lab2 实验报告

PB20000137 李远航

问题1: getelementptr

请给出 `IR.md` 中提到的两种 getelementptr 用法的区别,并稍加解释:

- `%2 = getelementptr [10 x i32], [10 x i32]* %1, i32 0, i32 %0`
- `%2 = getelementptr i32, i32* %1 i32 %0`

第一种指针类型是`[10 x i32]*`，后面的0是指指向`[10 x i32][0]`，然后偏移量为`%0`，我认为可以理解成二维数组

第二种指针类型是`i32*`，直接是一个`%0`的偏移

问题2: cpp 与 .ll 的对应

请说明你的 cpp 代码片段和 .ll 的每个 BasicBlock 的对应关系。

- assign

```
#include "BasicBlock.h"
#include "Constant.h"
#include "Function.h"
#include "IRBuilder.h"
#include "Module.h"
#include "Type.h"

#include <iostream>
#include <memory>

#ifdef DEBUG                                        // 用于调试信息,大家可以在编译过程中通过" -DDEBUG"来开启这一选项
#define DEBUG_OUTPUT std::cout << __LINE__ << std::endl; // 输出行号的简单示例
#else
#define DEBUG_OUTPUT
#endif

#define CONST_INT(num) ConstantInt::get(num, module)

#define CONST_FP(num) ConstantFP::get(num, module) // 得到常数值的表示,方便后面多次用到

int main()
{
    auto module = new Module("Cminus code"); // module name是什么无关紧要
    auto builder = new IRBuilder(nullptr, module);
    Type *Int32Type = Type::get_int32_type(module);

```

```
    auto mainFun = Function::create(FunctionType::get(Int32Type, {}),
                                    "main", module);
    auto bb = BasicBlock::create(module, "entry", mainFun);
    // BasicBlock的名字在生成中无所谓,但是可以方便阅读
    builder->set_insert_point(bb);

    auto retAlloca = builder->create_alloca(Int32Type);
    builder->create_store(CONST_INT(0), retAlloca); // 默认 ret 0
    // int a[10];
    auto *arrayType = ArrayType::get(Int32Type, 10);
    auto aAlloca = builder->create_alloca(arrayType);

    // a[0] = 10;
    auto a0GEP = builder->create_gep(aAlloca, {CONST_INT(0), CONST_INT(0)});
    builder->create_store(CONST_INT(10), a0GEP);

    // a[1] = a[0] * 2
    auto a1GEP = builder->create_gep(aAlloca, {CONST_INT(0), CONST_INT(1)});
    a0GEP = builder->create_gep(aAlloca, {CONST_INT(0), CONST_INT(0)});
    auto a0Load = builder->create_load(a0GEP);
    auto mul = builder->create_imul(a0Load, CONST_INT(2)); // a[0] * 2
    builder->create_store(mul, a1GEP);

    // return a[1];
    builder->create_store(mul, retAlloca);
    auto retLoad = builder->create_load(retAlloca);
    builder->create_ret(retLoad);

    std::cout << module->print();
    delete module;
    return 0;
}
```

```
define i32 @main() {
label_entry:
  %op0 = alloca i32
  store i32 0, i32* %op0
  %op1 = alloca [10 x i32]
  %op2 = getelementptr [10 x i32], [10 x i32]* %op1, i32 0, i32 0
  store i32 10, i32* %op2
  %op3 = getelementptr [10 x i32], [10 x i32]* %op1, i32 0, i32 1
  %op4 = getelementptr [10 x i32], [10 x i32]* %op1, i32 0, i32 0
  %op5 = load i32, i32* %op4
  %op6 = mul i32 %op5, 2
  store i32 %op6, i32* %op3
  store i32 %op6, i32* %op0
  %op7 = load i32, i32* %op0
  ret i32 %op7
}
```

