UNC CHARLOTTE

Using Clang as An Alternative C/C++ Frontend of The ROSE Source-to-Source Compiler

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Outline

- Motivation
- ROSE Compiler
  - Clang and EDG Frontend
  - Code Example: Source-to-Source Transformation
- Clang and ROSE AST
- Tech Details
  - Code Example: Clang AST to ROSE AST
- Conclusion and Future work

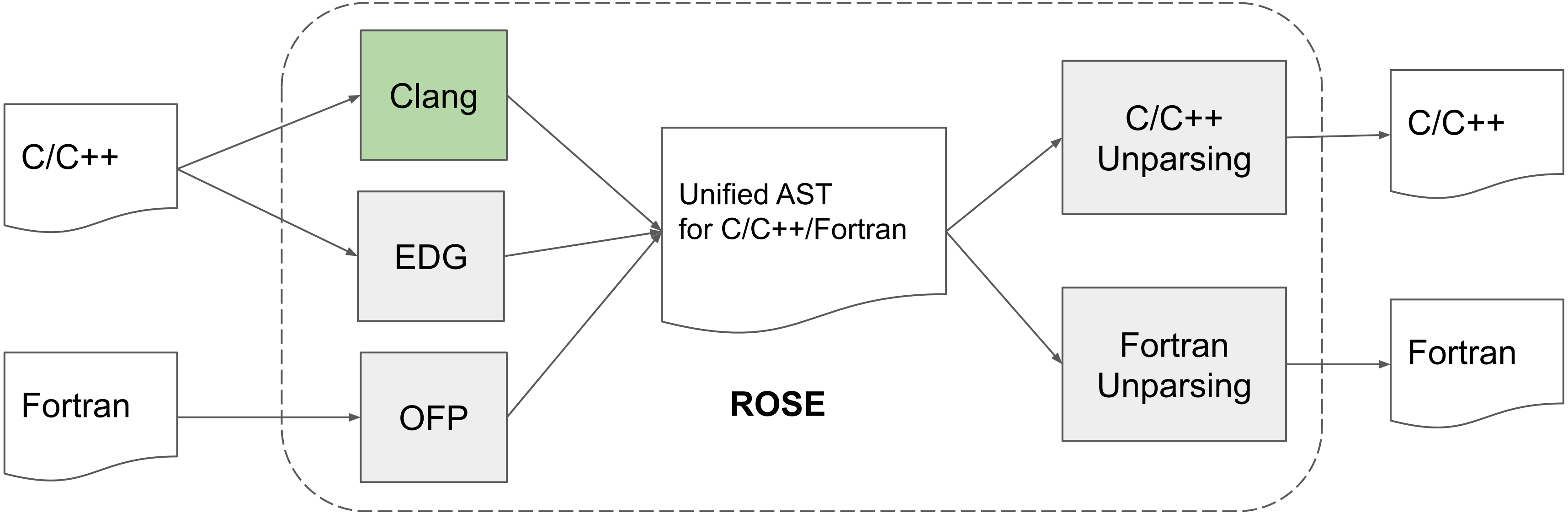
ROSE Compiler

- An open source compiler infrastructure to build **source-to-source** program transformation and analysis tools
- A unified AST as its IR for input codes written in C/C++ and Fortran
- Sophisticated compiler analyses, transformations and optimizations are developed on top of the AST and encapsulated as simple function calls

Motivation

- Clang: limited source-to-source translation support
  - Clang AST is immutable
  - No unparser to convert Clang AST to compilable source code
- ROSE: limitations of its current C/C++ EDG frontend
  - EDG is proprietary
  - Written in C with macros
  - EDG does not support OpenMP

Using Clang as An Alternative C/C++ Frontend of The ROSE



Comparing Clang and EDG Frontend

	Clang	EDG
License	Open Source	Proprietary
SLOC	1.67×10^6	1.59×10^6
IR	Clang AST	EDG IR
Language	Modern C++11/14	C with macros
User Community	Any companies or universities	Compiler/tool vendors
OpenMP	Yes	No

ROSE Source-to-Source Transformation Example

```
void axpy(int a, int* x, int* y, int size) {
#pragma omp target map(to: x[0:size], a)
map(tofrom: y[0:size])
#pragma omp parallel for
        for (int i = 0; i < size; i++)
          y[i] = y[i] + a * x[i];
}
```

```
__global__ void OUT__1__8216__(int a,int *_dev_x,int *_dev_y)
{
 int _dev_lower,_dev_upper, ... ,_dev_thread_num,_dev_thread_id = ...;

 XOMP_static_sched_init(0,size - 1,1,1,_dev_thread_num,_dev_thread_id,
&_dev_loop_chunk_size,&_dev_loop_sched_index,&_dev_loop_stride);

 while(XOMP_static_sched_next(&_dev_loop_sched_index,size - 1,1,_dev_loop_stride,
_dev_loop_chunk_size,_dev_thread_num,_dev_thread_id,&_dev_lower,&_dev_upper))
        for (i = _dev_lower; i <= _dev_upper; i += 1)
          _dev_y[i - 0] = _dev_y[i - 0] + a * _dev_x[i - 0];
}
void axpy(int a,int *x,int *y,int size)
{   …
     // transfer data and launch CUDA kernel
        int _threads_per_block_ = xomp_get_maxThreadsPerBlock(0);
        int _num_blocks_ = xomp_get_max1DBlock(0,size - 1 - 0 + 1);
        OUT__1__8216__<<<_num_blocks_,_threads_per_block_>>>(a,_dev_x,_dev_y);
        xomp_deviceDataEnvironmentExit(0);
}
```

