OS HW3

Operating System 106 Fall

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Goal

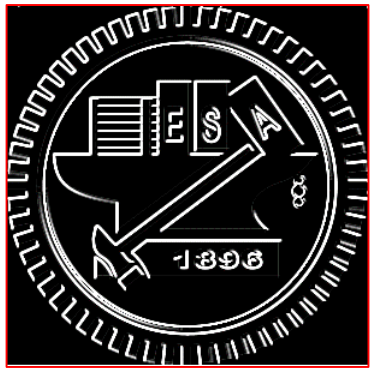
- Implement image processing by using threads and synchronization.
  - HW 3-1: Blur with Gaussian filter
  - HW 3-2: Edge Detection with Sobel filter

input

RGB2Gray

HW 3-1

HW 3-2



Introduction: Gaussian filter

- Gaussian filter: $G(u,v) = \frac{1}{2\pi\sigma^2} e^{-(u^2+v^2)/(2\sigma^2)}$

- For convenience, use integer versions.
  - For example:

$\frac{1}{16} \times$

1	2	1
2	4	2
1	2	1

$\frac{1}{273} \times$

1	4	7	4	1
4	16	26	16	4
7	26	41	26	7
4	16	26	16	4
1	4	7	4	1

- Gaussian filter is written in “mask_Gaussian.txt” →

```
9 16
1 2 1
2 4 2
1 2 1
```

Introduction: Blur algorithm

1. Convert RGB image to grey image:
   - grey(i, j) = (R(i, j)+G(i, j)+B(i, j))/3
2. Do Gaussian blur: convolving the grey image with a Gaussian filter.
   - Convolving:

Slide window

16	32	160	80	16
0	48	112	32	176
0	0	48	16	16
0	8	4	0	96
8	0	4	8	160

$$* \quad \frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} =$$

11	43	73	64	38
10	44			

   - →(16*1+32*2+160*1+0*2+48*4+112*2+0*1+0*2+48*1)/16 = 44
3. Extend the size of image from HxWx1 to HxWx3 (to save the image)
   - R(i, j) = grey(i, j)
   - G(i, j) = grey(i, j)
   - B(i, j) = grey(i, j)

Introduction: Blur algorithm (cont.)

1. Convert RGB image to grey image:
   - grey(i, j) = (R(i, j)+G(i, j)+B(i, j))/3
2. Do Gaussian blur: convolving the grey image with a Gaussian filter.
   - Convolving:

Slide window

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0	0	48	16	16
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$$* \quad \frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} =$$

11	43	73	64	38
10	44	72		

3. Extend the size of image from HxWx1 to HxWx3 (to save the image)
   - R(i, j) = grey(i, j)
   - G(i, j) = grey(i, j)
   - B(i, j) = grey(i, j)

Introduction: Blur algorithm (cont.)

1. Convert RGB image to grey image:
   - grey(i, j) = (R(i, j)+G(i, j)+B(i, j))/3
2. Do Gaussian blur: convolving the grey image with a Gaussian filter.
   - Convolving:

Slide window

16	32	160	80	16
0	48	112	32	176
0	0	48	16	16
0	8	4	0	96
8	0	4	8	160

$$* \quad \frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} =$$

11	43	73	64	38
10	44	72	71	

3. Extend the size of image from HxWx1 to HxWx3 (to save the image)
   - R(i, j) = grey(i, j)
   - G(i, j) = grey(i, j)
   - B(i, j) = grey(i, j)

Introduction: Blur algorithm (cont.)

1. Convert RGB image to grey image:
   - grey(i, j) = (R(i, j)+G(i, j)+B(i, j))/3
2. Do Gaussian blur: convolving the grey image with a Gaussian filter.
   - Convolving:

Slide window

16	32	160	80	16	
0	48	112	32	176	
0	0	48	16	16	
0	8	4	0	96	
8	0	4	8	160	

$*$ $\frac{1}{16} \times$

1	2	1
2	4	2
1	2	1

$=$

11	43	73	64	38
10	44	72	71	58

   - →(80*1+16*2+32*2+176*4+16*1+16*2)/16 = 58
3. Extend the size of image from HxWx1 to HxWx3 (to save the image)
   - R(i, j) = grey(i, j)
   - G(i, j) = grey(i, j)
   - B(i, j) = grey(i, j)

Introduction: Sobel filter

- Sobel filter:
  - Gradient of horizontal direction

$$\mathbf{G}_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$$

  - Gradient of vertical direction

$$\mathbf{G}_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix}$$

- Sobel filter is written in “mask_Sobel.txt”
  - The first number is the filter size
  - The second line is Gx
  - The third line is Gy
  - Note: the size of Gx and Gy must be the same.

