

“Concurrency in Go” Notes

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1 Concurrency Ideas

Color Scheme Key
Definition
Note

Amdahl's Law

Amdahl's Law models the improved performance of a fixed task when the resources are improved. In parallel computing, it is used to predict the speedup of using multiple processors. The relation is given as follows:

$$S_{\text{latency}}(s) = \frac{1}{(1-p) + \frac{p}{s}}$$

S_{latency}	the theoretical speedup of the whole program
s	the speedup of the part of the task from improved resources
p	the proportion of the execution time that benefits from the improved resources

Race Conditions

A race condition is when two or more operations must execute in the correct order, but the program leaves the order of execution unspecified.

Data Race

A data race is a race condition in which two concurrent operations attempt to read the same data at an unspecified time (namely one that could potentially conflict). In the following example, the program is not given a specified evaluation order, so the code that follows may execute before, during, or even after the goroutine. As such, the output is indeterminate.

```
var data int
go func() { data++ }()
fmt.Printf("%v\n" data)
```

Atomicity

An atomic operation is indivisible or uninteruptable in the context in which it is operating. For example, the statement `i++` consists of 3 atomic operations: retrieving, incrementing, and storing the value of `i`.

Critical Selection	<p>A critical selection is a section of code that requires exclusive access to a shared resource. In the following code, the <code>fmt.Printf()</code> and the goroutine are both critical selections.</p> <pre>var data int go func() { data++ }() fmt.Printf("%v\n" data)</pre>								
Memory Access Synchronization	To solve the problem of multiple critical selections, only enable one critical selection to access the same shared resource at a time. This can be achieved, for example, with a mutex.								
Deadlock	A deadlock is a state in which all concurrent processes are waiting on each other. A deadlock can be identified by the Coffman Conditions.								
Coffman Conditions	<p>There are 4 Coffman Conditions that detect, prevent, and correct deadlocks. The conditions are as follows:</p> <table> <tr> <td>Mutual Exclusion</td><td>A concurrent process must hold exclusive rights to a resource at any one time.</td></tr> <tr> <td>Wait For Condition</td><td>A concurrent process must hold a resource and be waiting for another resource.</td></tr> <tr> <td>No Preemption</td><td>A resource held by a concurrent process can only be released by that process.</td></tr> <tr> <td>Circular Wait</td><td>A process must be waiting on a chain of processes which is circular (meaning that the process is directly or indirectly waiting on itself to give a result).</td></tr> </table>	Mutual Exclusion	A concurrent process must hold exclusive rights to a resource at any one time.	Wait For Condition	A concurrent process must hold a resource and be waiting for another resource.	No Preemption	A resource held by a concurrent process can only be released by that process.	Circular Wait	A process must be waiting on a chain of processes which is circular (meaning that the process is directly or indirectly waiting on itself to give a result).
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Livelock	A livelock is when the current concurrent processes are performing operations, but these operations do not terminate or move the program closer to termination.								
Starvation	Starvation is a superset of a livelock or deadlock where, more generally, a concurrent process does not receive access to the resources it needs. A common example is having a “greedy worker” hold on to access to the resource, while a “polite worker” does not, and thus has less access to the resource: it is starved.								
“Finding a Balance”	What should the range of a memory lock be? Should it be broad and cover multiple critical selections, or should each critical selection get its own lock? It is important to strike a balance in answering this question because memory access synchronization is expensive, but you also want to avoid writing greedy processes to mitigate starvation.								
OS Threads	OS threads are a primitive at the OS context that can be used to run processes concurrently. The operating system is responsible for creating and managing the threads. The threads all have access to a shared resource space.								
Green Threads	Green threads are threads that are managed by a program’s runtime.								
Coroutines	Concurrent subroutines that are non-preemptive (meaning that they can’t be interrupted) are called coroutines. They feature multiple points to suspend or reenter computation.								
Thread Pools	Thread pools are a software design pattern that maintains a collection of threads to map incoming tasks to threads for concurrent execution.								

Concurrency vs. Parallelism	<p>Parallelism is a property of a machine to be able to run two tasks simultaneously in the considered context. On the other hand, concurrency refers to when two processes have a lifespan that overlaps. In this sense, you could have a concurrent program running on a single thread where multiple threads are simulated. It is also possible that the concurrent processes run in parallel.</p> <p>Concurrency is a property of the code, and parallelism is a property of the execution of the code.</p>
Process	A process is a portion of code that requires input to run and produces an output that is consumed by another process. The input and output of a process is called communication between processes.
Communicating Sequential Processes (CSP)	CSP is the name of a paper, programming language, and the idea of a describing programs as processes which are sequential and communicate. Used in the paper describing CSP, the CSP language supported the use of <code>!</code> and <code>?</code> to send input into and read output from a process respectively. In addition, it supported guarded commands. This is the style of concurrency programming that Golang's channels are based on.
Guarded Command	<p>When a statement should not be executed if another statement was false or a command exited, it is a guarded command. The CSP example below denotes a process <code>a</code>, from which a character <code>c</code> is continually read (while there is something to be read), and then inputted into the process <code>b</code>.</p> <pre>*[c:character; a?c -> b!c]</pre>
Process Calculus	Process calculus is a mathematical way to model concurrent systems and analyze their properties.
Should I use CSP style or OS threads?	<p>The CSP style has certain advantages that it comes with, and more generally, the Golang developing team suggest to use the CSP style over primitives like <code>sync.Mutex</code>, but there are certain guidelines outlined that help determine when you should use channels or OS thread primitives. Follow the first applicable statement.</p> <ol style="list-style-type: none"> 1. If your code is performance critical, use primitives 2. If you are trying to transfer ownership of data, use channels 3. If you are trying to guard the internal structure of a struct, use primitives 4. If you are coordinating multiple pieces of logic, use channels 5. Use primitives

2 Golang Features

Color Scheme Key
Concept
Type
Function
Keyword
Syntax

Format of a Golang Program	Every Golang program must contain at least one goroutine: the main goroutine that is started when the process begins.
Goroutines	A goroutine is a function, method, or closure that runs concurrently with some other code. A goroutine can be created with the keyword <code>go</code> . Each goroutine is a special class of coroutine where you do not have to manually describe the suspension and resuming of the routine.
<code>fmt.Printf()</code>	Similar to <code>printf()</code> in C.
<code>go</code>	Creates a <i>goroutine</i> that runs the function, method, or closure concurrently by multiplexing onto OS threads. The example below calls <code>go</code> on an anonymous function, running it concurrently. <pre> go func() { fmt.Printf("Golang!\n") }()</pre>
<code>defer</code>	Defers the execution of the statement to the end of the function. In the following example, the mutex isn't unlocked until the after the value of <code>data</code> increments. <pre> var data int = 0 var mu sync.Mutex func inc() { mu.Lock() defer mu.Unlock() data++ }()</pre>
<code>sync.Mutex</code>	A mutex type that supports the <code>.Lock()</code> and <code>.Unlock()</code> methods. These methods declare exclusive access to the shared resource that the mutex represents.
<code>func</code>	This keyword can be used to create named functions or anonymous functions. A named function example is show below. <pre> func helloWorld(numTimes int) { for ; numTimes > 0; numTimes-- { fmt.Printf("Hello World!\n") } }</pre> <p>An anonymous version of the same function is also shown below.</p> <pre> var f := func(numTimes int) { for ; numTimes > 0; numTimes-- { fmt.Printf("Hello World!\n") } }</pre>