Stage-3 Report

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实验内容

step7

在*Namer.visitBlock*中，在访问块内部每条语句之前，创建一个局部作用域对象，再调用*ctx.open*以开启这个新的作用域，将其加入作用域栈顶。而访问块内部每条语句结束后，调用*ctx.close*将此作用域关闭，即退栈。

```
    def visitBlock(self, block: Block, ctx: ScopeStack) -> None:
        ctx.open(Scope(ScopeKind.LOCAL))
        for child in block:
            child.accept(self, ctx)
        ctx.close()
```

实现了*CFG.unreachable*，具体实现方式为：

新增了一个成员数组*reachable*，代表从0号基本块能否到达该号基本块。在*__init__*并对其做全*False*初始化后，从0号基本块开始进行*DFS*，将访问到的每个基本块的*reachable*数组对应项置为*True*，表示可达。

值得注意的是，由于**step8**中加入了循环语句，导致控制流图中出现了环路，因此，每个被访问到的基本块，在递归地访问其后继的各个基本块时，只访问那些尚未确定可达，即满足*reachable[i] == False*的基本块，以避免无穷调用。

如此，在初始化阶段，就确定了每个基本块是否可达。*CFG.unreachable*直接根据成员*reachable*数组的内容，返回对应项的值取反即可。

```
    def __init__(self, nodes: list[BasicBlock], edges: list[(int, int)]) ->
None:
        self.nodes = nodes
        self.edges = edges

        self.links = []

        for i in range(len(nodes)):
            self.links.append((set(), set()))

        for (u, v) in edges:
            self.links[u][1].add(v)
            self.links[v][0].add(u)

        self.reachable = [False for _ in range(len(nodes))]
        self.dfs(0)
```

```
    def dfs(self, root):
        self.reachable[root] = True
        for child in self.getSucc(root):
            if not self.reachable[child]:
                self.dfs(child)
```

```
    def unreachable(self, id):
        return not self.reachable[id]
```

修改了*BruteRegAlloc.accept*，对控制流图中的每个基本块*bb*，先调用*bb.unreachable*，若其不可达，则跳过它。

```
    def accept(self, graph: CFG, info: SubroutineInfo) -> None:
        subEmitter = self.emitter.emitSubroutine(info)
        for bb in graph.iterator():
            # you need to think more here
            # maybe we don't need to alloc regs for all the basic blocks
            if graph.unreachable(bb.id):
                continue
            if bb.label is not None:
                subEmitter.emitLabel(bb.label)
            self.localAlloc(bb, subEmitter)
        subEmitter.emitEnd()
```

step8

在*tree.py*中添加了*For*、*DoWhile*、*Continue*三个类，作为分别对应*for*、*do while*、*continue*语句的*AST*节点类，其中大部分方法的实现可参照*While*和*Break*类。

值得注意的是，*for*语句初始化参数中，除了循环体*body*外，*init*、*cond*、*update*都可能为空，初始化时对应数据成员需要置为*NULL*。此外，*for*语句的*init*既可能是声明也可能是表达式。此外，当*cond*为空，对应的数据成员应为整数字面量1，即*IntLiteral(1)*。

```
class For(Statement):
    """
    AST node of for statement.
    """

    def __init__(
        self,
        body: Statement,
        init: Optional[Declaration | Expression] = None,
        cond: Optional[Expression] = None,
        update: Optional[Expression] = None,
        ) -> None:
        super().__init__('for')
        self.init = init or NULL
        self.cond = cond or IntLiteral(1)
        self.update = update or NULL
        self.body = body

    def __getitem__(self, key: int) -> Node:
        return (self.init, self.cond, self.update, self.body)[key]
```

```
    def __len__(self) -> int:
        return 4

    def accept(self, v: Visitor[T, U], ctx: T):
        return v.visitFor(self, ctx)
```

```
class DoWhile(Statement):
    """
    AST node of do while statement.
    """

    def __init__(self, body: Statement, cond: Expression) -> None:
        super().__init__('do while')
        self.body = body
        self.cond = cond

    def __getitem__(self, key: int) -> Node:
        return (self.body, self.cond)[key]

    def __len__(self) -> int:
        return 2

    def accept(self, v: Visitor[T, U], ctx: T):
        return v.visitDoWhile(self, ctx)
```

```
class Continue(Statement):
    """
    AST node of continue statement.
    """

    def __init__(self) -> None:
        super().__init__('continue')

    def __getitem__(self, key: int) -> Node:
        raise _index_len_err(key, self)

    def __len__(self) -> int:
        return 0

    def accept(self, v: Visitor[T, U], ctx: T):
        return v.visitContinue(self, ctx)

    def is_leaf(self):
        return True
```