→

```
9
1 0 -1 2 0 -2 1 0 -1
-1 -2 -1 0 0 0 1 2 1
```

Introduction: Edge Detection algorithm

1. Convert RGB image to grey image:
   - grey(i, j) = (R(i, j)+G(i, j)+B(i, j))/3
2. Convolving the grey image with Gx filter and Gy filter, respectively.

   → Get image_x and image_y
3. Compute:
   Image(i, j) = sqrt(image_x(i, j)*image_x(i, j) + image_y(i, j)* image_y(i, j))
4. Extend the size of image from HxWx1 to HxWx3 (to save the image)
   - R(i, j) = Image(i, j)
   - G(i, j) = Image(i, j)
   - B(i, j) = Image(i, j)

Thread

- Only use:
  #include <pthread.h>
- Declare:
  pthread_t thread1, thread2;
- Functions:
  - int pthread_create(pthread_t * thread, const pthread_attr_t * attr,
    void * (*start_routine)(void *), void *arg);
  - int pthread_join(pthread_t th, void **thread_return);
    - wait for termination of another thread
  - void pthread_exit(void *retval);

Synchronization - mutex lock

- Only use:
  #include <pthread.h>
- Declare: (global variable)
  pthread_mutex_t mutex1 = PTHREAD_MUTEX_INITIALIZER;
- Functions:
  - pthread_mutex_lock()
    - acquire a lock on the specified mutex variable. If the mutex is already locked by another thread, this call will block the calling thread until the mutex is unlocked.
  - pthread_mutex_unlock()
    - unlock a mutex variable. An error is returned if mutex is already unlocked or owned by another thread.
  - pthread_mutex_trylock()
    - attempt to lock a mutex or will return error code if busy. Useful for preventing deadlock conditions.

Synchronization - semaphore

- #include <pthread.h>
  - Declare: (global variable)
    pthread_cond_t cond1 = PTHREAD_COND_INITIALIZER;
  - Functions:
    - pthread_cond_wait
    - pthread_cond_signal
    - pthread_cond_broadcast
- #include <semaphore.h>
  - Declare: (global variable)
    sem_t sem1;
  - Functions:
    - int sem_post(sem_t *);
    - int sem_wait(sem_t *);
    - int sem_close(sem_t *);

Synchronization - semaphore (cont.)

- Only use:
  #include <pthread.h>
  #include <semaphore.h>

- Design your method to implement synchronization.

- See details below:
  - <pthread.h>
    http://www.yolinux.com/TUTORIALS/LinuxTutorialPosixThreads.html
  - <semaphore.h>
    http://pubs.opengroup.org/onlinepubs/7908799/xsh/semaphore.h.html

Synchronization

- In HW3, you need use BOTH mutex lock and semaphore.
- And for each part, you must use at least one of them.
- For example:
  - ✓HW3-1 with mutex lock, and HW3-2 with semaphore.
  - ✓HW3-1 with semaphore, and HW3-2 with mutex lock.
  - ✓HW3-1 with mutex lock and semaphore, and HW3-2 with mutex lock.
  - ✗HW3-1 with mutex lock and semaphore, and HW3-2 without them.
  - ✗HW3-1 with mutex lock, and HW3-2 with mutex lock.

