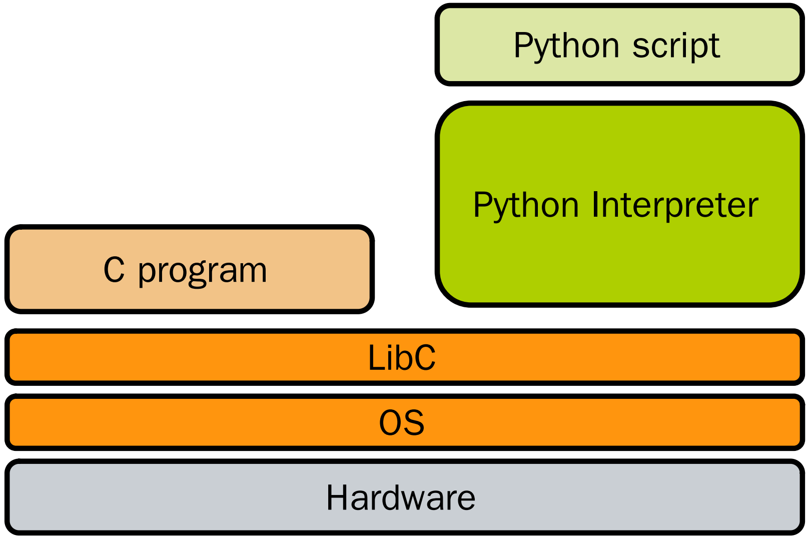
COMP26020 Programming Languages and Paradigms -- Part 1

