Script generated by TTT

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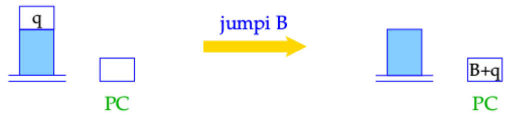
4.5 The switch-Statement

Idea

- Multi-target branching in constant time!
- Use a jump table, which contains at its i-th position the jump to the beginning of the i-th alternative.
- Realized by indexed jumps.



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SP--;

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PC = B + S[SP];
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Simplification

We only regard **switch**-statements of the following form:

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\begin{array}{lll}
s & \equiv & \textbf{switch}\ (e)\ \{ \\
 & & \quad \textbf{case}\ 0{:}\quad ss_0\ \textbf{break}; \\
 & & \quad \textbf{case}\ 1{:}\quad ss_1\ \textbf{break}; \\
 & & \quad \quad \vdots \\
 & & \quad \textbf{case}\ k-1{:}\quad ss_{k-1}\ \textbf{break}; \\
 & & \quad \textbf{default:}\quad ss_k \\
 & & \}
\end{array}
$$

s is then translated into the instruction sequence:

code s ρ	=	code_R e ρ	C_0:	code ss_0 ρ	B:	jump C_0
		check 0 k B		jump D		...
				...		jump C_k
			C_k:	code ss_k ρ	D:	...
				jump D		

- The Macro check 0 k B checks, whether the R-value of e is in the interval $[0, k]$, and executes an indexed jump into the table B
- The jump table contains direct jumps to the respective alternatives.
- At the end of each alternative is an unconditional jump out of the **switch**-statement.

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s ≡ **switch** (e) {
  case 0: ss_0 **break**;
  case 1: ss_1 **break**;
  ⋮
  case $k-1$: ss_{k-1} **break**;
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check 0 k B	=	dup	dup		jumpi B
		loadc 0	loadc k	A:	pop
		geq	le		loadc k
		jumpz A	jumpz A		jumpi B

- The R-value of e is still needed for indexing after the comparison. It is therefore copied before the comparison.
- This is done by the instruction dup.
- The R-value of e is replaced by k before the indexed jump is executed if it is less than 0 or greater than k.

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Remark

- The jump table could be placed directly after the code for the Macro check. This would save a few unconditional jumps. However, it may require to search the **switch**-statement twice.
- If the table starts with u instead of 0, we have to decrease the R-value of e by u before using it as an index.
- If all potential values of e are definitely in the interval $[0, k]$, the macro check is not needed.

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5 Storage Allocation for Variables

Goal:

Associate statically, i.e. at compile time, with each variable x a fixed (relative) address $\rho\,x$

Assumptions

- variables of basic types, e.g. **int**, … occupy one storage cell.
- variables are allocated in the store in the order, in which they are declared, starting at address 1.

Consequently, we obtain for the declaration $d \equiv t_1\ x_1;\ \ldots\ t_k\ x_k;$ (t_i basic type) the address environment ρ such that

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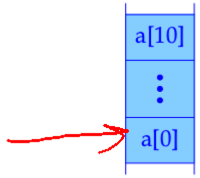
5.1 Arrays

Example $\textbf{int}\ [11]\ a;$

The array a consists of 11 components and therefore needs 11 cells.
$\rho\, a$ is the address of the component $a[0]$.



We need a function sizeof (notation: $|\cdot|$), computing the space requirement of a type:

$$|t| = \begin{cases} 1 & \text{if } t \text{ basic} \\ k \cdot |t'| & \text{if } t \equiv t'[k] \end{cases}$$

Accordingly, we obtain for the declaration $d \equiv t_1\ x_1; \ldots t_k\ x_k;$

$$\begin{aligned} \rho\, x_1 &= 1 \\ \rho\, x_i &= \rho\, x_{i-1} + |t_{i-1}| \qquad \text{for } i > 1 \end{aligned}$$

Since $|\cdot|$ can be computed at compile time, also ρ can be computed at compile time.

Task

Extend code_L and code_R to expressions with accesses to array components.

Be $t[c]\ a;$ the declaration of an array a.

To determine the start address of a component $a[i]$, we compute $\rho\, a + |t| * (\text{R-value of } i)$.