`auto bb = BasicBlock::create(module, "entry", mainFun);`对应 `label_entry`

- fun

```
#include "BasicBlock.h"
#include "Constant.h"
```

```cpp
#include "Function.h"
#include "IRBuilder.h"
#include "Module.h"
#include "Type.h"

#include <iostream>
#include <memory>

#ifdef DEBUG                                                    // 用于调试信息,大家可以在编译过程中通过" -DDEBUG"来开启这一选项
#define DEBUG_OUTPUT std::cout << __LINE__ << std::endl; // 输出行号的简单示例
#else
#define DEBUG_OUTPUT
#endif

#define CONST_INT(num) ConstantInt::get(num, module)

#define CONST_FP(num) ConstantFP::get(num, module) // 得到常数值的表示,方便后面多次用到

int main()
{
    auto module = new Module("Cminus code"); // module name是什么无关紧要
    auto builder = new IRBuilder(nullptr, module);
    Type *Int32Type = Type::get_int32_type(module);

    std::vector<Type *> Ints(1, Int32Type);

    //通过返回值类型与参数类型列表得到函数类型
    auto calleFunTy = FunctionType::get(Int32Type, Ints);

    // 由函数类型得到函数
    auto callee = Function::create(calleFunTy,
                                   "callee", module);

    // BB的名字在生成中无所谓,但是可以方便阅读
    auto bb = BasicBlock::create(module, "entry", callee);

    builder->set_insert_point(bb); // 一个BB的开始,将当前插入指令点的位置设在bb

    auto retAlloca = builder->create_alloca(Int32Type); // 在内存中分配返回值的位置
    auto aAlloca = builder->create_alloca(Int32Type);   // 在内存中分配参数a的位置

    std::vector<Value *> args; // 获取gcd函数的形参,通过Function中的iterator
    for (auto arg = callee->arg_begin(); arg != callee->arg_end(); arg++)
    {
        args.push_back(*arg); // * 号运算符是从迭代器中取出迭代器当前指向的元素
    }
    builder->create_store(args[0], aAlloca); // 将参数a store下来

    auto aLoad = builder->create_load(aAlloca);
    auto mul = builder->create_imul(aLoad, CONST_INT(2));
    builder->create_store(mul, retAlloca);
    auto retLoad = builder->create_load(retAlloca);
```

```
    builder->create_ret(retLoad);

    auto mainFun = Function::create(FunctionType::get(Int32Type, {}),
                                    "main", module);
    // BasicBlock的名字在生成中无所谓,但是可以方便阅读
    bb = BasicBlock::create(module, "entry", mainFun);
    builder->set_insert_point(bb);

    retAlloca = builder->create_alloca(Int32Type);
    builder->create_store(CONST_INT(0), retAlloca); // 默认 ret 0

    auto call = builder->create_call(callee, {CONST_INT(110)});
    builder->create_ret(call);

    std::cout << module->print();
    delete module;
    return 0;
}
```

```
define i32 @callee(i32 %arg0) {
label_entry:
  %op1 = alloca i32
  %op2 = alloca i32
  store i32 %arg0, i32* %op2
  %op3 = load i32, i32* %op2
  %op4 = mul i32 %op3, 2
  store i32 %op4, i32* %op1
  %op5 = load i32, i32* %op1
  ret i32 %op5
}
define i32 @main() {
label_entry:
  %op0 = alloca i32
  store i32 0, i32* %op0
  %op1 = call i32 @callee(i32 110)
  ret i32 %op1
}
```

- `auto bb = BasicBlock::create(module, "entry", callee);`对应`calle`中的`label_entry`
- `bb = BasicBlock::create(module, "entry", mainFun);`对应`main`中的`label_entry`

- if

```
#include "BasicBlock.h"
#include "Constant.h"
#include "Function.h"
#include "IRBuilder.h"
#include "Module.h"
#include "Type.h"

#include <iostream>
#include <memory>

