Static Single Assignment Form

CMPT 379: Compilers

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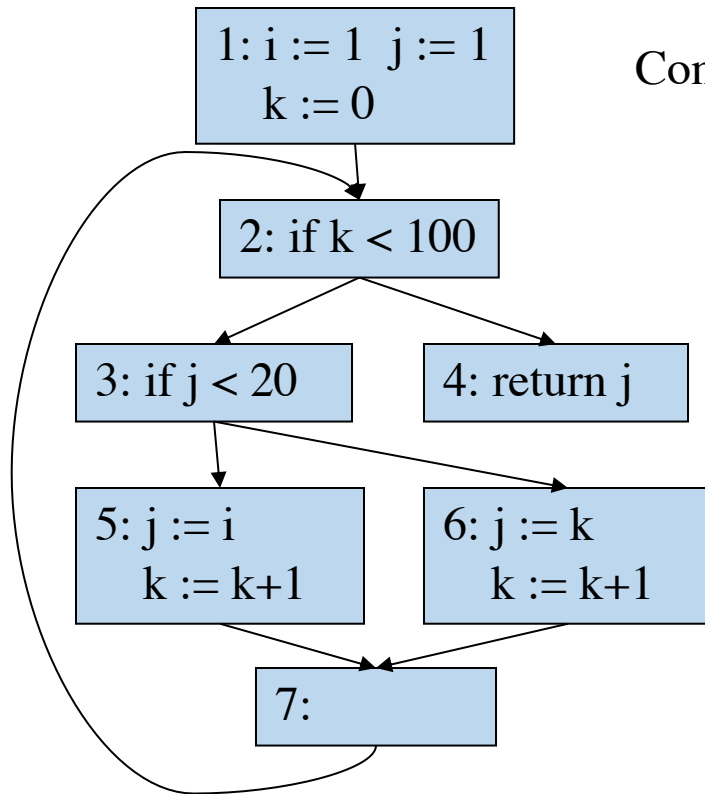
anoopsarkar.github.io/compilers-class

Converting to SSA Form

Program

i:=1
j:=1
k:=0
while k<100:
    if j < 20:
        j:=i
        k:=k+1
    else:
        j:=k
        k:=k+1
return j

Control Flow Graph

1: i := 1 j := 1
   k := 0

2: if k < 100

3: if j < 20

4: return j

5: j := i
   k := k+1

6: j := k
   k := k+1

7:

Converting to SSA Form

Control Flow Graph

1: i := 1 j := 1
   k := 0

2: if k < 100

3: if j < 20

4: return j

5: j := i
   k := k+1

6: j := k
   k := k+1

7:
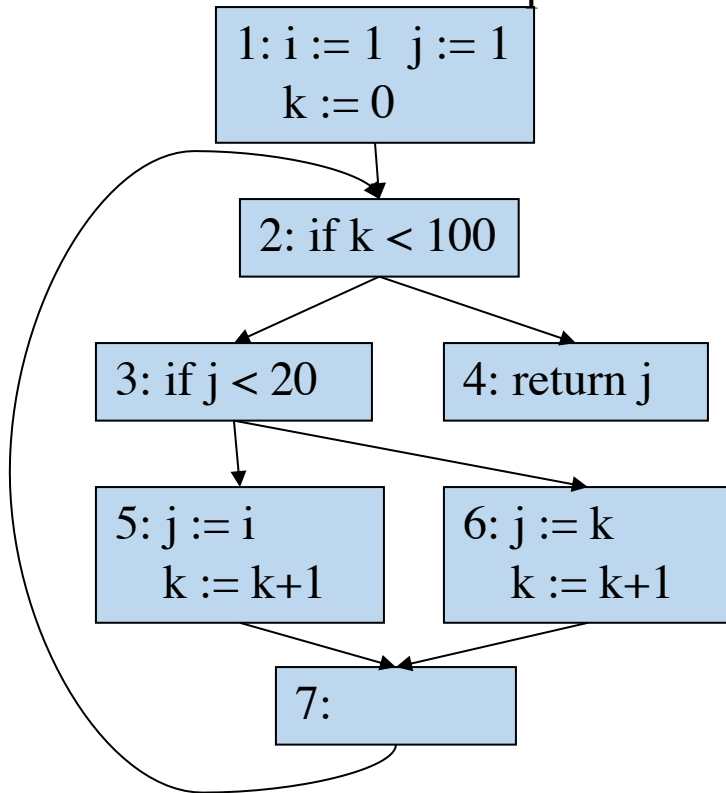
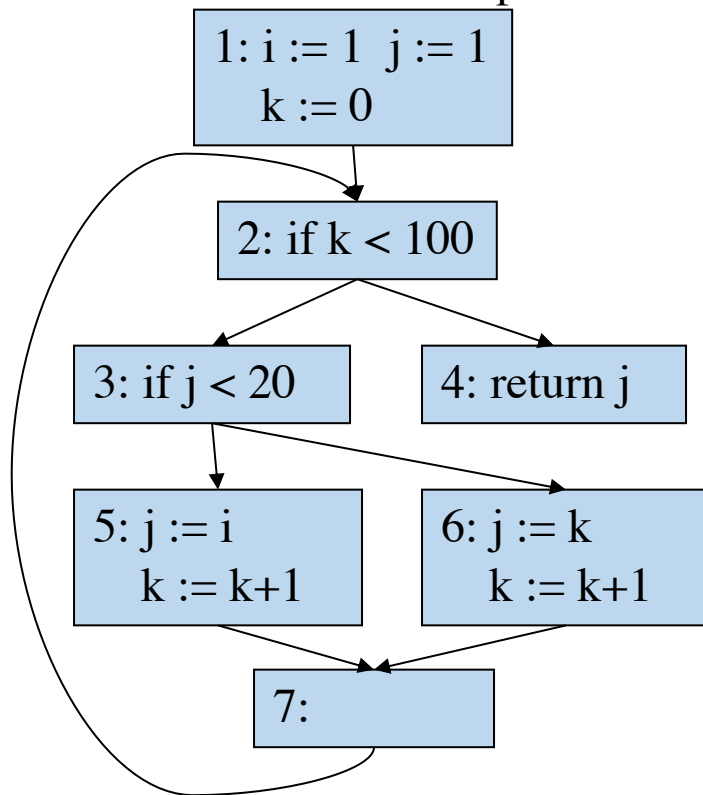## Dominance Relations

