Uppsala University
Informations Technology
Jarmo Rantakokko

Pthreads programming

Note: If you have attended the lectures and worked through the examples there you can skip sections 1-5 and go directly to section 6, Examples.

1 Compile and run Pthreads programs

Copy the tar file pthreads.tar from the course homepage. Study the `Makefile` to see how to compile Pthreads programs. Compile the program helloworld, `make helloworld`. Run the program by typing the program name `./helloworld`. Study the program source file and compare with the output. Re-run the program on more than one thread. Modify the program to also print the thread id, i.e., pass the thread number to the HelloWorld function.

If you want to pass more than one argument you must use structs. For this purpose, study and run the program hello_arg2.c (make hello2). Note also how the struct is used to return values from the threads. Modify the program to pass different messages to the different threads, e.g., by using the `messages` array.

2 Global and local data

In the thread model all global data are accessible to all threads while data defined within the thread functions are local and only accessible to the calling thread. In the program data.c we have two global arrays and each thread is reading and writing to them. Run the program and study its output. Is the value of the sum variable what you expect, re-run the program several times and explain the results.

3 Thread management

In Pthreads the threads can be defined as joinable or detached. What is the difference of joinable and detached? Run the program join.c (make join) and study the program flow. What would happen if we set the attribute to detached and remove the pthread_join function? What would happen if we also remove pthread_exit call in end of main?

4 Mutex Variables

Mutex variables (or locks) are used for protecting shared (global) data when multiple writes occur. Study and run the program mutex.c (make mutex). What would happen if we don’t use a mutex in the thread function, what will the value of sum be? Re-compile without the -O3 flag and re-run the program, what happens?

5 Condition Variables

A condition variable is used for synchronization of threads. It allows a thread to block (sleep) until a specified condition is reached. In the program synch.c a global barrier is implemented using a condition variable, study and run the program. What happens if we remove the barrier, how will the output change? Another way to implement a barrier would be to constantly read a global variable until it changes. This is implemented in spinwait.c. Why does this not work? How can we fix this? (*Hint:* What is the meaning of the keyword `volatile` in C?)

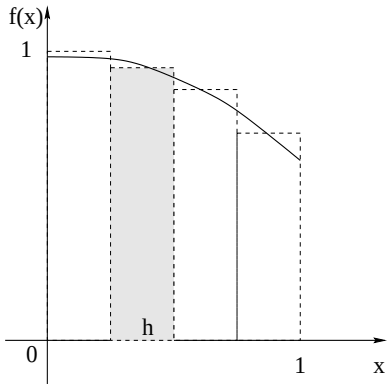
6 Examples

Below we have four different applications, a sorting algorithm, a numerical integration algorithm, a matrix-matrix multiplication and LU-factorization algorithm. We will look at different ways to parallelize these algorithms and compare their performance.

- The program `pi` computes π in parallel using numerical integration. A numerical way to compute π is the following:

$$\int_0^1 \frac{4}{1+x^2} dx = [4\,arctan(x)]_0^1 = \pi$$

If we use the midpoint rule, we can compute the above integral as follows (see Figure 1):



Figur 1: Numerical integration with the midpoint rule.

$$\int_0^1 \frac{4}{1+x^2} dx = h \sum_{i=1}^{n} \frac{4}{1+x_i^2} = h \sum_{i=1}^{n} \frac{4}{1+((i-1/2)h)^2}.$$

The trivial parallel implementation of the latter formula is that if we have p threads available, we slice the sum into p pieces, attach one interval to each of them to compute a partial sum, and then each thread adds its partial sum to a global sum. Parallelize the computations in program pi.c with appropriate Pthreads functions using global and local variables.

- The Enumeration-sort algorithm

  For each element (j) count the number of elements (i) that are smaller ($a(i) < a(j)$). This gives the rank of a(j), i.e. anew(rank(j))=a(j).

  Finding the rank of an element is an independent and perfectly parallel task, i.e., finding ranks of two different elements can be computed concurrently. This strategy is implemented in the program enumsort.c. Study, compile (make enumsort) and run the program.

  The overhead in creating a thread for finding the rank of one element is too high and the efficiency becomes poor. A better approach is to create tasks where the rank of several elements are found by one thread within the task. Implement this strategy and compare with the first approach.

- Consider the program matmul.c (make matmul). Here, two matrices A and B are multiplied and the result is the matrix C. Find the parallelism in the computations and create parallel tasks for the threads. What is the maximal speedup of your parallelization on 1000x1000 matrices? For how small matrices is it worth doing the parallelization? (Remark, the code is not optimal due to cache performance.)

- **Challenge (optional):** Parallelize the LU-factorization algorithm in lu.c file. Note, you can either make a straightforward parallelization of the two (perfectly parallel) inner loops or you can make a more efficient parallelization using locks as with the Gram-Schmidt algorithm which was demonstrated in the lectures.

7 Report

The laboration is a part of the examination. To pass you need to either attend the lab and work actively on the tasks or write a short informal report summarizing your results and answers together with your source code for the different tasks.