

Program Analysis

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# Code Optimizations

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# Recap

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- Optimizations
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  - Maintain semantic equivalence

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  - Maintain semantic equivalence
- Two levels
  - Machine Independent
  - Machine Dependent

# Machine Independent Optimizations

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  - Global

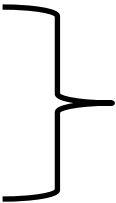


# Machine Independent Optimizations

- Scope of optimizations
  - Local
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Intraprocedural

# Machine Independent Optimizations

- Scope of optimizations
    - Local
    - Global
    - Interprocedural
- Intraprocedural
- 

# Local Optimizations

- Restricted to a basic block
- Simplifies the analysis
- Not all optimizations can be applied locally
  - E.g. Loop optimizations
- Gains are also limited
- Simplify global/interprocedural optimizations

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- Typically restricted within a procedure/function
  - Could be restricted to a smaller scope, e.g. a loop
- Most compiler implement up to global optimizations
  - Well founded theory
  - Practical gains

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- Spans multiple procedures, files
  - In some cases multiple languages!
- Not as popular as global optimizations
  - No single theory applicable to multiple scenarios
  - Time consuming

# A Catalogue of Code Optimizations

# Compile-time Evaluation

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j = i * 4;  
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x = u+v;  
...  
y = u+v+w;  
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```

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```
t0 = u+v;  
x = t0;  
...  
y = t0+w;  
...
```

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  - May result in dead code, common subexpr, ...
  - When can we apply it?

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Suppose `op` generates a large number of machine instructions

```
if (a < b)
    u = x op y;
else
    v = x op y;
```

Replaced by

```
t1 = x op y;
if (a < b)
    u = t1;
else
    v = t1;
```

# Code Movement

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```
if (a < b)
    u = ...;
else
    v = x*y;
w = x*y;
```

Replaced by

```
if (a < b) {
    t2 = x*y;
    u = ...;
} else {
    t2 = x*y;
    v = t2;
}
w = t2;
```

# Code Movement

- Execution frequency reduction

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    u = ...;
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    v = x*y;
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Replaced by

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- When can we do it?

# Loop Invariant Code Movement

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```
for (...) {  
    ...  
    u = a+b;  
    ...  
}
```

Replaced by

```
t3 = a+b;  
for (...) {  
    ...  
    u = t3;  
    ...  
}
```

# Loop Invariant Code Movement

- Execution frequency reduction

```
for (...) {  
    ...  
    u = a+b;  
    ...  
}
```

Replaced by

```
t3 = a+b;  
for (...) {  
    ...  
    u = t3;  
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}
```

- When can we do it?

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- Profitability of code motion

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  - Can we always do it?

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- Dead code elimination
  - Remove unreachable, unused code.
  - Can we always do it?
- Strength reduction
  - Use of *low strength* operators in place of *high strength* operators.
    - $i*i$  instead of  $i^2$ ,  $\text{pow}(i,2)$
    - $i \ll 1$  instead of  $i*2$
  - Typically performed for integers only (Why?)



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  - along program execution paths
- Used to answer questions such as:
  - whether two identical expressions evaluate to same value
    - used in common subexpression elimination
  - whether the result of an assignment is used later
    - used by dead code elimination

# Data Flow Abstraction

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- Flow graph
  - Graph representation of paths that program may exercise during execution
  - Typically one graph per procedure
  - Graphs for separate procedure have to be combined/connected for interprocedural analysis
    - Later!
    - Single procedure, single flow graph for now.

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- Basic Blocks (bb)
- Input state/Output state for Stmt
  - Program point before/after a stmt
  - Denoted  $IN[s]$  and  $OUT[s]$
  - Within a basic block:
    - Program point *after a stmt* is same as the program point *before the next stmt*