Script generated by TTT

Title: Seidl: Virtual_Machines (23.04.2013)

Date: Tue Apr 23 14:01:31 CEST 2013

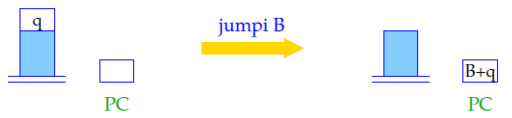
Duration: 91:29 min

Pages: 29

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.



PC = B + S[SP];
SP−−;

Simplification:

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

$s \equiv$ **switch** (e) {
  case 0: ss_0 ~~**break**~~;
  case 1: ss_1 **break**;
  ⋮
  case $k-1$: ss_{k-1} **break**;
  default: ss_k
}

s is then translated into the instruction sequence:

code $s\ \rho$ =	$\text{code}_R\ e\ \rho$	C_0:	code $ss_0\ \rho$	B:	jump C_0
	check 0 k B		jump D		. . .
			. . .		jump C_k
		C_k:	code $ss_k\ \rho$	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.

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		

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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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Note:

- 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.

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

$$\rho\, x_i = i, \quad i = 1, \ldots, k$$

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$$\rho\, x_i = i, \quad i = 1, \ldots, k$$

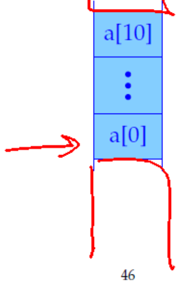
45

int a[11];

5.1 Arrays

Example: **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 $d \equiv t_1\; x_1; \ldots\; t_k\; x_k;$

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

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

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

In consequence:

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

... or more general:

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

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: $\quad \text{code}_R\ e\ \rho = \text{code}_L\ e\ \rho$
- 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.

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48

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 $\quad \rho_{st} \quad$ for each structure type st.

Be $\quad$ **struct** { **int** a; **int** b; } x; $\quad$ 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

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

We thus obtain:

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51

Example:

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

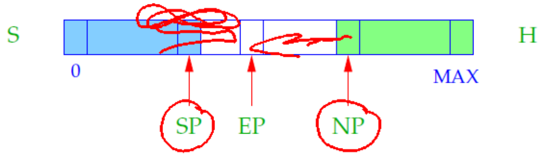
This yields:

$$\begin{array}{rcl} \text{code}_L\; (x.b)\; \rho & = & \text{loadc 13} \\ & & \text{loadc 1} \\ & & \text{add} \end{array}$$

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).

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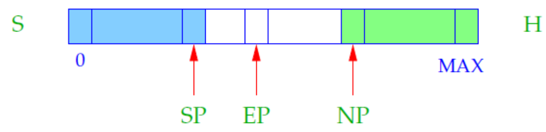

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Idea:

- 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.
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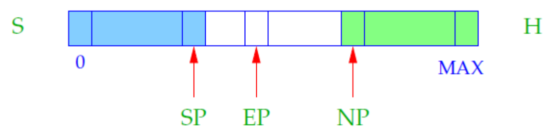

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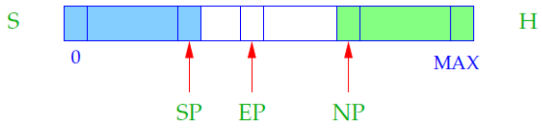

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What can we do with pointers (pointer values)?

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

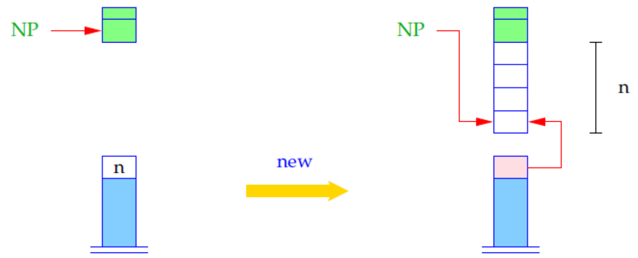
There a two ways to set a pointer:

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

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

(2) The application of the address operator & to a variable returns a pointer to this variable, i.e. its address (≙ L-value). Therefore:

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




```
if (NP - S[SP] ≤ EP)
        S[SP] = NULL;
else {
        NP = NP - S[SP];
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- NULL is a special pointer constant, identified with the integer constant 0.
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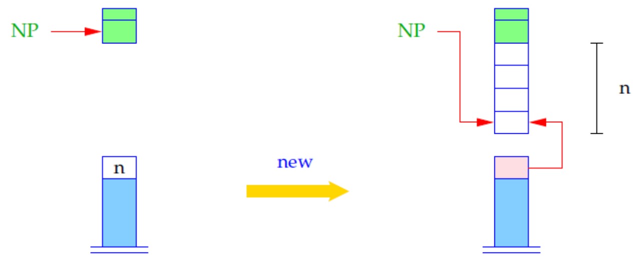


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