Homework 11

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November 18 2019

Exercise 1

针对第十二讲代码优化（2）P55 上流图，计算活跃变量数据流方程。

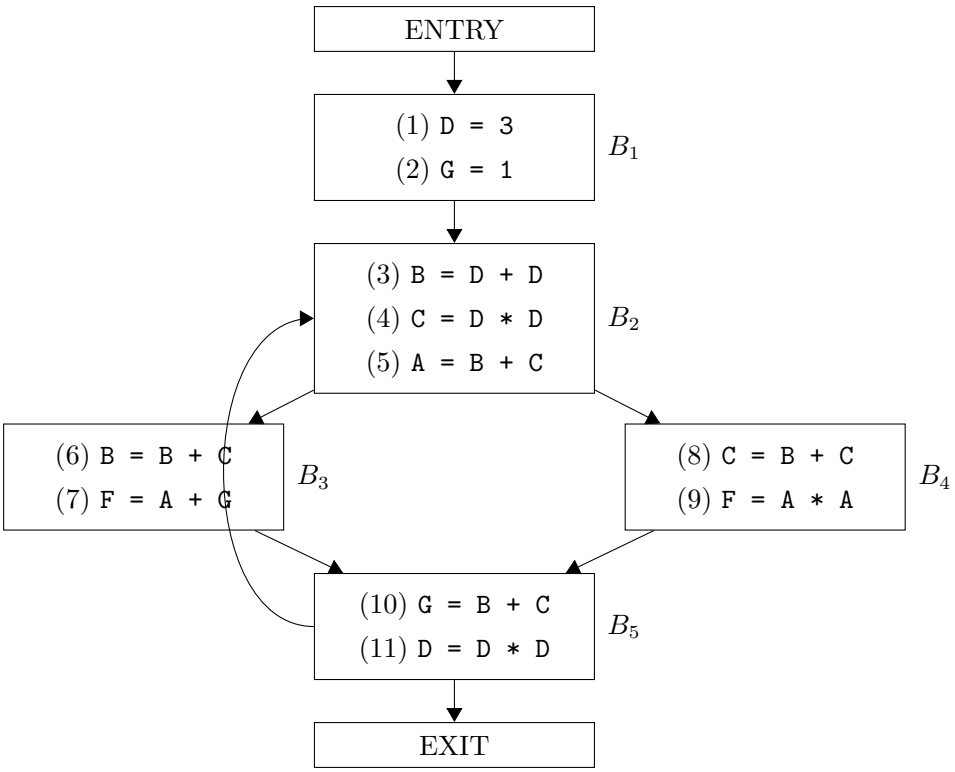

图 1: 第十二讲代码优化（2）P55 上流图

解 首先给出每个基本块的 use 和 def 集合

基本块	use	def
B_1	$use_1 = \{1, 2\}$	$def_1 = \{8, 10, 11\}$
B_2	$use_2 = \{3, 4\}$	$def_2 = \{5, 6\}$
B_3	$use_3 = \{5\}$	$def_3 = \{4, 6\}$
B_4	$use_4 = \{6, 7\}$	$def_4 = \{4, 5, 9\}$
B_5	$use_5 = \{8, 9\}$	$def_5 = \{2, 7, 11\}$

初始值

$$\mathrm{IN}[B_1] = \mathrm{IN}[B_2] = \mathrm{IN}[B_3] = \mathrm{IN}[B_4] = \mathrm{IN}[B_5] = \mathrm{IN}[B_6] = \varnothing$$
$$\mathrm{OUT}[B_1] = use_1 = \{1, 2\}$$
$$\mathrm{OUT}[B_2] = use_2 = \{3, 4\}$$
$$\mathrm{OUT}[B_3] = use_3 = \{5\}$$
$$\mathrm{OUT}[B_4] = use_4 = \{6, 7\}$$
$$\mathrm{OUT}[B_5] = use_5 = \{8, 9\}$$
$$\mathrm{OUT}[B_6] = use_6 = \{10, 11\}$$

