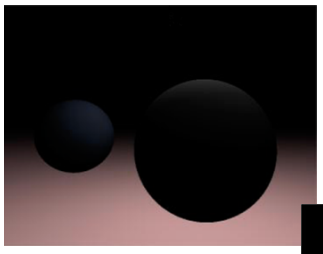
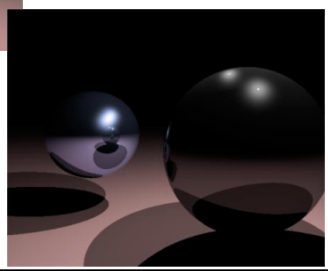
CS 35L Software Construction Lab
Week 6 – Multithreading

Ray Tracing

- An advanced computer graphics technique for rendering 3D images
- Mimics the propagation of light through objects
- Simulates the effects of a single light ray as it's reflected or absorbed by objects in the images



Without ray tracing



With ray tracing

Computational Resources

- Ray Tracing produces a very high degree of visual realism at a high cost
- The algorithm is *computationally intensive*

=> Good candidate for multithreading (embarrassingly parallel)

Homework 6

- Download the single-threaded ray tracer implementation
- Run it to get output image
- Multithread ray tracing
  - Modify main.c and Makefile
- Run the multithreaded version and compare resulting image with single-threaded one

Basic pthread Functions

There are 5 basic pthread functions:

1. pthread_create: creates a new thread within a process

2. pthread_join: waits for another thread to terminate

3. pthread_equal: compares thread ids to see if they refer to the same thread

4. pthread_self: returns the id of the calling thread

5. pthread_exit: terminates the currently running thread

pthread_create

- **Function:** creates a new thread and makes it executable
- Can be called any number of times from anywhere within code
- Return value:
  - Success: zero
  - Failure: error number

Parameters

```
int pthread_create( pthread_t *tid, const pthread_attr_t *attr,
                    void *(my_function)(void *), void *arg );
```

- **tid**: unique identifier for newly created thread
- **attr**: object that holds thread attributes (priority, stack size, etc.)
  - Pass in NULL for default attributes
- **my_function**: function that thread will execute once it is created
- **arg**: a *single* argument that may be passed to my_function
  - Pass in NULL if no arguments

pthread_create Example

```
#include <pthread.h> …
void *printMsg(void *thread_num) {
        int t_num = (int) thread_num;
        printf("It's me, thread #%d!\n", t_num); }

int main() {
        pthread_t tids[3];
        int t;
        for(t = 0; t < 3; t++) {
                ret = pthread_create(&tids[t], NULL, printMsg, (void *) t);
                if(ret) {
                        printf("Error creating thread. Error code is %d\n", ret");
                        exit(-1); }
        }
}
```

Possible problem with this code?
If main thread finishes before all threads finish their job -> incorrect results

pthread_join

- **Function:** makes originating thread wait for the completion of all its spawned threads' tasks
- Without join, the originating thread would exit as soon as it completes its job
  ⇒A spawned thread can get aborted even if it is in the middle of its chore
- Return value:
  ⇒Success: zero
  ⇒Failure: error number

Arguments

int pthread_join(pthread_t tid, void **status);

- **tid**: thread ID of thread to wait on
- **status:** the exit status of the target thread is stored in the location pointed to by *status
  – Pass in NULL if no status is needed

pthread_join Example

```
#include <pthread.h> …
#define NUM_THREADS 5

void *PrintHello(void *thread_ num) {
      printf("\n%d: Hello World!\n", (int) thread_num); }

int main() {
      pthread_t threads[NUM_THREADS];
      int ret, t;
      for(t = 0; t < NUM_THREADS; t++) {
            printf("Creating thread %d\n", t);
            ret = pthread_create(&threads[t], NULL, PrintHello, (void *) t);
            // check return value }

       for(t = 0; t < NUM_THREADS; t++) {
            ret =  pthread_join(threads[t], NULL);
            // check return value }
}
```

Homework 6

- Build a multi-threaded version of Ray tracer
- Modify “main.c” & “Makefile”
  - Include <pthread.h> in “main.c”
  - Use “pthread_create” & “pthread_join” in “main.c”
  - Link with –lpthread flag
- make clean check
  - Outputs “1-test.ppm”
  - Can’t see “1-test.ppm”
    - sudo apt-get install gimp (Ubuntu)
    - X forwarding (lnxsrv)
      - ssh –X username@lnxsrv.seas.ucla.edu
    - gimp 1-test.ppm

1-test.ppm

Figure. 1-test.ppm & baseline.ppm