CS3423 : Mini-assignment 1

Raj Patil : CS18BTECH11039

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1 Analysing differences between compilers and interpreters

1.1 Few decisions:

- I'll first be listing out the theoretical differences and then moving on to the experiments.
- I'll be using python as my interpreted language and C++ as my compiled language: dispatching their executions into shell scripts and evaluating them over multiple runs in jupyter notebooks for quick comparison.
- For their interpreted representation, I'll be presenting the source and the mapped representation here itself.
- For python, I'll use the dis.dis module (the dis-assembler that gives somewhat pseudo assembly code).

Compilers	Interpreters
converts source code to machine code (or an intermediate representation)	evaluates source code without an intermediate action required by the user
conversion and execution are decoupled	a REPL (read-eval-print-loop) system
relatively quicker	slower
displays all errors at once after the compilation	displays errors one by one
the execution toolchain can be clearly segmented into multiple phases at the user level	not the case

Table 1: Summary

1.2 Observations

1.2.1 Performance analysis:

```cpp
//cpp : test1.cpp
#include <iostream>
#include <functional>
using namespace std;
int main(){
	int n=10;
	const function <int(int&&,int&&)> fib = [&n,&fib](int&& i,int&& ans){
		if((i++)==n) return ans;
		return fib(move(i),ans*i);//tail call optimized
	};
	cout<<fib(0,1)<<endl;
	return 0;
}
```

```python
#python : test1.py
n=10
def fib(i,ans):
    if(i==n) :
        return ans
    else:
        i+=1
        return fib(i,ans*i)
print(fib(0,1))
```

The results are as follows:

Note that cpp compilation takes a lot of time compared to python execution but cpp execution is way faster(however, this is still not a fair test due to the preprocessing stage of CPP that is enlarged by a lot of unnecessary includes which are not being used but are needed for a single functionality). Also note the initial drop in cpp compilation and python execution(includes compilation) : that is probably due to cache benefits which is supported by the fact that it peaks again at around the 25th run for cpp due to a process switch.

Analysis_Q1

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1 Analysis for question 1

Raj Patil
CS18BTECH11039

[14]:
```
from time import perf_counter as pc
from dis import dis as da #dis-assembler
from matplotlib import pyplot as plt
import numpy as np
```

2 Performance analysis

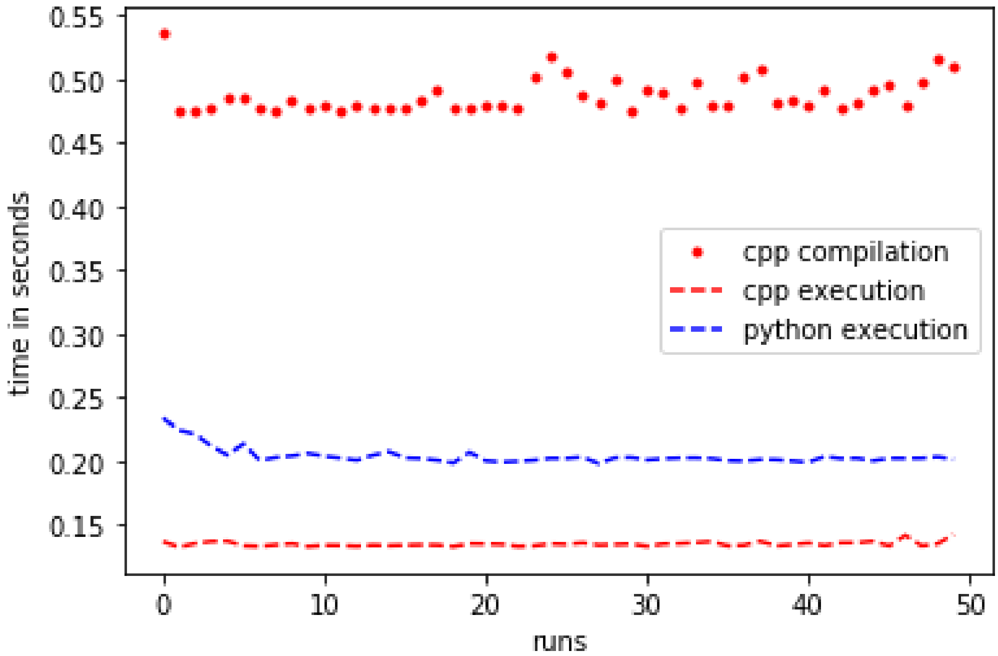
[68]:
```
compile_times_cpp=[]
execution_times_cpp=[]

for i in range(50):
    t0_cpp = pc()
    !clang++ test1.cpp
    t_cpp_compile=pc()-t0_cpp
    !./a.out > /dev/null
    t_cpp_all = pc()-t0_cpp
    compile_times_cpp.append(t_cpp_compile)
    execution_times_cpp.append(t_cpp_all-t_cpp_compile)
```