Comparing Clang and ROSE AST

	Clang	**ROSE**
Mutable	No	Yes
Source-to-Source	Limited	Yes
Programming Language	C++11/14	C++
Represented Languages	C/C++	C/C++, Fortran
Unparsing	No	Yes
API	Create/Traverse	Create/Update/Delete/Traverse

Immutable Clang AST VS mutable ROSE AST

- Clang immutable AST:
  - Canonicalization of the “meaning” of nodes is possible once node is created
  - AST nodes can be reused when they have the same meaning
  - Serialization and deserialization support
- ROSE mutable AST:
  - Easily adding, deleting, and changing AST nodes from AST tree
  - With an elegant means of manipulating source code
  - Use with caution to avoid incorrect source location information, invalidated semantic information, and generating illegal program

Technical Details

- Clang AST Generation
  - Clang takes the C/C++ source code and creates an AST.
- Connector in ROSE
  - The connector in ROSE traverses the Clang AST and creates a ROSE AST accordingly.

Driver in ROSE for Converting Clang AST

- Creating an ASTConsumer and define conversation APIs for all Clang AST nodes
  - class ClangToSageTranslator : public clang::ASTConsumer {}
    - virtual bool VisitDecl(clang::Decl * decl, SgNode ** node);
    - virtual bool VisitStmt(clang::Stmt * stmt, SgNode ** node);
    - virtual bool VisitType(clang::Type * type, SgNode ** node);
    - ...
- Translation process:
  - Create compiler instance
    - clang::CompilerInstance
  - Inform the diagnostic client the beginning of source file processing
    - compiler_instance->getDiagnosticClient().BeginSourceFile(compiler_instance->getLangOpts(), &(compiler_instance->getPreprocessor()));
  - Parse specified file and notify AST consumer, translator, as the file is parsed.
    - clang::ParseAST(compiler_instance->getPreprocessor(), &translator, compiler_instance->getASTContext());
  - Inform the diagnostic client the ending of source file processing
    - compiler_instance->getDiagnosticClient().EndSourceFile();

Current Status: Supported Clang AST Node Types

- Based on Clang 9 and excluding Objective-C support:

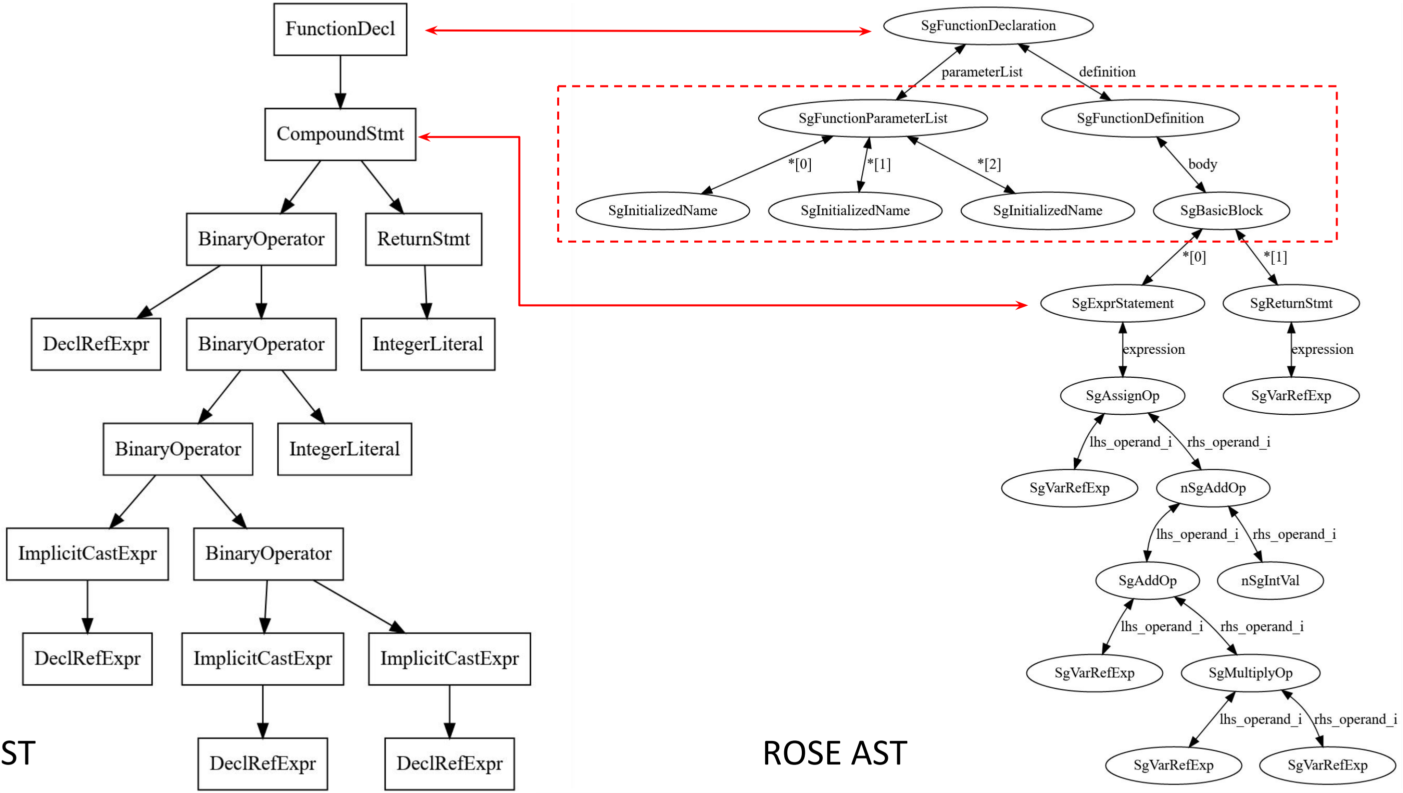
	Supported	Total	Ratio
Declaration	41	84	48.81%
Statement	63	198	31.82%
Type	18	58	31.03%
Total	122	340	35.88%

