

Homework 11

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Exercise 1

针对第十二讲代码优化 (2) P31 上流图, 计算到达-定值数据流方程, 并给出相应的 ud 链。

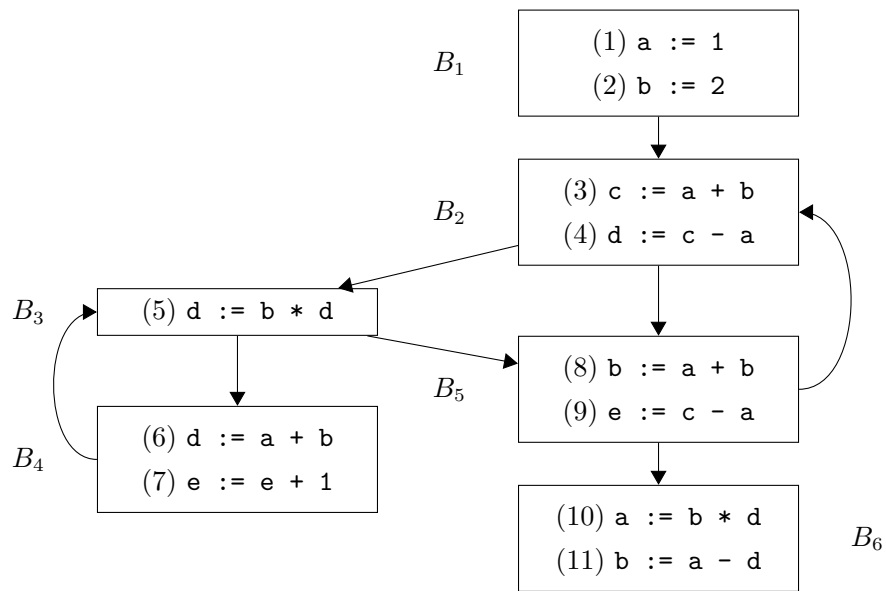


图 1: 第十二讲代码优化 (2) P31 上流图

解 首先给出每个基本块的 *gen* 和 *kill* 集合

基本块	gen	$kill$
B_1	$gen_1 = \{1, 2\}$	$kill_1 = \{8, 10, 11\}$
B_2	$gen_2 = \{3, 4\}$	$kill_2 = \{5, 6\}$
B_3	$gen_3 = \{5\}$	$kill_3 = \{4, 6\}$
B_4	$gen_4 = \{6, 7\}$	$kill_4 = \{4, 5, 9\}$
B_5	$gen_5 = \{8, 9\}$	$kill_5 = \{2, 7, 11\}$
B_6	$gen_6 = \{10, 11\}$	$kill_6 = \{1, 2, 8\}$

初始值

$$IN[B_1] = IN[B_2] = IN[B_3] = IN[B_4] = IN[B_5] = IN[B_6] = \emptyset$$

$$OUT[B_1] = gen_1 = \{1, 2\}$$

$$OUT[B_2] = gen_2 = \{3, 4\}$$

$$OUT[B_3] = gen_3 = \{5\}$$

$$OUT[B_4] = gen_4 = \{6, 7\}$$

$$OUT[B_5] = gen_5 = \{8, 9\}$$

$$OUT[B_6] = gen_6 = \{10, 11\}$$

第一次迭代

$$IN[B_1] = \emptyset$$

$$OUT[B_1] = gen_1 \cup (IN[B_1] - kill_1) = gen_1 = \{1, 2\}$$

$$IN[B_2] = OUT[B_1] \cup OUT[B_5] = \{1, 2, 8, 9\}$$

$$OUT[B_2] = gen_2 \cup (IN[B_2] - kill_2) = \{3, 4\} \cup \{1, 2, 8, 9\} = \{1, 2, 3, 4, 8, 9\}$$

$$IN[B_3] = OUT[B_2] \cup OUT[B_4] = \{1, 2, 3, 4, 6, 7, 8, 9\}$$

$$OUT[B_3] = gen_3 \cup (IN[B_3] - kill_3) = \{5\} \cup \{1, 2, 3, 7, 8, 9\} = \{1, 2, 3, 5, 7, 8, 9\}$$

$$IN[B_4] = OUT[B_3] = \{1, 2, 3, 5, 7, 8, 9\}$$

$$OUT[B_4] = gen_4 \cup (IN[B_4] - kill_4) = \{6, 7\} \cup \{1, 2, 3, 7, 8\} = \{1, 2, 3, 6, 7, 8\}$$

$$IN[B_5] = OUT[B_2] \cup OUT[B_3] = \{1, 2, 3, 4, 5, 7, 8, 9\}$$

$$OUT[B_5] = gen_5 \cup (IN[B_5] - kill_5) = \{8, 9\} \cup \{1, 3, 4, 5, 8, 9\} = \{1, 3, 4, 5, 8, 9\}$$

$$IN[B_6] = OUT[B_5] = \{1, 3, 4, 5, 8, 9\}$$

$$OUT[B_6] = gen_6 \cup (IN[B_6] - kill_6) = \{10, 11\} \cup \{3, 4, 5, 9\} = \{3, 4, 5, 9, 10, 11\}$$