```

```
#ifdef DEBUG                                                    // 用于调试信息,大家可以在编译过程中通过" -DDEBUG"来开启这一选项
#define DEBUG_OUTPUT std::cout << __LINE__ << std::endl; // 输出行号的简单示例
#else
#define DEBUG_OUTPUT
#endif

#define CONST_INT(num) ConstantInt::get(num, module)

#define CONST_FP(num) ConstantFP::get(num, module) // 得到常数值的表示,方便后面多次用到

int main()
{
    auto module = new Module("Cminus code"); // module name是什么无关紧要
    auto builder = new IRBuilder(nullptr, module);
    Type *Int32Type = Type::get_int32_type(module);

    auto mainFun = Function::create(FunctionType::get(Int32Type, {}),
                                    "main", module);
    auto bb = BasicBlock::create(module, "entry", mainFun);
    // BasicBlock的名字在生成中无所谓,但是可以方便阅读
    builder->set_insert_point(bb);

    auto retAlloca = builder->create_alloca(Int32Type);
    builder->create_store(CONST_INT(0), retAlloca); // 默认 ret 0

    Type *FloatType = Type::get_float_type(module);
    auto aAlloca = builder->create_alloca(FloatType); // a
    builder->create_store(CONST_FP(5.555), aAlloca);

    auto aLoad = builder->create_load(aAlloca);               // load a
    auto fcmp = builder->create_fcmp_gt(aLoad, CONST_FP(1)); // if

    auto trueBB = BasicBlock::create(module, "trueBB", mainFun);   // true分支
    auto falseBB = BasicBlock::create(module, "falseBB", mainFun); // false分支
    auto retBB = BasicBlock::create(module, "", mainFun);          // return分支

    auto br = builder->create_cond_br(fcmp, trueBB, falseBB);

    builder->set_insert_point(trueBB); // if true; 分支的开始需要SetInsertPoint设置
    builder->create_store(CONST_INT(233), retAlloca);
    builder->create_br(retBB); // br retBB

    builder->set_insert_point(falseBB); // if false
    builder->create_store(CONST_INT(0), retAlloca);
    builder->create_br(retBB);

    builder->set_insert_point(retBB); // ret分支
    auto retLoad = builder->create_load(retAlloca);
    builder->create_ret(retLoad);

```

```
    std::cout << module->print();
    delete module;
    return 0;
}
```

```
define i32 @main() {
label_entry:
  %op0 = alloca i32
  store i32 0, i32* %op0
  %op1 = alloca float
  store float 0x40163851e0000000, float* %op1
  %op2 = load float, float* %op1
  %op3 = fcmp ugt float %op2,0x3ff0000000000000
  br i1 %op3, label %label_trueBB, label %label_falseBB
label_trueBB:                                             ; preds =
%label_entry
  store i32 233, i32* %op0
  br label %label4
label_falseBB:                                            ; preds =
%label_entry
  store i32 0, i32* %op0
  br label %label4
label4:                                                   ; preds =
%label_trueBB, %label_falseBB
  %op5 = load i32, i32* %op0
  ret i32 %op5
}
```

- `auto bb = BasicBlock::create(module, "entry", mainFun);`对应`label_entry`
- `auto trueBB = BasicBlock::create(module, "trueBB", mainFun);`对应`label_trueBB`
- `auto falseBB = BasicBlock::create(module, "falseBB", mainFun);`对应`label_falseBB`
- `auto retBB = BasicBlock::create(module, "", mainFun);`对应`label4`

- while

```
#include "BasicBlock.h"
#include "Constant.h"
#include "Function.h"
#include "IRBuilder.h"
#include "Module.h"
#include "Type.h"

#include <iostream>
#include <memory>

#ifdef DEBUG                                        // 用于调试信息,大家可
以在编译过程中通过" -DDEBUG"来开启这一选项
#define DEBUG_OUTPUT std::cout << __LINE__ << std::endl; // 输出行号的简单示例
#else
#define DEBUG_OUTPUT
#endif

#define CONST_INT(num) ConstantInt::get(num, module)

