# Code Generation

- **Syntax Directed translation: Attribute *code* vs Side Effects**
- **The intermediate language: 3AC**
- **Code Generation for non control transfer code**

# An Intermediate Language
# 3-address code - 3AC

**1. (assignment)**

x:= y op z
x:= op z

$$\frac{S \equiv \langle S\rho, S_M \rangle \vdash loc(x) \to lx = S\rho(x) \quad S \vdash r(y) \to ry = S_M(S\rho(y)) \quad S \vdash r(z) \to rz \quad \vdash [op](ry,rz) = v}{S \vdash x := y\ op\ z \to S[lx/v] = S_M(lx) \leftarrow v}$$

**2. (copy)**

x:=y

$$\frac{S \vdash loc(x) \to lx \quad S \vdash r(z) \to rz}{S \vdash x := y \to S[lx/ry]}$$

**3. (location names - values)**

*newtemp*- a meta operator for fresh location names, e.g. newtemp:=-newtemp
values - scalar values of the meta prefixed by #, e.g. newtemp:=#3+newtemp

# 3-address code/2

**4. (uncoditioned jump)**

goto l

$$\frac{S \vdash code(l) \rightarrow P = S\rho(l) \quad S \vdash P \rightarrow S'}{S \vdash goto(l) \parallel Ps \rightarrow S'}$$

**5. (conditioned jump)**

If x opr y goto l

$$\frac{S \vdash code(l) \rightarrow P \quad S \vdash r(x) \rightarrow rx \quad S \vdash r(y) \rightarrow ry \quad \vdash [opr](rx,ry)=false \quad S \vdash Ps \rightarrow S'}{S \vdash \text{if } x \text{ opr } y \text{ goto } l \parallel Ps \rightarrow S'}$$

?

# 3-address code/3

**6. (i-structure)**

x:=y[i]
x[i]:=y

$$\frac{\begin{array}{l} S \vdash loc(x) \rightarrow lx \\ S \vdash loc(y) \rightarrow ly \\ S \vdash r(i) \rightarrow ri \\ \vdash ly+ri = add \\ S \vdash S_M(add) \rightarrow lv \end{array}}{S \vdash x:=y[i] \rightarrow S_M(lx) \leftarrow lv}$$

**complete with the other statement**

# 3-address code/4

**7. (pointer)**

x:=&y
x:=*y
*x:=y

$$\frac{S \vdash loc(x) \rightarrow lx \quad S \vdash loc(y) \rightarrow ly}{S \vdash x:=\&y \rightarrow S_M(lx) \leftarrow ly}$$

$$\frac{S \vdash loc(x) \rightarrow lx \quad S \vdash r(y) \rightarrow ry \quad S \vdash S_M(ry) \rightarrow v}{S \vdash x:=*y \rightarrow S_M(lx) \leftarrow v}$$

$$\frac{S \vdash r(x) \rightarrow rx \quad S \vdash r(y) \rightarrow ry}{S \vdash *x:=y \rightarrow S_M(rx) \leftarrow rv}$$

**where:**

- **$S_M(l/r) = S_M(l) \leftarrow r$ = updade of cell l with value r**
- **. = location of the current statement of the program**
- **|| = code concatenation (sequencing)**

# 3-address code/5

**8. (P-call)**

param x1
param x2
…
param xn
call p n

$$\frac{S \vdash r(x) \rightarrow rx}{S \vdash param\ x \rightarrow S_M(.)\leftarrow rx}$$

$$\frac{S \vdash code(p) \rightarrow P \quad S \vdash P \rightarrow S',v \quad \langle S\rho, S_M'|_v\rangle \vdash Ps \rightarrow S''}{S \vdash call\ p\ n \parallel Ps \rightarrow S''}$$