- D(1) = {2,3,4,5,6,7}
- D(2) = {3,4,5,6,7}
- D(3) = {5,6,7}
- D(4) = {}
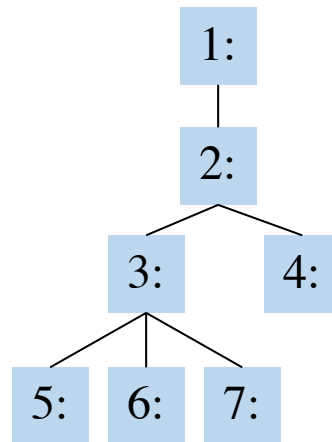- D(5) = {}
- D(6) = {}
- D(7) = {}

Converting to SSA Form

Control Flow Graph

1: i := 1 j := 1
   k := 0

2: if k < 100

3: if j < 20

4: return j

5: j := i
   k := k+1

6: j := k
   k := k+1

7:

Dominance Relations
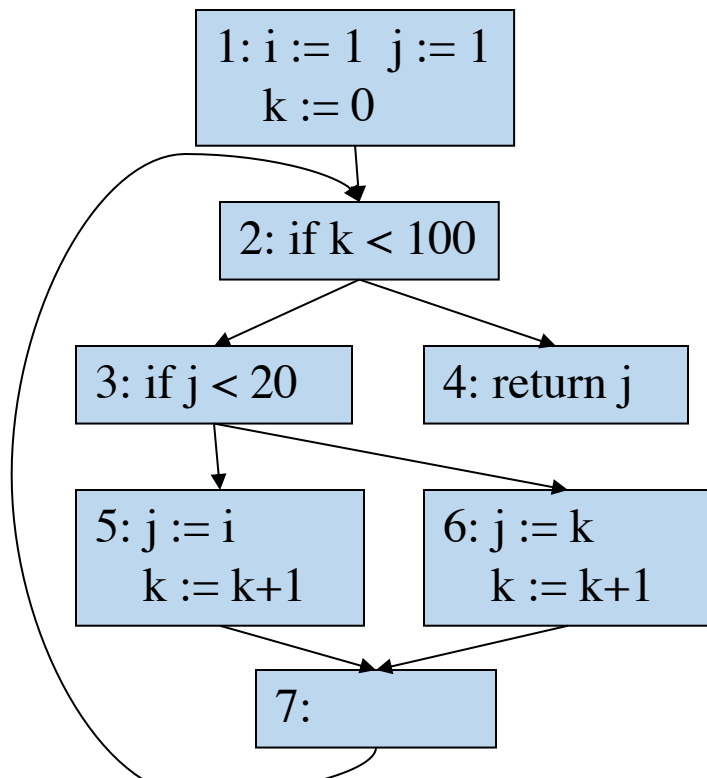
- D(1) = {2,3,4,5,6,7}
- D(2) = {3,4,5,6,7}
- D(3) = {5,6,7}
- D(4) = {}
- D(5) = {}
- D(6) = {}
- D(7) = {}

Dominator Tree

1:

2:

3:

4:

5:

6:

7:

Converting to SSA Form

Control Flow Graph

```
┌─────────────────────┐
│ 1: i := 1  j := 1   │
│      k := 0         │
└─────────────────────┘
           │
           ▼
   ┌───────────────┐
   │ 2: if k < 100 │
   └───────────────┘
       │        │
       ▼        ▼
┌────────────┐  ┌──────────────┐
│ 3: if j < 20│  │ 4: return j  │
└────────────┘  └──────────────┘
     │      
     ▼        
┌───────────┐  ┌───────────┐
│ 5: j := i │  │ 6: j := k │
│   k := k+1│  │   k := k+1│
└───────────┘  └───────────┘
       │          │
       └────┬─────┘
            ▼
      ┌──────────┐
      │ 7:       │
      └──────────┘
```
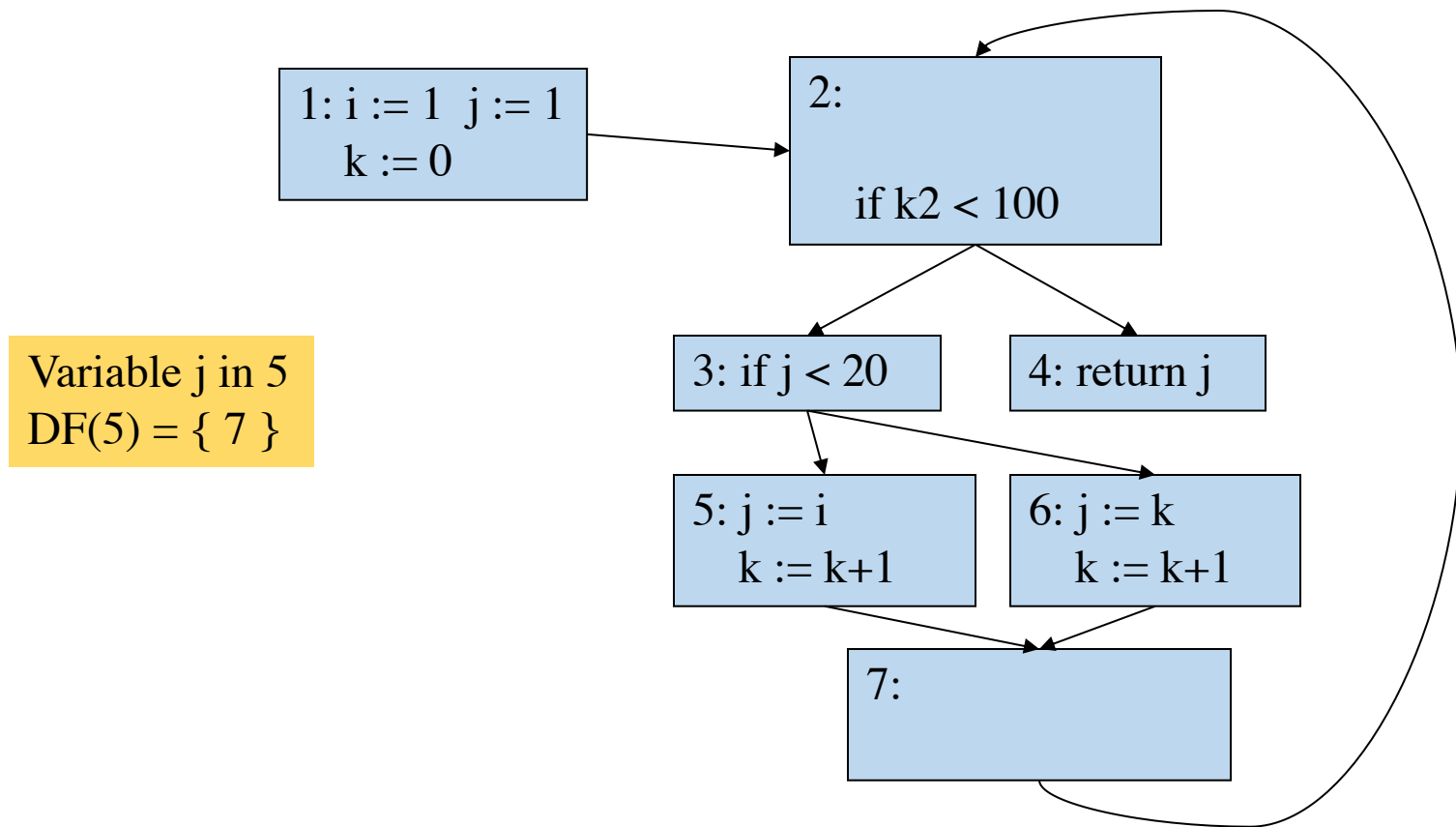
Dominance Relations

- D(1) = {2,3,4,5,6,7}
- D(2) = {3,4,5,6,7}
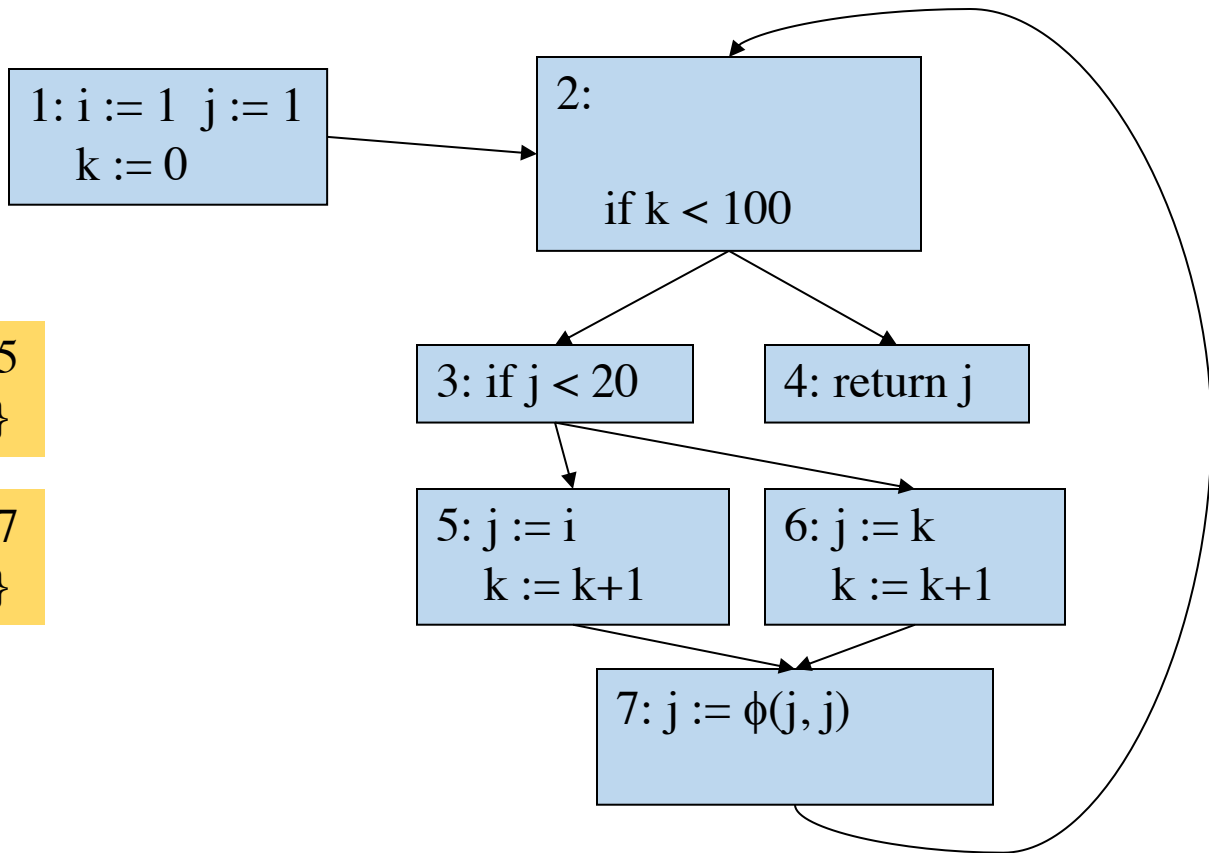- D(3) = {5,6,7}
- D(4) = {}
- D(5) = {}
- D(6) = {}
- D(7) = {}