[47]:
```
execution_times_py=[]
for i in range(50):
    t0_py = pc()
    !python test1.py > /dev/null
    t_py = pc() - t0_py
    execution_times_py.append(t_py)
```

[69]:
```
plt.plot(range(50),compile_times_cpp,"r.",label="cpp compilation")
plt.plot(range(50),execution_times_cpp,"r--",label="cpp execution")
plt.plot(range(50),execution_times_py,"b--",label="python execution")
plt.xlabel("runs")
```

```
plt.ylabel("time in seconds")
plt.legend()
plt.show()
```



2.1 mean speedup:

cpp execution over python execution

[78]:
```
(np.asarray(execution_times_py)/np.asarray(execution_times_cpp)).mean()
```

[78]: 1.5119598619465746

1.3 specifics

From here onwards, I'll be talking in terms of clang and not gcc. The interpreter on the other hand, does all this at once.

1.3.1 Errors, Type inference and memory management: generic commments

This is done in the Parsing and Semantic analysis stage and if you only run the compiler with -E flag, you won't get type warnings. This time, I use the following type incoherent program

```
//test2.cpp
int main(){
        auto temp = [](vector<int> x){
                return  true;
        };
                int x = /x/;
        temp(x++);
        return 0;
}
```

This, by no means, makes sense. It shouldn't compile and it doesn't as :

- the compiler doesn't know what's a vector
- it doesn't know what is /x/ is supposed to do
- temp's type at call time is incorrect.

But, if you run 'clang++ -E test2.cpp' : you recieve no errors as in the pre-processing stage only includes and macros are expanded along with producing a token stream. However, 'clang++ test2.cpp' gives you all the expected errors.

Talking in terms of the interpreter, you would get this all at once during the REPL.

The Memory management model is a part of the language and not the implementation(compiler vs interpreter). In our case, python has a garbage collector but also allows for manual management using a wrapper API calling C's memory management utitilies. C++ on the other hand is manually managed, but one could alway dispatch a sibling process acting as a garbage collecter implemented using shared_ptr : which is what JAVA can be described by.

For the intermediate representation, I use the dis.dis module from python and -S flag for C++ and these are the results(I kept the programs very simple)

```
//test3.cpp
int main(){
        int x=2;
        return x+2;
}

// run using 'clang++ -S test3.cpp' and observe test3.s

#test3.py
from dis import dis as da

def main():
        x=2
        return x+2;

da(main)
# observe test3_py_ir using 'python test3.py > test3_py_ir'
```

They are somewhat similar (ignore size). I did not use any #includes to limit the size of the generated cpp assembly. The python version imitates a DFA : functions manipulating the stack state: you can also push in lambdas to the dis-assembler and treat it as data rather than code. You also have a call stack over that and hence two stacks make it a turing complete interpretation.

The C++ version looks more like a turing machine with a definite amount of registers and is somewhat more cryptic.

Here are the outputs.

1.3.2 test3.s

Listing 1: test3.s

```
        .text
        .file   "test3.cpp"
        .globl  main                    # -- Begin function main
        .p2align        4, 0x90
        .type   main,@function
main:                                   # @main
        .cfi_startproc
# %bb.0:
        pushq   %rbp
        .cfi_def_cfa_offset 16
        .cfi_offset %rbp, -16
        movq    %rsp, %rbp
        .cfi_def_cfa_register %rbp
        movl    $0, -4(%rbp)
        movl    $2, -8(%rbp)
        movl    -8(%rbp), %eax
        addl    $2, %eax
        popq    %rbp
        retq
.Lfunc_end0:
        .size   main, .Lfunc_end0-main
        .cfi_endproc
                                        # -- End function

        .ident  "clang version 6.0.0-1ubuntu2 (tags/RELEASE_600/final)"
        .section        ".note.GNU-stack","",@progbits
```

1.3.3 test3_py_ir

Listing 2: test3$_py_ir$

```
  4           0 LOAD_CONST               1 (2)
              2 STORE_FAST               0 (x)

  5           4 LOAD_FAST                0 (x)
              6 LOAD_CONST               1 (2)
              8 BINARY_ADD
             10 RETURN_VALUE
```

2 Lexical analysers and parsers in GCC & Clang

GCC uses a handwritten lexical analyser (I'll check the c++ lexer) that lies in the file libcpp/lex.c libcpp/lex.c . Some observations regarding the same:

- lines :247-263 : the actual word(the computing sense) stream reader that reads the source byte stream word by word, making calls to handle the intricacies.
  - too low a level: bitmasking and other stuff is being handled manually.
- a lot of low level special handling cases have separate calls : string, raw string , whitespace, numbers, macros and so on

