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Sequence 4.5 – IRBuilder

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Creating an IR of the program

How to build an IR representation of our program ?

Instead of writing IR directly, we call a programmatic API, the *IR Builder*.

Advantages:

- Faster: IR is directly built in memory
- Robust: The API enforces many legality rules of the IR
- Cleaner: The IR Builder offers high-level abstractions for building the IR

Principles of Design

- An IR Builder keeps track of an *insert point*. New instructions are added after the insert point which is then automatically moved forward.

- High level builders for complex patterns such as:
    - Calling multi-parameters functions
    - Accessing the fields of a structure
    - Creating conditional branches

Context and Function

- A Builder operates in a given *Context*

    - The *Context* captures the global data of a compilation unit

    - Whenever the builder creates a new global variable, global type, or function declaration, it is added to the *Context*

- A Builder inserts instructions in a given *BasicBlock*

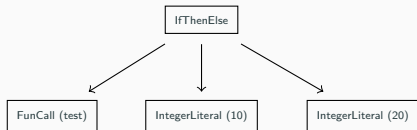   - A *BasicBlock* operates within a *Context* and belongs to a *Function*

Inserting new instructions

How to translate (10+5)*2 in IR ?

```
1   llvm::IRBuilder Builder(Context);
2   [...]
3   llvm::BasicBlock *const body =
4       llvm::BasicBlock::Create(Context, "body", current_function);
5
6   Builder.SetInsertPoint(body);
7
8   llvm::Value * a =
9       Builder.CreateAdd(Builder.getInt32(10), Builder.getInt32(5));
10  llvm::Value * b =
11      Builder.CreateMul(a, Builder.getInt32(2));
```
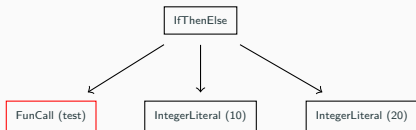
How to translate Tiger AST to LLVM IR

`if test() then 10 else 20`

```
                           ┌──────────┐
                           │ IfThenElse│
                           └──────────┘
             ┌──────────────────┼──────────────────┐
             ▼                  ▼                  ▼
    ┌──────────────┐  ┌──────────────────┐  ┌──────────────────┐
    │ FunCall (test)│  │ IntegerLiteral (10)│  │ IntegerLiteral (20)│
    └──────────────┘  └──────────────────┘  └──────────────────┘
```

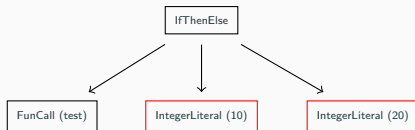Translate with a visitor that returns LLVM values.

FunCall

```
1  // Simplified (no static link + no arguments)
2  llvm::Value *IRGenerator::visit(const FunCall &call) {
3    const FunDecl &decl = call.get_decl().get();
4    llvm::Function *callee =
5      Module->getFunction(decl.get_external_name().get());
6    return Builder.CreateCall(callee, {}, "call");
7  }
```
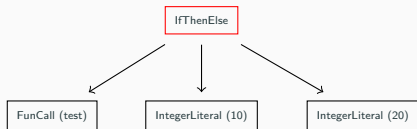
```
1  llvm::Value *IRGenerator::visit(const IntegerLiteral &literal) {
2    return Builder.getInt32(literal.value);
3  }
```

IfThenElse

IfThenElse is more complex: diverging control requires multiple basic blocks. To simplify, in the following we assume that the if always returns a value.

IfThenElse: Prolog

```
1   llvm::Value *IRGenerator::visit(const IfThenElse &ite) {
2
3     // We create an allocation in the function entry block
4     // to store the if result (see lecture 4.4)
5     llvm::Value *const result =
6       alloca_in_entry(llvm_type(ite.get_type()), "if_result");
7
8     // We create three empty basic blocks
9     llvm::BasicBlock *const then_block =
10        llvm::BasicBlock::Create(Context, "if_then", current_function);
11    llvm::BasicBlock *const else_block =
12        llvm::BasicBlock::Create(Context, "if_else", current_function);
13    llvm::BasicBlock *const end_block =
14        llvm::BasicBlock::Create(Context, "if_end", current_function);
```

IfThenElse: Condition

We branch depending on the condition,

```
Builder.CreateCondBr(
    Builder.CreateIsNotNull(ite.get_condition().accept(*this)),
    then_block,
    else_block);
```

`ite.get_condition().accept(*this)` returns the result LLVM
Value of the FunCall `test()` translation.

IfThenElse: Then and Else bodies

```
llvm::Value *const result = alloca_in_entry(...);
```

Block for the `then` part:

```
1    Builder.SetInsertPoint(then_block);
2    llvm::Value *const then_result =
3      ite.get_then_part().accept(*this);
4    Builder.CreateStore(then_result, result);
5    Builder.CreateBr(end_block);
```

Block for the `else` part:

```
1    Builder.SetInsertPoint(else_block);
2    llvm::Value *const else_result =
3      ite.get_else_part().accept(*this);
4    Builder.CreateStore(else_result, result);
5    Builder.CreateBr(end_block);
```

IfThenElse: Epilog

```
llvm::Value *const result = alloca_in_entry(...);
```

Block for joining the `then` and `else` parts:

```
1    Builder.SetInsertPoint(end_block);
2    return Builder.CreateLoad(result);
```