Dominance Frontier

- DF(1) = {}
- DF(2) = {2}
- DF(3) = {2}
- DF(4) = {}
- DF(5) = {7}
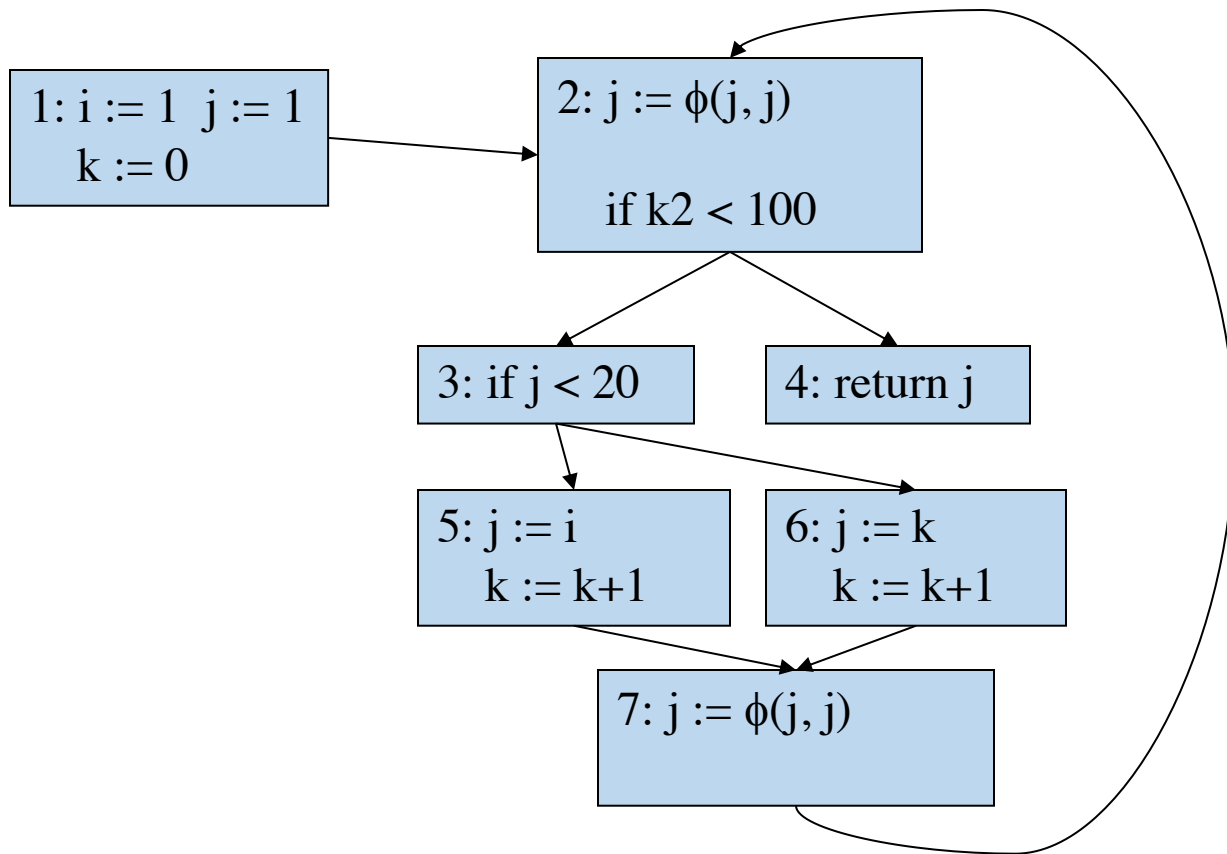- DF(6) = {7}
- DF(7) = {2}

5

Converting to SSA Form

1: i := 1 j := 1
   k := 0

2:

   if k2 < 100

3: if j < 20

4: return j

5: j := i
   k := k+1

6: j := k
   k := k+1

7:

