

CS 5130 Homework II

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From Computer Science

1. Answer the following questions related to reaching definitions analysis for the CFG

(a) Give the GEN and PRSV sets for each basic block

$U = \{r1@1, r10@2, r2@3, r11@4, r3@5, r15@6, r4@7, r13@8, r5@9, r14@10, r6@12, r14@13, r4@15, r14@16, r1@17, r7@18, r15@19, r4@21, r11@22, r5@23, r15@24, r6@26, r10@27, r8@28, r11@29\}$

BB	GEN	PRSV
B0	$r1@1, r10@2, r2@3, r11@4, r3@5$	$r15@6, r4@7, r13@8, r5@9, r14@10, r6@12, r14@13, r4@15, r14@16, r7@18, r15@19, r4@21, r5@23, r15@24, r6@26, r10@27, r8@28$
B1	$r15@6, r4@7, r13@8, r5@9, r14@10$	$r1@1, r10@2, r2@3, r11@4, r3@5, r6@12, r1@17, r7@18, r11@22, r6@26, r10@27, r8@28, r11@29$
B2	$r6@12, r14@13$	$r1@1, r10@2, r2@3, r11@4, r3@5, r15@6, r4@7, r13@8, r5@9, r4@15, r1@17, r7@18, r15@19, r4@21, r11@22, r5@23, r15@24, r10@27, r8@28, r11@29$
B3	$r4@15, r14@16, r1@17, r7@18, r15@19$	$r10@2, r2@3, r3@5, r13@8, r5@9, r14@10, r6@12, r14@13, r5@23, r6@26, r10@27, r8@28$
B4	$r4@21, r11@22, r5@23, r15@24$	$r1@1, r10@2, r2@3, r3@5, r13@8, r14@10, r6@12, r14@13, r14@16, r1@17, r7@18, r6@26, r10@27, r8@28$
B5	$r6@26, r10@27, r8@28, r11@29$	$r1@1, r2@3, r3@5, r15@6, r4@7, r13@8, r5@9, r14@10, r14@13, r4@15, r14@16, r1@17, r7@18, r15@19, r4@21, r5@23, r15@24$

(b)

Init.(iter.0)

$IN(b) = \emptyset, OUT(b) = Gen(b) \cup (IN(b) \cap PRSV(b)) = Gen(b)$

BB	IN	OUT
B0	\emptyset	$r1@1, r10@2, r2@3, r11@4, r3@5$
B1	\emptyset	$r15@6, r4@7, r13@8, r5@9, r14@10$
B2	\emptyset	$r6@12, r14@13$
B3	\emptyset	$r4@15, r14@16, r1@17, r7@18, r15@19$
B4	\emptyset	$r4@21, r11@22, r5@23, r15@24$
B5	\emptyset	$r6@26, r10@27, r8@28, r11@29$

iter.1

$IN(b) = \bigcup_{p \in pred(b)} OUT(p)$

$OUT(b) = Gen(b) \cup (IN(b) \cap PRSV(b)) = Gen(b)$

BB	IN	OUT
B0	\emptyset	$r1@1, r10@2, r2@3, r11@4, r3@5$
B1	$r1@1, r10@2, r2@3, r11@4, r3@5, r4@21, r11@22, r5@23, r15@24$	$r1@1, r10@2, r2@3, r11@4, r3@5, r15@6, r4@7, r13@8, r5@9, r14@10, r11@22$
B2	$r1@1, r10@2, r2@3, r11@4, r3@5, r15@6, r4@7, r13@8, r5@9, r14@10, r4@15, r14@16, r1@17, r7@18, r15@19, r11@22$	$r1@1, r10@2, r2@3, r11@4, r3@5, r15@6, r4@7, r13@8, r5@9, r6@12, r14@13, r4@15, r1@17, r7@18, r15@19, r11@22$
B3	$r1@1, r10@2, r2@3, r11@4, r3@5, r15@6, r4@7, r13@8, r5@9, r6@12, r14@13, r4@15, r1@17, r7@18, r15@19, r11@22$	$r10@2, r2@3, r3@5, r13@8, r5@9, r6@12, r14@13, r4@15, r14@16, r1@17, r7@18, r15@19$
B4	$r1@1, r10@2, r2@3, r11@4, r3@5, r15@6, r4@7, r13@8, r5@9, r14@10, r6@12, r14@13, r4@15, r1@17, r7@18, r15@19, r11@22$	$r1@1, r10@2, r2@3, r3@5, r13@8, r14@10, r6@12, r14@13, r1@17, r7@18, r4@21, r11@22, r5@23, r15@24$
B5	$r1@1, r10@2, r2@3, r3@5, r13@8, r14@10, r6@12, r14@13, r1@17, r7@18, r4@21, r11@22, r5@23, r15@24$	$r1@1, r2@3, r3@5, r13@8, r14@10, r14@13, r1@17, r7@18, r4@21, r5@23, r15@24, r6@26, r10@27, r8@28, r11@29$