GCC, naturally, also uses a handwritten parser (checking the one for c this time) that lies in c/c-parser.cc/c-parser.c. Some observations regarding the same:

- This is relatively more understandable(compared to the lexer) as it works on high level tokens provided by the lexer rather than words.
- a high level observation: it reads in a token one by one in a *token stream of type struct c_token which is defined in c/c-parser.h
  - check lines 51 to 81 of this file to get an idea : c/c-parser.hc/c-parser.h

Clang also uses a hand-written lexer and parser. On a first pass, The variable names and the source code overall seems to be more sensible compared to that of the GCC source tree. these are the links to the same:

- Lexer lib/Lex/Lexer.cpplib/Lex/Lexer.cpp:
- Parser lib/Parse/Parser.cpplib/Parse/Parser.cpp

3 A note on compilation flags

sources : gcc and clang man pages

A compiler can be broken down (in accordance to the toolchain level) in multiple stages as follows:

1. Frontend
   (a) source code ⟶**Lexical analyser** ⟶Token stream
   (b) Token stream ⟶**Parser** ⟶AST
   (c) AST ⟶**Intermediate code generation** ⟶representative code
2. Backend
   (a) representative code ⟶**Optimization** ⟶optimized representation(semantically consistent though)
   (b) optimized representation ⟶**Target code generation** ⟶target platfrom machine code (x86,ARM and so on)

All the flags play around tweaking these processes to different extents and here is the quick overview of the same (source : GCC and Clang man pages)

Clang	GCC	description	Output
-c	-c	compile and assemble but do not link	*.o
-E	-E	the preprocessor stage: expanding macros and includes here	*.i / *.ii
-S	-S	until assembly code generation	*.s
flagless	flagless	everything + linker	machine code
-g	-g	produces machine code with symbol table sustained with meaningful names	machine code *
-fsyntax-only	-fsyntax-only	run the preprocessor, parser and type-checking stage(syntax checking)	*i/*.ii + console output for errors

Table 2: quick overview of compilation flags

flag	description
default	reduce compilation cost and be meaningfully debuggable(depends on compiler)
-O0	no optimization
-O1	between O0 and O2
-Og	O1 + better debugging experience
-O2 / -O	moderate level of optimizations : might mess up bad multithreading code
-Os	O2 + reduced code size
-Oz	O2 + further reduced code size
-O3	O2 + some more optimizations,longer compilations, generates larger code
-Ofast	O3 + some aggressive optimizations + can deviate from language standards
-O4	currently = O3 (in clang); read appendix to find more about this in the context of gcc

Table 3: Optimization passes

4 Bonus

For this question, I am using a fairly complex program that covers a lot of the complex features of C++ and is also computationally (space and time-wise) intensive (asymptotically).

4.1 source code : test4.cpp

Listing 3: test4.cpp

```
#include <bits/stdc++.h>
using namespace std;

// code to enumerate all possible subsets of {0,..,n-1}


void compute(const int& n){
        vector<int> chosen;
        vector<vector<int>> collect;
        const function<void(int&&)> backtrack = [&n,&chosen,&collect,&backtrack](int&& state){
                if(state==n)
                        collect.emplace_back(chosen);
                else{
                        chosen.emplace_back(state);
                        backtrack(state+1);
                        chosen.pop_back();
                        backtrack(state+1);
                }
        };
        backtrack(0);
        auto print_vec = [](const vector<int>& v){
                for(auto x:v)
                        cout<<x<<" ";
                cout<<endl;
        };
        auto print_collections = [&collect,&print_vec](){
                for(auto v:collect)
                        print_vec(v);
        };
        print_collections();
}

int main(){
        int n=10;
        compute(n);
        return 0;
}
```

4.2 Analysis

4.2.1 comments

- I've tested the two tool chains using two ways
  - -ftime-report : this outputs what the compiler records as their execution times
  - via a python interpreter: calling shell commands
- The results are visualized and discussed in bonus.pdf which is also appended here

Bonus

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1 Bonus question

Raj Patil
CS18BTECH11039

[7]:
```
from time import perf_counter as pc
import numpy as np
import matplotlib.pyplot as plt
from collections import namedtuple
```

2 nomenclature:

clg: clang related
gcc: gcc related
prp: preprocessing times
prs: parsing times
cg_ot: optimization times with code generation: using O2
cg: code generation times with no optimization