Updates from Clang 9 to Clang 10

- API changes
  - ArrayRef'ized CompilerInvocation::CreateFromArgs
  - OpenMP token definitions moved from Clang into LLVM
- Increased OpenMP 5.x support
  - OpenMP master taskloop directive
  - OpenMP parallel master taskloop directive
  - OpenMP master taskloop simd directive
  - OpenMP parallel master taskloop simd directive
  - OpenMP parallel master directive

Clang AST and ROSE AST

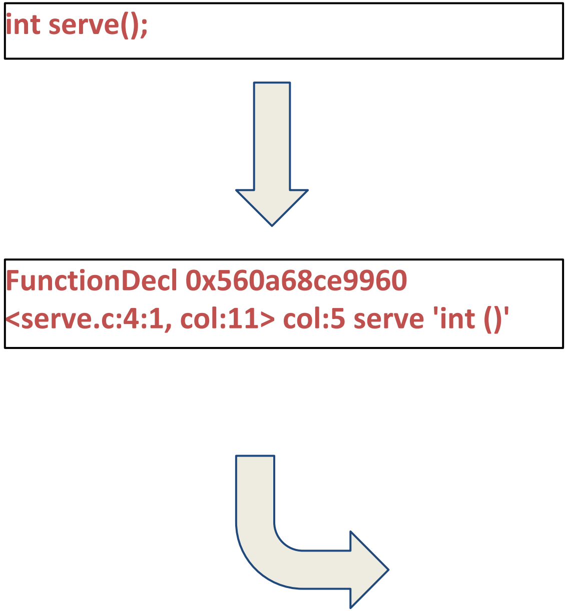
```
int calc(int a, int x, int y) {
        y = y + a * x + 10;
        return y;
}
```



Clang AST

ROSE AST

Code example: Clang AST to ROSE AST



int serve();

FunctionDecl 0x560a68ce9960 <serve.c:4:1, col:11> col:5 serve 'int ()'

```
bool ClangToSageTranslator::VisitFunctionDecl(clang::FunctionDecl * function_decl,
SgNode ** node) {
        SgName name(function_decl->getNameAsString());
        SgType * ret_type = SageBuilder::buildTypeFromQualifiedType
(function_decl->getReturnType());
        SgFunctionParameterList * param_list =
SageBuilder::buildFunctionParameterList_nfi();
        applySourceRange(param_list, function_decl->getSourceRange());
        for (unsigned i = 0; i < function_decl->getNumParams(); i++) {
                SgNode * tmp_init_name = Traverse(function_decl->getParamDecl(i));
                SgInitializedName * init_name = isSgInitializedName(tmp_init_name);
                param_list->append_arg(init_name);
        }
        SgFunctionDeclaration * sg_function_decl;
        sg_function_decl = SageBuilder::buildNondefiningFunctionDeclaration(name,
ret_type, param_list, NULL);
        SgInitializedNamePtrList & init_names = param_list->get_args();
        ... // rest of conversion
        *node = sg_function_decl;
        return VisitDeclaratorDecl(function_decl, node) && res;
}
```

Conclusion

- Clang works well with ROSE as an alternative C/C++ frontend.
  - Using Clang instead of EDG: open-source and better OpenMP support.
  - ROSE AST provides more flexible source-to-source transformation than Clang AST.
- Ongoing/future work
  - Upgrade Clang 9.x to Clang 10.x in ROSE.
  - Support the conversion of all the Clang AST nodes.
  - Replace OFP (Open Fortran Parser) with Flang.

Thank You!

Questions and Answers

https://github.com/rose-compiler/rose/wiki/Install-ROSE-with-Clang-as-frontend

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