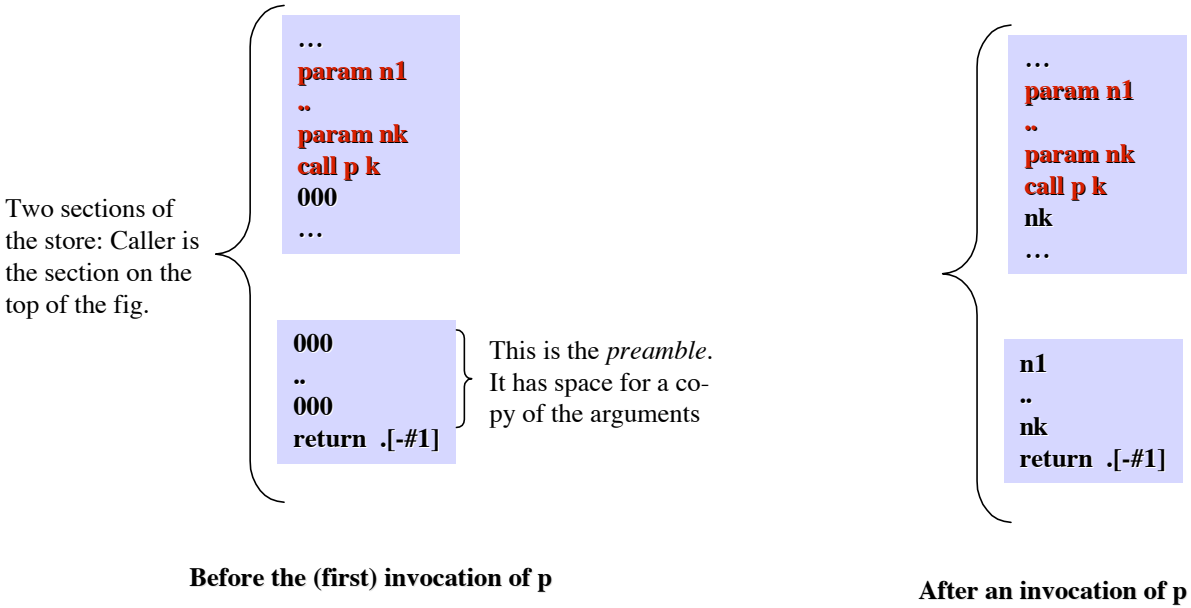
**9. (call-ret)**

return v

$$\frac{}{S \vdash return\ v \parallel ps \rightarrow S,v}$$

**-The caller puts the arguments before the invocation and waits for a result in the word that is located immediately, following the invocation**
**-The callee has a copy of the arguments immediately before its first statement**
**-The return from the callee, puts the result immediately below the caller invocation statement**
**-The store is updated accordingly: $S_M'|_v$ is $S_M'$ where the word following invocation is set to v**

# 3-address code/6 caller-callee

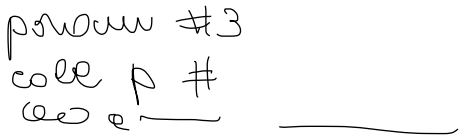



**Complete by giving a text that says what procedured p is supposed to compute.**

# 3-address code
# Defining a procedure for Factorial

procedure entry point,
i.e. address p is here

```
000
n = .[#-1]
rec = .+#3
if n≠ 0 goto rec
return #1
n1 = n-#1
param n1
call p #1
000
arg = .[-#3]
arg = arg +#1
val = .[-#3]
r = arg * val
return r
```



+ Use it in the computation of:
  call p 3
  where p is the address of the first statement;
+ Show the "activation records" (that the machine executor of 3AC is supposed to use) generated by the computation

# Translation of Expressions in 3-address code (compositional)

x+y*3 *is translated into*: t1:= y.loc [*] #3
t2:= x.loc [+] t1

**where**:
t1 and t2 = 3AC locations
.loc = attribute for 3AC locations
[op] is the 3AC operation that corresponds to p

**How does it to do it ?**

$$\frac{S \vdash e1 \rightarrow (S,v1) \qquad S \vdash e2 \rightarrow (S,v2)}{S \vdash e1\ op\ e2 \rightarrow (S, op(v1,v2))}$$

**(Semantics of expressions without side-effects)**

$$\frac{\vdash e1 \Rightarrow ([]e1[],l1) \qquad \vdash e2 \Rightarrow ([]e2[],l2) \qquad l=newtemp()}{\vdash e1\ op\ e2 \Rightarrow ([]e1[]\,||\,[]e2[]\,||\,emit(l:=l1\ [op]\ l2),\ l)}$$

**(Code Translation of exps without side-effects)**

**Meta**:
*newtemp*: -> **loc** **-It is executed at compile time and furnishes a fresh 3AC location**
*emit*: string -> void **-It is executed at compile time and updates the output code file (called emit-file) by inserting, as the last line, the 3AC command, if any, whose textual represen tation is the argument of emit.**

# Translation of Expressions in 3-address code - 2

## Attributes:

***loc***:- location where the execution of the translated code, in the given state, will put the value of expression, in suc a state

-synthesized of any grammatical deriving expressions, or parts of them {E,E',F,F',T,num,ide}

Side-effect: the translated code is put in the emit-file

**[15]E::= F** {E'.in = F.loc;}
**E'** {E.loc:= E'.loc;}
**[16]$E'_1$::= op-l F** {l:=newtemp; emit(l":="$E'_1$.in [op-l] F.loc); $E'_2$.in:=l;}
**$E'_2$** {$E'_1$.loc:= $E'_2$.loc;}
**[17]E'::= ε** {E'.loc = E'.in}
**[18]F::= T** {…}
**F'** {…}
**[19]F'::= op-h T** {…}
**F'** {…}
**[20]F'::= ε** {…}
**[21]T::= num** {T.loc = num.loc;}
**[22]T::= ide** {T.loc = ide.loc;}
**[23]T::= ( E )** {T.loc = E.loc;}