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A1 Assignment report

Implementation of Actor and CSP on solving Longest Common Subsequence problem

Abstract

Parallel and concurrent programming are a well-known difficult subject. In the past few years, great progress has been made in improving parallel and concurrent programming abstractions, techniques, and tools to simplify parallel and concurrent programming practices. In this report, we introduce two most used Parallel programming model-Actors and CSP (channel). We investigate them by setting up an experiment on solving the Longest Common Subsequence (LCS) problem. Mainly compare their performance results and concluded that the utilization of these two models could improve our computational performance on LCS problem.

Background

Although the concept of concurrency and parallelism has existed since the first computer was introduced [13], multi-core processors became mainstream about 10 years ago, when AMD and Intel began selling dual-core processors for desktops. In order to make better use of multi-core technology, applications must be concurrent and parallel, which poses a challenge because it is well known that concurrent and parallel programming is difficult [12]. In order to reduce the burden of concurrent and parallel programming, great progress has been made in introducing new concurrent programming frameworks [8], models [6], and empirical researches on, for instances, about how developers use/misuse concurrent and parallel programming constructs[21], as well as performance [2], satisfaction and error-propensities[10], and even energy assessments[11].

Concurrency vs Parallelism

Over the past decades, the CPU has been following the development of Moore's law, a single core frequency faster and faster. However, in recent years, Moore's law has failed [1], the CPU is difficult to choose between technological process and heat stability. Instead, the strategy is to increase the number of cores, quad-core home computers are very common, the server is reached 32 nuclear 64 threads. To make effective use of multicore CPUs, we should consider concurrency at the code level.

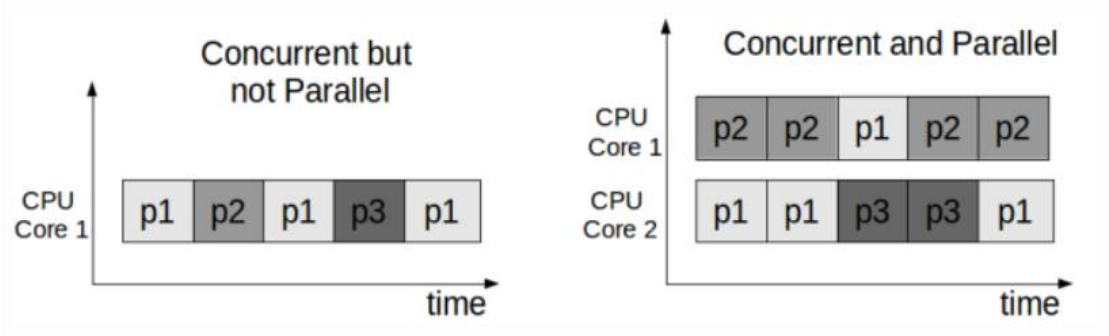
- Concurrency: When there are multiple threads operating, if the system has only one CPU, divide the CPU running time into several time periods and allocate them to each thread to execute. While the thread code of one time period is running, the other threads are suspended. This is called Concurrent.

  Concurrency = interval occurs

- Parallelism: When the system has more than one CPU, it is possible for threads to operate concurrently. When one CPU executes one thread, the other CPU can execute another thread. The two threads do not preempt the CPU resources and can do so simultaneously. This method is called Parallel.

  Parallel = simultaneous occurs

- Distinction: parallelism refers to the occurrence of two or more events at the same time; Concurrency is when two or more events occur at the same time interval. (1)



