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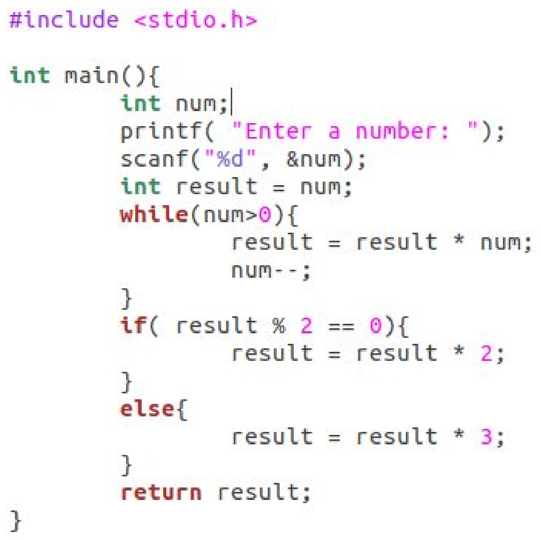
In-Lab 9

Optimized Code:

To analyze differences between optimized code made in the compiler using the -O2 versus regular code, I created a simple program and examined how their assembly files differed. Surprisingly, my first attempt at writing a C++ program did not result in a simpler assembly file when compiled with the -O2 flag. I attempted this using clang++ -mllvm --x86-asm-syntax=intel -m64 -S -O2 test1.cpp, but did not get any good results. I rewrote my program as a C program and was able to see definitive results. I compiled the code with the optimization flag using gcc -S -O2 test1.c.

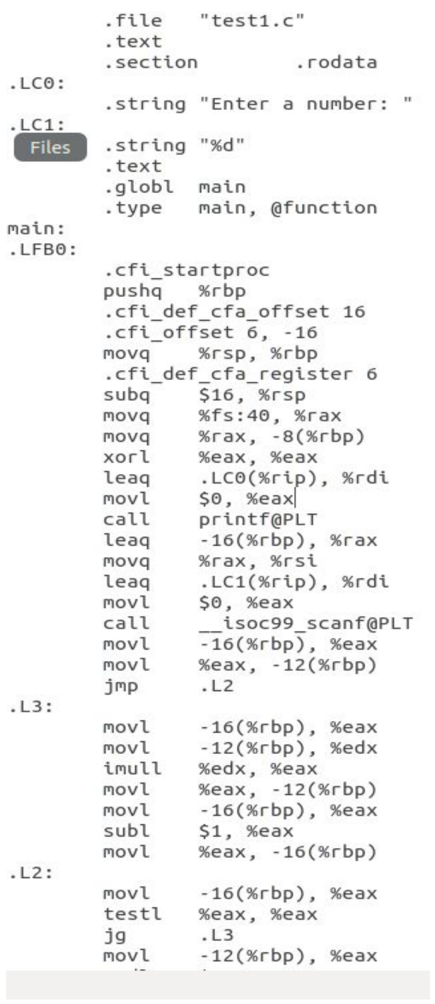
The C Program:



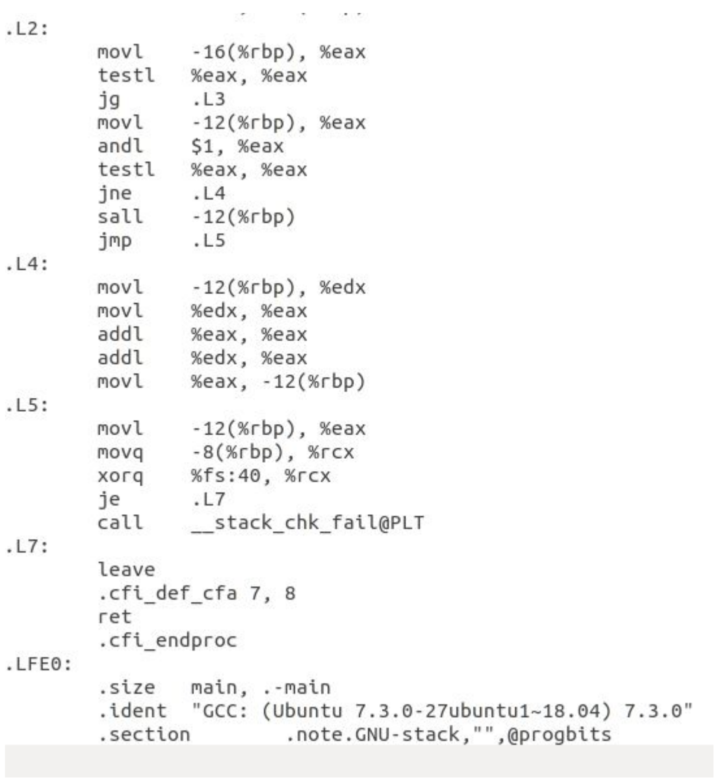
```c
#include <stdio.h>

int main(){
        int num;
        printf( "Enter a number: ");
        scanf("%d", &num);
        int result = num;
        while(num>0){
                result = result * num;
                num--;
        }
        if( result % 2 == 0){
                result = result * 2;
        }
        else{
                result = result * 3;
        }
        return result;
}
```