NOT USING old files and beginning compilation again at all times

[65]:
```
num_runs = range(50)
```

3 Clang toolchain

[64]:
```
#inbuilt analysis tools
!time clang++ -ftime-report test4.cpp
```

```
===-------------------------------------------------------------------------===
                         Miscellaneous Ungrouped Timers
===-------------------------------------------------------------------------===

   ---User Time---   --System Time--   --User+System--   ---Wall Time---  ---
Name ---
```

```
   0.0580 ( 68.2%)   0.0000 (  0.0%)   0.0580 ( 67.6%)   0.0580 ( 66.6%)  Code
Generation Time
   0.0271 ( 31.8%)   0.0007 (100.0%)   0.0278 ( 32.4%)   0.0290 ( 33.4%)  LLVM
IR Generation Time
   0.0851 (100.0%)   0.0007 (100.0%)   0.0858 (100.0%)   0.0871 (100.0%)  Total

===-------------------------------------------------------------------------===
                      Instruction Selection and Scheduling
===-------------------------------------------------------------------------===
  Total Execution Time: 0.0042 seconds (0.0042 wall clock)

   ---User Time---   --User+System--   ---Wall Time---  --- Name ---
   0.0009 ( 21.9%)   0.0009 ( 21.9%)   0.0009 ( 21.8%)  Instruction Selection
   0.0009 ( 21.2%)   0.0009 ( 21.2%)   0.0009 ( 21.0%)  Instruction Scheduling
   0.0007 ( 16.5%)   0.0007 ( 16.5%)   0.0007 ( 16.9%)  DAG Combining 1
   0.0005 ( 12.8%)   0.0005 ( 12.8%)   0.0005 ( 12.9%)  Instruction Creation
   0.0005 ( 11.2%)   0.0005 ( 11.2%)   0.0005 ( 11.1%)  DAG Combining 2
   0.0003 (  6.4%)   0.0003 (  6.4%)   0.0003 (  6.3%)  DAG Legalization
   0.0003 (  6.0%)   0.0003 (  6.0%)   0.0003 (  6.1%)  Type Legalization
   0.0001 (  1.9%)   0.0001 (  1.9%)   0.0001 (  2.0%)  Instruction Scheduling
Cleanup
   0.0001 (  2.0%)   0.0001 (  2.0%)   0.0001 (  2.0%)  Vector Legalization
   0.0042 (100.0%)   0.0042 (100.0%)   0.0042 (100.0%)  Total

===-------------------------------------------------------------------------===
                                 DWARF Emission
===-------------------------------------------------------------------------===
  Total Execution Time: 0.0010 seconds (0.0011 wall clock)

   ---User Time---   --User+System--   ---Wall Time---  --- Name ---
   0.0006 ( 59.1%)   0.0006 ( 59.1%)   0.0006 ( 57.9%)  DWARF Exception Writer
   0.0004 ( 40.7%)   0.0004 ( 40.7%)   0.0005 ( 41.9%)  Debug Info Emission
   0.0000 (  0.2%)   0.0000 (  0.2%)   0.0000 (  0.2%)  DWARF Debug Writer
   0.0010 (100.0%)   0.0010 (100.0%)   0.0011 (100.0%)  Total

===-------------------------------------------------------------------------===
                      … Pass execution timing report …
===-------------------------------------------------------------------------===
  Total Execution Time: 0.0381 seconds (0.0381 wall clock)

   ---User Time---   --User+System--   ---Wall Time---  --- Name ---
   0.0118 ( 31.0%)   0.0118 ( 31.0%)   0.0118 ( 31.0%)  X86 DAG->DAG Instruction
Selection
   0.0051 ( 13.3%)   0.0051 ( 13.3%)   0.0051 ( 13.4%)  X86 Assembly Printer
   0.0026 (  6.8%)   0.0026 (  6.8%)   0.0026 (  6.8%)  Prologue/Epilogue
Insertion & Frame Finalization
   0.0016 (  4.3%)   0.0016 (  4.3%)   0.0016 (  4.3%)  Expand Atomic
instructions
```

```
   0.0017 (  4.4%)   0.0017 (  4.4%)   0.0016 (  4.3%)  Fast Register Allocator
   0.0009 (  2.4%)   0.0009 (  2.4%)   0.0010 (  2.6%)  Two-Address instruction
pass
   0.0008 (  2.0%)   0.0008 (  2.0%)   0.0008 (  2.0%)  Insert stack protectors
   0.0007 (  1.8%)   0.0007 (  1.8%)   0.0007 (  1.8%)  Dominator Tree
Construction
   0.0006 (  1.6%)   0.0006 (  1.6%)   0.0006 (  1.6%)  MachineDominator Tree
Construction
   0.0006 (  1.4%)   0.0006 (  1.4%)   0.0006 (  1.5%)  Free MachineFunction
   0.0005 (  1.3%)   0.0005 (  1.3%)   0.0005 (  1.3%)  Exception handling
preparation
   0.0005 (  1.4%)   0.0005 (  1.4%)   0.0005 (  1.3%)  Machine Natural Loop
Construction
   0.0004 (  1.2%)   0.0004 (  1.2%)   0.0004 (  1.1%)  Dominator Tree
Construction
   0.0004 (  1.1%)   0.0004 (  1.1%)   0.0004 (  1.1%)  Post-RA pseudo
instruction expansion pass
   0.0004 (  1.0%)   0.0004 (  1.0%)   0.0004 (  1.0%)  MachineDominator Tree
Construction
   0.0004 (  0.9%)   0.0004 (  0.9%)   0.0004 (  0.9%)  Expand reduction
intrinsics
   0.0003 (  0.9%)   0.0003 (  0.9%)   0.0004 (  0.9%)  X86 pseudo instruction
expansion pass
   0.0004 (  0.9%)   0.0004 (  0.9%)   0.0004 (  0.9%)  Eliminate PHI nodes for
register allocation
   0.0003 (  0.9%)   0.0003 (  0.9%)   0.0003 (  0.9%)  StackMap Liveness
Analysis
