Tour of common optimizations

Simple example

```
foo(z) {
   x := 3 + 6;
   y := x - 5
   return z * y
}
```

Simple example

foo(z) {

x := ~~3 + 6~~; 9   Constant folding (CF)

Const prop (CP) 9

y := ~~x - 5~~ 4 (CF)

return ~~z * y~~ 4 (CP)

z << 2

}

Strength reduction

Arith simpl

Another example

```
x := a + b;

...

y := ~~a + b~~ x ;
```

z + (a + b)

z + x

Another example

`x := a + b;`

`...`

`y :=` ~~`a + b`~~`;` x

only if x, a, b not modified!

Another example

```
a := 0

if (...) {
 a := v()
    x := a + b; t := x
} else { t := a + b }

...
            t
y := ~~a +~~ b;
```

Another example

```
if (...) {            t := a + b
    x := ~~a + b~~;t
} else { t := a + b }

...

y := ~~a + b~~;t
```

Partial Redundancy Elimination PRE

Another example

```
x := y
...
z := z + ~~x~~ y
```

Another example

`x := y`

`...`

`z := z +` ~~x~~ y

} x,y not modified

Copy prop

Another example

$x := \overset{E}{y}$

. . .

$z := z + \overset{x}{\cancel{y}}$

What if we run CSE now?

$x := E$

$\vdots$

$\textcircled{E} \to x$

Another example

```
x := y
...
z := z + ~~y~~ x
```

What if we run CSE now?

Another example

```
~~x := y**z~~

...

x := ...
```

Another example

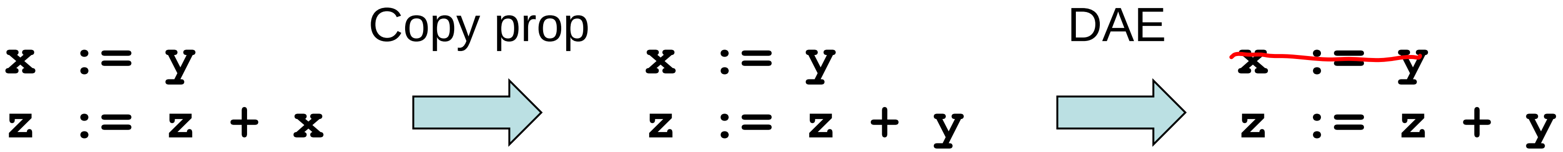
```
~~x := y**z~~

...

x := ...
```

if x is not used

dead assignment elim

(unused assignment elim)

- Often used as a clean-up pass



```
x := y
z := z + x
```

Copy prop

```
x := y
z := z + y
```

DAE

```
~~x := y~~
z := z + y
```

Another example

```
if (false) {

    ...

}
```

Another example

```
if (false) {

    ...

}
```

dead code elim
(unreachable code elim)

Another common clean up opt

Another example

- In Java:

```
a = new int [10];
for (index = 0; index < 10; index ++) {
   a[index] = 100;
}
```

Another example

- In “lowered” Java:

```
a = new int [10];
for (index = 0; index < 10; index ++) {
   if (index < 0 || index >= ~~a.length()~~10) {
      throw OutOfBoundsException;
   }
   a[index] = 0;
}
```

Another example

- In “lowered” Java:

```
a = new int [10];   ①
for (index = 0; index < 10; index ++) {
    if (index < 0 || index >= a.length()) {
        throw OutOfBoundsException;
    }
    a[index] = 0;
}
```

10 ← Kinda like CP if we assume stmt ① acts like a.length := 10

Branch folding + unreachable code elim

index ∈ [0..9] ← Range analysis

Another example

```
p := &x;
*p := 5
y := ~~x~~ + 1;
       5
```

Another example

```
  p := &x;
X ~~*p~~ := 5
  y := ~~x + 1;~~ 6
       5
```

pointer / alias analysis

```
x := 5;
*p := 3
y := x + 1;
```

⇒ ???

Another example

```
for j := 1 to N t := b[j]
    for i := 1 to M
        a[i] := a[i] + ~~b[j]~~ t
```

for (i=0; i<10; i++)

a[i]

=>

Another example

```
for j := 1 to N          t := b[j]
   for i := 1 to M
      a[i] := a[i] + ~~b[j]~~ t
```

Loop invariant

Code motion

Another example

```
     x y           x   y
area(h,w) { return h * w }

h := ...;
w := 4;
a := area(h,w)
```

h * ~~w~~ 4

h << 2

Another example

```
area(h,w) { return h * w }

h := ...;
w := 4;
```

a := ~~area(h,w)~~

~~h * w~~

~~h * 4~~

h << 2

Many "silly" opts become important after inlining

Optimization themes

- Don’t compute if you don’t have to
  - unused assignment elimination
- Compute at compile-time if possible
  - constant folding, loop unrolling, inlining
- Compute it as few times as possible
  - CSE, PRE, PDE, loop invariant code motion
- Compute it as cheaply as possible
  - strength reduction
- Enable other optimizations
  - constant and copy prop, pointer analysis
- Compute it with as little code space as possible
  - unreachable code elimination