There were 72 lines of assembly code in the non-optimized version of my program. However, the optimized version produced a much simpler 56 line file of assembly code.

Non-optimized Assembly:

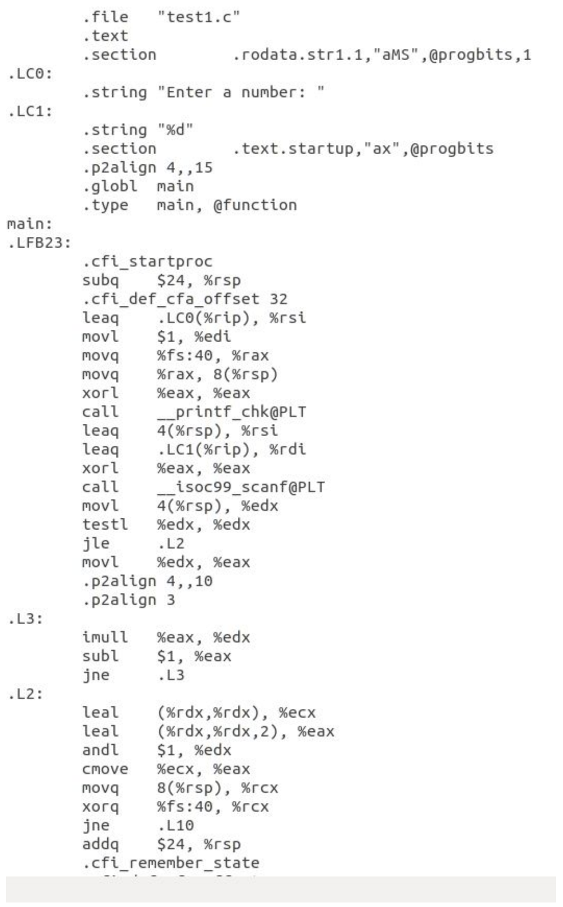


```
        .file   "test1.c"
        .text
        .section        .rodata
.LC0:
        .string "Enter a number: "
.LC1:
        .string "%d"
        .text
        .globl  main
        .type   main, @function
main:
.LFB0:
        .cfi_startproc
        pushq   %rbp
        .cfi_def_cfa_offset 16
        .cfi_offset 6, -16
        movq    %rsp, %rbp
        .cfi_def_cfa_register 6
        subq    $16, %rsp
        movq    %fs:40, %rax
        movq    %rax, -8(%rbp)
        xorl    %eax, %eax
        leaq    .LC0(%rip), %rdi
        movl    $0, %eax
        call    printf@PLT
        leaq    -16(%rbp), %rax
        movq    %rax, %rsi
        leaq    .LC1(%rip), %rdi
        movl    $0, %eax
        call    __isoc99_scanf@PLT
        movl    -16(%rbp), %eax
        movl    %eax, -12(%rbp)
        jmp     .L2
.L3:
        movl    -16(%rbp), %eax
        movl    -12(%rbp), %edx
        imull   %edx, %eax
        movl    %eax, -12(%rbp)
        movl    -16(%rbp), %eax
        subl    $1, %eax
        movl    %eax, -16(%rbp)
.L2:
        movl    -16(%rbp), %eax
        testl   %eax, %eax
        jg      .L3
        movl    -12(%rbp), %eax
```