第一次迭代

$$\mathrm{IN}[B_1] = \varnothing$$
$$\mathrm{OUT}[B_1] = use_1 \cup (\mathrm{IN}[B_1] - def_1) = use_1 = \{1, 2\}$$
$$\mathrm{IN}[B_2] = \mathrm{OUT}[B_1] \cup \mathrm{OUT}[B_5] = \{1, 2, 8, 9\}$$
$$\mathrm{OUT}[B_2] = use_2 \cup (\mathrm{IN}[B_2] - def_2) = \{3, 4\} \cup \{1, 2, 8, 9\} = \{1, 2, 3, 4, 8, 9\}$$
$$\mathrm{IN}[B_3] = \mathrm{OUT}[B_2] \cup \mathrm{OUT}[B_4] = \{1, 2, 3, 4, 6, 7, 8, 9\}$$
$$\mathrm{OUT}[B_3] = use_3 \cup (\mathrm{IN}[B_3] - def_3) = \{5\} \cup \{1, 2, 3, 7, 8, 9\} = \{1, 2, 3, 5, 7, 8, 9\}$$
$$\mathrm{IN}[B_4] = \mathrm{OUT}[B_3] = \{1, 2, 3, 5, 7, 8, 9\}$$
$$\mathrm{OUT}[B_4] = use_4 \cup (\mathrm{IN}[B_4] - def_4) = \{6, 7\} \cup \{1, 2, 3, 7, 8\} = \{1, 2, 3, 6, 7, 8\}$$
$$\mathrm{IN}[B_5] = \mathrm{OUT}[B_2] \cup \mathrm{OUT}[B_3] = \{1, 2, 3, 4, 5, 7, 8, 9\}$$
$$\mathrm{OUT}[B_5] = use_5 \cup (\mathrm{IN}[B_5] - def_5) = \{8, 9\} \cup \{1, 3, 4, 5, 8, 9\} = \{1, 3, 4, 5, 8, 9\}$$
$$\mathrm{IN}[B_6] = \mathrm{OUT}[B_5] = \{1, 3, 4, 5, 8, 9\}$$
$$\mathrm{OUT}[B_6] = use_6 \cup (\mathrm{IN}[B_6] - def_6) = \{10, 11\} \cup \{3, 4, 5, 9\} = \{3, 4, 5, 9, 10, 11\}$$

第二次迭代

$$
\begin{aligned}
&\mathrm{IN}[B_1] = \varnothing \\
&\mathrm{OUT}[B_1] &&= use_1 \cup (\mathrm{IN}[B_1] - def_1) && = use_1 && = \{1,2\} \\
&\mathrm{IN}[B_2] &&= \mathrm{OUT}[B_1] \cup \mathrm{OUT}[B_5] && && = \{1,2,3,4,5,8,9\} \\
&\mathrm{OUT}[B_2] &&= use_2 \cup (\mathrm{IN}[B_2] - def_2) && = \{3,4\} \cup \{1,2,3,4,8,9\} && = \{1,2,3,4,8,9\} \\
&\mathrm{IN}[B_3] &&= \mathrm{OUT}[B_2] \cup \mathrm{OUT}[B_4] && && = \{1,2,3,4,6,7,8,9\} \\
&\mathrm{OUT}[B_3] &&= use_3 \cup (\mathrm{IN}[B_3] - def_3) && = \{5\} \cup \{1,2,3,7,8,9\} && = \{1,2,3,5,7,8,9\} \\
&\mathrm{IN}[B_4] &&= \mathrm{OUT}[B_3] && && = \{1,2,3,5,7,8,9\} \\
&\mathrm{OUT}[B_4] &&= use_4 \cup (\mathrm{IN}[B_4] - def_4) && = \{6,7\} \cup \{1,2,3,7,8\} && = \{1,2,3,6,7,8\} \\
&\mathrm{IN}[B_5] &&= \mathrm{OUT}[B_2] \cup \mathrm{OUT}[B_3] && && = \{1,2,3,4,5,7,8,9\} \\
&\mathrm{OUT}[B_5] &&= use_5 \cup (\mathrm{IN}[B_5] - def_5) && = \{8,9\} \cup \{1,3,4,5,8,9\} && = \{1,3,4,5,8,9\} \\
&\mathrm{IN}[B_6] &&= \mathrm{OUT}[B_5] && && = \{1,3,4,5,8,9\} \\
&\mathrm{OUT}[B_6] &&= use_6 \cup (\mathrm{IN}[B_6] - def_6) && = \{10,11\} \cup \{3,4,5,9\} && = \{3,4,5,9,10,11\}
\end{aligned}
$$

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`