```

```cpp
#define CONST_FP(num) ConstantFP::get(num, module) // 得到常数值的表示,方便后面多次用到

int main()
{
    auto module = new Module("Cminus code"); // module name是什么无关紧要
    auto builder = new IRBuilder(nullptr, module);
    Type *Int32Type = Type::get_int32_type(module);

    auto mainFun = Function::create(FunctionType::get(Int32Type, {}),
                                    "main", module);
    auto bb = BasicBlock::create(module, "entry", mainFun);
    // BasicBlock的名字在生成中无所谓,但是可以方便阅读
    builder->set_insert_point(bb);

    auto retAlloca = builder->create_alloca(Int32Type);
    builder->create_store(CONST_INT(0), retAlloca); // 默认 ret 0

    auto aAlloca = builder->create_alloca(Int32Type);
    builder->create_store(CONST_INT(10), aAlloca);
    auto iAlloca = builder->create_alloca(Int32Type);
    builder->create_store(CONST_INT(0), iAlloca);
    auto aLoad = builder->create_load(aAlloca);
    auto iLoad = builder->create_load(iAlloca);

    auto trueBB = BasicBlock::create(module, "trueBB", mainFun);   // true分支
    auto falseBB = BasicBlock::create(module, "falseBB", mainFun); // false分支

    auto icmp = builder->create_icmp_lt(iLoad, CONST_INT(10)); // while
    auto br = builder->create_cond_br(icmp, trueBB, falseBB);

    builder->set_insert_point(trueBB);
    // i = i + 1;
    iLoad = builder->create_load(iAlloca);
    auto addi = builder->create_iadd(iLoad, CONST_INT(1));
    builder->create_store(addi, iAlloca);
    // a = a + i;
    aLoad = builder->create_load(aAlloca);
    iLoad = builder->create_load(iAlloca);
    auto adda = builder->create_iadd(iLoad, aLoad);
    builder->create_store(adda, aAlloca);
    //
    icmp = builder->create_icmp_lt(iLoad, CONST_INT(10));
    br = builder->create_cond_br(icmp, trueBB, falseBB);

    builder->set_insert_point(falseBB);
    aLoad = builder->create_load(aAlloca);
    builder->create_store(aLoad, retAlloca);
    auto retLoad = builder->create_load(retAlloca);
    builder->create_ret(retLoad);

    std::cout << module->print();
    delete module;
    return 0;
```

```
}
```

```
define i32 @main() {
label_entry:
  %op0 = alloca i32
  store i32 0, i32* %op0
  %op1 = alloca i32
  store i32 10, i32* %op1
  %op2 = alloca i32
  store i32 0, i32* %op2
  %op3 = load i32, i32* %op1
  %op4 = load i32, i32* %op2
  %op5 = icmp slt i32 %op4, 10
  br i1 %op5, label %label_trueBB, label %label_falseBB
label_trueBB:                                             ; preds =
%label_entry, %label_trueBB
  %op6 = load i32, i32* %op2
  %op7 = add i32 %op6, 1
  store i32 %op7, i32* %op2
  %op8 = load i32, i32* %op1
  %op9 = load i32, i32* %op2
  %op10 = add i32 %op9, %op8
  store i32 %op10, i32* %op1
  %op11 = icmp slt i32 %op9, 10
  br i1 %op11, label %label_trueBB, label %label_falseBB
label_falseBB:                                            ; preds =
%label_entry, %label_trueBB
  %op12 = load i32, i32* %op1
  store i32 %op12, i32* %op0
  %op13 = load i32, i32* %op0
  ret i32 %op13
}
```

