Lab3 Week2

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截图

/home/eunice/Desktop/compiler/compiler2025spring/lab3/code/tests/lian_workspace/semantic/glang_bundle0.stmt_status

	unit_id	method_id	stmt_id	defined_symbol	used_symbols	field	operation	in_bits	out_bits
0	1	10	15	0	[]		3	0	1
1	1	10	16	2	[1]		2	1	2
2	1	10	17	3	[]		3	2	6
3	1	10	18	5	[4]		2	6	10
4	1	10	19	8	[6, 7]		2	10	26
5	1	10	20	9	[]		3	26	58
6	1	10	21	11	[10]		2	58	90
7	1	10	22	13	[12]		2	90	218
8	1	10	23	16	[14, 15]		2	218	474
9	1	10	24	-1	[17]		2	4058	4058
10	1	10	26	20	[18, 19]		2	4058	4058
11	1	10	27	22	[21]		2	4058	3930
12	1	10	28	25	[23, 24]		2	3930	3674
13	1	10	29	27	[26]		2	4058	8146
14	1	10	30	-1	[]		0	8146	8146

补充完成reaching_symbol_analysis

```
    @profile
    def reaching_symbol_analysis(self):

        worklist = list(self.stmt_to_status.keys())
        while len(worklist) != 0:
            stmt_id = worklist.pop(0)
            if stmt_id not in self.stmt_to_status:
                continue
            status = self.stmt_to_status[stmt_id]
            old_outs = status.out_bits

            status.in_bits = 0
            for parent_stmt_id in self.cfg.predecessors(stmt_id):
                if parent_stmt_id in self.stmt_to_status:
                    parent_out_bits = self.stmt_to_status[parent_stmt_id].out_bits
                    # TODO task1 根据cfg准备并设置status.in_bits
                    status.in_bits |= parent_out_bits

            status.out_bits = status.in_bits
            # if current stmt has def
            defined_symbol_index = status.defined_symbol
            if defined_symbol_index != -1:
                defined_symbol = self.symbol_state_space[defined_symbol_index]
                if isinstance(defined_symbol, Symbol):
                    # TODO task2 根据当前defined_symbol的all_def_stmts,通过
self.bit_vector_manager,应用kill-gen算法对status.out_bits进行更新
                    all_def_stmts = self.symbol_to_def_stmts[defined_symbol.name]
                    # Kill phase
                    status.out_bits =
self.bit_vector_manager.kill_stmts(status.out_bits, all_def_stmts)
                    # Gen phase (current statement)
```

```
                    status.out_bits =
self.bit_vector_manager.gen_stmts(status.out_bits, [stmt_id])


            # TODO task3 通过判断out_bits是否变化来判断是否到达不动点
            if status.out_bits != old_outs:
                worklist = util.merge_list(worklist,
list(self.cfg.successors(stmt_id)))
```

关于`task1`根据`cfg`准备并设置`status.in_bits`:

```
            status.in_bits = 0
            for parent_stmt_id in self.cfg.predecessors(stmt_id):
                if parent_stmt_id in self.stmt_to_status:
                    parent_out_bits = self.stmt_to_status[parent_stmt_id].out_bits
                    # TODO task1 根据cfg准备并设置status.in_bits
                    status.in_bits |= parent_out_bits
```

这里需要我们做的其实非常简单了，对于每个`parent_stmt_id`，它们的`out_bits`就是现在这个语句的`in_bits`，因此直接把`status.in_bits`和`parent_out_bits`做按位或操作即可。

关于`task2`根据当前`defined_symbol`的`all_def_stmts`,通过`self.bit_vector_manager`,应用`kill-gen` 算法对`status.out_bits`进行更新:

```
            status.out_bits = status.in_bits
            # if current stmt has def
            defined_symbol_index = status.defined_symbol
            if defined_symbol_index != -1:
                defined_symbol = self.symbol_state_space[defined_symbol_index]
                if isinstance(defined_symbol, Symbol):
                    # TODO task2 根据当前defined_symbol的all_def_stmts,通过
self.bit_vector_manager,应用kill-gen算法对status.out_bits进行更新
                    all_def_stmts = self.symbol_to_def_stmts[defined_symbol.name]
                    # Kill phase
                    status.out_bits =
self.bit_vector_manager.kill_stmts(status.out_bits, all_def_stmts)
                    # Gen phase (current statement)
                    status.out_bits =
self.bit_vector_manager.gen_stmts(status.out_bits, [stmt_id])
```

`kill-gen`算法是很符合直觉的，首先`defined_symbol = self.symbol_state_space[defined_symbol_index]` 通过在 `method_analysis` 中初始化和填充的 `self.symbol_state_space` 获取此处被`def`的符号对象；然后调用`kill`，将此时`out_bits`中可能与此处被`def`的符号对象重复的部分去掉，因为此处被新`def`的会导致原先旧的`def`不可用；最后再用`gen`把当前的新的可达`def`加上。

