## CSE 443 Compilers

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## Phases



## Reminder:

## Friday is a workshop day

- Come ready to work
- Ensure all team members are present
- Bring along a list of questions


## function calls

## Function calls

int foo(int $x$, int $y$ ) \{ int temp;
temp $=2 * x+3 * y$; return temp;
\}

What happens during function call?
int main() \{

$$
\begin{aligned}
& \text { int } a=\cdots \\
& \text { int } b=\cdots \\
& \text { int } c=\text { foo }(a * b, a+b) ;
\end{aligned}
$$

\}

## Function calls

- Basic form: id(e1,e2,...ek)

Function calls

- Basic form: id (e1,e2,...ek)
- General form: assignable (e1,e2,.., ck)
- If $f$ is a function, $g(4,5)$ yields a function, and rh yields a function, then the following are legal:

$$
f(3) \quad g(4,6)(3) \quad r \operatorname{hn}(3)
$$

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# How is function call carried out? 

1. evaluate each of the argument expressions
2. mark the resulting values as parameters
3. invoke the function

How is function call carried out?

1. evaluate each of the argument expressions use compiler-generated temporaries
2. mark the resulting values as parameters
3. invoke the function
use 'call( $f, n$ )' IR instruction: $f$ is a function
$n$ is arily of function $\#$ of parameters
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## examples

$f(x+1)$

## examples

$f(x+1)$

Remember that the function call has structure.

## examples



## examples

$f(x+1)$
$t_{1}=x+1$
param $t_{1}$

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## examples

$f(x+1)$
$11=x+1$
param C 1
$k_{2}=\operatorname{call}(f, 1)$

Call the function. The second argument of the call indicates the arily of the function (ie. how many parameters it has)
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## examples

$f(x+1)$
$f(x+1,2 * y)$
$61=x+1$
param E 1
$E 2=\operatorname{call}(f, 1)$

## examples

$$
\begin{aligned}
& f(x+1) \\
& t 1=x+1 \\
& \text { param } t 1 \\
& t 2=\operatorname{call}(f, 1)
\end{aligned}
$$



## examples

$$
\begin{aligned}
& f(x+1) \\
& t 1=x+1 \\
& \text { param t1 } \\
& t 2=\operatorname{call}(f, 1)
\end{aligned}
$$

$$
f(x+1,2 * y)
$$

## examples

$$
\begin{aligned}
& f(x+1) \\
& t 1=x+1 \\
& \text { param } t 1 \\
& t 2=\operatorname{call}(f, 1)
\end{aligned}
$$

$2+2,+\infty$

param E1
param E1

Evaluate the second argument expression.
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## examples

$$
\begin{array}{ll}
f(x+1) & f(x+1,2 * y) \\
\epsilon_{1}=x+1 & \ell 1=x+1 \\
\text { param } \ell 1 & \text { param } k 1 \\
\epsilon_{2}=\operatorname{call}(f, 1) & t 2=2 * y \\
& \text { param } k 2
\end{array}
$$

Mark the resulk as a parameter.

## examples

$$
\begin{array}{ll}
f(x+1) & f(x+1,2 * y) \\
t 1=x+1 & t 1=x+1 \\
\text { param t1 } & \text { param } t 1 \\
t 2=\operatorname{call}(f, 1) & t 2=2 * y \\
& \text { param } t 2 \\
& t 3=\operatorname{call}(f, 2)
\end{array}
$$

Call the function.
$2 \times 2 x+2 y+\infty$

$$
\left.\begin{array}{ll}
f(x+1) & f(x+1,2 * y) \\
k 1=x+1 & t 1=x+1 \\
\text { param } k 1 & \text { param } t 1 \\
t 2=2 * y \\
\text { param } k 2 \\
t 3=\operatorname{call}(f, 2)
\end{array}\right)
$$

## exercise


$\cos x+3+\infty$

$$
\begin{array}{ll}
f(x+1) & f(x+1,2 * y) \\
k 1=x+1 & t 1=x+1 \\
\text { param } t 1 \\
t 2=\operatorname{call}(f, 1) & \text { param } k 1 \\
t 2=2 * y \\
\text { param } t 2 \\
t 3=\operatorname{call}(f, 2)
\end{array}, f(g(3 * z), h(a+b, a * b))
$$


$f(x+1)$
$k 1=x+1$
param Cl 1

$$
\mathrm{c}_{2}=\operatorname{call}(f, 1)
$$

$f(x+1,2 * y)$
$k 1=x+1$
param $E 1$
$62=2 * y$
param CR

$$
\mathrm{E} 3=\operatorname{call}(f, 2)
$$

$$
g(3 * z)
$$

$$
1
$$

$$
4
$$

...view this as a function call in isolation.
$\cos \operatorname{Hyy}+2 \rightarrow$
$f(x+1)$

$$
f(x+1,2 * y)
$$

$g(3 * z)$

$$
k 1=x+1
$$

$\mathrm{k} 1=x+1$

$$
\mathrm{k} 1=3 * z
$$

param $\mathrm{E1}$
param E 1

$$
\mathrm{E} 2=\operatorname{call}(f, 1)
$$

$$
t 2=2 * y
$$

param E 2

$$
\mathrm{t} 3=\operatorname{call}(f, 2)
$$

...first compute the argument value...
examples
$f(x+1)$
$f(x+1,2 * y)$
$g(3 * z)$
$k 1=x+1$
param E1