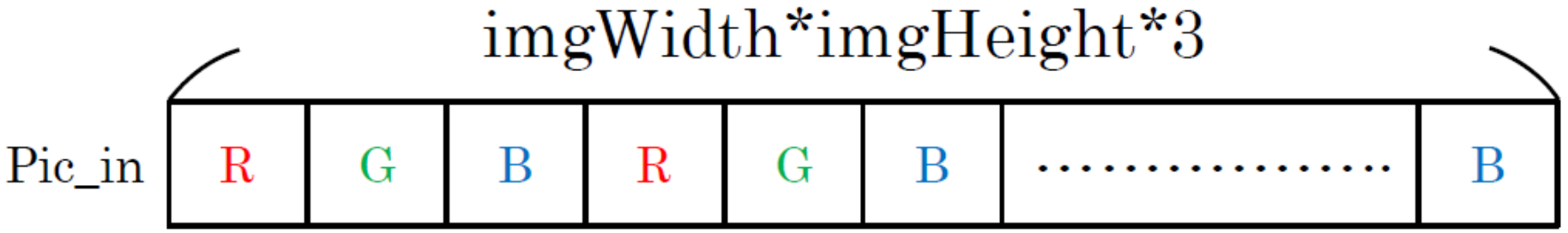
Synchronization (optional)

- Idea about synchronization (you can try other way):
  - Mutex lock:
    - Pthread: p1, p2, p3
    - Zero-matrix: Z (size = HxWx1)
    - p1, p2, p3 do convolve the R,G,B-image with filter, respectively.
    - p1, p2, p3 add their results into Z when doing convolve.
  - Semaphore:
    - Pthread: p1, p2
    - p1: convert RGB image to grey image.
    - p2: do convolve the grey image with filter.
    - After p1 has converted enough pixels (but p1 hasn’t finished), p2 start.

Image read & write

- Only use “bmpReader.h“ and ”bmpReader.cpp” we provide to read or write images. (Don’t modify “bmpReader.h” and “bmpReader.cpp”.)
- Unsigned char Pic_in[x] array
- Each pixel is represented by three values.
  R G B R G B…..
- Accessing the i-th row, j-th col pixel :
  - pic_in[3*(i*imgWidth+j)+color], color = 0,1,2

- Be careful of the conversion between integer, double (float), and unsigned char.



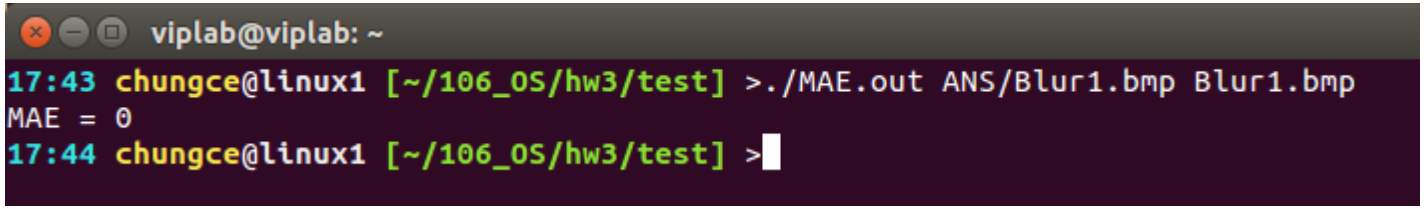
Input & output format

- Input: 5 BMP images and a mask file
  - Image name: input1.bmp, input2.bmp, input3.bmp, input4.bmp, input5.bmp
  - Mask file name:
    HW 3-1: mask_Gaussian.txt
    HW 3-2: mask_Sobel.txt
  - Input location:
    In the same folder with cpp file.

- Output: 5 BMP images for each part
  - Name:
    HW 3-1: Blur1.bmp, Blur2.bmp, Blur3.bmp, Blur4.bmp, Blur5.bmp
    HW 3-2: Sobel1.bmp, Sobel2.bmp, Sobel3.bmp, Sobel4.bmp, Sobel5.bmp
  - Output location:
    In the same folder with cpp file.