而在*Vistor*类下添加了*visitFor*、*visitDoWhile*、*visitContinue*。

```
    def visitFor(self, that: For, ctx: T) -> Optional[U]:
        return self.visitOther(that, ctx)

    def visitDoWhile(self, that: DoWhile, ctx: T) -> Optional[U]:
        return self.visitOther(that, ctx)

    def visitContinue(self, that: Continue, ctx: T) -> Optional[U]:
        return self.visitOther(that, ctx)
```

在*lex.py*下保留字*reserved*下添加了*for*、*do*、*continue*三个关键字。

```
# Reserved keywords
reserved = {
    "return": "Return",
    "int": "Int",
    "if": "If",
    "else": "Else",
    "while": "While",
    'for': 'For',
    'do': 'Do',
    'continue': 'Continue',
    "break": "Break",
}
```

在*ply_parser.py*下添加了*for*循环、*do while*循环、*continue*语句的对应文法。由于*for*循环的*init*、*cond*、*update*都可能为空，因而添加了共8个*p_for_xxx*，对应于不同形式的产生式。而实际上共有24条不同产生式。

```
def p_for_000(p):
    """
    statement_matched : For LParen Semi Semi RParen statement_matched
    statement_unmatched : For LParen Semi Semi RParen statement_unmatched
    """
    p[0] = For(body=p[6])


def p_for_100(p):
    """
    statement_matched : For LParen expression Semi Semi RParen statement_matched
    statement_matched : For LParen declaration Semi Semi RParen
statement_matched
    statement_unmatched : For LParen expression Semi Semi RParen
statement_unmatched
    statement_unmatched : For LParen declaration Semi Semi RParen
statement_unmatched
    """
    p[0] = For(body=p[7], init=p[3])


def p_for_010(p):
    """
    statement_matched : For LParen Semi expression Semi RParen statement_matched
    statement_unmatched : For LParen Semi expression Semi RParen
statement_unmatched
```

```
    """
    p[0] = For(body=p[7], cond=p[4])


def p_for_001(p):
    """
    statement_matched : For LParen Semi Semi expression RParen statement_matched
    statement_unmatched : For LParen Semi Semi expression RParen
statement_unmatched
    """
    p[0] = For(body=p[7], update=p[5])


def p_for_110(p):
    """
    statement_matched : For LParen expression Semi expression Semi RParen
statement_matched
    statement_matched : For LParen declaration Semi expression Semi RParen
statement_matched
    statement_unmatched : For LParen expression Semi expression Semi RParen
statement_unmatched
    statement_unmatched : For LParen declaration Semi expression Semi RParen
statement_unmatched
    """
    p[0] = For(body=p[8], init=p[3], cond=p[5])


def p_for_101(p):
    """
    statement_matched : For LParen expression Semi Semi expression RParen
statement_matched
    statement_matched : For LParen declaration Semi Semi expression RParen
statement_matched
    statement_unmatched : For LParen expression Semi Semi expression RParen
statement_unmatched
    statement_unmatched : For LParen declaration Semi Semi expression RParen
statement_unmatched
    """
    p[0] = For(body=p[8], init=p[3], update=p[6])


def p_for_011(p):
    """
    statement_matched : For LParen Semi expression Semi expression RParen
statement_matched
    statement_unmatched : For LParen Semi expression Semi expression RParen
statement_unmatched
    """
    p[0] = For(body=p[8], cond=p[4], update=p[6])


def p_for_111(p):
    """
    statement_matched : For LParen expression Semi expression Semi expression
RParen statement_matched
```

```
    statement_matched : For LParen declaration Semi expression Semi expression
RParen statement_matched
    statement_unmatched : For LParen expression Semi expression Semi expression
RParen statement_unmatched
    statement_unmatched : For LParen declaration Semi expression Semi expression
RParen statement_unmatched
    """
    p[0] = For(body=p[9], init=p[3], cond=p[5], update=p[7])
```

```
def p_do_while(p):
    """
    statement_matched : Do statement_matched While LParen expression RParen Semi
    statement_unmatched : Do statement_unmatched While LParen expression RParen
Semi
    """
    p[0] = DoWhile(p[2], p[5])
```

```
def p_continue(p):
    """
    statement_matched : Continue Semi
    """
    p[0] = Continue()
```

实现了*Namer.visitFor*，即：

①为*for*循环开启一个新的局部作用域；

②若*init*非空，则访问之；访问*cond*；若*update*非空，则访问之；

③调用*ctx.openLoop*记录循环层数；

④访问*body*；

⑤调用*ctx.closeLoop*，代表该层循环结束；

⑥关闭该局部作用域。

```
    def visitFor(self, stmt: For, ctx: ScopeStack) -> None:
        """
        1. Open a local scope for stmt.init.
        2. Visit stmt.init, stmt.cond, stmt.update.
        3. Open a loop in ctx (for validity checking of break/continue)
        4. Visit body of the loop.
        5. Close the loop and the local scope.
        """
        ctx.open(Scope(ScopeKind.LOCAL))
        if not stmt.init is NULL:
            stmt.init.accept(self, ctx)
        stmt.cond.accept(self, ctx)
        if not stmt.update is NULL:
            stmt.update.accept(self, ctx)
        ctx.openLoop()
        stmt.body.accept(self, ctx)
        ctx.closeLoop()
        ctx.close()
```

