

CSCD70 Compiler Optimization

Tutorial #2 Introduction to LLVM (ii)

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Review

In the previous tutorial, we have discussed the following topics:

- ▶ C++ (P?)Review
 - ▶ Pass by Reference
 - ▶ Public Inheritance
 - ▶ Standard Template Library (STL)
- ▶ How to write an LLVM Analysis Pass?
 - ▶ Intermediate Representation (IR) and Optimization Passes
 - ▶ Analysis vs. Transform
 - ▶ LLVM Module, Iterators, Downcasting, LLVM Pass Interfaces

Abstract

In this tutorial, we will be further discussing the following topics:

- ▶ C++ (P?)Review
- ▶ How to write an LLVM Analysis pass?
- ▶ How to write an LLVM Transform pass?
- ▶ How to connect between passes?



LLVM Transform Pass

Basic Instruction Manipulation

- ▶ There are many ways of manipulating instructions:
Instruction, BasicBlock, BasicBlockUtils

👉 [Example1-Transform_Pass_Sample](#)

User-Use-Value

Suppose that we have the following code to optimize:

```
%2 = add %1, 0 ; Algebraic Identity
```

```
%3 = mul %2, 2
```

- ▶ Program **crashes** because **we did not update the references properly**.
- ▶ How to make sure that all references (i.e. **uses**) are updated properly?
⇒ LLVM **User-Use-Value** Relationship

User-Use-Value

LLVM Class Hierarchy



Goal

We are going to show how the `Instruction` plays the role *both* as an **User** and as an **Usee** (Value).

Value

- ▶ The Value class is the most important *base* class in LLVM, as almost all object types inherit from it.
- ▶ A Value has a *type* (e.g., integer, floating point): `getType`.
- ▶ A Value might or might not have a *name*: `hasName`, `getName`.
- ▶ Most importantly, a Value has a list of **Users** that are using itself.

Instruction as an User

An Instruction is an User.

- ▶ Each User (Instruction) has a list of values it is using. Those values are known as the **Operands**, of type Value.

```
User &Inst = ...
```

```
for (auto Iter = Inst.op_begin();  
      Iter != Inst.op_end(); ++Iter)
```

```
{ Value *Operand = *Iter; }
```

```
// %2 = add %1, 0 → operand %1 & 0
```

Instruction as an Use

- ▶ Why is an Instruction is an **Use**?
- ▶ The answer lies in our interpretation of LLVM Instruction:

```
%2 = add %1, 0
```

- ✗ The result of instruction add %1, 0 is assigned to %2.
 - ✓ %2 is the Value **representation of instruction** add %1, 0.
- ▶ Therefore, wherever in later text we use the value %2, we mean to use the instruction add %1, 0.

Summary

Let us now return back to the problem we have at the very beginning:

```
%2 = add %1, 0 ; Algebraic Identity
```

```
%3 = mul %2, 2
```

- ▶ Let Inst be a reference to instruction `%2 = add %1, 0`

```
for (auto Iter = Inst.op_begin();  
      Iter != Inst.op_end(); ++Iter)  
{ Value *Operand = *Iter; }
```

⇒ Operand %1, 0

```
for (auto Iter = Inst.user_begin();  
      Iter != Inst.user_end(); ++Iter)  
{ User *InstUser = *Iter; }
```

⇒ Instruction `mul %2, 2` (alternatively, Value %3)

Homework Assignments

In addition to going through [Example1-Transform_Pass_Sample](#), we strongly suggest that you think about the following problems:

- 1 Assume that we have the C code below:

```
y = p + 1;
```

```
y = q * 2;
```

```
z = y + 3;
```

What shall be returned as the users of the instruction `y = p + 1`?

- 2 Think about an alternative way of counting the number of explicit call sites in Assignment 1, by making use of the User-Use-Value relationship.
- 3 Check the documentation for [llvm::Value](#), and see whether there is any method that you benefit from to update all use references at once.

A faint, stylized illustration of a dragon in a light gray color, serving as a background for the slide. The dragon is depicted in a crouching or coiled position, with its wings partially spread and its tail curved. It has a long, pointed snout, small horns, and a mane along its neck. The illustration is centered and occupies most of the slide area.

LLVM Pass Manager

LLVM Pass Manager

Recall

Why such isolation exists?

- ▶ Better **Readability**
- ▶ Very frequently, multiple passes might require the **same** information.
⇒ The isolation **avoids redundant analysis** (more later).

Now that we have the isolation, how should we build up the connection?

- ▶ **LLVM Pass Manager**
- ▶ Where is it?

```
virtual void getAnalysisUsage(  
    AnalysisUsage &AU) const override {  
    AU.setPreservesAll();  
}
```

LLVM Pass Manager

What does the Pass Manager do?

- ▶ **Requires & Preserves** Information

- ▶ If a pass *A* **requires** pass *B*, by the time *A* initiates, LLVM will automatically run *B* if *B* has not been run before.
 - ▶ If a pass *A* **preserves** pass *B*, by the time pass *A* terminates, LLVM will preserve *B*, and *B* will NOT be rerun unless subsequent passes invalidate it.
- ▶ By default, a pass requires and preserves _____ other passes.
- ▶ The documentation [here](#) has more details on the Pass Manager.

LLVM Pass Manager

In this course, we will be mostly using the function calls below:

- ▶ `setPreservesAll`: Preserves all previous passes.
- ▶ `setPreservesCFG`: Preserves the CFG.
- ▶ `addPreserved<A>`: Preserves pass *A* after **this** pass.
- ▶ `addRequired<A>`: Requires pass *A* to run before **this** pass.
`getAnalysis<A>` gets the information from the required pass *A*.

👉 [Example2-Pass_Manager](#)

Review

In this tutorial, we have discussed about the followings:

- ▶ C++ (P?)Review
- ▶ How to write an LLVM Analysis pass?
- ▶ How to write an LLVM Transform pass?
 - ▶ User-Use-Value Relationship
- ▶ How to connect between passes?
 - ▶ LLVM Pass Manager: Require & Preserve

☞ **Homework Assignment:** LocalOpt