Variable j in 5
DF(5) = { 7 }

Converting to SSA Form

Variable j in 5
DF(5) = { 7 }

Variable j in 7
DF(7) = { 2 }

1: i := 1 j := 1
   k := 0

2:

   if k < 100

3: if j < 20

4: return j

5: j := i
   k := k+1

6: j := k
   k := k+1

7: j := φ(j, j)

Converting to SSA Form

Variable j in 5
DF(5) = { 7 }

Variable j in 7
DF(7) = { 2 }

Variable j in 6
DF(6) = { 7 }

1: i := 1 j := 1
    k := 0

2: j := ϕ(j, j)

    if k2 < 100

3: if j < 20

4: return j

5: j := i
    k := k+1

6: j := k
    k := k+1

7: j := ϕ(j, j)

Converting to SSA Form

1: i := 1 j := 1
     k := 0

2: j := φ(j, j)
     k := φ(k,k)
     if k2 < 100

3: if j < 20

4: return j

5: j := i
     k := k+1

6: j := k
     k := k+1

7: j := φ(j, j)
     k := φ(k,k)
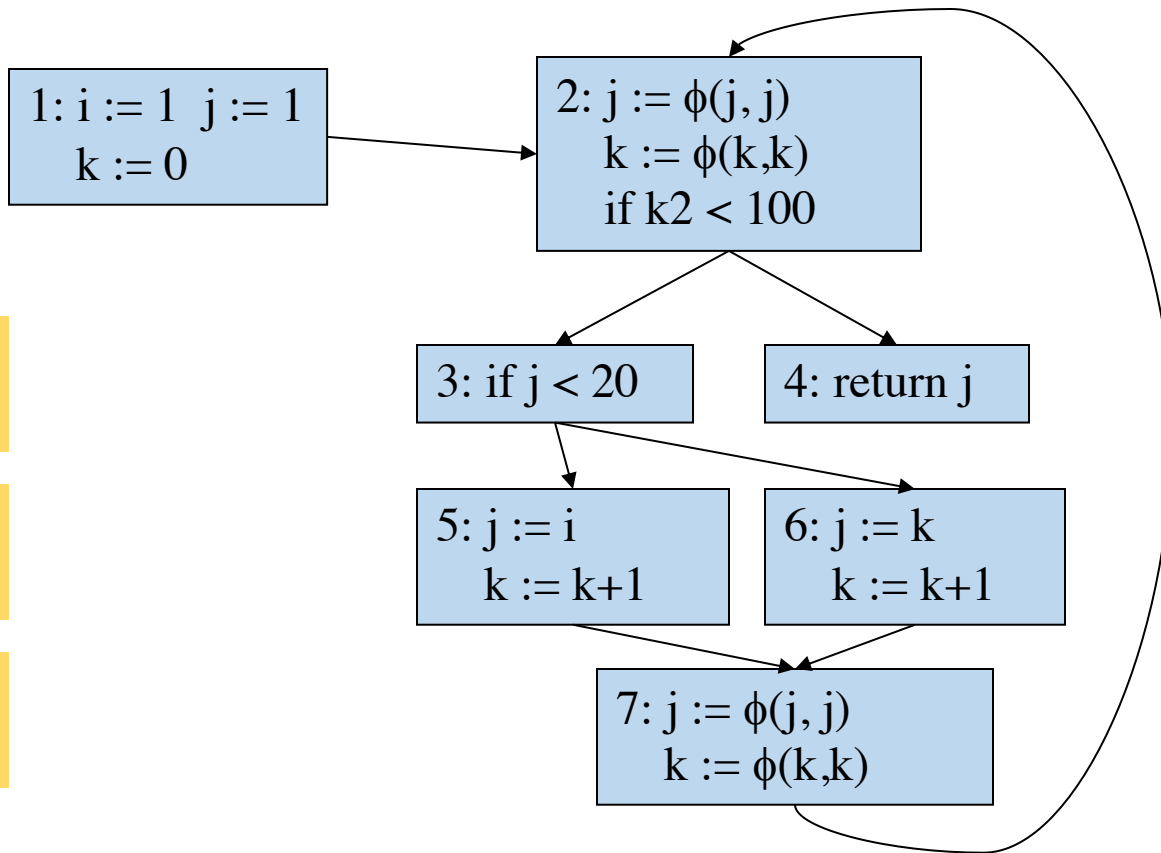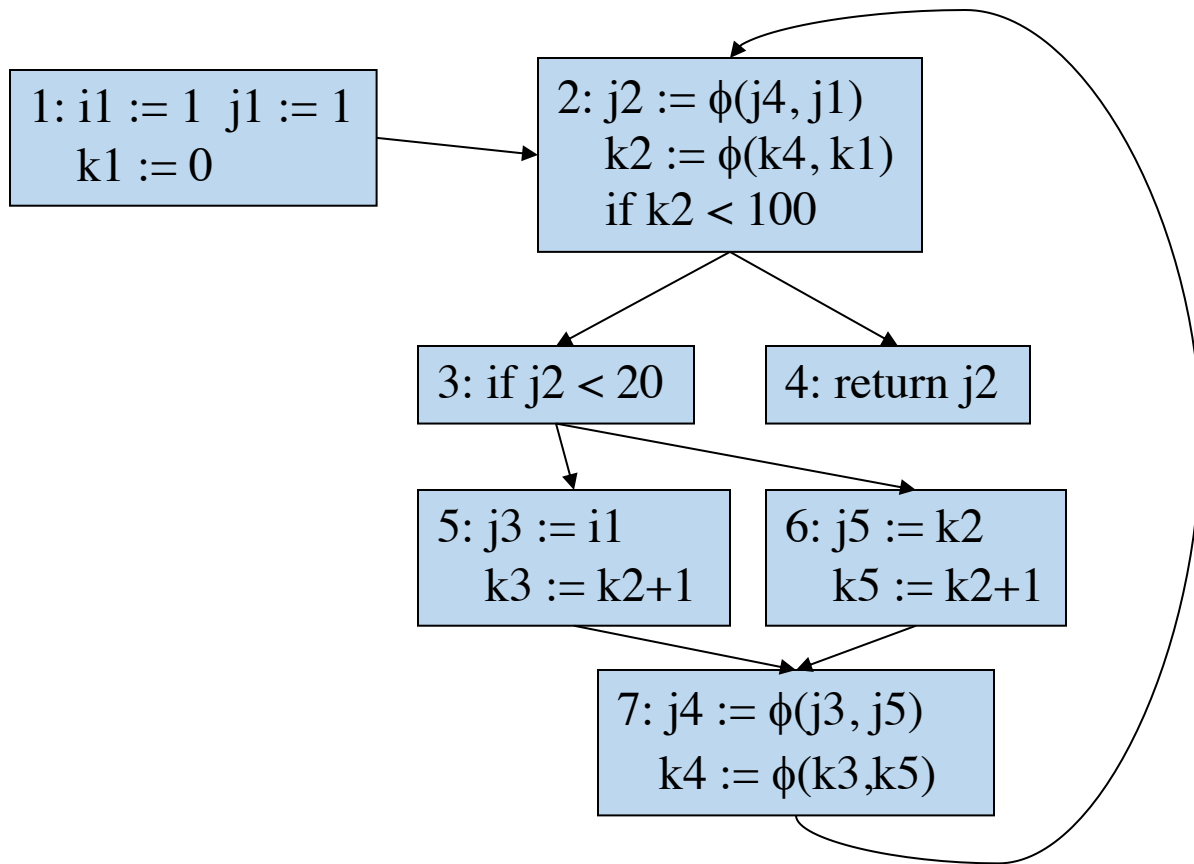
Variable k in 5
DF(5) = { 7 }

