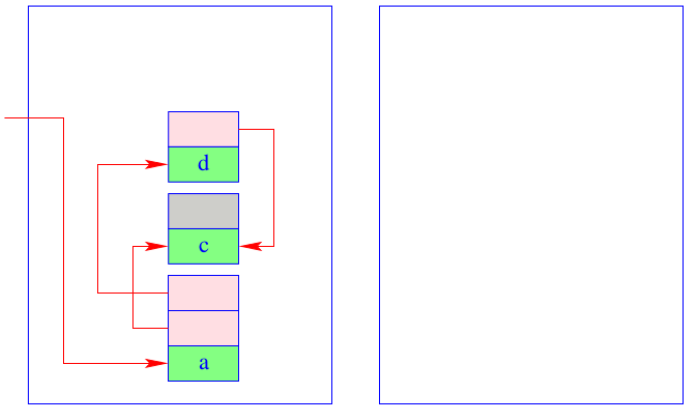
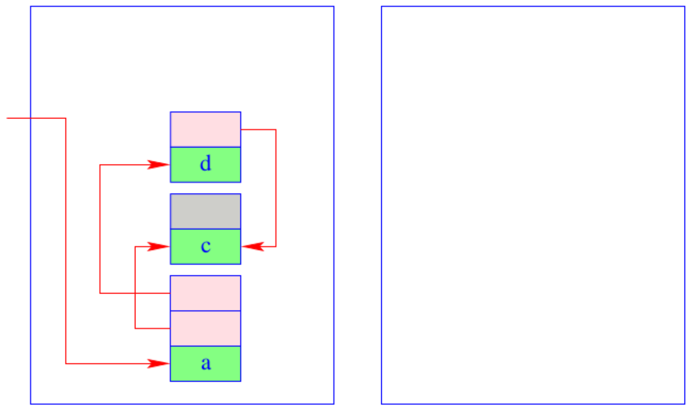


(3) Traversing of the to-space in order to correct the references.









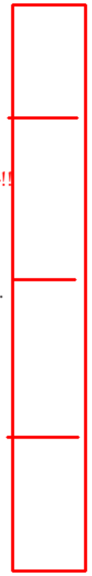
"young people die young, old live for ever!"

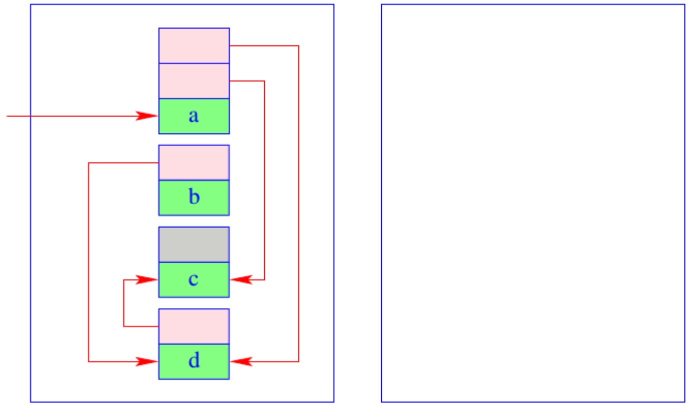
Warning:

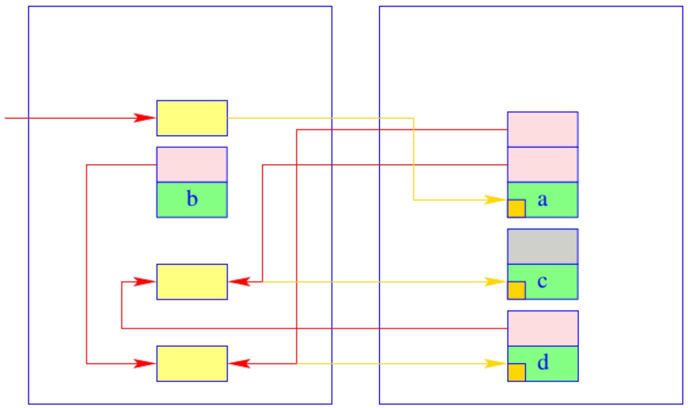
The garbage collection of the WiM must harmonize with backtracking.

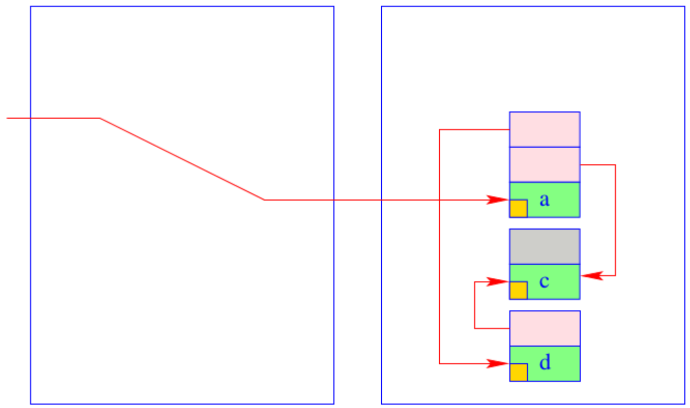
This means:

- The relative position of heap objects must not change during copying :-!!
- The heap references in the trail must be updated to the new positions.
- If heap objects are collected which have been created before the last backtrack point, then also the heap pointers in the stack must be updated.









Classes and Objects

Example:

```
int count = 0;
class list {
        int info;
        class list * next;
        list (int x) {
                info = x;  count++;  next = null;
            }
        virtual int last () {
                if (next == null) return info;
                else return next → last ();
            }
    }
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