Workshop on Essential Abstractions in GCC

Introduction to Gimple IR

GCC Resource Center
(www.cse.iitb.ac.in/grc)

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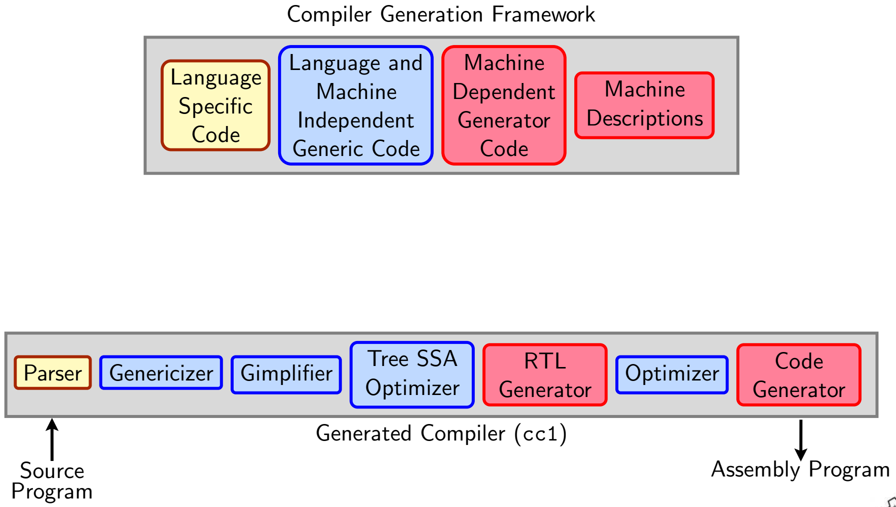
Outline

- Introduction to Gimple IR
- Adding a pass to GCC
- Working with the Gimple API

Part 1

Introduction to GIMPLE

Recall GCC CGF



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Recall GCC CGF

Notes

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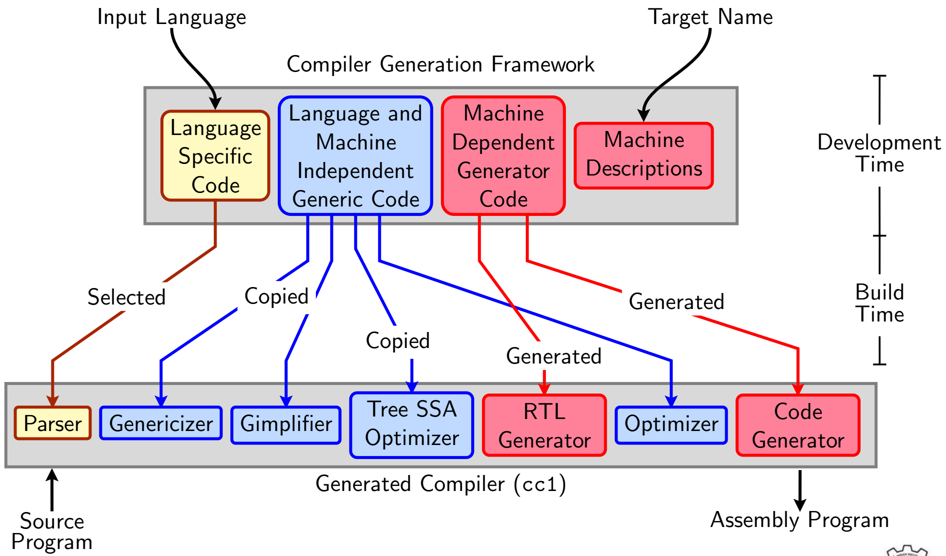
Recall GCC CGF



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Recall GCC CGF

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Basics of GIMPLE

- GIMPLE is a language-independent IR for GCC.
- It is based on *tree* data structure.
- GIMPLE is *simple.*

Basics of GIMPLE

Notes

Motivation behind GIMPLE

- Previously, the only common IR was RTL (Register Transfer Language)
- Drawbacks of RTL for performing high-level optimizations :
  - RTL is a low-level IR, works well for optimizations close to machine (e.g., register allocation)
  - Some high level information is difficult to extract from RTL (e.g. array references, data types etc.)
  - Optimizations involving such higher level information are difficult to do using RTL.
  - Introduces stack too soon, even if later optimizations dont demand it.