iter.2

$IN(b) = \bigcup_{p \in pred(b)} OUT(p)$

$OUT(b) = Gen(b) \cup (IN(b) \cap PRSV(b)) = Gen(b)$

BB	IN	OUT
B0	\emptyset	r1@1,r10@2,r2@3,r11@4,r3@5
B1	r1@1,r10@2,r2@3,r11@4,r3@5,r13@8,r14@10,r6@12,r14@13 r1@17,r7@18, r4@21,r11@22,r5@23,r15@24	r1@1,r10@2,r2@3,r11@4,r3@5,r15@6,r4@7,r13@8,r5@9, r14@10,r1@17,r7@18,r11@22
B2	r1@1,r10@2,r2@3,r11@4,r3@5,r15@6,r4@7,r13@8,r5@9, r14@10,r6@12,r14@13,r4@15,r14@16,r1@17,r7@18,r15@19,r11@22	r1@1,r10@2,r2@3,r11@4,r3@5,r15@6,r4@7,r13@8,r5@9, r6@12,r14@13,r4@15,r1@17,r7@18,r15@19,r11@22
B3	r1@1,r10@2,r2@3,r11@4,r3@5,r15@6,r4@7,r13@8,r5@9, r6@12,r14@13,r4@15,r1@17,r7@18,r15@19,r11@22	r10@2,r2@3,r3@5,r13@8,r5@9,r6@12, r14@13,r4@15,r14@16,r1@17,r7@18,r15@19
B4	r1@1,r10@2,r2@3,r11@4,r3@5,r15@6,r4@7,r13@8, r5@9,r14@10,r6@12,r14@13,r4@15,r1@17,r7@18,r15@19,r11@22	r1@1,r10@2,r2@3,r3@5,r13@8,r14@10, r6@12,r14@13,r1@17,r7@18,r4@21,r11@22,r5@23,r15@24
B5	r1@1,r10@2,r2@3,r3@5,r13@8,r14@10, r6@12,r14@13,r1@17,r7@18,r4@21,r11@22,r5@23,r15@24	r1@1,r2@3,r3@5,r13@8,r14@10,r14@13, r1@17,r7@18,r4@21,r5@23,r15@24,r6@26,r10@27,r8@28,r11@29

iter.3

No change

(c)

B0 $r1 \Rightarrow r1@1, r2 \Rightarrow r2@3$

B1 $r3 \Rightarrow r3@5, r10 \Rightarrow r10@2, r11 \Rightarrow r11@4orr11@22, r4 \Rightarrow r4@7, r13 \Rightarrow r13@8, r10 \Rightarrow r10@2, r5 \Rightarrow r5@9, r14 \Rightarrow r14@10$

B2 $r11 \Rightarrow r11@4orr11@22, r14 \Rightarrow r14@13, r6 \Rightarrow r6@12, r14 \Rightarrow r14@13$

B3 $r10 \Rightarrow r10@2, r11 \Rightarrow r11@22orr11@4, r4 \Rightarrow r4@15, r15 \Rightarrow r15@19orr15@6, r1 \Rightarrow r1@17, r7 \Rightarrow r7@18$

B4 $r10 \Rightarrow r10@2, r11 \Rightarrow r11@22orr11@4, r4 \Rightarrow r4@21, r13 \Rightarrow r13@8, r10 \Rightarrow r10@2, r5 \Rightarrow r5@23, r15 \Rightarrow r15@24$