   0.0004 (  0.9%)   0.0004 (  0.9%)   0.0003 (  0.9%)  Inliner for
always_inline functions
   0.0003 (  0.9%)   0.0003 (  0.9%)   0.0003 (  0.9%)  Insert fentry calls
   0.0004 (  1.0%)   0.0004 (  1.0%)   0.0003 (  0.9%)  Machine Natural Loop
Construction
   0.0003 (  0.8%)   0.0003 (  0.8%)   0.0003 (  0.8%)  Expand indirectbr
instructions
   0.0003 (  0.8%)   0.0003 (  0.8%)   0.0003 (  0.8%)  Implement the
'patchable-function' attribute
   0.0003 (  0.8%)   0.0003 (  0.8%)   0.0003 (  0.8%)  Basic Alias Analysis
(stateless AA impl)
   0.0003 (  0.8%)   0.0003 (  0.8%)   0.0003 (  0.8%)  Insert XRay ops
   0.0003 (  0.8%)   0.0003 (  0.8%)   0.0003 (  0.8%)  Expand ISel Pseudo-
instructions
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.8%)  Bundle Machine CFG Edges
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  Instrument function
entry/exit with calls to e.g. mcount() (post inlining)
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  Live DEBUG_VALUE
analysis
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  Machine Optimization
Remark Emitter
```

```
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  Remove unreachable
blocks from the CFG
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  X86 PIC Global Base Reg
Initialization
   0.0002 (  0.7%)   0.0002 (  0.7%)   0.0003 (  0.7%)  Local Stack Slot
Allocation
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  Contiguously Lay Out
Funclets
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  Instrument function
entry/exit with calls to e.g. mcount() (pre inlining)
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  X86 Retpoline Thunks
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  X86 FP Stackifier
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0003 (  0.7%)  X86 WinAlloca Expander
   0.0002 (  0.7%)   0.0002 (  0.7%)   0.0003 (  0.7%)  Machine Optimization
Remark Emitter
   0.0002 (  0.6%)   0.0002 (  0.6%)   0.0003 (  0.7%)  Lazy Machine Block
Frequency Analysis
   0.0002 (  0.6%)   0.0002 (  0.6%)   0.0002 (  0.7%)  Lazy Machine Block
Frequency Analysis
   0.0003 (  0.7%)   0.0003 (  0.7%)   0.0002 (  0.6%)  Analyze Machine Code For
Garbage Collection
   0.0002 (  0.6%)   0.0002 (  0.6%)   0.0002 (  0.6%)  Safe Stack
instrumentation pass
   0.0002 (  0.6%)   0.0002 (  0.6%)   0.0002 (  0.6%)  X86 vzeroupper inserter
   0.0002 (  0.6%)   0.0002 (  0.6%)   0.0002 (  0.6%)  Scalarize Masked Memory
Intrinsics
   0.0002 (  0.6%)   0.0002 (  0.6%)   0.0002 (  0.6%)  Lower Garbage Collection
Instructions
   0.0002 (  0.6%)   0.0002 (  0.6%)   0.0002 (  0.6%)  Shadow Stack GC Lowering
   0.0002 (  0.5%)   0.0002 (  0.5%)   0.0002 (  0.5%)  CallGraph Construction
   0.0001 (  0.1%)   0.0001 (  0.1%)   0.0001 (  0.1%)  Assumption Cache Tracker
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Pre-ISel Intrinsic
Lowering
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Rewrite Symbols
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Force set function
attributes
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  A No-Op Barrier Pass
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Assumption Cache Tracker
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Target Transform
Information
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Target Pass
Configuration
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Machine Module
Information
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Machine Branch
Probability Analysis
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Target Library
Information
```

```
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Profile summary info
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Target Library
Information
   0.0000 (  0.0%)   0.0000 (  0.0%)   0.0000 (  0.0%)  Create Garbage Collector
Module Metadata
   0.0381 (100.0%)   0.0381 (100.0%)   0.0381 (100.0%)  Total

===-------------------------------------------------------------------------===
                         Clang front-end time report
===-------------------------------------------------------------------------===
  Total Execution Time: 0.8360 seconds (0.8366 wall clock)

   ---User Time---   --System Time--   --User+System--   ---Wall Time---  ---
Name ---
   0.7756 (100.0%)   0.0604 (100.0%)   0.8360 (100.0%)   0.8366 (100.0%)  Clang
front-end timer
   0.7756 (100.0%)   0.0604 (100.0%)   0.8360 (100.0%)   0.8366 (100.0%)  Total

clang++ -ftime-report test4.cpp  0.92s user 0.11s system 83% cpu 1.229 total
```