Notice

Inlining at tree level could partially address the the last limitation of RTL.

Motivation behind GIMPLE

Notes

Why not ASTs for optimization ?

- ASTs contain detailed function information but are not suitable for optimization because
  - Lack of a common representation
    - No single AST shared by all front-ends
    - So each language would have to have a different implementation of the same optimizations
    - Difficult to maintain and upgrade so many optimization frameworks
  - Structural Complexity
    - Lots of complexity due to the syntactic constructs of each language

Why not ASTs for optimization ?

Notes

Need for a new IR

- In the past, compiler would only build up trees for a single statement,and then lower them to RTL before moving on to the next statement.
- For higher level optimizations, entire function needs to be represented in trees in a language-independent way.
- Result of this effort - GENERIC and GIMPLE

Need for a new IR

Notes

What is GENERIC ?

- Language independent IR for a complete function in the form of trees
- Obtained by removing language specific constructs from ASTs
- All tree codes defined in `$(SOURCE)/gcc/tree.def`

- Each language frontend may still have its own AST.
- Once parsing is complete they must emit GENERIC

What is GENERIC ?

Notes

What is GIMPLE ?

- GIMPLE is influenced by SIMPLE IR of McCat compiler
- But GIMPLE is not same as SIMPLE (Gimple supports GOTO)
- It is a simplified subset of GENERIC
  - 3 address representation
  - Control flow lowering
  - Cleanups and simplification, restricted grammar
- Benefit : Optimizations become easier

What is GIMPLE ?

Notes

GIMPLE Phase sequence in `cc1` and GCC

Converting GENERIC to GIMPLE

```
c_genericize()                          c-gimplify.c
   gimplify_function_tree()               gimplify.c
      gimplify_body()                     gimplify.c
         gimplify_stmt()                  gimplify.c
            gimplify_expr()               gimplify.c
lang_hooks.callgraph.expand_function()
 tree_rest_of_compilation()          tree-optimize.c
  tree_register_cfg_hooks()               cfghooks.c
   execute_pass_list()                      passes.c
 /* TO: Gimple Optimisations passes */
               ...
          NEXT_PASS(pass_lower_cf)
```


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GIMPLE Phase sequence in cc1 and GCC

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GIMPLE Goals

The Goals of GIMPLE are

- Lower control flow
  Program = sequenced statements + unrestricted jump
- Simplify expressions
  Typically: two operand assignments!
- Simplify scope
  move local scope to block begin, including temporaries

Notice
Lowered control flow → nearer to register machines + Easier SSA!

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GIMPLE Goals

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High GIMPLE

- GIMPLE that is not fully lowered.
- Consists of Intermediate Language before the pass *pass_lower_cf*.
- Contains some container statements like lexical scopes and nested expressions.
- High GIMPLE Instruction Set : GIMPLE_BIND, GIMPLE_CALL, GIMPLE_CATCH, GIMPLE_GOTO, GIMPLE_EH_FILTER, GIMPLE_RETURN, GIMPLE_SWITCH, GIMPLE_TRY, GIMPLE_ASSIGN

High GIMPLE

Notes

Low GIMPLE

- Gimple that is fully lowered after the pass *pass_lower_cf*.
- Exposes all of the implicit jumps for control and exception expressions.
- Low GIMPLE Instruction Set : GIMPLE_CALL, GIMPLE_GOTO, GIMPLE_RETURN, GIMPLE_SWITCH, GIMPLE_ASSIGN
- Lowered Instruction Set : GIMPLE_BIND, GIMPLE_CATCH, GIMPLE_EH_FILTER, GIMPLE_TRY

