Lecture 3

Local Optimizations

I Basic blocks/Flow graphs

II Abstraction 1: DAG

III Abstraction 2: Value numbering

I. Basic Blocks & Flow Graphs

- **What is**
  - a basic block?
  - a flow graph?
- **How do we restructure a sequential list of instructions into a flow graph of basic blocks?**
  - Muchnick pp. 174-177
- **Reachability of basic blocks**

```
if x {                bfls r1, L1
   ...                ...
   return;            ret
                      jmp L2
} else {        L1:   ...
   ...
}               L2:   ...
```

II. Local Optimizations

- **Common subexpression elimination**
  - array expressions
  - field access in records
  - access to parameters

Graph Abstractions

- **Example 1: an expression**

  `a+a*(b-c)+(b-c)*d`

- **Muchnick Section 4.9.3**

How well do DAGs hold up across statements?

- **Example 2**

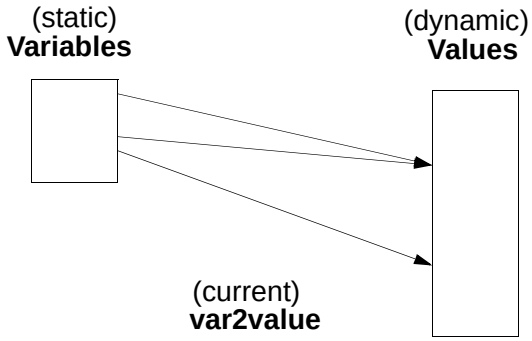
```
a  =  b+c;
b  =  a-d;
c  =  b+c;
d  =  a-d;
```


Critique of DAGs

- **Cause of problems**
  - Assignment statements
  - Value of variable depends on TIME
- **How to fix problem?**
  - build graph in order of execution
  - attach variable name to latest value
- **Final graph created is not very interesting**
  - Key: variable->value mapping across time
  - loses appeal of abstraction

III. Value Numbering: Another Abstraction

- John Cocke & Jack Schwartz in unpublished book: “Programming Languages and their Compilers”, (1970) (*Muchnick Section 12.4*)
- More explicit with respect to VALUES, and TIME



  - **each value has its own “number”**
    - **common subexpression means same value number**
  - var2value: current map of variable to value
    - used to determine the value number of current expression

```
r1 + r2 => var2value(r1)+var2value(r2)
```


Algorithm

```
Data structure:
     VALUES = Table of
        expression
        var        (temporary holding variable)


For each instruction (dst = op src1 src2) in execution order

  IF  [OP var2value(src1) var2value(src2)] is in VALUES
     v = the index of expression
     Replace instruction with CPY dst = VALUES[v].var
  ELSE
     Add
        expression =[OP var2value(src1) var2value(src2)]
        var        =dst
     to VALUES
     v = index of new entry

  set_var2value (dst, v)
```

More Details

- **What are the initial values of the variables?**
  - values at beginning of the basic block
- **Possible implementations:**
  - Initialization: create “initial values” for all variables
  - Or dynamically create them as they are used
- **Implementation of VALUES and var2value: hash tables**

Example

```
                 Assign: a->r1,b->r2,c->r3,d->r4
a  =  b+c;       ADD  t1 =  r2,r3
                 CPY  r1 =  t1
b  =  a-d;       SUB  t2 =  r1,r4
                 CPY  r2 =  t2
c  =  b+c;       ADD  t3 =  r2,r3
                 CPY  r3 =  t3
d  =  a-d;       SUB  t4 =  r1,r4
                 CPY  r4 = t4
```

Conclusions

- **Comparisons of two abstractions**
  - DAGs
  - Value numbering
- **Value numbering**
  - VALUE: distinguish between variables and VALUES
  - TIME
    - Interpretation of instructions in order of execution
    - Keep dynamic state information

Question

- **How do you extend value numbering to constant folding?**

```
a = 1
b = 2
c = a+b
```