关于`task3`通过判断`out_bits`是否变化来判断是否到达不动点:

```
            # TODO task3 通过判断out_bits是否变化来判断是否到达不动点
            if status.out_bits != old_outs:
                worklist = util.merge_list(worklist,
list(self.cfg.successors(stmt_id)))
```

如果当前out_bits与前一轮的out_bits有变化，就需要通知所有直接后继语句重新计算它们的in_bits 和 out_bits。这里利用在 method_analysis 中构建好的 self.cfg 获取当前语句的所有后继节点 (self.cfg.successors(stmt_id))，并将它们的 ID 添加到 worklist 中。否则说明到达了不动点，就可以不再加入后继节点了。

补充完成对bit_vector的操作

```
    def kill_stmts(self, bit_vector, stmts):
    # TODO 实现kill,获取stmt对应的bit_pos，通过位操作更新bit_vector
        for stmt in stmts:
            # Get the bit position for this statement
            bit_pos = self.stmt_to_bit_pos.get(stmt)
            # Clear the bit at this position (using AND with NOT)
            bit_vector &= ~(1 << bit_pos)
        return bit_vector
```

kill操作需要遍历输入的语句列表也即要杀掉的对象stmts，对于其中每一个单独的语句stmt拿对应的bit_pos，表示它在位向量中对应的位位置；将1左移对应bit_pos位然后取反，这样在1的位置变为0，其余位置全部为1，这使得最后与整个bit_vector取与的时候使得bit_pos位置被置为0，其余位置不变，杀掉不可用的旧def。

```
    def gen_stmts(self, bit_vector, stmts):
    # TODO 实现gen,获取stmt对应的bit_pos，通过位操作更新bit_vector
        for stmt in stmts:
            # Get the bit position for this statement
            bit_pos = self.stmt_to_bit_pos.get(stmt)
            # Set the bit at this position (using OR)
            bit_vector |= (1 << bit_pos)
        return bit_vector
```

gen操作也很类似，一样是遍历传入的要更新的stmts然后逐个拿bit_pos，这会儿我们左移的时候就是保证bit_pos位是1而其他位置全是0，然后和bit_vector取或运算就把bit_pos的位置置为了1，其余位置不变，更新新的def。