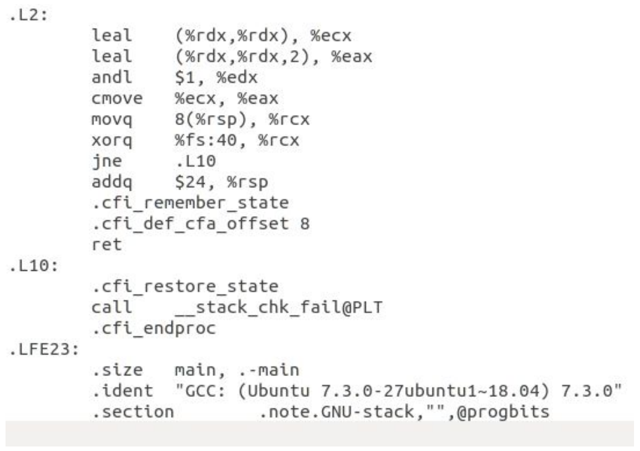


```
.L2:
        movl    -16(%rbp), %eax
        testl   %eax, %eax
        jg      .L3
        movl    -12(%rbp), %eax
        andl    $1, %eax
        testl   %eax, %eax
        jne     .L4
        sall    -12(%rbp)
        jmp     .L5
.L4:
        movl    -12(%rbp), %edx
        movl    %edx, %eax
        addl    %eax, %eax
        addl    %edx, %eax
        movl    %eax, -12(%rbp)
.L5:
        movl    -12(%rbp), %eax
        movq    -8(%rbp), %rcx
        xorq    %fs:40, %rcx
        je      .L7
        call    __stack_chk_fail@PLT
.L7:
        leave
        .cfi_def_cfa 7, 8
        ret
        .cfi_endproc
.LFE0:
        .size   main, .-main
        .ident  "GCC: (Ubuntu 7.3.0-27ubuntu1~18.04) 7.3.0"
        .section        .note.GNU-stack,"",@progbits
```

Optimized Assembly:



```
        .file   "test1.c"
        .text
        .section        .rodata.str1.1,"aMS",@progbits,1
.LC0:
        .string "Enter a number: "
.LC1:
        .string "%d"
        .section        .text.startup,"ax",@progbits
        .p2align 4,,15
        .globl  main
        .type   main, @function
main:
.LFB23:
        .cfi_startproc
        subq    $24, %rsp
        .cfi_def_cfa_offset 32
        leaq    .LC0(%rip), %rsi
        movl    $1, %edi
        movq    %fs:40, %rax
        movq    %rax, 8(%rsp)
        xorl    %eax, %eax
        call    __printf_chk@PLT
        leaq    4(%rsp), %rsi
        leaq    .LC1(%rip), %rdi
        xorl    %eax, %eax
        call    __isoc99_scanf@PLT
        movl    4(%rsp), %edx
        testl   %edx, %edx
        jle     .L2
        movl    %edx, %eax
        .p2align 4,,10
        .p2align 3
.L3:
        imull   %eax, %edx
        subl    $1, %eax
        jne     .L3
.L2:
        leal    (%rdx,%rdx), %ecx
        leal    (%rdx,%rdx,2), %eax
        andl    $1, %edx
        cmove   %ecx, %eax
        movq    8(%rsp), %rcx
        xorq    %fs:40, %rcx
        jne     .L10
        addq    $24, %rsp
        .cfi_remember_state
```