实现了*Namer.visitDoWhile*，即：

①调用*ctx.openLoop*记录循环层数；

②访问*body*；

③调用*ctx.closeLoop*，代表该层循环结束；

④访问*cond*；

```
    def visitDoWhile(self, stmt: DoWhile, ctx: ScopeStack) -> None:
        """
        1. Open a loop in ctx (for validity checking of break/continue)
        2. Visit body of the loop.
        3. Close the loop.
        4. Visit the condition of the loop.
        """
        ctx.openLoop()
        stmt.body.accept(self, ctx)
        ctx.closeLoop()
        stmt.cond.accept(self, ctx)
```

实现了*Namer.visitContinue*，和*Namer.visitBreak*行为一致，只需通过检查当前循环层数，确保*continue*语句位于某循环内，否则抛出*DecafContinueOutsideLoopError*。

```
    def visitContinue(self, stmt: Continue, ctx: ScopeStack) -> None:
        """
        1. Refer to the implementation of visitBreak.
        """
        if not ctx.inLoop():
            raise DecafContinueOutsideLoopError()
```

实现了*TACGen.visitFor*、*TACGen.visitDoWhile*、*TACGen.visitContinue*。

前两方法同*TACGen.visitWhile*实现类似，调整循环体、控制表达式、跳转标签等部分的位置即可。

*TACGen.visitContinue*也与*TACGen.visitBreak*类似。

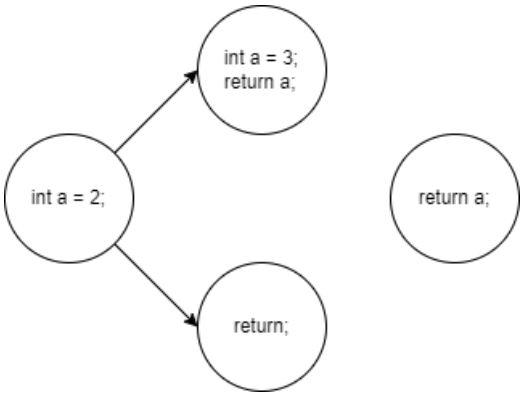
```
    def visitFor(self, stmt: For, mv: FuncVisitor) -> None:
        beginLabel = mv.freshLabel()
        loopLabel = mv.freshLabel()
        breakLabel = mv.freshLabel()
        mv.openLoop(breakLabel, loopLabel)
        if not stmt.init is NULL:
            stmt.init.accept(self, mv)
        mv.visitLabel(beginLabel)
        stmt.cond.accept(self, mv)
        mv.visitCondBranch(tacop.CondBranchOp.BEQ, stmt.cond.getattr('val'),
breakLabel)
        stmt.body.accept(self, mv)
        mv.visitLabel(loopLabel)
        if not stmt.update is NULL:
            stmt.update.accept(self, mv)
        mv.visitBranch(beginLabel)
        mv.visitLabel(breakLabel)
        mv.closeLoop()
```

```
    def visitDoWhile(self, stmt: DoWhile, mv: FuncVisitor) -> None:
        beginLabel = mv.freshLabel()
        loopLabel = mv.freshLabel()
        breakLabel = mv.freshLabel()
        mv.openLoop(breakLabel, loopLabel)
        mv.visitLabel(beginLabel)
        stmt.body.accept(self, mv)
        mv.visitLabel(loopLabel)
        stmt.cond.accept(self, mv)
        mv.visitCondBranch(tacop.CondBranchOp.BEQ, stmt.cond.getattr('val'),
breakLabel)
        mv.visitBranch(beginLabel)
        mv.visitLabel(breakLabel)
        mv.closeLoop()
```

```
    def visitContinue(self, stmt: Continue, mv: FuncVisitor) -> None:
        mv.visitBranch(mv.getContinueLabel())
```

思考题

step7



step8

设循环体执行了n次。

则两种翻译方式下*cond*和*body*部分执行次数一样，因此在这两部分，两种翻译方式下*CPU*执行的指令条数一样多。

除去*cond*和*body*部分指令，第一种翻译方式下，*CPU*执行的指令条数为$2n+1$；而第二种翻译方式下，*CPU*执行的指令条数为$n+1$。

由于循环体执行次数一定的情况下，执行的指令条数越少越好，而第二种翻译方式少执行n条指令，且考虑到实际情况中，一段程序中所有*while*循环的循环体执行次数均为0的概率较低，因此第二种翻译方式更好。