OS HW3 Multithread Programming

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Implementation

Parameters Structure

```
typedef struct _merge_sort_arg_t {
    int i;
    int j;
    int *a;
} merge_sort_arg_t;
```

> *因為thread執行目標function需要傳遞參數，所以創建一個structure，裡面包含sorting起始位置 `i` 結束位置 `j` 以及需要sorting的array `a` .*

Thread Entry Function

```
void merge_sort_entry(void *data) {
    // convert parameter type
    merge_sort_arg_t *arg = (merge_sort_arg_t*) data;

    merge_sort(arg->a, arg->i, arg->j);
}
```

> *先轉換輸入structure type，再去執行真正想要執行的function `merge_sort()` .*

Thread Creation

```
merge_sort_arg_t left_arg, right_arg;
left_arg.i = 0;
left_arg.j = mid;
left_arg.a = input_data;
err_l = pthread_create(&left_t, NULL, merge_sort_entry, &left_arg);
```

> *(上以左thread為例)分別創建merge sort左右兩個threads所需要傳遞parameters的structure，並初始化structure裡的variables，再使用pthread.h提供的 `pthread_create()` 讓thread去執行指定的function.*

Merge Result

```
pthread_join(left_t, NULL);
pthread_join(right_t, NULL);
```

```
merge_struct merge_arg = {input_data, 0, mid, input_data_size-1};
err_m = pthread_create(&merge_t, NULL, merge_entry, &merge_arg);
if(err_l != 0 || err_r != 0) {
    printf("ERROR return code from merge pthread_create()\n");
}
pthread_join(merge_t, NULL);
```

> *使用 `pthread_join()` 讓main thread等待左右兩個threads完成sorting，完成兩部份sorting後，用merge thread執行 `merge_entry()` 合併左右兩個部分.*

Merge Sort

```
void merge_sort(int *arr, int l, int r) {
    // check boundary
    if(l >= r) return;

    int m = l + (r-l)/2;

    merge_sort(arr, l, m);
    merge_sort(arr, m+1, r);

    merge(arr, l, m, r);
}

void merge(int *arr, int l, int m, int r) {
    // printf("merge\n");
    int i, j, k;
    int n1 = m-l+1;
    int n2 = r-m;

    int L[n1], R[n2];

    for(i=0; i<n1; i++) {
        L[i] = *(arr+l+i);
    }
    for(j=0; j<n2; j++) {
        R[j] = *(arr+m+1+j);
    }

    i = 0;
    j = 0;
    k = l;
```

