LLVM & Clang

LLVM : Low Level Virtual Machine

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Hands On Session for `LLVM` & `clang`

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Clang AST

```
1  int retsum(int a, int b) {
2    return a + b;
3  }
4  # clang -Xclang -ast-dump -fsyntax-only code.cpp
5  `-FunctionDecl <test.cc:1:1, line:3:1> retsum 'int (int, int)'
6    |-ParmVarDecl <col:12, col:16> col:16 used a 'int'
7    |-ParmVarDecl <col:19, col:23> col:23 used b 'int'
8    `-CompoundStmt <col:26, line:3:1>
9      `-ReturnStmt <line:2:3, col:14>
10       `-BinaryOperator <col:10, col:14> 'int' '+'
11         |-ImplicitCastExpr <col:10> 'int' <LValueToRValue>
12         | `-DeclRefExpr <col:10> 'int' lvalue ParmVar 'a' 'int'
13         `-ImplicitCastExpr <col:14> 'int' <LValueToRValue>
14           `-DeclRefExpr <col:14> 'int' lvalue ParmVar 'b' 'int'
```

Clang AST

```
1  int main()
2  {
3    int a = 90;
4  }
5  # ./clang_ast "int main() { int a = 90; }"
6  FunctionDecl 0x3705db0 <input.cc:1:1, col:26> col:5 main 'int ()'
7    `-CompoundStmt 0x3705f78 <col:12, col:26>
8      `-DeclStmt 0x3705f60 <col:14, col:24>
9        `-VarDecl 0x3705ed8 <col:14, col:22> col:18 a 'int' cinit
10         `-IntegerLiteral 0x3705f40 <col:22> 'int' 90
```

AST Visual

```
x > 0xff2
```

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|-BinaryOperator 0x3c32fb0 '_Bool' '>'
| |-ImplicitCastExpr 0x3c32f98 'int' <LValueToRValue>
| | `-DeclRefExpr 0x3c32f58 'int' lvalue Var 0x3c32ed8 'x' 'int'
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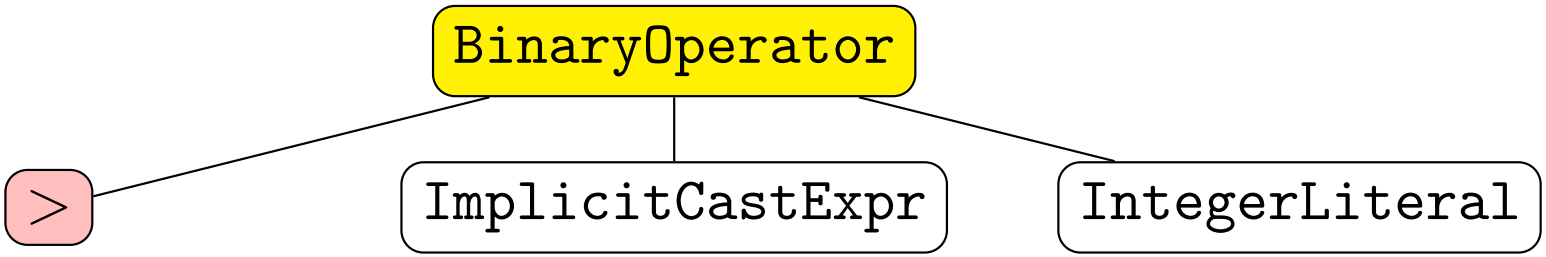

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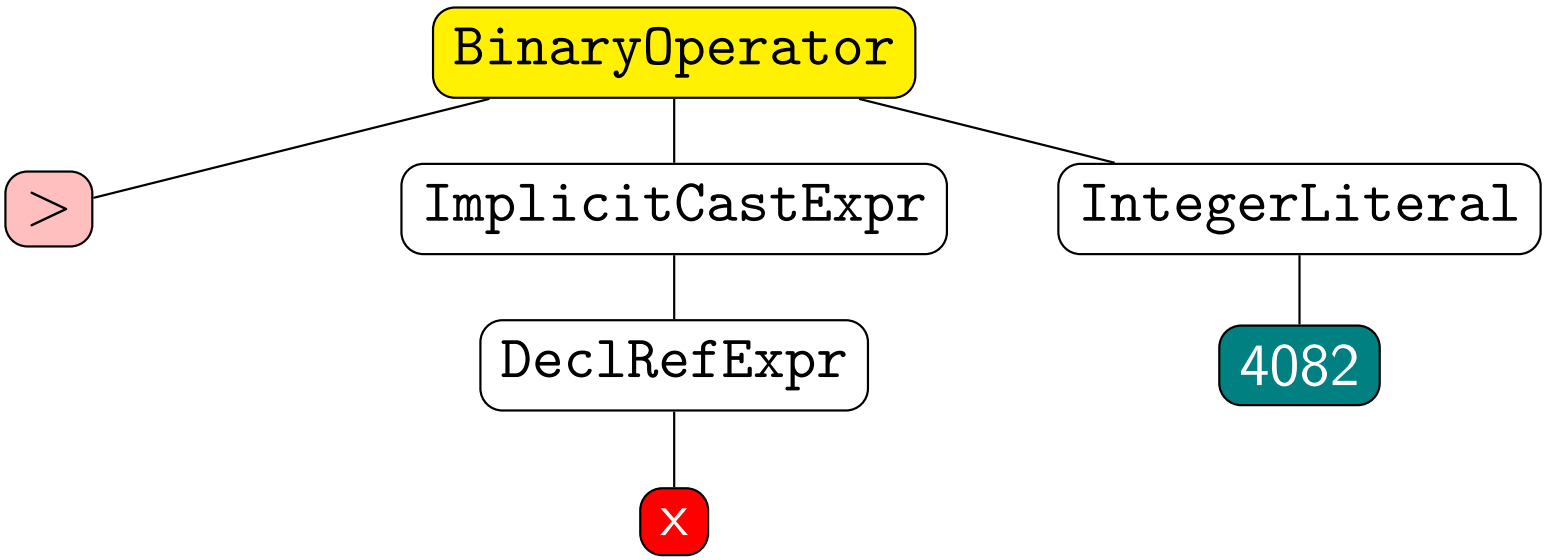