Low GIMPLE

Notes

Some GIMPLE Node types

Binary Operator	MAX_EXPR
Comparison	EQ_EXPR, LT_EXPR
Constants	INTEGER_CST, STRING_CST
Declaration	FUNCTION_DECL, LABEL_DECL , VAR_DECL
Expression	PLUS_EXPR, ADDR_EXPR
Reference	COMPONENT_REF, ARRAY_RANGE_REF
Statement	GIMPLE_MODIFY_STMT, RETURN_EXPR, COND_EXPR, INIT_EXPR
Type	BOOLEAN_TYPE, INTEGER_TYPE
Unary	ABS_EXPR, NEGATE_EXPR

Tip :

All tree nodes ($\sim$ 152) in GCC are listed in: `$(SOURCE)/gcc/tree.def`.

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Some GIMPLE Node types

Notes

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Journey through GIMPLE

Generic Code (gimple.c)

```
int main()
{
    int a;
    if (a)
    {
        int b;
        b = 2 + a + b;
    }
    return 0;
}
```


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Journey through GIMPLE

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Journey through GIMPLE

High GIMPLE (`gimple.c.004t.gimple`)

```
main ()
{
  int D.1195;
  int D.1196;
  int a;

  if (a != 0)
    {
      {
        int b;

        D.1195 = a + 2;
        b = D.1195 + b;
      }
    }
  else
    {

    }
  D.1196 = 0;
  return D.1196;
}
```


Journey through GIMPLE

Notes

Journey through GIMPLE

Low GIMPLE (`gimple.c.013t.cfg`) : Lexical scopes removed

```
main ()
{
  int b;
  int a;
  int D.1196;
  int D.1195;

  # BLOCK 2
  # PRED: ENTRY (fallthru)
  if (a != 0)
    goto <bb 3>;
  else
    goto <bb 4>;
  # SUCC: 3 (true) 4 (false)

  # BLOCK 3
  # PRED: 2 (true)
  D.1195 = a + 2;
  b = D.1195 + b;
  # SUCC: 4 (fallthru)

  # BLOCK 4
  # PRED: 2 (false) 3 (fallthru)
  D.1196 = 0;
  # SUCC: 5 (fallthru)

  # BLOCK 5
  # PRED: 4 (fallthru)
  return D.1196;
  # SUCC: EXIT
}
```


Journey through GIMPLE

Notes

Important Dump Files

- Compile using `./gcc -fdump-tree-all <file-name >.c`
- Examine `<file-name >.c.013t.cfg`

Important Dump Files

Notes

Resolving doubts by inspecting GIMPLE

Inspect GIMPLE when in doubt

```
int main(void)
{
  int x=2,y=3;
  x= y++ + ++x + ++y ;
  printf("\nx = %d", x);
  printf("\ny = %d", y);
  return 0;
}
```

```
x = 2;
y = 3;
x = x + 1;
D.1572 = y + x;
y = y + 1;
x = D.1572 + y;
y = y + 1;
printf (&"\nx = %d"[0], x);
printf (&"\y = %d"[0], y);
```

`x = 10 , y =5`

Resolving doubts by inspecting GIMPLE

Notes

Part 2

Adding a Pass to GCC

Adding a Pass on Gimple IR

- Step 0. Write function gccwk09_main() in file gccwk09.c.
- Step 1. Create the following data structure in file gccwk09.c.

```
struct tree_opt_pass pass_gccwk09 =
{ "gccwk09",  /* name */
  NULL,       /* gate, for conditional entry to this pass */
  gccwk09_main, /* execute, main entry point */
  NULL,       /* sub-passes, depending on the gate predicate */
  NULL,       /* next sub-passes, independ of the gate predicate */
  0,          /* static_pass_number , used for dump file name*/
  0,          /* tv_id */
  0,          /* properties_required, indicated by bit position */
  0,          /* properties_provided , indicated by bit position*/
  0,          /* properties_destroyed , indicated by bit position*/
  0,          /* todo_flags_start */
  0,          /* todo_flags_finish */
  0           /* letter for RTL dump */
};
```