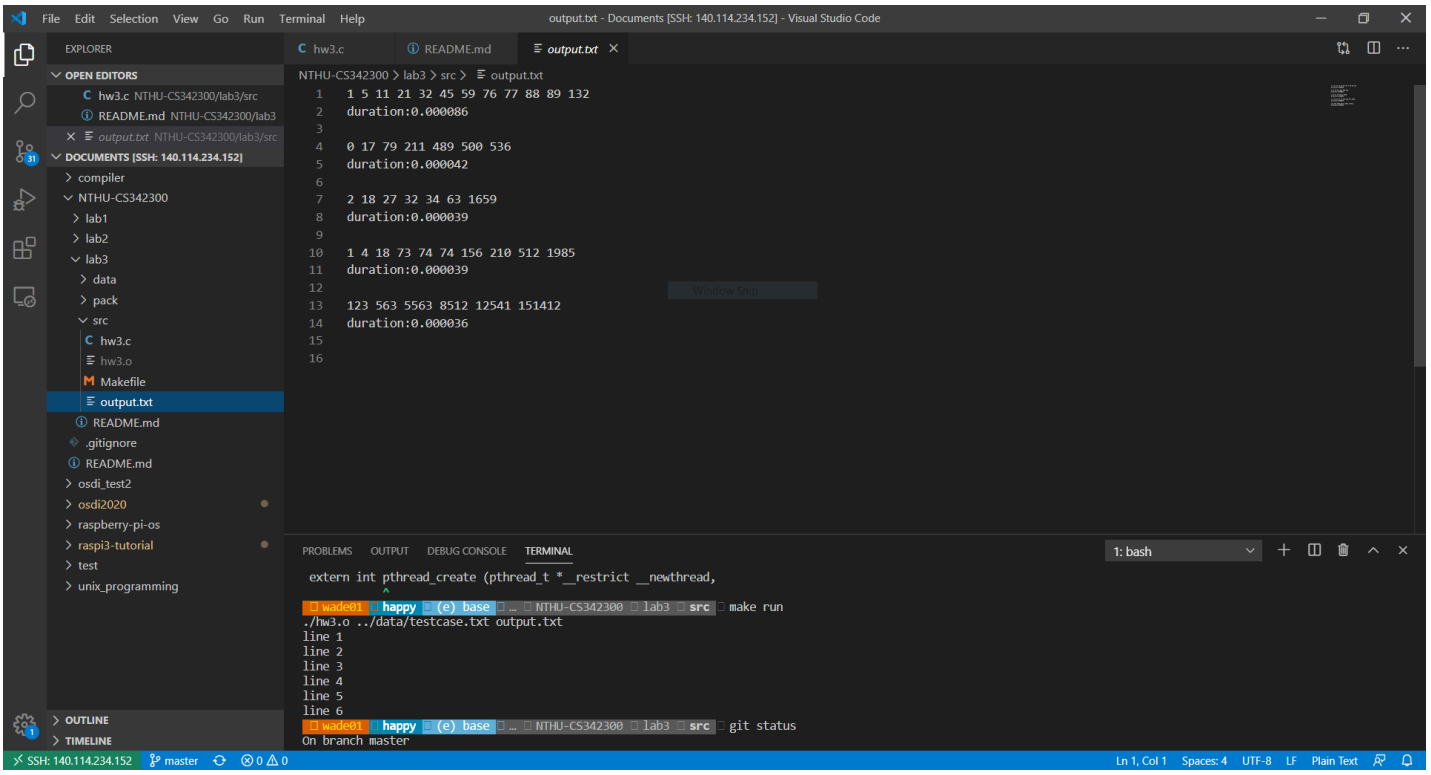
```
    while(i<n1 && j<n2) {
        if(L[i] <= R[j]) {
            *(arr+k) = L[i];
            i++;
        } else {
            *(arr+k) = R[j];
            j++;
        }
        k++;
    }

    // copy the remaining part
    while(i<n1) {
        *(arr+k) = L[i];
        i++;
        k++;
    }
    while(j<n2) {
        *(arr+k) = R[j];
        j++;
        k++;
    }
}
```

> *上面的code就是一般merge sort的implementation*

Result

> *用助教提供的 `testcase.txt` 執行結果如下：*



Reference

1. https://www.techiedelight.com/find-execution-time-c-program/
2. https://www.edureka.co/blog/merge-sort-in-c/
3. http://blog.gitdns.org/2016/12/06/pthread/

Appendix - source code

Makefile

```
CC := gcc

OPS := -pthread

TARGET := hw3.c


all: hw3.o


.PHONY: clean all run


hw3.o: $(TARGET)

    $(CC) $< $(OPS) -o [email protected]


run:

    ./hw3.o ../data/testcase.txt output.txt
```

```
clean:
    rm *.o output.txt
```