Variable k in 7
DF(7) = { 2 }

Variable k in 6
DF(6) = { 7 }

Converting to SSA Form

1: i1 := 1 j1 := 1
    k1 := 0
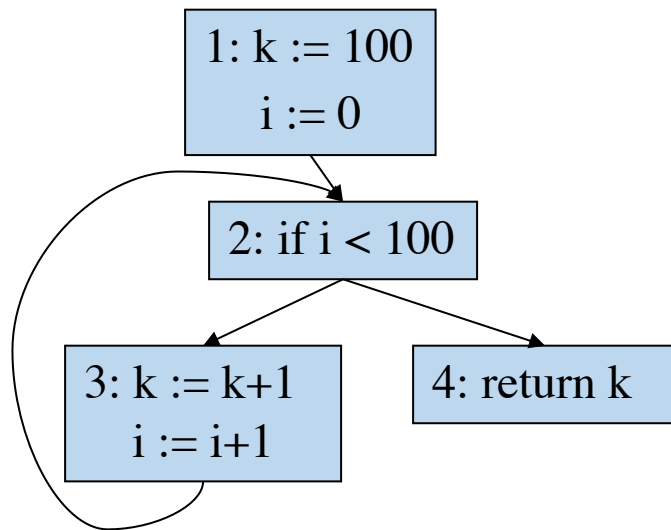
2: j2 := ϕ(j4, j1)
    k2 := ϕ(k4, k1)
    if k2 < 100

3: if j2 < 20

4: return j2

5: j3 := i1
    k3 := k2+1

6: j5 := k2
    k5 := k2+1

7: j4 := ϕ(j3, j5)
    k4 := ϕ(k3,k5)

Converting to SSA Form

Program

k:=100
i:=0
while
i<100:
    k:=k+1
    i:=i+1
return k

Control Flow Graph

1: k := 100
i := 0

2: if i < 100

3: k := k+1
i := i+1

4: return k

Dominance Relations
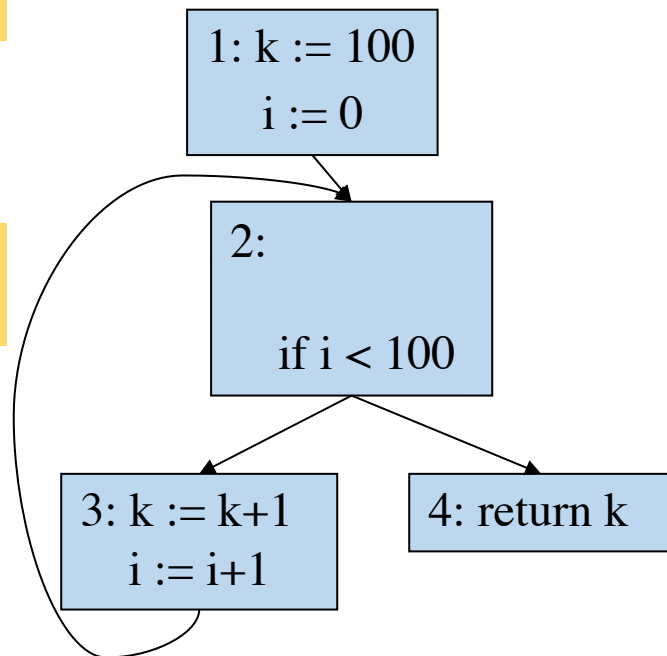
- D(1) = {2,3,4}
- D(2) = {3,4}
- D(3) = {}
- D(4) = {}