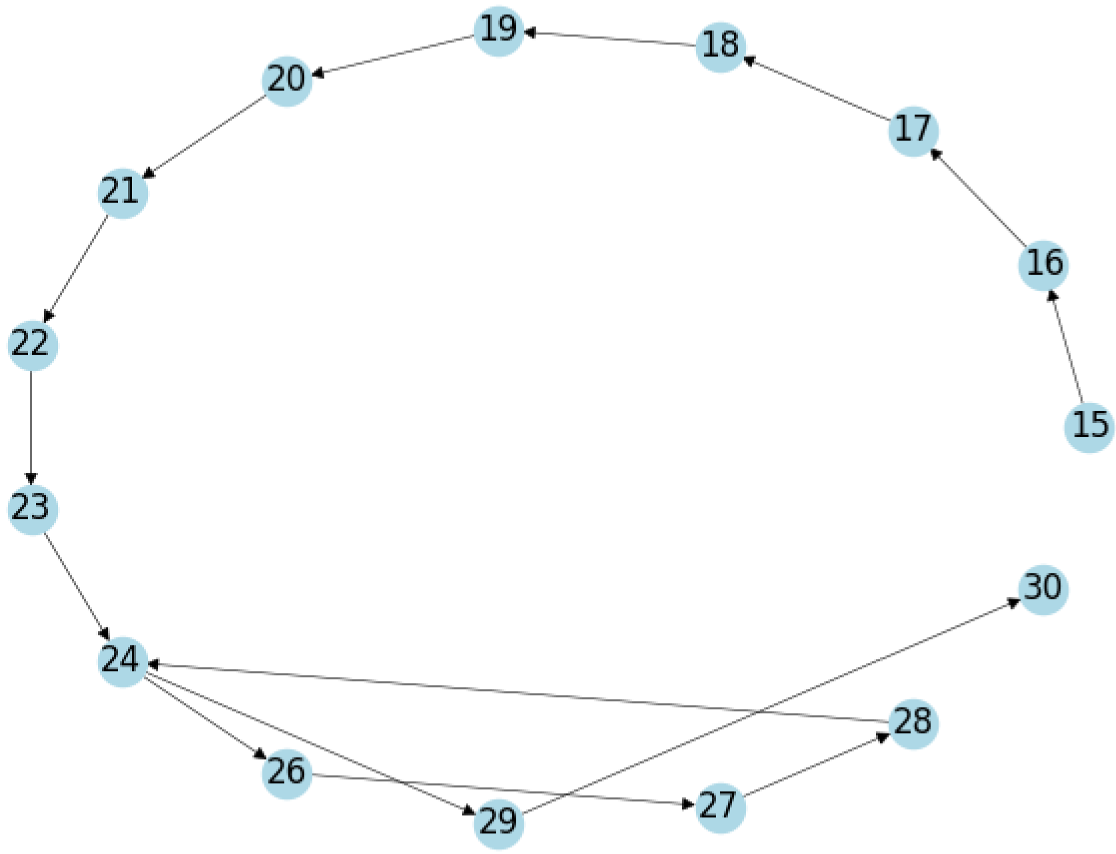
结果分析

打印了详细的计算过程：

```
```

```
Stmt 15 (Out bits): define stmts of current bits{15}
Stmt 16 (Out bits): define stmts of current bits{16}
Stmt 17 (Out bits): define stmts of current bits{16, 17}
Stmt 18 (Out bits): define stmts of current bits{16, 18}
Stmt 19 (Out bits): define stmts of current bits{16, 18, 19}
Stmt 20 (Out bits): define stmts of current bits{16, 18, 19, 20}
Stmt 21 (Out bits): define stmts of current bits{16, 18, 19, 21}
Stmt 22 (Out bits): define stmts of current bits{16, 18, 19, 21, 22}
Stmt 23 (Out bits): define stmts of current bits{16, 18, 19, 21, 22, 23}
Stmt 24 (Out bits): define stmts of current bits{16, 18, 19, 21, 22, 23}
Stmt 26 (Out bits): define stmts of current bits{16, 18, 19, 21, 22, 23, 26}
Stmt 27 (Out bits): define stmts of current bits{16, 18, 19, 21, 23, 26, 27}
Stmt 28 (Out bits): define stmts of current bits{16, 18, 19, 21, 26, 27, 28}
Stmt 29 (Out bits): define stmts of current bits{16, 19, 21, 22, 23, 29}
Stmt 30 (Out bits): define stmts of current bits{16, 19, 21, 22, 23, 29}
Stmt 24 (Out bits): define stmts of current bits{16, 18, 19, 21, 22, 23, 26, 27,
28}
Stmt 26 (Out bits): define stmts of current bits{16, 18, 19, 21, 22, 23, 26, 27,
28}
Stmt 29 (Out bits): define stmts of current bits{16, 19, 21, 22, 23, 26, 27, 28,
29}
Stmt 27 (Out bits): define stmts of current bits{16, 18, 19, 21, 23, 26, 27, 28}
Stmt 30 (Out bits): define stmts of current bits{16, 19, 21, 22, 23, 26, 27, 28,
29}
Stmt 28 (Out bits): define stmts of current bits{16, 18, 19, 21, 26, 27, 28}
```

这里的关键其实在`stmt_id = 24`的那个`while stmt`，它有两种前驱，一种是从第一次进循环时的条件判断计算进，另一种是从循环执行至少依次后的条件判断计算进。结合`cfg`可以看得更清楚：



因此详细的计算过程会有这样的内容（下面均为`stmt_id`）

23-24-26-27-28

28-24-26-27-28，此时要把23，28取或运算；

23-24-29-30

28-24-29-30，此时要把23，28取或运算；

中间节点对应的前驱在有多个的情况下也要把这些前驱的bits取或作为输入继续计算。

对于输出的表格，分析如下：

stmt_id	out_bits	statememt	对应的gen/kill操作	in_bits
15	`------------1`	let a	gen 15	
16	`-----------10`	a=d	gen 15, kill 15	15
17	`----------110`	let b	gen 17	16
18	`---------1010`	b=2	gen 18, kill 17	17
19	`--------11010`	%v0=a+b	gen 19	18
20	`-------111010`	let c	gen 20	19
21	`------1011010`	c=%v0	gen 21, kill 20	20

stmt_id	out_bits	statememt	对应的gen/kill操作	in_bits
22	`-----11011010`	d=f	gen 22	21
23	`----111011010`	%v1=(d<10)	gen 23	22
24	`-111111011010`	while_stmt, condition %v1		23or28
26	`-111111011010`	%v2=d+1	gen 26	24
27	`-111101011010`	d=%v2	gen 27	26
28	`-111001011010`	%v1=(d<10)	gen 28, kill 23	27
29	`1111111010010`	b=d	gen 29	24
30	`1111111010010`	return c		29

注意，在上面表格中，`stmt_id`为24、26、27和28的语句的`out_bits`为编译的最终结果，而对应的`gen/kill`操作是第一次解析到这些语句时需要做的操作。也即如下：

stmt_id	out_bits	statememt	对应的gen/kill操作	in_bits
24	`----111011010`	while_stmt, condition %v1		23
26	`---1111011010`	%v2=d+1	gen 26	24
27	`--11101011010`	d=%v2	gen 27	26
28	`-111001011010`	%v1=(d<10)	gen 28, kill 23	27