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Adding a Pass on Gimple IR

Notes

Adding a Pass on Gimple IR

- Step 2. Add the following line to `tree-pass.h`
  `extern struct tree_opt_pass pass_gccwk09;`
- Step 3. Include the following call at an appropriate place in the function `init_optimization_passes()` in the file `passes.c`
  `NEXT_PASS (pass_gccwk09);`
- Step 4. Add the file name in the Makefile
  - Either in `$SOURCE/gcc/Makefile.in`
    Reconfigure and remake
  - Or in `$BUILD/gcc/Makefile`
    Remake
- Step 5. Build the compiler
- Step 6. Debug using gdb if need arises

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Adding a Pass on Gimple IR

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Part 3

Working with the GIMPLE API

GIMPLE Statements

- GIMPLE Statements are nodes of type tree
- Every basic block contains a doubly linked-list of statements
- Processing of statements can be done through iterators

```
block_statement_iterator bsi;
basic_block bb;
FOR_EACH_BB (bb)
   for ( bsi =bsi_start(bb); !bsi_end_p(bsi); bsi_next(&bsi))
      print_generic_stmt (stderr, bsi_stmt(bsi), 0);
```

FOR_EACH_BB → Basic Block Iterator

bsi → Block Statement Iterator

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GIMPLE Statements

Notes

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A simple application

Counting the number of assignment statements in GIMPLE

```
#include <stdio.h>
int m,q,p;
int main(void)
{
  int x,y,z,w;
  x = y + 5;
  z = x * m;
  p = m + q + w ;
  return 0;
}
```

```
x = y + 5;
m.0 = m;
z = x * m.0;
m.1 = m;
q.2 = q;
D.1580 = m.1 + q.2;
p.3 = D.1580 + w;
p = p.3;
D.1582 = 0;
return  D.1582;
```

The statements in blue are the assignments corresponding to the source.

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A simple application

Notes

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A simple application

Counting the number of assignment statements in GIMPLE

```
struct tree_opt_pass pass_gccwk09 =
{
    "gccwk09",
     NULL,
     gccwk09_main,
     NULL,
     NULL,
     0,
     0,
     0,
     0,
     0,
     0,
     0,
     0
};
```


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A simple application

Notes

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A simple application

Counting the number of assignment statements in GIMPLE

```
static unsigned int gccwk09_main(void)
{  basic_block bb;
   block_stmt_iterator si;

   initialize_stats();

   FOR_EACH_BB (bb)
   {
      for (si=bsi_start(bb); !bsi_end_p(si); bsi_next(&si))
          {
           tree stmt = bsi_stmt(si);
           process_statement(stmt);
          }
   }
   return 0;
}
```


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A simple application

Notes

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A simple application

Counting the number of assignment statements in GIMPLE

```
void process_statement(tree stmt)
{  tree lval,rval;
    switch (TREE_CODE(stmt))
    {    case GIMPLE_MODIFY_STMT:
              lval=GIMPLE_STMT_OPERAND(stmt,0);
              rval=GIMPLE_STMT_OPERAND(stmt,1);
              if(TREE_CODE(lval) == VAR_DECL)
              {   if(!DECL_ARTIFICIAL(lval))
                  {  print_generic_stmt(stderr,stmt,0);
                     numassigns++;
                  }
                  totalassigns++;
              }
              break;
        default :
              break;
    }
}
```


A simple application

Notes

A simple application

Counting the number of assignment statements in GIMPLE

- Add the following in `$(SOURCE)/gcc/common.opt` :
- `fpass_gccwk09`
- Common Report Var (`flag_pass_gccwk09`)
- Enable pass named `pass_gccwk09`

Compile using `./gcc -fdump-tree-all -fpass_gccwk09 test.c`

A simple application

Notes

Assignment and Reference

API Reference

- http://gcc.gnu.org/onlinedocs/gccint.pdf Pg- 233-235
- Refere the same document for some detailed documentation

Assignments (by traversing the GIMPLE IR)

- Count the number of copy statements in a program
- Count the number of variables declared "const" in the program
- Count the number of occurances of arithmatic operators in the program
- Count the number of references to global variables in the program

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Assignment and Reference

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