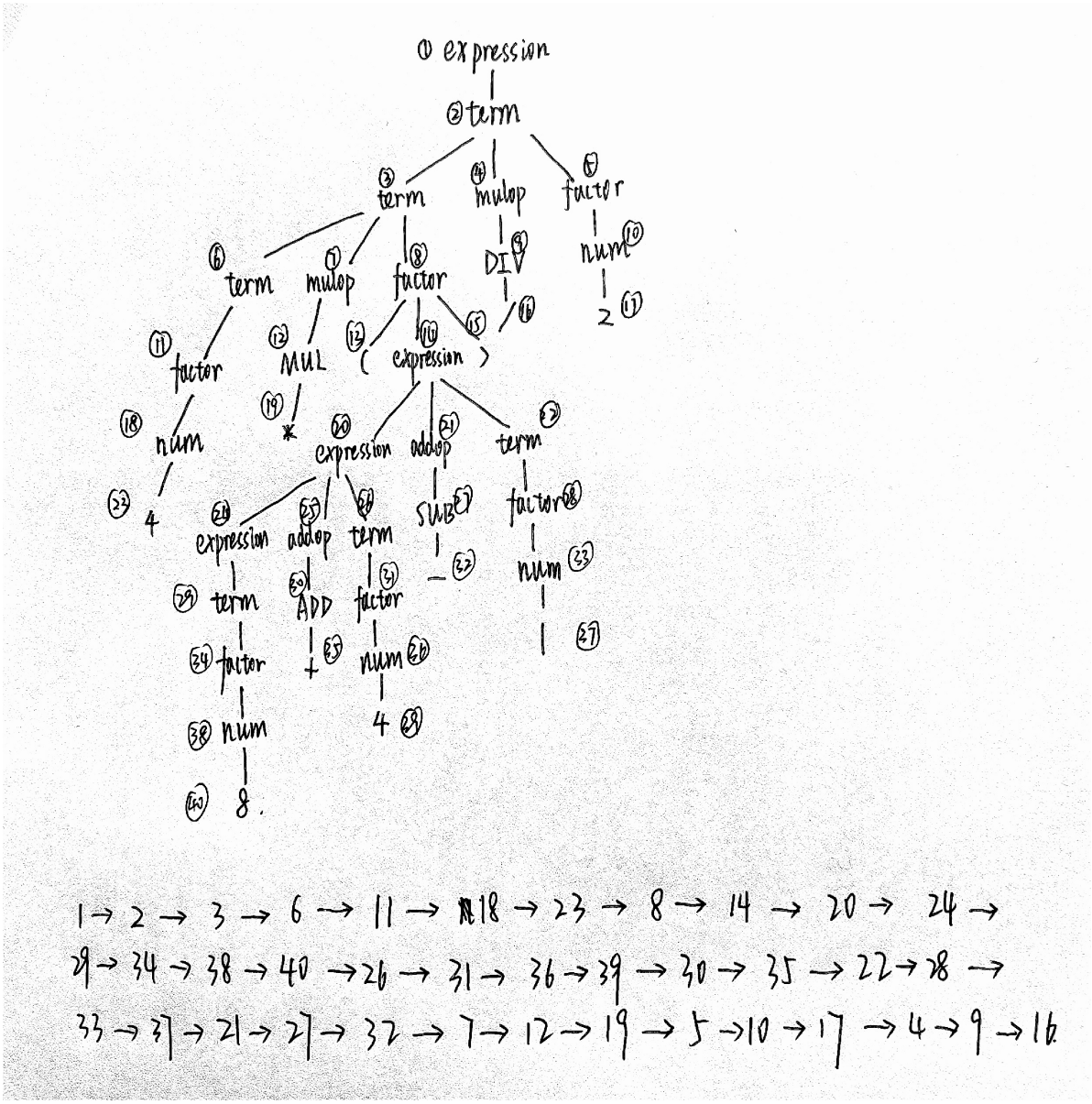
- `auto bb = BasicBlock::create(module, "entry", mainFun);`对应`label_entry`
- `auto trueBB = BasicBlock::create(module, "trueBB", mainFun);`对应`label_trueBB`
- `auto falseBB = BasicBlock::create(module, "falseBB", mainFun);`对应`label_falseBB`

问题3: Visitor Pattern

分析`calc`程序在输入为`4 * (8 + 4 - 1) / 2`时的行为:

1. 请画出该表达式对应的抽象语法树（使用`calc_ast.hpp`中的`CalcAST*`类型和在该类型中存储的值来表示），并给节点使用数字编号。
2. 请指出示例代码在用访问者模式遍历该语法树时的遍历顺序。

序列请按如下格式指明（序号为问题 3.1 中的编号）：
3->2->5->1



实验难点

描述在实验中遇到的问题、分析和解决方案。

- 实验文档中好像没有解释 `nsw` 的地方，找了挺久
- `generator` 能够正常输出比较容易，但是判断输出的 `.ll` 是否符合要求或者出错在哪里，比较困难，搞不清楚，然后换一种写法，就能正常完成实验
- `ret` 分支可以直接顺序执行的时候，不需要单独开辟一个 `block`
- `generator` 中有的参数有的是分配的内存，有的参数是值，需要仔细区分
- 插件的直接跳转很好用，能快速看清函数结构

实验反馈

吐槽?建议?

- `calc` 好多各种各样的 `visit`
- 感觉题目问题描述的有点抽象，就按照自己理解写了