B5 $r11 \Rightarrow r11@22, r14 \Rightarrow r14@13, r6 \Rightarrow r6@26, r10 \Rightarrow r10@27, r14 \Rightarrow r14@13, r8 \Rightarrow r8@28$

2. Answer the following questions related to liveness analysis analysis for the CFG

(a) Give the GEN and PRSV sets for each basic block

$U = \{r1, r2, r3, r4, r5, r6, r7, r8, r10, r11, r13, r14, r15\}$

BB	GEN	PRSV
B5	r11,r14	r1,r2,r3,r4,r5,r7,r13,r14,r15
B4	r10,r11,r13	r1,r2,r3,r6,r7,r8,r10,r13,r14
B3	r10,r11,r15	r2,r3,r5,r6,r8,r10,r13
B2	r11,r14	r1,r2,r3,r4,r5,r7,r8,r10,r11,r13,r15
B1	r3,r10,r11	r1,r2,r3,r6,r7,r8,r10,r11
B0	\emptyset	r4,r5,r6,r7,r8,r13,r14,r15

(b) Liveness is a backwards problem, That is because to verify a node is liveness or not we , so we need to take postOrder to analysis it.

(c)

Init.(iter.0)

$OUT(b) = \emptyset, IN(b) = Gen(b) \cup (OUT(b) \cap PRSV(b)) = Gen(b)$

BB	OUT	IN
B5	\emptyset	r11,r14
B4	\emptyset	r10,r11,r13
B3	\emptyset	r10,r11,r15
B2	\emptyset	r11,r14
B1	\emptyset	r3,r19,r11
B0	\emptyset	\emptyset

iter.1

$OUT(b) = \bigcup_{s \in succs(b)} IN(s)$

$IN(b) = Gen(b) \cup (OUT(b) \cap PRSV(b)) = Gen(b)$

BB	OUT	IN
B5	\emptyset	r11,r14
B4	r3,r11,r14,r10	r3,r10,r11,r13,r14
B3	r11,r14	r10,r11,r15
B2	r3,r10,r11,r13,r14,r15	r3,r10,r11,r13,r14,r15
B1	r3,r10,r11,r13,r14,r15	r3,r10,r11
B0	r3,r10,r11	\emptyset

iter.2

$OUT(b) = \bigcup_{s \in succs(b)} IN(s)$

$IN(b) = Gen(b) \cup (OUT(b) \cap PRSV(b)) = Gen(b)$

BB	OUT	IN
B5	\emptyset	r11,r14
B4	r3,r11,r14,r10	r3,r10,r11,r13,r14
B3	r3,r10,r11,r13,r14,r15	r3,r10,r11,r13,r14,r15
B2	r3,r10,r11,r13,r14,r15	r3,r10,r11,r13,r14,r15
B1	r3,r10,r11,r13,r14,r15	r3,r10,r11
B0	r3,r10,r11	\emptyset

iter.3

$$\text{OUT}(b) = \bigcup_{s \in \text{succs}(b)} \text{IN}(s)$$

$$\text{IN}(b) = \text{Gen}(b) \cup (\text{OUT}(b) \cap \text{PRSV}(b)) = \text{Gen}(b)$$

No change

3 living analysis

(a) pointer reference.

if we could know which variable the pointer reference, we can just use this variable instead, however, sometimes we could not verify until run-time, so we need to find all possible variables, the simple ideas is to think it points to all variables.

Assume pointer on the right, GEN need to insert ,PRSV no change, Assume pointer on the left, GEN no change ,PRSV becomes empty set,

(b) procedure calls

Same situations for procedure calls. functions can do anything redene variables, use variables So $\text{DEF}(\text{foo}())$ is \emptyset and $\text{USE}(\text{foo}())$ is \bigcup

4.sinking transformation.

(a)

Sinking is a transformation that move an instruction to its succsor when its result is first needed. So we need make sure the operands of the instruction could not be changed during its node to sinking point, also we need to find where the lvalue of the instruction is first used, then copy the instruction here and eliment the former one.

Forward, allpath problem.

(b) available set. if found the instruction in this set, we need to delete ,if found the operand in this set we insert a new instruction and delete the sets.