Dominance Frontier

- DF(1) = {}
- DF(2) = {2}
- DF(3) = {2}
- DF(4) = {}

Converting to SSA Form

Control Flow Graph

Variable i,k in 1
DF(1) = {}

Variable i in 2
DF(2) = {2}

Variable i,k in 3
DF(3) = {2}

Variable k in 4
DF(4) = {}

```
1: k := 100
    i := 0
```

```
2:

    if i < 100
```
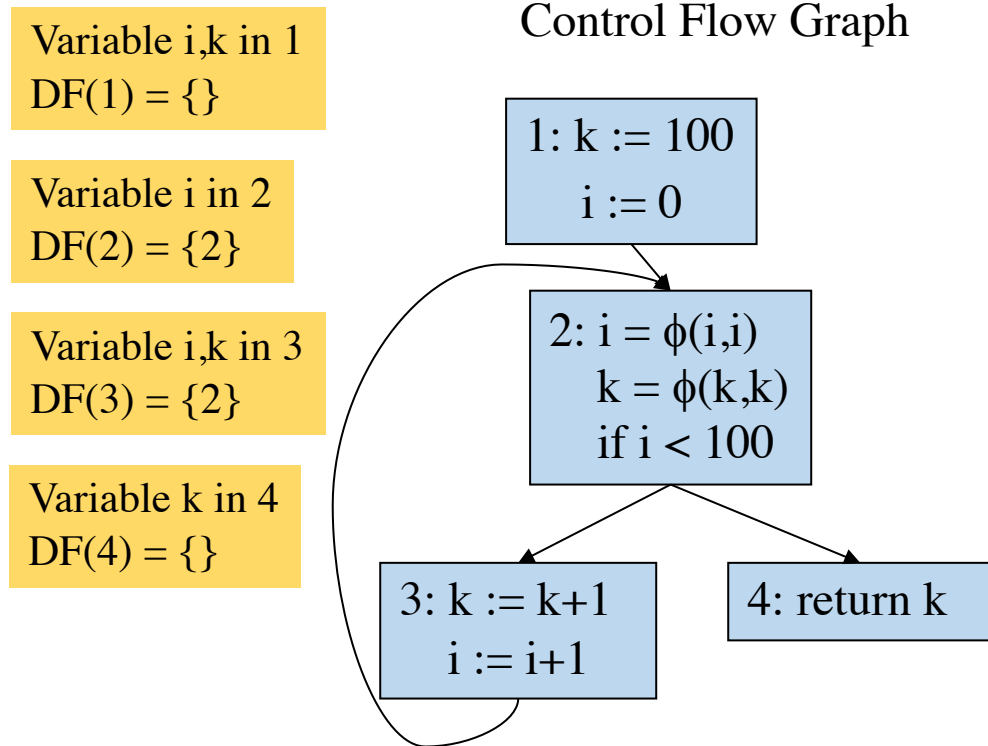
```
3: k := k+1
    i := i+1
```

```
4: return k
```

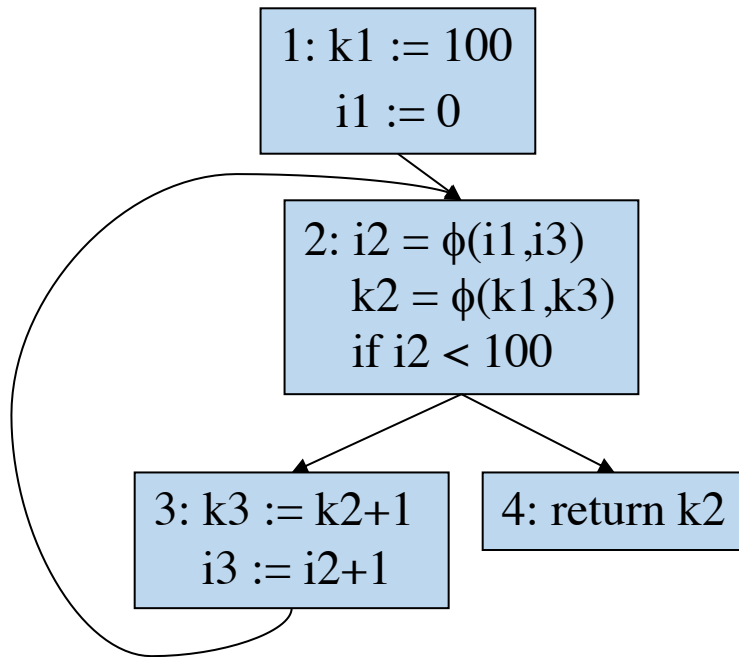## Dominance Relations

- D(1) = {2,3,4}
- D(2) = {3,4}
- D(3) = {}
- D(4) = {}

Dominance Frontier

- DF(1) = {}
- DF(2) = {2}
- DF(3) = {2}
- DF(4) = {}

Converting to SSA Form

Dominance Relations

- D(1) = {2,3,4}
- D(2) = {3,4}
- D(3) = {}
- D(4) = {}

Control Flow Graph

Variable i,k in 1
DF(1) = {}

Variable i in 2
DF(2) = {2}

Variable i,k in 3
DF(3) = {2}

Variable k in 4
DF(4) = {}

```
1: k := 100
   i := 0
```

```
2: i = φ(i,i)
   k = φ(k,k)
   if i < 100
```

```
3: k := k+1
   i := i+1
```

```
4: return k
```