[66]:
```
clang = namedtuple('Clang','prp prs cg cg_ot')
```

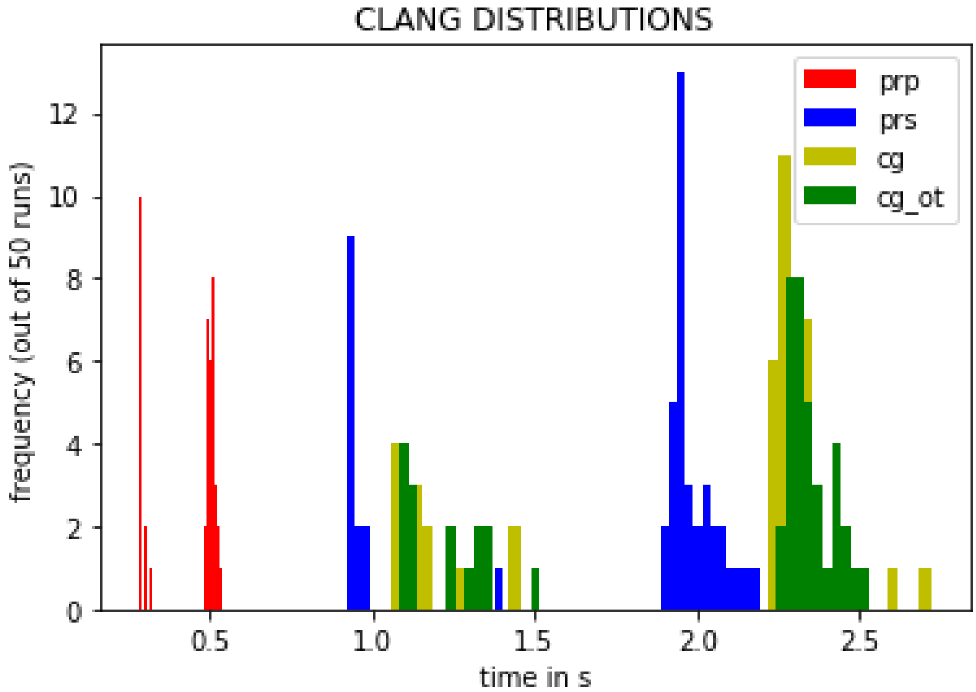
[67]:
```
# custom runs
clang_runs=[]
for i in num_runs:
    t0 = pc()
    !clang++  -E test4.cpp &>/dev/null
    t1=pc()-t0
    !clang++ -fsyntax-only test4.cpp &>/dev/null
    t2=pc()-(t0+t1)
    !clang++ -O0 -S test4.cpp &> /dev/null
    t3=pc()-(t0+t1+t2)
    !clang++ -O2 -S test4.cpp &>/dev/null
    t4=pc()-(t0+t1+t2+t3)
    clang_runs.append(clang(t1,t2,t3,t4))
```

[68]:
```
np_clg = np.asarray(clang_runs)
np_clg.shape
```

[68]: (50, 4)

[69]:
```
plt.hist(np_clg[:,0],bins=50,color='r',label="prp")
plt.hist(np_clg[:,1],bins=50,color='b',label="prs")
plt.hist(np_clg[:,2],bins=50,color='y',label="cg")
plt.hist(np_clg[:,3],bins=50,color='g',label="cg_ot")
plt.title("CLANG DISTRIBUTIONS")
plt.legend()
```

```
plt.xlabel("time in s")
plt.ylabel("frequency (out of " + str(len(num_runs)) + " runs)")
plt.show()
```