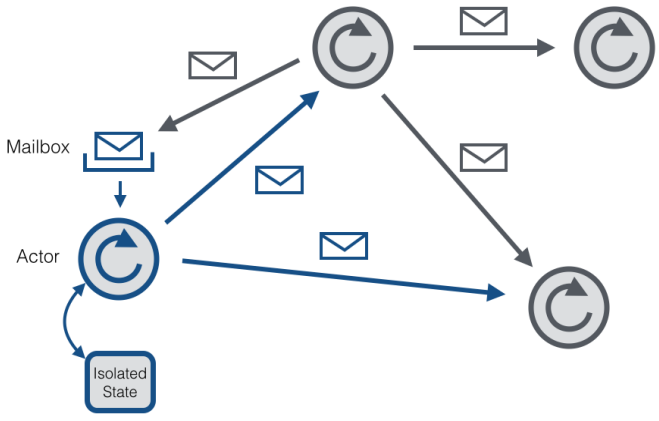
1. **Concurrency and Parallelism**

Actor

The Actor model was proposed in a 1973 by Carl Hewitt, Peter Bishop and Richard Steiger [3]. An actor responds to incoming messages, makes local decisions, creates more actors, or sends more messages. Also prepare to receive the next message. In Actor theory, everything is thought of as Actor, much like in object-oriented programming (OOP) everything is thought of as an object. But software, including object-oriented languages, usually executes sequentially, while the Actor model is essentially concurrent.

- Message

  In OOP, objects communicate with other objects through calling functions. Class A calls A function on class B, waits for the function to return, and then class A can continue with the rest of the work. Actors communicate with other actors through message. Messages are sent asynchronously, and it may take an arbitrarily long time to reach the recipient's mailbox. Moreover, the actor model does not guarantee the order of the messages (2). The message queuing and exit queues in the mailbox are atomic operations, so there is no race condition.

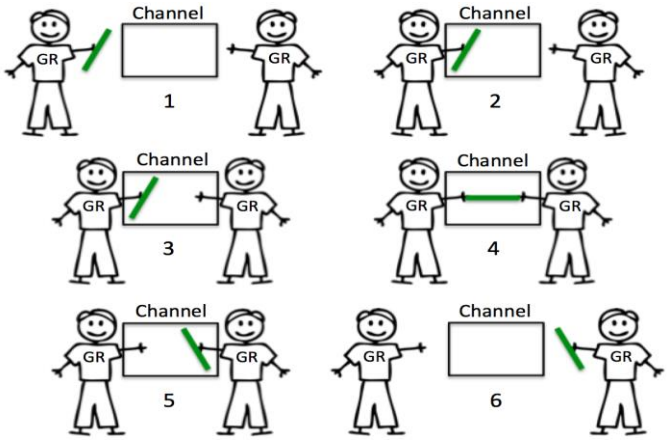


2. The bird view of Actor model

CSP(Channel)

The CSP version proposed by Hoare in his original paper in 1978 is essentially a concurrent programming language, not a process calculus [4]. A channel is a model for inter-process communication and synchronization through messaging. Messages can be sent through the channel, while another process or thread can receive messages, such as streams, that are

sent through the channel they reference (3). Different implementations of the channel can be buffered or unbuffered, either synchronous or asynchronous.



3. The conceptional picture of CSP

Longest Common Subsequence

The LCS problem is to find the longest subsequence shared by all sequences in a set of sequences (usually only two sequences). It differs from the longest common substring problem: unlike substrings, substrings do not need to occupy consecutive positions in the original sequence.

For two sequences of n and m elements, the dynamic programming method runs for O(n×m) for any number of input sequences, and the solution given by the dynamic programming method is

$$O\left(N\prod_{i=1}^{N}n_i\right)$$

Literature review

The development of concurrent programming has gained significant popularity over the last decade. Dominik C vt.el [7] designed and built CAF, a C++ Framework. They introduced a type-safe messaging interface to enhance the robustness of the actor program. They demonstrate the feasibility of CAF in several scenarios, and found CAF continuously outperforms the competing actor environments Erlang, Charm++, SalsaLite, Scala, and ActorFoundry. But for improvement, CAF needs a design towards effective monitoring and debugging facilities.

In terms of solving problems with LCS, dynamic programming is the classic method for solving LCS problems [5]. It is based on filling a score matrix through a scoring mechanism. The best score is the length of the LCS, and the subsequence of the LCS can be found through the track back table. The time and space complexity of this dynamic programming approach is O(mn), where m and n are the length of the two compared strings.

[9] proposed Chemical Reaction Optimization (CRO), which a new meta-heuristic method has widely used in solving optimization problems. They found that the CRO has superior performance when comparing with Dynamic LCS and Fast Dynamic LCS. However, the experiment test instances they used is small, the longest length of one of the strings is 360. It

could underperform when given relatively larger, e.g. length of two strings are 30000.

Experiment

To compare the Actor and CSP model with sequential implementation, we can directly see how parallel programming boost the performance on computing the LCS.

