# COMP 515: Advanced Compilation for Vector and Parallel Processors

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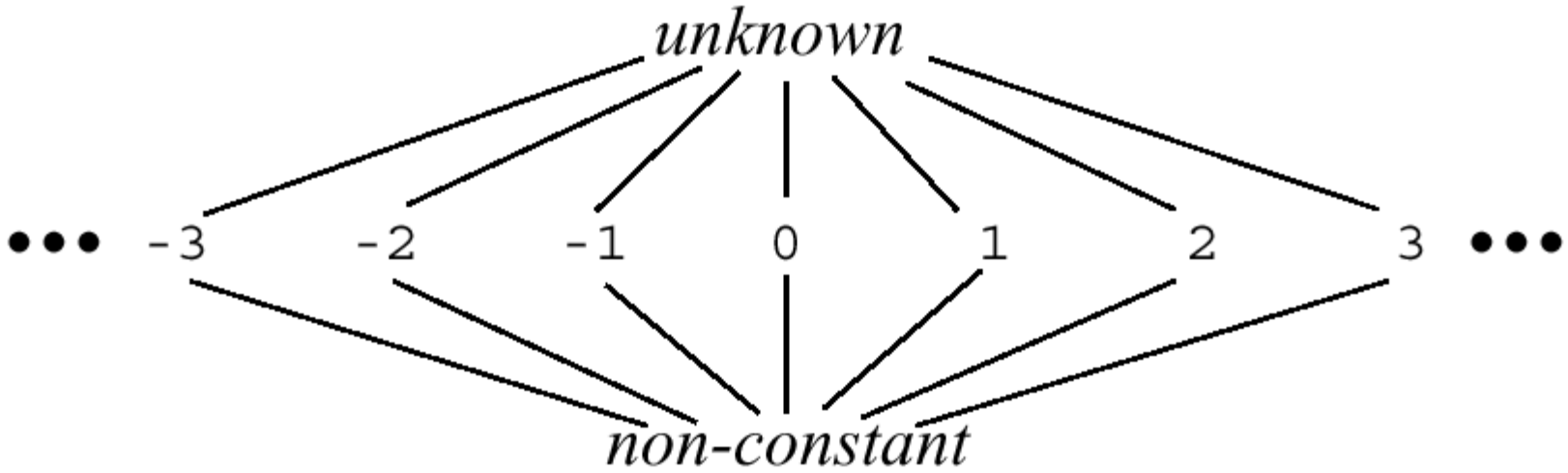
https://wiki.rice.edu/confluence/display/PARPROG/COMP515

# Preliminary Transformations (contd)

Chapter 4 of Allen and Kennedy

# Constant Propagation

- Replace all variables that have constant values at runtime with those constant values



# Constant Propagation

```
procedure propagateConst(P);
    // P is the procedure in which constants are to be propagated
    // valin(w, s) is the best approximate value of input w to s
    // valout(v, s) is the best value of output v from s
    // μ(s)(inputs to s) is the result of symbolic interpretation of
    //     statement s over the lattice values of its inputs. The
    //    output is the lattice value of the output of the statement

    for all statements s in the program do begin
        for each output v of s do valout(v, s) := unknown;
        for each input w of s do
            if w is a variable then valin(w, s) := unknown;
            else valin(w, s) := the constant value of w;
    end;
```

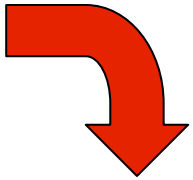
# Constant Propagation

```
worklist := {all statements of constant form, e.g., x = 5};

while worklist ≠ ∅ do begin
    choose and remove an arbitrary statement x from worklist;
    let v denote the output variable for x;

    // Symbolic interpretation of the statement x
    newval := μ(x)(valin(v, x), for all inputs v to x);
    if newval ≠ valout(v, x) then begin
        valout(x, v) := newval;
        for all (x, y) ∈ defuse do begin
            oldval := valin(v, y);
            valin(v, y) := oldval ∧ valout(v, x) ;
            if valin(v, y) ≠ oldval then worklist := worklist ∪ {x};
        end
    end
end
end propagateConst
```

# Forward Expression Substitution

- **Example**

```
DO I = 1, 100
   K = I + 2
   A(K) = A(K) + 5
ENDDO
```



```
DO I = 1, 100
   A(I+2) = A(I+2) + 5
ENDDO
```

# Forward Expression Substitution

- Need definition-use edges and control flow analysis
- Need to guarantee that the definition is always executed on a loop iteration before the statement into which it is substituted
- Data structure to find out if a statement S is in loop L
  - Test whether level-K loop containing S is equal to L