4 GCC toolchain

[60]:
```
# gcc inbuilt analysis
!time g++ -ftime-report test4.cpp
```

```
Execution times (seconds)
 phase setup             :   0.00 ( 0%) usr   0.00 ( 0%) sys   0.00 ( 0%) wall
1495 kB ( 1%) ggc
 phase parsing           :   1.26 (85%) usr   0.54 (89%) sys   1.80 (86%) wall
135869 kB (82%) ggc
 phase lang. deferred    :   0.15 (10%) usr   0.02 ( 3%) sys   0.18 ( 9%) wall
18801 kB (11%) ggc
 phase opt and generate  :   0.07 ( 5%) usr   0.05 ( 8%) sys   0.11 ( 5%) wall
8608 kB ( 5%) ggc
 |name lookup            :   0.36 (24%) usr   0.08 (13%) sys   0.48 (23%) wall
10851 kB ( 7%) ggc
 |overload resolution    :   0.31 (21%) usr   0.01 ( 2%) sys   0.28 (13%) wall
```

```
29805 kB (18%) ggc
 dump files              :   0.01 ( 1%) usr   0.00 ( 0%) sys   0.00 ( 0%) wall
0 kB ( 0%) ggc
 callgraph construction  :   0.01 ( 1%) usr   0.01 ( 2%) sys   0.02 ( 1%) wall
801 kB ( 0%) ggc
 callgraph optimization  :   0.00 ( 0%) usr   0.00 ( 0%) sys   0.01 ( 0%) wall
4 kB ( 0%) ggc
 trivially dead code     :   0.00 ( 0%) usr   0.00 ( 0%) sys   0.01 ( 0%) wall
0 kB ( 0%) ggc
 df scan insns           :   0.01 ( 1%) usr   0.00 ( 0%) sys   0.01 ( 0%) wall
8 kB ( 0%) ggc
 df live regs            :   0.00 ( 0%) usr   0.00 ( 0%) sys   0.01 ( 0%) wall
0 kB ( 0%) ggc
 preprocessing           :   0.24 (16%) usr   0.13 (21%) sys   0.30 (14%) wall
5075 kB ( 3%) ggc
 parser (global)         :   0.23 (16%) usr   0.15 (25%) sys   0.49 (23%) wall
34358 kB (21%) ggc
 parser struct body      :   0.14 ( 9%) usr   0.05 ( 8%) sys   0.21 (10%) wall
22475 kB (14%) ggc
 parser function body    :   0.12 ( 8%) usr   0.03 ( 5%) sys   0.15 ( 7%) wall
8946 kB ( 5%) ggc
 parser inl. func. body  :   0.06 ( 4%) usr   0.04 ( 7%) sys   0.08 ( 4%) wall
3892 kB ( 2%) ggc
 parser inl. meth. body  :   0.09 ( 6%) usr   0.06 (10%) sys   0.21 (10%) wall
14458 kB ( 9%) ggc
 template instantiation  :   0.53 (36%) usr   0.10 (16%) sys   0.54 (26%) wall
65346 kB (40%) ggc
 tree SSA other          :   0.00 ( 0%) usr   0.01 ( 2%) sys   0.00 ( 0%) wall
24 kB ( 0%) ggc
 out of ssa              :   0.00 ( 0%) usr   0.00 ( 0%) sys   0.01 ( 0%) wall
21 kB ( 0%) ggc
 expand                  :   0.01 ( 1%) usr   0.00 ( 0%) sys   0.00 ( 0%) wall
712 kB ( 0%) ggc
 integrated RA           :   0.01 ( 1%) usr   0.00 ( 0%) sys   0.01 ( 0%) wall
4231 kB ( 3%) ggc
 LRA non-specific        :   0.01 ( 1%) usr   0.01 ( 2%) sys   0.00 ( 0%) wall
31 kB ( 0%) ggc
 reload                  :   0.00 ( 0%) usr   0.00 ( 0%) sys   0.01 ( 0%) wall
0 kB ( 0%) ggc
 rest of compilation     :   0.01 ( 1%) usr   0.02 ( 3%) sys   0.02 ( 1%) wall
419 kB ( 0%) ggc
 TOTAL                 :   1.48             0.61             2.10
164785 kB
g++ -ftime-report test4.cpp  1.56s user 0.63s system 95% cpu 2.298 total
```

This, unlike clang, provides the complete time analysis and

[70]:
```
gcc = namedtuple('GCC','prp prs cg cg_ot')
```

[71]:

```
# custom runs
gcc_runs=[]
for i in num_runs:
    t0 = pc()
    !g++  -E test4.cpp &>/dev/null
    t1=pc()-t0
    !g++ -fsyntax-only test4.cpp &>/dev/null
    t2=pc()-(t0+t1)
    !g++ -O0 -S test4.cpp &> /dev/null
    t3=pc()-(t0+t1+t2)
    !g++ -O2 -S test4.cpp &>/dev/null
    t4=pc()-(t0+t1+t2+t3)
    gcc_runs.append(gcc(t1,t2,t3,t4))
```