Dominance Frontier

- DF(1) = {}
- DF(2) = {2}
- DF(3) = {2}
- DF(4) = {}

Converting to SSA Form

Extra Slides

entry

1: i := 1
j := 2
k := 10

2: if i < k goto 3

3: i := i + 1
j := j * 2

4: if j > k*10 goto 5

5: print j

6: i := i + 1
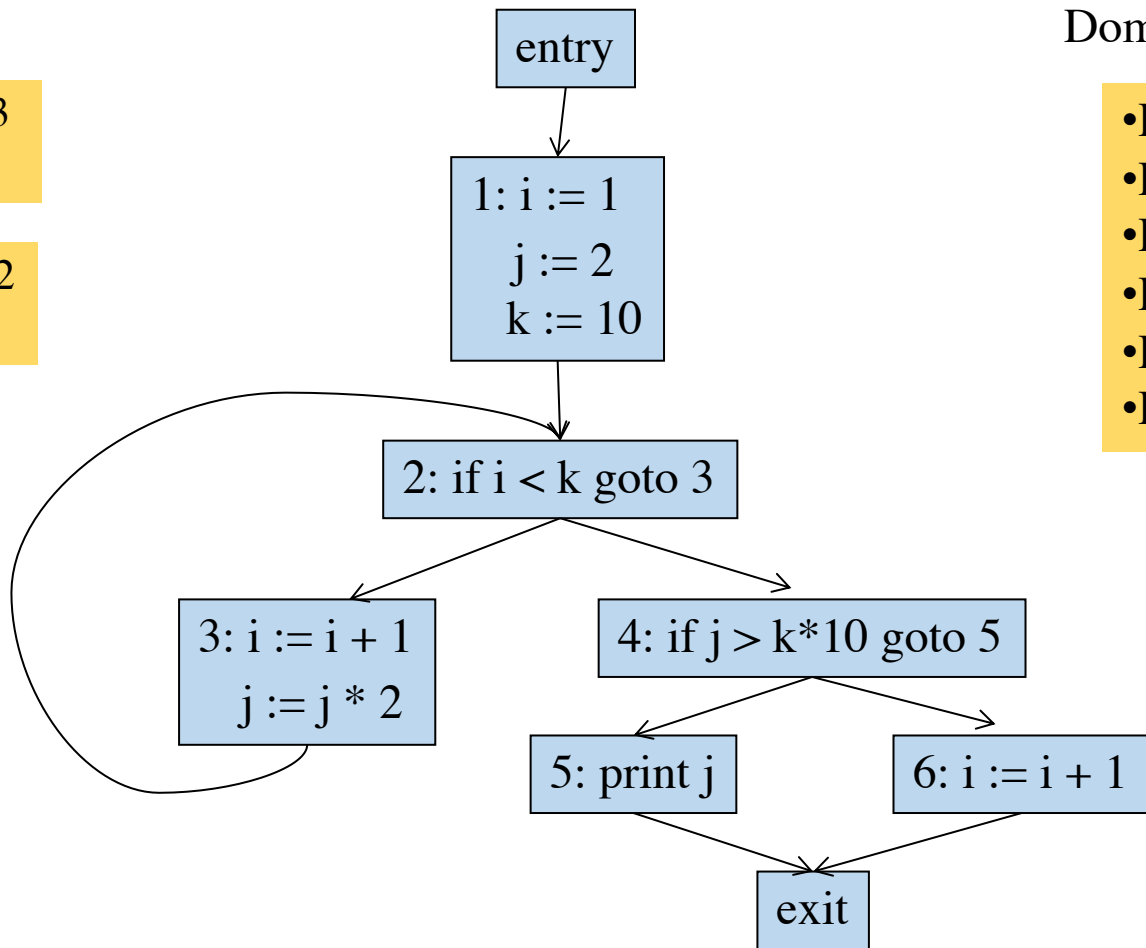
exit

Variable i,j in 3
DF(3) = {2}

Variable i,k in 2
DF(2) = {2}

Dominance Relations

- D(1) = {2,3,4,5,6}
- D(2) = {3,4,5,6}
- D(3) = {}
- D(4) = {5,6}
- D(5) = {}
- D(6) = {}

Dominance Frontier

- DF(1) = {}
- DF(2) = {2}
- DF(3) = {2}
- DF(4) = {}
- DF(5) = {}
- DF(6) = {}

entry

1: k1 := 10
   i1 := 1
   j1 := 2

Variable i,j in 3
DF(3) = {2}

Variable i,k in 2
DF(2) = {2}

2: i2 := ϕ(i1,i3)
    j2 := ϕ(j1,j3)
    k1:= ϕ(k1,k1)
    if i2 < k1 goto 3

can be removed

3: i3 := i2 + 1
   j3 := j2 * 2

4: if j2 > k1*10 goto 5

5: print j2

6: i4 := i2 + 1

exit