COMPILER PROJECT DOCUMENTATION

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- TITLE: CONSTANT PROPAGATION
- COMPILER 1: GCC
- COMPILER 2: LLVM

PROBLEM STATEMENT:

Constant propagation is the process of substituting the values of known constants in expressions at compile time. Such constants include those defined above, as well as intrinsic functions applied to constant values.

OPTIMISATION DEFINITION:

Optimization = Analysis + Transformation

Transformation may make the code more efficient. But it may also change the meaning of the code. **Analysis** determines when transformations can be applied safely.

Constant propagation did not remove any instructions, but it enabled **dead-code elimination** which did remove instructions. Together, the optimizations made the code more efficient. Hence, constant propagation is known as an **enabling optimization**.

We will explore two analyses:

1. **Liveness analysis**: Can deduce when dead-code elimination is safe. Also used in register allocation. Is a “backward analysis”.

2. **Reaching-definitions analysis:** Can deduce when constant propagation is safe. Is a “forward analysis”.

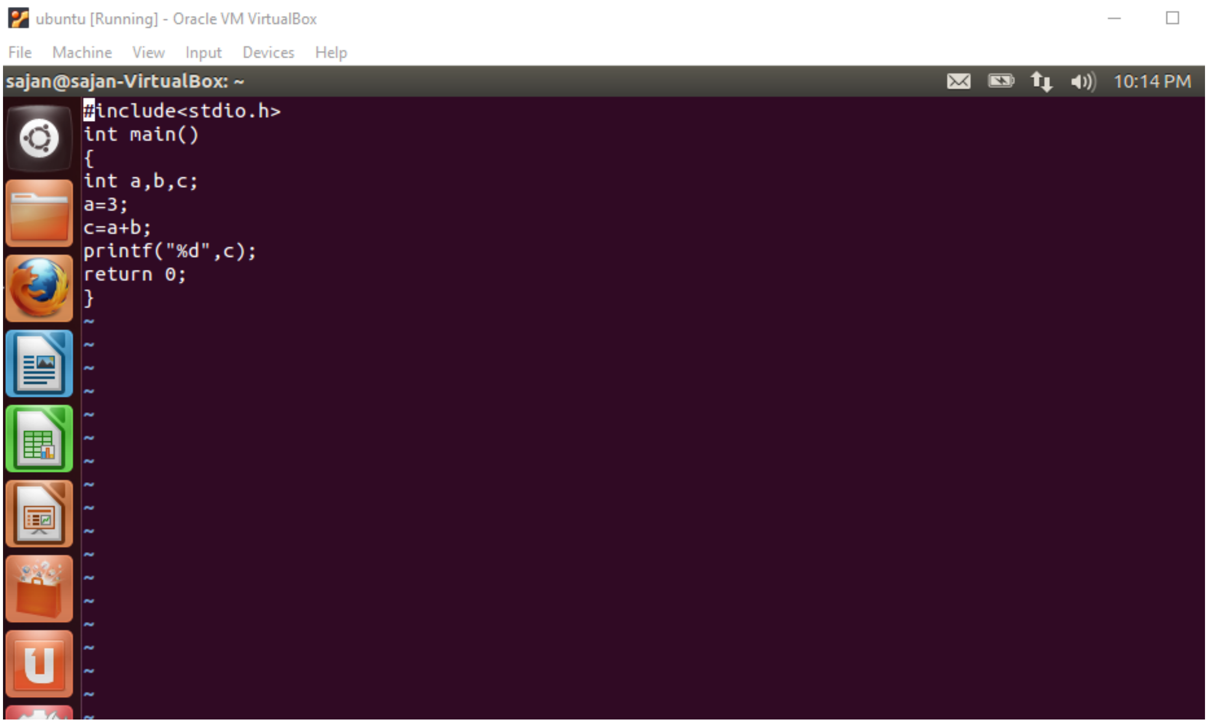
Using the results of analysis, to precisely and safely, define constant propagation.

IMPLEMENTATION:

1. GCC COMPILER:

STEP 1: OPEN THE BASH TERMINAL IN LINUX OS

STEP 2: TYPE A PROGRAM IN WHICH CONSTANT PROPAGATION CAN BE IMPLEMENTED

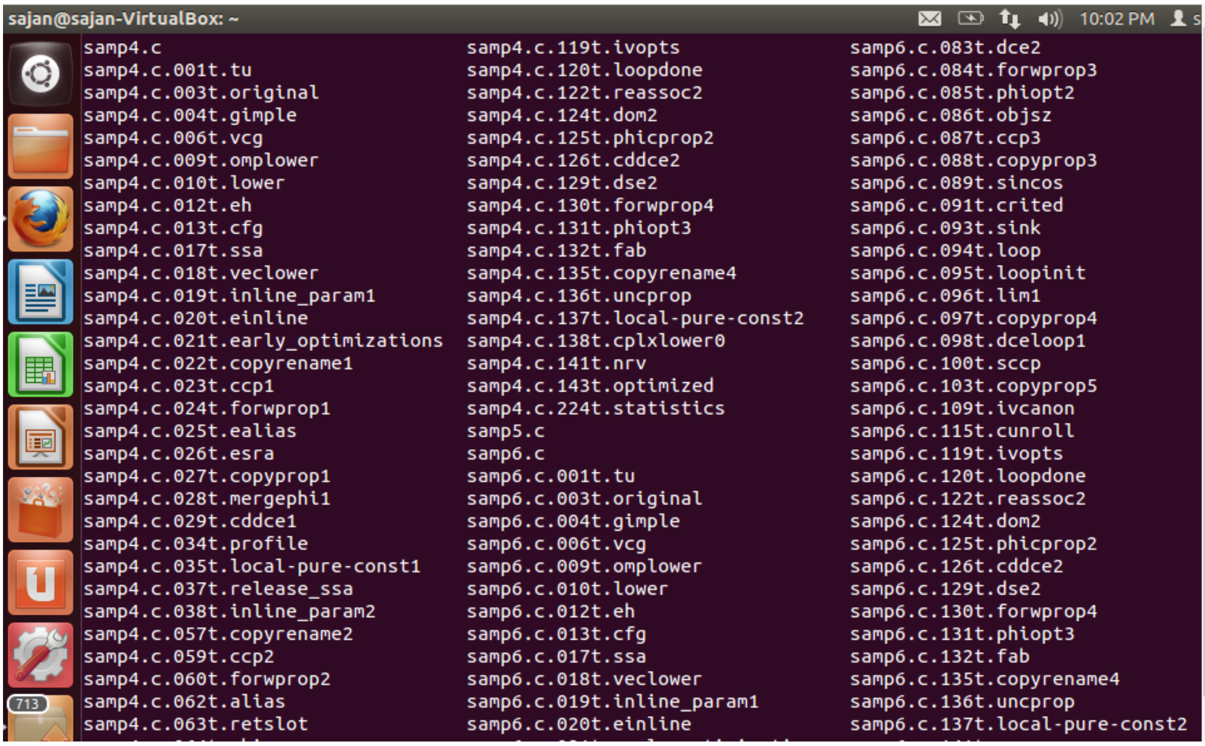


STEP 3: CHECK WHETHER THE PROGRAM EXECUTES WITHOUT ANY ERROR

STEP 4: CONVERT SOURCE CODE INTO OPTIMIZED CODE USING THE COMMAND “ gcc filename.c -O -fdump-tree-all “

```
sajan@sajan-VirtualBox:~$ gcc samp6.c -O -fdump-tree-all
```

