

Table 5.1 Some Key Terms Related to Concurrency

atomic operation	A sequence of one or more statements that appears to be indivisible; that is, no other process can see an intermediate state or interrupt the operation.
critical section	A section of code within a process that requires access to shared resources and that must not be executed while another process is in a corresponding section of code.
deadlock	A situation in which two or more processes are unable to proceed because each is waiting for one of the others to do something.
livelock	A situation in which two or more processes continuously change their states in response to changes in the other process(es) without doing any useful work.
mutual exclusion	The requirement that when one process is in a critical section that accesses shared resources, no other process may be in a critical section that accesses any of those shared resources.
race condition	A situation in which multiple threads or processes read and write a shared data item and the final result depends on the relative timing of their execution.
starvation	A situation in which a runnable process is overlooked indefinitely by the scheduler; although it is able to proceed, it is never chosen.

Table 5.2 Process Interaction

Degree of Awareness	Relationship	Influence that one Process Has on the Other	Potential Control Problems
Processes unaware of each other	Competition	<ul style="list-style-type: none"> •Results of one process independent of the action of others •Timing of process may be affected 	<ul style="list-style-type: none"> •Mutual exclusion •Deadlock (renewable resource) •Starvation
Processes indirectly aware of each other (e.g., shared object)	Cooperation by sharing	<ul style="list-style-type: none"> •Results of one process may depend on information obtained from others •Timing of process may be affected 	<ul style="list-style-type: none"> •Mutual exclusion •Deadlock (renewable resource) •Starvation •Data coherence
Processes directly aware of each other (have communication primitives available to them)	Cooperation by communication	<ul style="list-style-type: none"> •Results of one process may depend on information obtained from others •Timing of process may be affected 	<ul style="list-style-type: none"> •Deadlock (consumable resource) •Starvation

Table 5.3 Common Concurrency Mechanisms

Semaphore	An integer value used for signaling among processes. Only three operations may be performed on a semaphore, all of which are atomic: initialize, decrement, and increment. The decrement operation may result in the blocking of a process, and the increment operation may result in the unblocking of a process. Also known as a counting semaphore or a general semaphore
Binary Semaphore	A semaphore that takes on only the values 0 and 1.
Mutex	Similar to a binary semaphore. A key difference between the two is that the process that locks the mutex (sets the value to zero) must be the one to unlock it (sets the value to 1).
Condition Variable	A data type that is used to block a process or thread until a particular condition is true.
Monitor	A programming language construct that encapsulates variables, access procedures and initialization code within an abstract data type. The monitor's variable may only be accessed via its access procedures and only one process may be actively accessing the monitor at any one time. The access procedures are <i>critical sections</i> . A monitor may have a queue of processes that are waiting to access it.
Event Flags	A memory word used as a synchronization mechanism. Application code may associate a different event with each bit in a flag. A thread can wait for either a single event or a combination of events by checking one or multiple bits in the corresponding flag. The thread is blocked until all of the required bits are set (AND) or until at least one of the bits is set (OR).
Mailboxes/Messages	A means for two processes to exchange information and that may be used for synchronization.
Spinlocks	Mutual exclusion mechanism in which a process executes in an infinite loop waiting for the value of a lock variable to indicate availability.

Table 5.4 Possible Scenario for the Program of Figure 5.9

	Producer	Consumer	s	n	Delay
1			1	0	0
2	semWaitB(s)		0	0	0
3	n++		0	1	0
4	if (n==1) (semSignalB(delay))		0	1	1
5	semSignalB(s)		1	1	1
6		semWaitB(delay)	1	1	0
7		semWaitB(s)	0	1	0
8		n--	0	0	0
9		semSignalB(s)	1	0	0
10	semWaitB(s)		0	0	0
11	n++		0	1	0
12	if (n==1) (semSignalB(delay))		0	1	1
13	semSignalB(s)		1	1	1
14		if (n==0) (semWaitB(delay))	1	1	1
15		semWaitB(s)	0	1	1
16		n--	0	0	1
17		semSignalB(s)	1	0	1
18		if (n==0) (semWaitB(delay))	1	0	0
19		semWaitB(s)	0	0	0
20		n--	0	-1	0
21		semSignalB(s)	1	-1	0

Note: White areas represent the critical section controlled by semaphore s.

Table 5.5 Design Characteristics of Message Systems for Interprocess Communication and Synchronization

Synchronization	Format
Send	Content
blocking	Length
nonblocking	fixed
Receive	variable
blocking	Queuing Discipline
nonblocking	FIFO
test for arrival	Priority
Addressing	
Direct	
send	
receive	
explicit	
implicit	
Indirect	
static	
dynamic	
ownership	

Table 5.6 State of the Process Queues for Program of Figure 5.23

Readers only in the system	<ul style="list-style-type: none">• <i>wsem</i> set• no queues
Writers only in the system	<ul style="list-style-type: none">• <i>wsem</i> and <i>rsem</i> set• writers queue on <i>wsem</i>
Both readers and writers with read first	<ul style="list-style-type: none">• <i>wsem</i> set by reader• <i>rsem</i> set by writer• all writers queue on <i>wsem</i>• one reader queues on <i>rsem</i>• other readers queue on <i>z</i>
Both readers and writers with write first	<ul style="list-style-type: none">• <i>wsem</i> set by writer• <i>rsem</i> set by writer• writers queue on <i>wsem</i>• one reader queues on <i>rsem</i>• other readers queue on <i>z</i>