Case Study: High Performance Computing

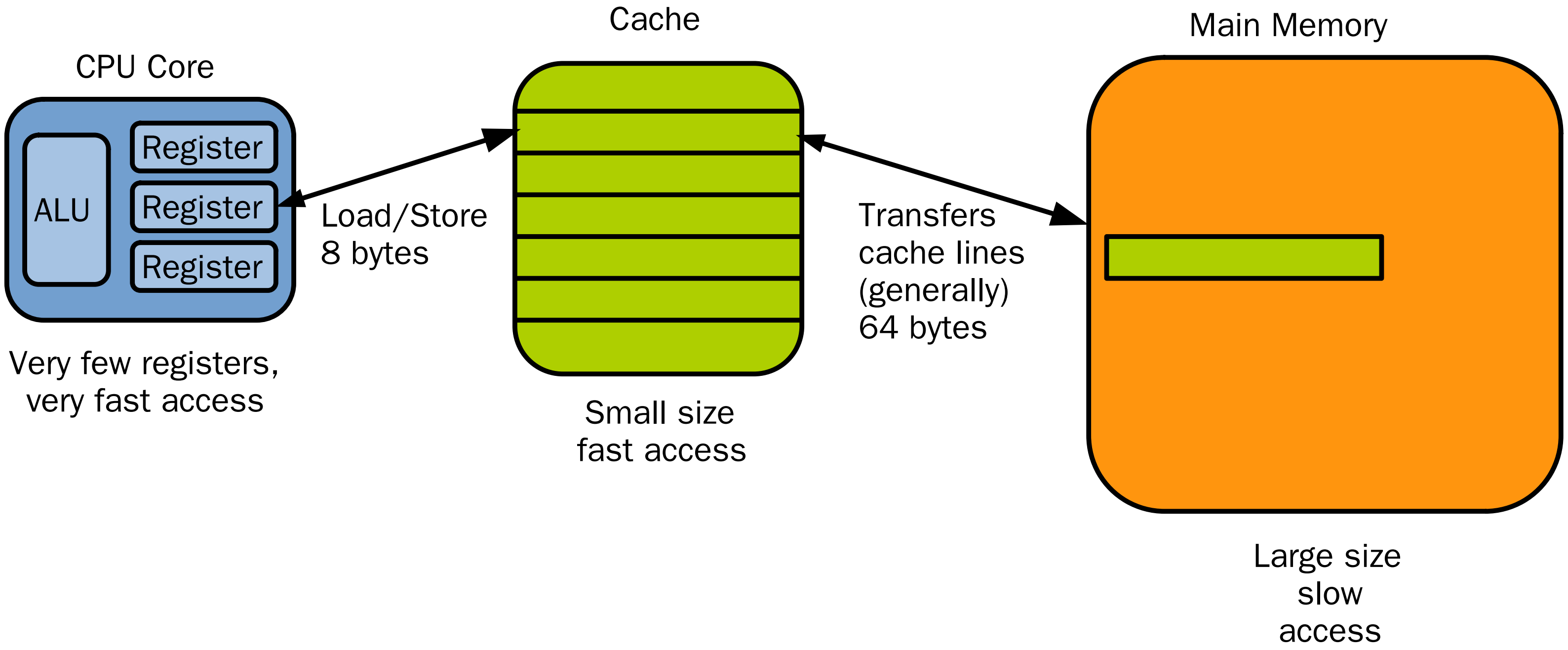
C/C++ in HPC

C/C++ are extensively used in High Performance Computing (HPC) because of their **speed**



- Due to many reasons, including the fact that they **gives the programmer control over the data memory layout**

Controlling Memory Layout



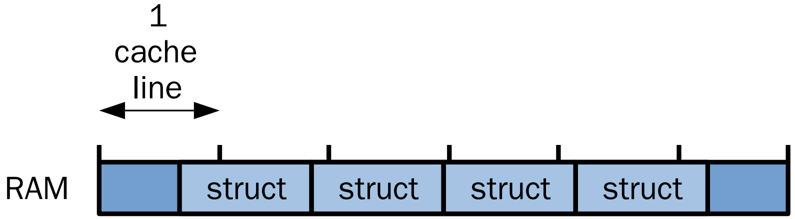
- For performance reasons it is very important to fit as much of the data set as possible in the cache

Controlling Memory Layout

```c
typedef struct {
    char c[60];
    int i;
    double d;
} my_struct;

#define N 100000000
my_struct array[N];

int main(int argc, char **argv) {
    struct timeval start, stop, res;
    my_struct s;

    gettimeofday(&start, NULL);

    /* Randomly access N elements */
    for(int i=0; i<N; i++)
        memcpy(&s, &array[rand()%N],
            sizeof(my_struct));

    gettimeofday(&stop, NULL);
    timersub(&stop, &start, &res);
    printf("%ld.%06ld\n", res.tv_sec,
        res.tv_usec);

    return 0; }
```

20-hpc-case-study/original.c

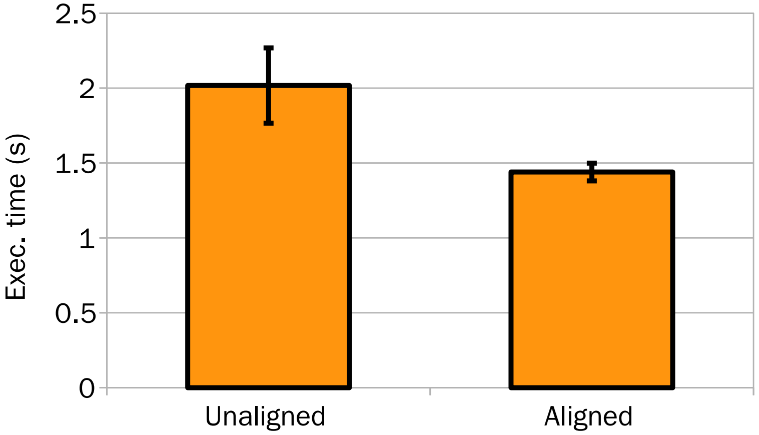
- Struct size: 60 + 4 (int) + 8 (double) = 72 bytes
    - Larger and not a multiple of the cache line size (64 bytes)
    - Most objects in the array will require to fetch 2 cache lines from main memory



Controlling Memory Layout

```c
typedef struct {
    char c[52]; // down from 60, we have 52 + 4 + 8 == 64 bytes i.e. a cache line
    int i;
    double d;
} my_struct;

my_struct array[N] __attribute__ ((aligned(64)));  /* force alignment of the array itself */


/* ... */
```

20-hpc-case-study/optimized.c



- About 25% faster!
- How much is it on your computer? check out your CPU's cache line size with `cat /sys/devices/system/cpu/cpu0/cache/index0/coherency_line_size`

Summary

- C/C++ extensively used in HPC because of their speed
    - Run close to the hardware
    - No additional software layers
    - No runtime overhead
    - Integrates well with assembly
    - **Control of the memory layout**

Feedback form: https://bit.ly/3yz2jzh