STEP 5: VIEW ALL OPTIMIZED CODE USING “ ls “ COMMAND

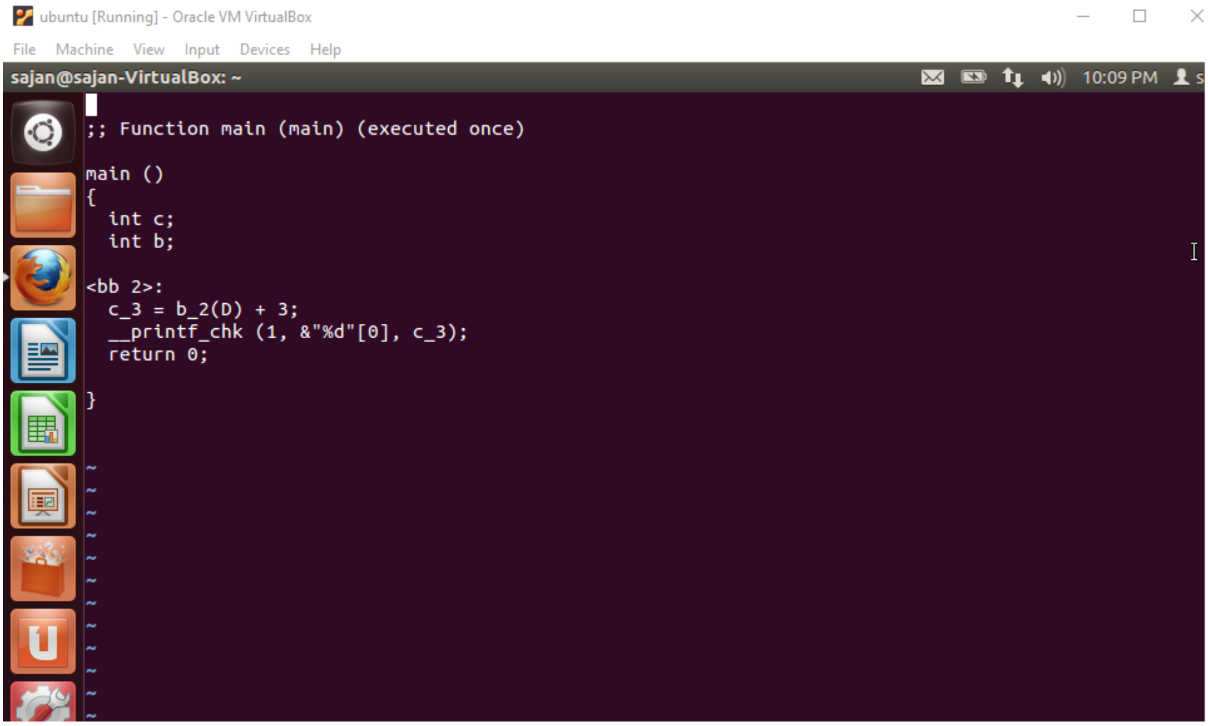


STEP 6: VARIOUS OPTIMIZED CODES ARE AVAILABLE WHICH CAN BE VIEWED USING “ vi required_filename “.

STEP 7: IN-ORDER TO VIEW CONSTANT PROPAGATION USE COMMAND

```
sajan@sajan-VirtualBox:~$ vi samp4.c.066t.copyprop2
```

STEP 8: THE OPTIMIZED CODE CAN BE VIEWED



2. LLVM (IMPLEMENTATION USING LLVM AND CLANG)

LLVM is a compiler infrastructure designed as a set of reusable libraries with well defined interfaces. It is Open Source and a framework that comes with a lot of tools to compile and optimize code .

LLVM is fairly easy to install. For a quick overview on the process, we recommend: http://llvm.org/releases/3.4/ docs/GettingStarted.html

INSTALLATION STEPS OF LLVM:

```
$> svn co http://llvm.org/svn/llvm-project/llvm/tags/RELEASE_34/final llvm
$> cd llvm/tools
$> svn co http://llvm.org/svn/llvm-project/cfe/tags/RELEASE_34/final clang
$> cd ../projects/
$> svn co http://llvm.org/svn/llvm-project/compiler-rt/tags/RELEASE_34/final
compiler-rt
$> cd ../tools/clang/tools/
$> svn co http://llvm.org/svn/llvm-project/clang-tools-extra/tags/RELEASE_34/
final extra
```

INSTALL CLANG/CLANG++:

CLANG ACTS LIKE FRONT END AND LLVM ACTS LIKE BACK END. CLANG/CLANG++ IS VERY COMPETITIVE WHEN COMPARED WITH GCC AS CLANG HAVE FASTER COMPILATION TIMES.

VARIOUS TOOLS AVAILABLE UNDER LLVM FRAMEWORK:

```
$> cd llvm/Debug+Asserts/bin
$> ls
FileCheck         count              llvm-dis          llvm-stress
FileUpdate        diagtool           llvm-dwarfdump    llvm-symbolizer
arcmt-test        fpcmp              llvm-extract      llvm-tblgen
bugpoint          llc                llvm-link         macho-dump
c-arcmt-test      lli                llvm-lit          modularize
c-index-test      lli-child-target   llvm-lto          not
clang             llvm-PerfectSf     llvm-mc           obj2yaml
clang++           llvm-ar            llvm-mcmarkup     opt
llvm-as           llvm-nm            pp-trace          llvm-size
clang-check       llvm-bcanalyzer    llvm-objdump      rm-cstr-calls
clang-format      llvm-c-test        llvm-ranlib       tool-template
clang-modernize   llvm-config        llvm-readobj      yaml2obj
clang-tblgen      llvm-cov           llvm-rtdyld       llvm-diff
clang-tidy
```

COMPILATION OF C/C++ PROGRAMS:

```
$> echo "int main() {return 42;}" > test.c
$> clang test.c
$> ./a.out
$> echo $?
42
```

COMPILING LLVM:

Once you have gotten all the files, via svn, you must compile LLVM. There are more than one way to compile it.