Score

1. Correctness: from 0 to 10 pts for each part
   - Mean Absolute Error: $\mathrm{MAE}(\mathrm{X},\mathrm{Y}) = \frac{1}{\mathrm{W}\cdot H\cdot 3}\Sigma|\mathrm{X}(i,j,c) - \mathrm{Y}(i,j,c)|$,where c=0,1,2
   - If MAE==0, then your output is correct.
   - We will give you “MAE.out”. Then you can use it to check the correctness.
     Use the following command:
     ./MAE.out [image 1] [image 2]

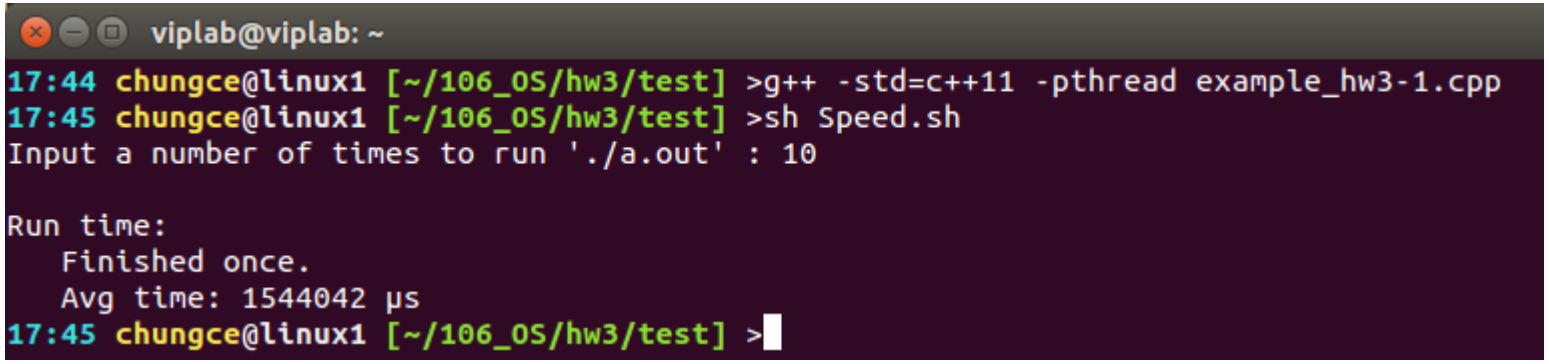


   - If you get “Permission denied” (拒絕不符權限操作), use the following command:
     chmod +x MAE.out

Score (cont.)

2. Speed: from 0 to 40 pts for each part
   - We will provide “example_hw3-1.cpp”, which doesn’t use multithread programming and synchronized, as a speed baseline.
   - We will give you “Speed.sh”. Use the following command: sh Speed.sh

	HW3-1	HW3-2
Baseline	1544042 μs	1430390 μs
filter size	5*5	3*3



Speedup	HW3-1	HW3-2
< 0.9	0	0
0.9~1.1	0	20
1.1~1.5	20	25
1.5~2	30	30
2~3	35	35
> 3	40	40
*This is a provisional standard table, we may modify after checking all students’ HW3.		

   - We will use it to compute your average run time. (Input = 10 fixed.)

Score (cont.)

3. Report (20 pts):
   - Format is in “report.docx”
   - Written in English or Chinese, up to 2 pages
4. Final score (Total 100 pts):
   Speed score 1 * Correctness score 1 /10 +
   Speed score 2 * Correctness score 2 /10 +
   Report score
5. Others:
   - Must use thread, mutex lock and semaphore. (otherwise -10pts)
   - Use other library NOT in “example_hw3-1.cpp”: will get 0pt directly
   - Wrong input/output format: -10pts
   - Wrong hand-in file name: -10pts
   - Copy or be copied: will get 0pt directly

(you only can use these library)
“example_hw3-1.cpp”:

```
#include "bmpReader.h"
#include "bmpReader.cpp"
#include <stdio.h>
#include <iostream>
#include <math.h>
#include <pthread.h>
#include <semaphore.h>
using namespace std;
```

Requirements

- Use NCTU CS Workstation **linux1~linux6** as your programming environment. (No bsd1~bsd6)
- We only use these commends on NCTU CS Workstation linux**2**:
  - g++ -std=c++11 -pthread StudentID_hw3-1.cpp
  - g++ -std=c++11 -pthread StudentID_hw3-2.cpp
  - ./a.out
    ↑ no argument
- Put the 3 files into a compressed file named "**StudentID_OS_hw3.zip**"
  - StudentID_hw3-1.cpp
  - StudentID_hw3-2.cpp
  - report.docx (or report.pdf)
- Deadline: 2017/12/09 (Saturday) 23:59