第二次迭代

$$\begin{aligned}
\text{IN}[B_1] &= \emptyset \\
\text{OUT}[B_1] &= \text{gen}_1 \cup (\text{IN}[B_1] - \text{kill}_1) = \text{gen}_1 = \{1, 2\} \\
\text{IN}[B_2] &= \text{OUT}[B_1] \cup \text{OUT}[B_5] = \{1, 2, 3, 4, 5, 8, 9\} \\
\text{OUT}[B_2] &= \text{gen}_2 \cup (\text{IN}[B_2] - \text{kill}_2) = \{3, 4\} \cup \{1, 2, 3, 4, 8, 9\} = \{1, 2, 3, 4, 8, 9\} \\
\text{IN}[B_3] &= \text{OUT}[B_2] \cup \text{OUT}[B_4] = \{1, 2, 3, 4, 6, 7, 8, 9\} \\
\text{OUT}[B_3] &= \text{gen}_3 \cup (\text{IN}[B_3] - \text{kill}_3) = \{5\} \cup \{1, 2, 3, 7, 8, 9\} = \{1, 2, 3, 5, 7, 8, 9\} \\
\text{IN}[B_4] &= \text{OUT}[B_3] = \{1, 2, 3, 5, 7, 8, 9\} \\
\text{OUT}[B_4] &= \text{gen}_4 \cup (\text{IN}[B_4] - \text{kill}_4) = \{6, 7\} \cup \{1, 2, 3, 7, 8\} = \{1, 2, 3, 6, 7, 8\} \\
\text{IN}[B_5] &= \text{OUT}[B_2] \cup \text{OUT}[B_3] = \{1, 2, 3, 4, 5, 7, 8, 9\} \\
\text{OUT}[B_5] &= \text{gen}_5 \cup (\text{IN}[B_5] - \text{kill}_5) = \{8, 9\} \cup \{1, 3, 4, 5, 8, 9\} = \{1, 3, 4, 5, 8, 9\} \\
\text{IN}[B_6] &= \text{OUT}[B_5] = \{1, 3, 4, 5, 8, 9\} \\
\text{OUT}[B_6] &= \text{gen}_6 \cup (\text{IN}[B_6] - \text{kill}_6) = \{10, 11\} \cup \{3, 4, 5, 9\} = \{3, 4, 5, 9, 10, 11\}
\end{aligned}$$

迭代终止。ud 链如下

- (3)(4)(6)(8)(9) 中 a 的引用的 ud 链为 (1)a := 1; (11) 中 a 的引用的 ud 链为 (10)a := b * d
- (3)(5)(6)(8) 中 b 的引用的 ud 链为 (2)b := 2, (10) 中 b 的引用的 ud 链为 (8)b := a + b
- (4)(9) 中 c 引用的 ud 链为 (3)c := a + b
- (5) 中 d 引用的 ud 链为 (6)d := a + b (4)d := c - a; (6) 中 d 引用的 ud 链为 (5)d := b * d; (10)(11) 中 d 引用的 ud 链为 (4)d := c - a (5)d := b * d
- (7) 中 e 引用的 ud 链为 (7)e := e + 1 (9)e := c - a

Exercise 2

针对以下 C 函数，给出其函数体三地址码，流图及自然循环。

```
#define N 32
```

```

int a[N], b[N];
int arr[N + 1][N + 1];

void lcs()
{
    for (i = 1; i <= length1; ++i)
    {
        for (j = 1; j <= length2; ++j)
        {
            if (a[i - 1] == b[j - 1]) // 串中的下标从 0 开始
            {
                arr[i][j] = arr[i - 1][j - 1] + 1;
            }
            else
            {
                arr[i][j] = arr[i - 1][j] > arr[i][j - 1] ? arr[i - 1][j] :
                    arr[i][j - 1];
            }
        }
    }
}

```

解 首先给出三地址中间代码结构

```

i = 1
L1: t1 = a - 128
    t2 = b - 128
L2: j = 1
    t3 = i - 1
    t4 = j - 1
    t5 = t1[t3]
    t6 = t2[t4]
    t8 = arr - 132
    t7 = i * 33
    t7 = t7 + j
    t7 = t7 * 4
    if t5 != t6 goto L3

```

```

    t9 = t3 * 33
    t9 = t9 + t4
    t9 = t9 * 4
    t10 = t8[t9]
    t10 = t10 + 1
    t8[t7] = t10
    goto L5
L3: t11 = i - 1
    t11 = t11 * 33
    t11 = t11 + j
    t11 = t11 * 4
    t12 = i * 33
    t12 = t12 + j
    t12 = t12 - 1
    t12 = t12 * 4
    t13 = t8[t11]
    t14 = t8[t12]
    if t13 <= t14 goto L4
L4: t8[t7] = t11
    goto L5
    t8[t7] = t12
L5: j = j + 1
    if j <= length2 goto L2
    i = i + 1
    if i <= length1 goto L1

```

据此构建流图，并列出自然循环：

- 回边 $B_8 \rightarrow B_3$ ：循环 $B_3, B_4, B_5, B_6, B_7, B_8$
- 回边 $B_9 \rightarrow B_2$ ：循环 $B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9$