In consequence:

$$\begin{aligned} \text{code}_L\ a[e]\ \rho \quad = \quad & \text{loadc}\ (\rho\, a) \\ & \text{code}_R\ e\ \rho \\ & \text{loadc}\ |t| \\ & \text{mul} \\ & \text{add} \end{aligned}$$

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$$\begin{aligned} \text{code}_L\ e_1[e_2]\ \rho \quad = \quad & \text{code}_R\ e_1\ \rho \\ & \text{code}_R\ e_2\ \rho \\ & \text{loadc}\ |t| \\ & \text{mul} \\ & \text{add} \end{aligned}$$

Remark

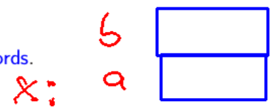
- In C, an array is a pointer. A declared array a is a pointer-constant, whose R-value is the start address of the array.
- Formally, we define for an array e: $\text{code}_R\ e\ \rho = \text{code}_L\ e\ \rho$
- In C, the following are equivalent (as L-values):

$$2[a] \qquad a[2] \qquad a + 2$$

Normalization: Array names and expressions evaluating to arrays occur in front of index brackets, index expressions inside the index brackets.

5.2 Structures

In Modula and Pascal, structures are called Records.



Simplification

Names of structure components are not used elsewhere.
Alternatively, one could manage a separate environment ρ_{st} for each structure type st.

Be **struct** { **int** a; **int** b; } x; part of a declaration list.

- x has as relative address the address of the first cell allocated for the structure.
- The components have addresses relative to the start address of the structure. In the example, these are $a \mapsto 0$, $b \mapsto 1$.

Let $t \equiv \textbf{struct}\,\{t_1\; c_1; \ldots t_k\; c_k;\}$. We have

$$\begin{array}{lll} |t| & = & \sum_{i=1}^{k} |t_i| \\ \rho\, c_1 & = & 0 \quad \text{and} \\ \rho\, c_i & = & \rho\, c_{i-1} + |t_{i-1}| \quad \text{for } i > 1 \end{array}$$

We thus obtain:

$$\begin{array}{lll} \text{code}_\text{L}\; (e.c)\; \rho & = & \text{code}_\text{L}\; e\; \rho \\ & & \text{loadc}\; (\rho\, c) \\ & & \text{add} \end{array}$$

Example

Be $\textbf{struct}\,\{\,\textbf{int}\; a;\, \textbf{int}\; b;\,\}\; x;$ such that $\rho = \{x \mapsto 13, a \mapsto 0, b \mapsto 1\}$.

This yields:

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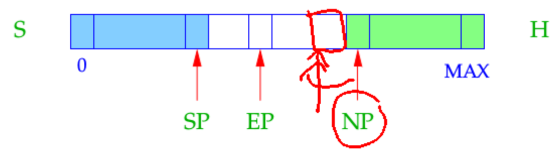
6 Pointer and Dynamic Storage Management

Pointer allow the access to anonymous, dynamically generated objects, whose life time is not subject to the LIFO-principle.

$\Longrightarrow$ We need another potentially unbounded storage area H – the Heap.



NP $\widehat{=}$ New Pointer; points to the lowest occupied heap cell.

EP $\widehat{=}$ Extreme Pointer; points to the uppermost cell, to which SP can point (during execution of the actual function).

Idea

- Stack and Heap grow toward each other in S, but must not collide. (Stack Overflow).
- A collision may be caused by an increment of SP or a decrement of NP.
- EP saves us the check for collision at the stack operations.
- The checks at heap allocations are still necessary.

What can we do with pointers (pointer values)?

- set a pointer to a storage cell,
- dereference a pointer, access the value in a storage cell pointed to by a pointer.

There a two ways to set a pointer:

(1) A call **malloc** (e) reserves a heap area of the size of the value of e and returns a pointer to this area:

$$\text{code}_R\ \textbf{malloc}\,(e)\ \rho \quad = \quad \text{code}_R\ e\ \rho$$
$$\textbf{new}$$

(2) The application of the address operator & to a variable returns a pointer to this variable, i.e. its address ($\widehat{=}$ L-value). Therefore:

$$\text{code}_R\ (\&e)\ \rho = \text{code}_L\ e\ \rho$$