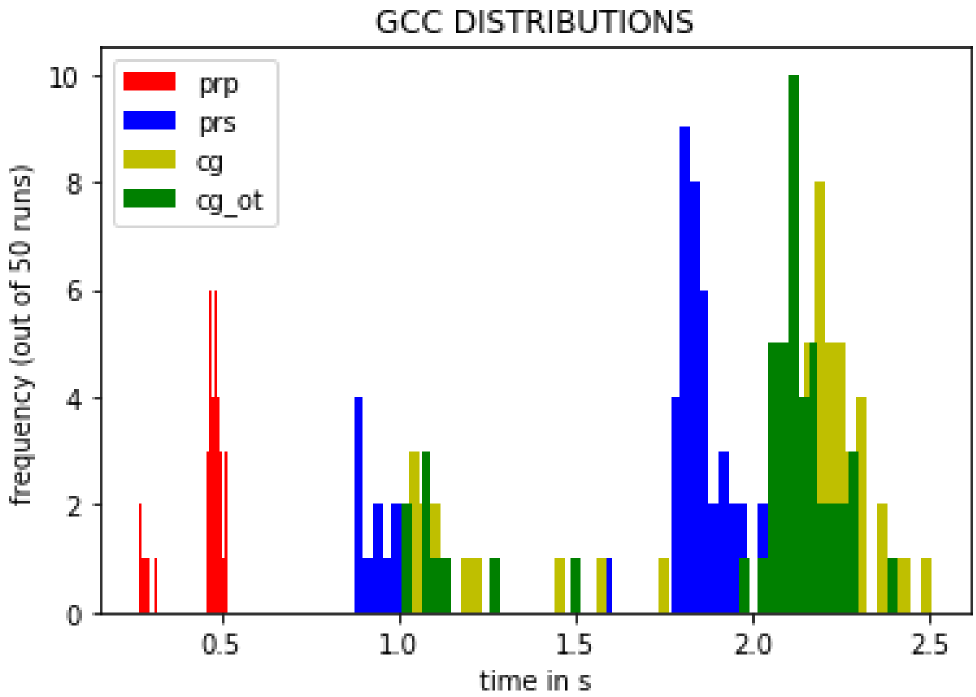
[72]:

```
np_gcc = np.asarray(gcc_runs)
np_gcc.shape
```

[72]: (50, 4)

[73]:

```
plt.hist(np_gcc[:,0],bins=50,color='r',label="prp")
plt.hist(np_gcc[:,1],bins=50,color='b',label="prs")
plt.hist(np_gcc[:,2],bins=50,color='y',label="cg")
plt.hist(np_gcc[:,3],bins=50,color='g',label="cg_ot")
plt.title("GCC DISTRIBUTIONS")
plt.legend()
plt.xlabel("time in s")
plt.ylabel("frequency (out of " + str(len(num_runs)) + " runs)")
plt.show()
```



5 collecting means

[82]:
```
print("\n","GCC")
print("gcc_prp",np_gcc[:,0].mean())
print("gcc_prs",np_gcc[:,1].mean())
print("gcc_cg",  np_gcc[:,2].mean())
print("gcc_cg_ot", np_gcc[:,3].mean())

print("\n","CLANG")
print("clg_prp" ,np_clg[:,0].mean())
print("clg_prs" , np_clg[:,1].mean())
print("clg_cg" , np_clg[:,2].mean())
print("clg_cg_ot" , np_clg[:,3].mean())
```

```
 GCC
gcc_prp 0.4530730939997011
gcc_prs 1.6781543300001067
gcc_cg 1.995258301999711
gcc_cg_ot 1.9667276100002347

 CLANG
```

```
clg_prp 0.4522343220002949
clg_prs 1.706136847999587
clg_cg 2.00593066399917
clg_cg_ot 2.011734538000019
```

That is very close

6 Notes

- cg_ot is not very different from cg and is in fact lesser in the case of gcc which is not expected.
- inbuilt tools paint a different picture which is expected : the python interpreter adds its own delays into this
  - ftime-report shows clang to be a bit faster
  - but the pythonic analysis doesn't show a significant difference
- However, given the effect weared of due to python's delays, We have reason to believe that clang is faster.
- Also note that the histograms observed are bimodal due to the presence of a cache and hence we should only compare corresponding peaks.

5 Appendix

5.1 sources

- man pages for gcc and clang
- gcc source tree: linked at corresponding place
- clang source tree: linked at corresponding place
- -O4 in gcc : probably a joke:
  - https://cboard.cprogramming.com/c-programming/125896-gcc-o4-what-use.html