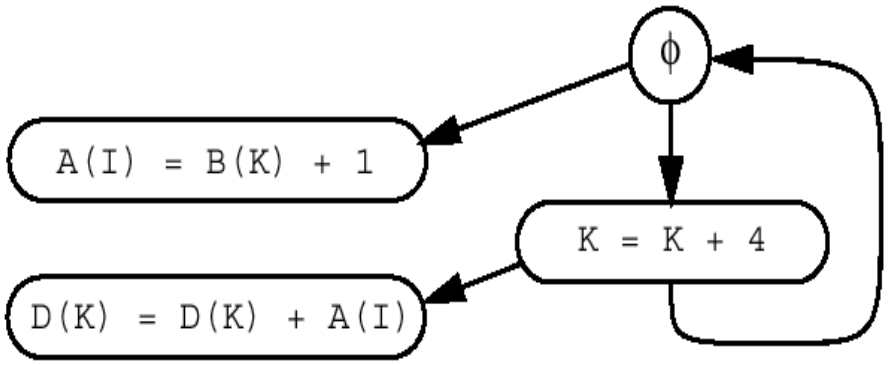
# Induction Variable Substitution

- Definition: an auxiliary induction variable in a DO loop headed by `DO I = LB, UB, S` is any variable that can be correctly expressed as `cexpr * I + iexpr`$_L$ at every location L where it is used in the loop, where cexpr and iexpr$_L$ are expressions that do not vary in the loop, although different locations in the loop may require substitution of different values of iexpr$_L$

# Induction Variable Substitution

- **Example:**

```
DO I = 1, N
    A(I) = B(K) + 1
    K = K + 4
    …
    D(K) = D(K) + A(I)
ENDDO
```



# Induction Variable Substitution

- More complex example

```
DO I = 1, N, 2
    K = K + 1
    A(K) = A(K) + 1
    K = K + 1
    A(K) = A(K) + 1
ENDDO
```

- Alternative strategy is to recognize region invariance

```
DO I = 1, N, 2
    A(K+1) = A(K+1) + 1
    K = K+1 + 1
    A(K) = A(K) + 1
ENDDO
```

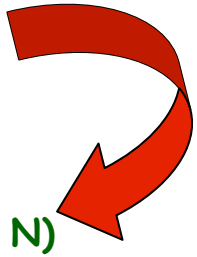
# Induction Variable Substitution

- **Driver**

```
procedure IVDrive(L);
    // L is the loop being processed, assume SSA graph available
    // IVDrive performs forward substitution and induction variable
    // substitution on the loop L, recursively calling itself where
    // necessary.

    foreach statement S in L in order do
        case(kind(S))
            assignment:
                FS_not_done := ForwardSub(S,L);
                if FS_not_done then IVSub(S,L);
            DO-loop:
                IVDrive(S);
            default:
        end case
    end do
end IVDrive;
```

# IVSub without loop normalization

```
DO I = L, U, S
   K = K + N
   … = A(K)
ENDDO
```



```
DO I = L, U, S
   … = A(K + (I – L + S) / S * N)
ENDDO
K = K + (U – L + S) / S * N
```

# IVSub without loop normalization

- Problem:
  - Inefficient code
  - Nonlinear subscript

# IVSub with Loop Normalization

```
I = 1
DO J = 1, (U-L+S)/S, 1
   K = K + N
   … = A (K)
   I = I + 1
ENDDO
```

# IVSub with Loop Normalization

```
I = 1
DO J = 1, (U - L + S) / S, 1
   … = A (K + J * N)
ENDDO
K = K + (U - L + S) / S * N
I = I + (U - L + S) / S
```

# Summary

- Transformations to put more subscripts into standard form
  - Loop Normalization
  - Constant Propagation
  - Induction Variable Substitution
- Do loop normalization before induction-variable substitution
- Leave optimizations to compilers
  - Alternatively, perform preliminary transformations as look-aside analyses (then you're guaranteed to "do no harm")

# Homework #3 (Written Assignment)

1. **Solve exercise 3.6 in book**
   - This is case 4 of Lemma 3.3
   - Read Definitions 3.1, 3.2, 3.3 and Lemmas 3.1, 3.2, 3.3 before starting

- **Due in class on Thursday, Oct 3rd**
- Honor Code Policy: All submitted homeworks are expected to be the result of your individual effort. You are free to discuss course material and approaches to problems with your other classmates, the teaching assistants and the professor, but you should never misrepresent someone else's work as your own. If you use any material from external sources, you must provide proper attribution.