$61=x+1$
param $\mathrm{E}_{1}$
$t 2=2 * y$
param $E 2$
$t_{3}=\operatorname{call}(f, 2)$

$$
k 1=3 * z
$$

param El $\mathrm{E}_{2}=\operatorname{call}(9,1)$

examples
$f(x+1)$

$$
11=x+1
$$

param E1

$$
t_{2}=\operatorname{call}(f, 1)
$$

$f(x+1,2 * y)$
$\mathrm{t} 1=x+1$
param E 1

$$
t 2=2 * y
$$

param EL
$f(g(3 * z), h(a+b, a * b))$
$t_{1}=3 * z$ param El 1 $\mathrm{t}_{2}=\operatorname{call}(\mathrm{g}, 1)$

This Eranslation will happen automatically due to the recursive structure of the function call for $f \ldots$
examples
$f(x+1)$

$$
k 1=x+1
$$

param 61

$$
\mathrm{k} 2=\operatorname{calL}(f, 1)
$$

$$
f(x+1,2 * y)
$$

$k 1=x+1$
param E1
$t 2=2 * y$
param E 2
$t 3=\operatorname{call}(f, 2)$

$$
f(g(3 * z), h(a+b, a * b))
$$

$$
k_{1}=3 * z
$$

param $\mathrm{E1}$ $E 2=\operatorname{call}(9,1)$ param 62

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examples

| $f(x+1)$ | $f(x+1,2 * y)$ | $f(g(3 * z), h(a+b, a * b))$ |
| :--- | :--- | :--- |
| $k 1=x+1$ | $k 1=x+1$ | $t 1=3 * z$ |
| param $k 1$ | param $k 1$ | param $k 1$ |
| $k 2=\operatorname{call}(f, 1)$ | $t 2=2 * y$ | param $k 2$ |

examples
$f(x+1)$

$$
61=x+1
$$

param $\mathrm{E1}$

$$
f(x+1,2 * y)
$$

$61=x+1$
param E1

$$
t 2=2 * y
$$

param E 2
$t 3=\operatorname{call}(f, 2)$

$$
f(g(3 * z), h(a+b, a * b))
$$

$$
t_{1}=3 * z
$$

param 61

$$
E 2=\operatorname{call}(9,1)
$$

param 62

$$
t 3=a+b
$$

expression
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$2 x+2 y+2$

$$
\begin{array}{lll}
f(x+1) & f(x+1,2 * y) & f(g(3 * z), h(a+b, a * b)) \\
t 1=x+1 & t 1=x+1 & t 1=3 * z \\
\text { param t1 } & \text { param } t 1 & \text { param } t 1 \\
& t 2=2 * y & t 2=\operatorname{call}(f, 1) \\
\text { param } t 2 & \text { param } t 2 \\
t 3=\operatorname{call}(f, 2) & t 3=a+b \\
\text { param } t 3
\end{array}
$$

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$2 x \cos \mathrm{y}+5$
$f(x+1)$

$$
61=x+1
$$

param $\mathrm{E1}$

$$
f(x+1,2 * y)
$$

$61=x+1$
param E1

$$
t 2=2 * y
$$

param E 2
$t 3=\operatorname{call}(f, 2)$

$$
f(g(3 * z), h(a+b, a * b))
$$

$$
t_{1}=3 * z
$$

param 61

$$
E 2=\operatorname{call}(9,1)
$$

param E 2

$$
63=a+b
$$

param t 3

$$
k 4=a * b
$$

examples

$$
\begin{aligned}
& f(x+1) \\
& f(x+1,2 * y) \\
& f(g(3 * z), h(a+b, a * b)) \\
& 61=x+1 \\
& 61=x+1 \\
& t 1=3 * z \\
& \text { param E1 } \\
& \text { param E1 } \\
& 62=\operatorname{call}(f, 1) \\
& t 2=2 * y \\
& \text { param } \mathrm{E} 2 \\
& t 3=\operatorname{call}(f, 2) \\
& t 4=a * b \\
& \text { param } t 4 \\
& \mathrm{ts}=\operatorname{call}(h, 2)
\end{aligned}
$$

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$\cos x+2 y+5$

$$
\begin{aligned}
& f(x+1) \\
& k 1=x+1 \\
& t 1=x+1 \\
& t 1=3 * z \\
& \text { para E1 } \\
& t 2=\operatorname{call}(f, 1) \\
& \text { pram E1 } \\
& t 2=2 * y \\
& \text { para } \mathrm{E} 2 \\
& t 3=\operatorname{call}(f, 2) \\
& \text { parameter marking } \\
& \text { and call }
\end{aligned}
$$

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## Memory Organizalion

## Memory organizacion

| stack |
| :---: |
| free memory |
| heap |
| BSS |
| data |
| code |

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## Memory organization


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## Memory organization


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Memory organization

| slack |
| :---: |
| free memory |
| heap |
| ES |
| data |
| code |

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## Memory organization


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## Memory organization



$$
\begin{aligned}
& \text { slack grows } \\
& \text { towards heap }
\end{aligned}
$$

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## Memory organization


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## Memory organization



These regions are handled dynamically (ie. as runtime)
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## Memory organization

| stack |
| :---: |
| free memory |
| heap |
| ES |
| data |
| code |

## Heap allocation: reserve

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## Memory organization


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## stack frame organization

| aclual paramelers <br> (arguments) |
| :---: |
| relurned value |
| conkrol link <br> (dynamic link) |
| access link <br> (static link) |
| saved machine skakus <br> (return address) <br> Local data <br> temporaries |

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