Tour of common optimizations

Simple example

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

print

9

4

3

z << 2

Simple example

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

constant folding (CF)

const prop (CP)

9

4 (CF)

4 (CP)

z << 2

strength reduction

Arith simpl

Another example

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

x

Another example

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

only if x, a, b not modified!

x

Another example

```
if (...) {
   a := read();
   x' := a + b;
   print(x);
} else {x' := a + b}
...
y := a + b;
```

x:=x'

print(y)

x'

Another example

```
if (...) {
   a := read();
   x := a + b;
   print(x);
}

...

y := a + b;
```

t := a + b

t

else { t := a + b }

Partial Redundancy Elimination PRE

Another example

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

Another example

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

x, y not modified

copy prop

Another example

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

What if we run CSE now?

x := E

... E ...
x

Another example

```
x := y
...
z := z + 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          Copy prop    x := y          DAE    x := y
z := z + x   ⇒               z := z + 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) {
      throw OutOfBoundsException;
   }
   a[index] = 0;
}
```

a.length = 10

false

10

index ∈ [0..9]

10

Another example

- In "lowered" Java:

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

①

Branch folding + unreachable code elim

index ∈ [0..9] ← Range analysis

10 ← Kinda like CP if we assume start 0 acts like a.length := 10

Another example

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

Another example

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

pointer / alias analysis

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

⇒ ???

Another example

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

Another example

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

Loop invariant code motion

Another example

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

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

Another example

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

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

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