First, we need a Sequential implementation (SEQ), used as a baseline to evaluate the parallel speedup.

Actor (ACT) implementation, used to evaluate the parallel speedup for the Actor model.

CSP (CSP) implementation, used to evaluate the parallel speedup for the CSP model.

In this experiment, I used dynamic LSC algorithm as my SEQ, the algorithm obeys the state transition equation, analyzing as below:

Set X = < x1, x2, x3, x4... , xm >, Y = < y1, y2, y3, y4... ,yn> is two sequences, Z=<z1,z2,z3,z4... Zk > is any common subsequence of them.

After analysis, we know that:

1. If *xm* = yn, zk = xm = yn and zk -1 is an LCS of xm -1 and yn -1
2. If xm! = yn and zk! Is equal to xm, then Z is an LCS of xm minus 1 and Y
3. If xm! = yn and zk! Is equal to yn, so Z is an LCS of X and yn minus 1.

$$C(i,j)\mathrm{f(x)} = \begin{cases} 0, & if\ i = 0\ or\ j = 0 \\ C[i-1,j-1]+1, & If\ i,j > 0,\ x_i = y_i \\ max\{C[i,j-1], C[i-1,j]\}, & If\ i,j > 0,\ x_i \neq y_i \end{cases}$$

State Transition equation

Set: P1 is the length of the longest common subsequence of the first i -1 character of X and the first j character of Y

P2 is the length of the longest common subsequences of the first i characters of X and the first j - 1 characters of Y

P is the length of the longest common subsequences of the first i -1 character of X and the first j-1 character of Y

P0 is the length of the longest common subsequence of the first i characters of X and the first j characters of Y

If the ith character of X is the same as the JTH character of Y, then p0 = p + 1

If the ith character of X is not equal to the JTH character of Y, then p0 = Max (p1, p2)

ACT:

For the algorithm mentioned above perform in actor model, consider using multiple actors can compute small substring for 2 entire strings separately, a divide string mechanism was proposed, so that multiple smaller substring can sent to each actor. Divided substrings are the defined by bands. For instances, if the bands' number are 80, 80 of horizontal and vertical bands respectively, then there are 80 x 80 divided substring to be computed by actors. After computing the LCS of the smaller substring, Actors then sent the result to the mailbox of other actors. The waiting actors received the message and perform the same computation.

CSP:

The mechanism is the same as ACT. Instead of using sent message through mailbox, CSP allows each entity can sent message through channel. Other entities listen to the channel,

then receive message and do further processing.

1. Experiment result:

The Lab computer runs the experiment has hardware support of:
Inter® Core ™ i5-6600 CPU @ 3.30GHz
Installed memory (RAM) 8.00GB (7.86 GB usable)
System type: 64-bit operating System, x64-based processor
Number of cores: 4
Two text files with great number of string length will be used as input. Length of file input 1: 100256, Length of file length 2: 100300.
10 sets of bands will be tested on both ACT and CSP. Measure the time duration of these models. Compare their result. The result is shown as follows:

Bands tested	ACT model time used (ms)	CSP model time used (ms)
1, 1	58381	58321
5, 5	24284	24491
10, 10	17010	17045
20, 20	14226	14404
30, 30	15085	13818
40, 40	17309	13680
50, 50	17548	13624
60, 60	18349	13529
80, 80	19994	13717
100, 100	23378	13800

We can see both ACT and CSP models decreased the time used as the horizontal and vertical bands increased. ACT model shows increased trend of duration after 30, 30 bands. Whereas, CSP continuously decreased duration.

Conclusion

The aim of the report is present abstraction of ACT and CSP parallel programming models, and implement them to solve the LCS problem, and compare their time used to solve two strings with large lengths, and with different sizes of bands used. This revealed that the more bands used the less time duration to solve the LCS problem. The ACT is generally outperformed by the CSP model. Even the ACT and CSP are outperforming, in the practical situation, using actors or CSP is subject to changes in the whole application architecture mechanism and way of thinking. The concept of parallel programming can meaningful for computation, specifically when Moore's law is failing. Parallel programming could be the future trend of computer programming. Future work could focus on how implementation of parallel programming be easier.

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