hw3.c

```c
#include <stdio.h>
#include <stdlib.h>
#include <pthread.h>
#include <time.h>

typedef struct _merge_sort_arg_t {
    int i;
    int j;
    int *a;
} merge_sort_arg_t;

// merge(input_data, 0, mid, input_data_size-1);
typedef struct _merge_struct {
    int *input_data;
    int start;
    int mid;
    int end;
} merge_struct;

void merge_sort_entry(void *data);
void merge_entry(void *data);
void merge_sort(int *arr, int l, int r);
void merge(int *arr, int l, int m, int r);

int main(int argc, char* argv[]) {
    FILE *in_file  = fopen(argv[1], "r");
    FILE *out_file = fopen(argv[2], "w");

    // check file
    if (in_file == NULL) {
        printf("Error! Could not open input file.\n");
        exit(-1);
    }

    pthread_t left_t, right_t, merge_t;
    int input_data[10000];
    int input_data_size;
    int fscanf_return = 0;
```

```
for(int m=1; !feof (in_file); m++) {
    printf("line %d\n", m);
    // read data
    input_data_size = 0;
    char c = '0';
    int err_l, err_r, err_m;
    clock_t begin = clock();

    for(int i=0; (!feof (in_file) && c != '\n' && c != '\r'); i++) {
        fscanf_return = fscanf(in_file, "%d%c", &input_data[i], &c);
        if(fscanf_return < 2) break;
        input_data_size++;
    }

    if(input_data_size == 0) continue;

    int mid = input_data_size/2;
    merge_sort_arg_t left_arg, right_arg;

    left_arg.i = 0;
    left_arg.j = mid;
    left_arg.a = input_data;
    err_l = pthread_create(&left_t, NULL, merge_sort_entry, &left_arg);

    right_arg.i = mid+1;
    right_arg.j = input_data_size-1;
    right_arg.a = input_data;
    err_r = pthread_create(&right_t, NULL, merge_sort_entry, &right_arg);

    if(err_l != 0 || err_r != 0) {
        printf("ERROR return code from pthread_create()\n");
    }
    pthread_join(left_t, NULL);
    pthread_join(right_t, NULL);

    merge_struct merge_arg = {input_data, 0, mid, input_data_size-1};
    err_m = pthread_create(&merge_t, NULL, merge_entry, &merge_arg);
    if(err_l != 0 || err_r != 0) {
        printf("ERROR return code from merge pthread_create()\n");
    }
    pthread_join(merge_t, NULL);
    // merge(input_data, 0, mid, input_data_size-1);
```

```
        // print data
        for(int i=0; i<input_data_size; i++) {
            fprintf(out_file, "%d ", input_data[i]);
        }
        fprintf(out_file, "\n");

        clock_t end = clock();
        double duration = end - begin;
        fprintf(out_file, "duration:%f\n\n", duration / CLOCKS_PER_SEC);
    }

    fclose (in_file);
    fclose(out_file);
}

void merge_sort_entry(void *data) {
    // convert parameter type
    merge_sort_arg_t *arg = (merge_sort_arg_t*) data;

    merge_sort(arg->a, arg->i, arg->j);
}

void merge_entry(void *data) {
    merge_struct *arg = (merge_struct*) data;

    merge(arg->input_data, arg->start, arg->mid, arg->end);
}

void merge_sort(int *arr, int l, int r) {
    // check boundary
    if(l >= r) return;

    int m = l + (r-l)/2;

    merge_sort(arr, l, m);
    merge_sort(arr, m+1, r);

    merge(arr, l, m, r);
}

void merge(int *arr, int l, int m, int r) {
    // printf("merge\n");
```

```
    int i, j, k;
    int n1 = m-l+1;
    int n2 = r-m;

    int L[n1], R[n2];

    for(i=0; i<n1; i++) {
        L[i] = *(arr+l+i);
    }
    for(j=0; j<n2; j++) {
        R[j] = *(arr+m+1+j);
    }

    i = 0;
    j = 0;
    k = l;

    while(i<n1 && j<n2) {
        if(L[i] <= R[j]) {
            *(arr+k) = L[i];
            i++;
        } else {
            *(arr+k) = R[j];
            j++;
        }
        k++;
    }

    // copy the remaining part
    while(i<n1) {
        *(arr+k) = L[i];
        i++;
        k++;
    }
    while(j<n2) {
        *(arr+k) = R[j];
        j++;
        k++;
    }
}
```

testcase.txt

```
5 132 89 45 76 21 1 59 88 11 32 77
536 211 489 500 17 0 79
32 18 2 63 34 27 1659
74 73 1985 512 74 210 156 4 18 1
12541 151412 123 8512 5563 563
```

output.txt

```
1 5 11 21 32 45 59 76 77 88 89 132
duration:0.000176

0 17 79 211 489 500 536
duration:0.000054

2 18 27 32 34 63 1659
duration:0.000027

1 4 18 73 74 74 156 210 512 1985
duration:0.000042

123 563 5563 8512 12541 151412
duration:0.000043
```