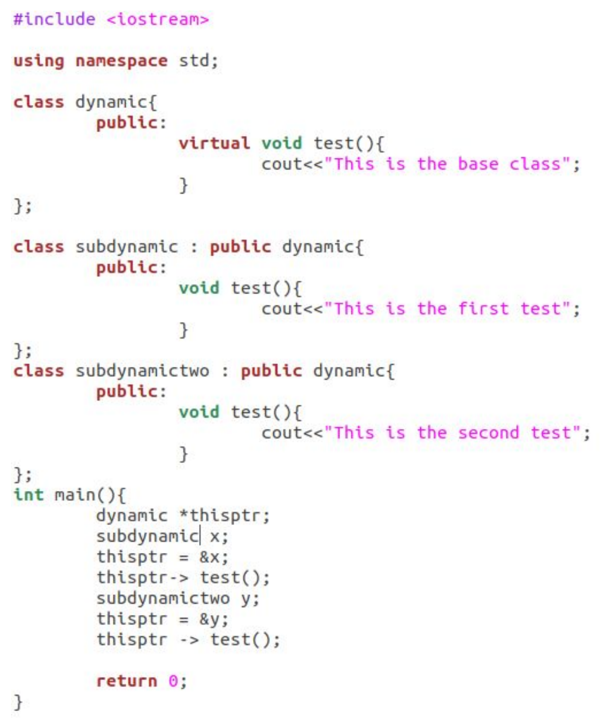
```
.L2:
        leal    (%rdx,%rdx), %ecx
        leal    (%rdx,%rdx,2), %eax
        andl    $1, %edx
        cmove   %ecx, %eax
        movq    8(%rsp), %rcx
        xorq    %fs:40, %rcx
        jne     .L10
        addq    $24, %rsp
        .cfi_remember_state
        .cfi_def_cfa_offset 8
        ret
.L10:
        .cfi_restore_state
        call    __stack_chk_fail@PLT
        .cfi_endproc
.LFE23:
        .size   main, .-main
        .ident  "GCC: (Ubuntu 7.3.0-27ubuntu1~18.04) 7.3.0"
        .section        .note.GNU-stack,"",@progbits
```

When the -O2 flag is used, the compiler will try to minimize the instructions needed to run out the output. This means that instructions that do not directly influence the return value will often be omitted in the -O2 optimized version. One example of this is with the use of scanf. Scanf will have a return value, but it will be unused in creating the output and is thus omitted in the optimized assembly version. Another thing I noticed is that there were less loops used in the optimized version in comparison with the regular. Extraneous loops can be very detrimental for runtime as many iterations of useless instructions may be executed and slowing down the program. The optimized versions only executes the critical tasks. Another way -O2 is optimizing this program is by saving significant data early. Instructions are repositioned to make important data available in memory early and removes the need for certain mov load instructions that are called late in the original assembly and would slow runtime. Another example of how -O2 optimizes the code is by ignoring the base pointer. Typical assembly would push the pointer and allocate room on the stack, but this is significant memory usage and is not important to the simpler tasks the program is intended to complete. -O2 optimization then chooses to ignore managing the base pointer. Optimization in compilers using the -O2 flag is greatly effective in eliminating unnecessary instructions and generating the correct output in the shortest runtime.

Dynamic Dispatch:

I implemented dynamic dispatch using a simple c++ program. While languages like Java and python have virtual methods naturally implemented, c++ and c allow the programmers to choose when to use these. An example is when you want to wait for runtime to execute a method. This ability is beneficial for polymorphism, but would not be desired in a simple program meant to execute most efficiently.

My c++ program dynamic.cpp:



```
#include <iostream>

using namespace std;

class dynamic{
        public:
                virtual void test(){
                        cout<<"This is the base class";
                }
};

class subdynamic : public dynamic{
        public:
                void test(){
                        cout<<"This is the first test";
                }
};
class subdynamictwo : public dynamic{
        public:
                void test(){
                        cout<<"This is the second test";
                }
};
int main(){
        dynamic *thisptr;
        subdynamic x;
        thisptr = &x;
        thisptr-> test();
        subdynamictwo y;
        thisptr = &y;
        thisptr -> test();

        return 0;
}
```

This program implements dynamic dispatch twice. I wait until runtime in the main function to override how a class will implement the function. I first create a base dynamic pointer thisptr. I create a subdynamic class instantiation. Then I set thisptr to the address of the subdynamic class in order to override the function test(). I then execute test. I do this same process as another example using subdynamic two. After calling test() with thisptr after each of these processes, I will have outputted “This is the first test” and “This is the second test,” but never will have outputted “This is the base class” because that test() method was overridden in both examples. This demonstrates dynamic dispatch and the polymorphism ability it enables users with.