If you want to do it quickly, you can configure LLVM with the option --enable-optimized set. Otherwise, a default compilation, with debug symbols, will be performed.

```
$> cd ~/Programs/llvm # that's where I have downloaded it.

$> mkdir build

$> ../configure

$> make -j16          # Assuming you have more than 1 core.
```

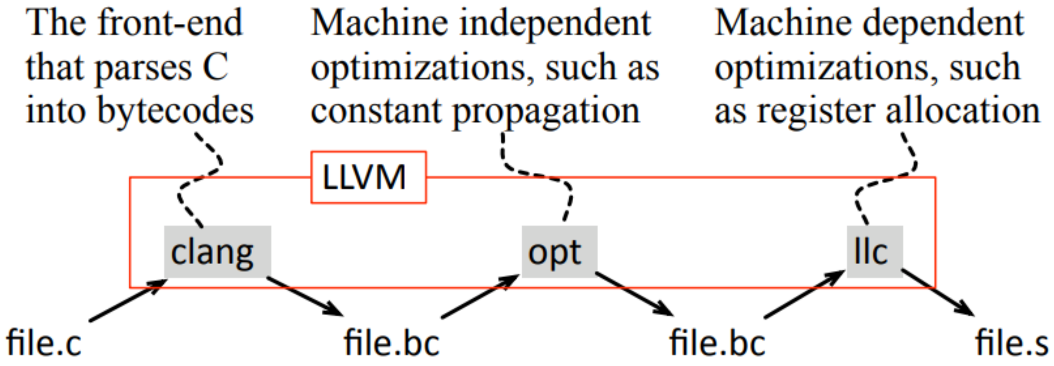
OPTIMIZATION:

The opt tool, available in the LLVM toolbox, performs machine independent optimization.

There are many optimizations available through opt. To have an idea, type opt --help.

```
$> opt --help
  Optimizations available:
    -adce                          - Aggressive Dead Code Elimination
    -always-inline                 - Inliner for always_inline functions
    -break-crit-edges              - Break critical edges in CFG
    -codegenprepare                - Optimize for code generation
    -constmerge                    - Merge Duplicate Global Constants
    -constprop                     - Simple constant propagation
    -correlated-propagation        - Value Propagation
    -dce                           - Dead Code Elimination
    -deadargelim                   - Dead Argument Elimination
    -die                           - Dead Instruction Elimination
    -dot-cfg                       - Print CFG of function to 'dot' file
    -dse                           - Dead Store Elimination
    -early-cse                     - Early CSE
    -globaldce                     - Dead Global Elimination
    -globalopt                     - Global Variable Optimizer
    -gvn                           - Global Value Numbering
    -indvars                       - Induction Variable Simplification
    -instcombine                   - Combine redundant instructions
    -instsimplify                  - Remove redundant instructions
    -ipconstprop                   - Interprocedural constant propagation
    -loop-reduce                   - Loop Strength Reduction
```

Working concept of clang and llvm:



LEVELS OF OPTIMIZATION

Like gcc, clang supports different levels of optimizations, e.g., **-O0** (default), **-O1**, **-O2** and **-O3**

llvm-as is the LLVM assembler. It reads a file containing human-readable LLVM assembly language, translates it to LLVM bytecode, and writes the result into a file or to standard output.

To find out which optimization each level uses, you can try:

```
$> llvm-as < /dev/null | opt -O3 -disable-output -debug-pass=Arguments
```

PROGRAM AND EXPLANATION OF CONSTANT PROPAGATION:

One of the most basic optimizations that **opt** performs is to map memory slots into variables. This optimization is very useful, because the clang front end maps every variable to memory.

```
$> clang -c -emit-llvm const.c -o const.bc

$> opt –view-cfg const.bc
```

Code:

```
void main() {
  int c1 = 17;
  int c2 = 25;
  int c3 = c1 + c2;
  printf("Value = %d\n", c3);
}
```

After performing opt -view-cfg const.bc , the cfg will be,

```
%0:
 %1 = alloca i32, align 4
 %c1 = alloca i32, align 4
 %c2 = alloca i32, align 4
 %c3 = alloca i32, align 4
 store i32 0, i32* %1
 store i32 17, i32* %c1, align 4
 store i32 25, i32* %c2, align 4
 %2 = load i32* %c1, align 4
 %3 = load i32* %c2, align 4
 %4 = add nsw i32 %2, %3
 store i32 %4, i32* %c3, align 4
 %5 = load i32* %c3, align 4
 %6 = call @printf(...)
 %7 = load i32* %1
 ret i32 %7
```

Now perform opt-mem2reg const.bc

```
$> opt -mem2reg const.bc > const.reg.bc

$> opt –view-cfg const.reg.bc
```

Now cfg changes as register storage is implemented,

```
%0:
 %1 = add nsw i32 17, 25
 %2 = call @printf(...), i32 %1)
 ret i32 0
```

CONSTANT PROPAGATION:

We can fold the computation of expressions that are known at compilation time with the constprop pass.

```
$> opt -constprop const.reg.bc > const.cp.bc

$> opt –view-cfg const.cp.bc
```

now cfg changes as like,

```
%0:
 %1 = call i32 (i8*, ...)* @printf(..., i32 42)
 ret i32 0
```

Which is the optimized code.