LLVM IR

```
1  int retsum(int a, int b) {
2    return a + b;
3  }
4  # clang -S -emit-llvm code.cpp -O0 -o code.ll
5  ; ModuleID = 'test.cc'
6  source_filename = "test.cc"
7  target datalayout = "e-m:e-p270:32:32-p271:32:32-p272:64:64-i64:..."
8  target triple = "x86_64-unknown-linux-gnu"
9
10 ; Function Attrs: mustprogress noinline nounwind optnone uwtable
11 define dso_local i32 @_Z6retsumii(i32 %0, i32 %1) #0 {
12   %3 = alloca i32, align 4
13   %4 = alloca i32, align 4
14   store i32 %0, i32* %3, align 4
15   store i32 %1, i32* %4, align 4
16   %5 = load i32, i32* %3, align 4
17   %6 = load i32, i32* %4, align 4
18   %7 = add nsw i32 %5, %6
19   ret i32 %7
20 }
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  - Code up pass logic in `struct` inherited from `PassInfoMixin`, must have a `run()` function.
  - Register the `Pass` and build your pass into a shared library which can be loaded and used by `opt` tool to run pass on LLVM IR.

LLVM Pass

```
1  struct MyPass : public PassInfoMixin<MyPass> {
2    PreservedAnalyses run(Function \&F, FunctionAnalysisManager \&FM){
3      # Your code logic
4      ...
5      return PreservedAnalyses::all();
6    }
7    ...
8  };
9  extern "C" ::llvm::PassPluginLibraryInfo LLVM_ATTRIBUTE_WEAK
10 llvmGetPassPluginInfo() {
11   return {LLVM_PLUGIN_API_VERSION, "MyPass", "v0.1",
12     [](PassBuilder &PB) {
13       PB.registerPipelineParsingCallback(
14       [](StringRef Name, FunctionPassManager &FPM,
15       ArrayRef<PassBuilder::PipelineElement>) {
16         if (Name == "mypass") {
17           FPM.addPass(ModifyBuildCFG());
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- Clang Plugin or Standalone tool (`clang LibTooling`).

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Clang ASTFrontendAction

```
1  class ClassAction : public clang::ASTFrontendAction {
2    public:
3    # returns a uniq ptr to your consumer.
4    virtual std::unique_ptr<clang::ASTConsumer>
5    CreateASTConsumer(clang::CompilerInstance &Compiler,
6      llvm::StringRef InFile) {
7      return
8        # Instantiate your consumer.
9        std::make_unique<ClassConsumer>(
10         &Compiler.getASTContext()
11       );
12   }
13 };
```

Clang ClassConsumer

```
1  class ClassConsumer : public clang::ASTConsumer {
2    public:
3      explicit ClassConsumer(ASTContext *Context)
4        : Visitor(Context) {}
5      virtual void HandleTranslationUnit(clang::ASTContext &Context) {
6        # Called on each TranslationDeclUnit
7        Visitor.TraverseDecl(Context.getTranslationUnitDecl());
8      }
9    private:
10     # Implements the actual recursive visit strategy.
11     ClassVisitor Visitor;
12 };
```

Clang ClassConsumer

```
1  class ClassVisitor
2  : public RecursiveASTVisitor<ClassVisitor> {
3  public:
4    explicit FindNamedClassVisitor(ASTContext *Context)
5      : Context(Context) {}
6
7    bool VisitWhileStmt(WhileStmt *S) {
8      llvm::outs() << "While Condition : ";
9      if (S)
10     VisitDecl(S->getConditionVariable());
11     return true;
12   }
13   # ... More Visit Logic.
14   bool VisitDecl(clang::Decl *Declaration) {
15     Declaration->dump();
16     return true;
17   }
18
19 private:
20   ASTContext *Context;
21 };
```

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Links

- Docker Image : https://hub.docker.com/r/prodrelworks/llvm-examples
- LLVM Example : https://github.com/lahiri-phdworks/LLVM-Examples