

```
#include <stdlib.h>
#include <string.h>
#include <ctype.h>
```

```
#define MAXPAROLA 30
#define MAXRIGA 80
```

```
int main(int argc, char *argv[])
{
    int freq[MAXPAROLA]; /* vettore di contatori
delle frequenze delle lunghezze delle parole */
    char riga[MAXRIGA];
    int i, inizio, lunghezza;
    FILE *f;
```

```
for(i=0; i<MAXPAROLA; i++)
    freq[i]=0;
```

```
if(argc != 2)
```

```
{
    fprintf(stderr, "ERRORE, serve un parametro con il nome del file\n");
    exit(1);
}
```

```
f = fopen(argv[1], "r");
if(f==NULL)
```

```
{
    fprintf(stderr, "ERRORE, impossibile aprire il file %s\n", argv[1]);
    exit(1);
}
```

```
while( fgets( riga, MAXRIGA, f ) != NULL )
```



# Synchronization

## Introduction to Synchronization

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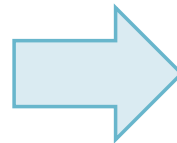
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# Introduction

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# Introduction

## ❖ Critical Section (**CS**) or Critical Region (**CR**)

These are sections of code or variables that are accessed by multiple threads. Proper synchronization ensures that only one thread accesses these sections at a time to prevent inconsistencies.

- A section of code, common to multiple threads, in which each thread can read and **write** shared objects

Critical Sections (CS): These are the parts of your program that access shared resources and must be executed by only one thread at a time.

## ❖ Access to CS is subject to **race conditions**

- The result depends on the execution order of the processes instructions

Race Conditions: This happens when the outcome of a program depends on the sequence or timing of uncontrollable events such as the scheduling of threads.

# Example

## FIFO, Queue, Circular Buffer

Code Explanation:

The enqueue function adds an element to the queue.

The dequeue function removes an element from the queue.

**T<sub>i</sub>**

```
void enqueue (int val) {  
    if (n>SIZE) return;  
    queue[tail] = val;  
    tail=(tail+1)%SIZE;  
    n++;  
    return;  
}
```

register = n  
register = register + 1  
n = register

**T<sub>j</sub>**

```
int dequeue (int *val) {  
    if (n<=0) return;  
    *val=queue[head];  
    head=(head+1)%SIZE;  
    n--;  
    return;  
}
```

register = n  
register = register - 1  
n = register

❖ Even if **enqueue** and **dequeue** operate on the different ends of the queue, the variable **n** is shared

Shared Variable (n):

Even though enqueue and dequeue operate on different ends of the queue, they both modify the shared variable n, which tracks the number of elements in the queue.

A race condition can occur if both functions try to modify n simultaneously, leading to incorrect updates.

Race condition:  
Increments and decrements can be lost

If enqueue and dequeue are called simultaneously:  
enqueue reads n, increments it, and stores it back.  
dequeue reads n, decrements it, and stores it back.  
Without proper synchronization, both may read the same value of n and update it incorrectly.



# Critical sections

Preventing Race Conditions: Use access protocols to enforce mutual exclusion (ensuring only one thread accesses the critical section at a time).

Reservation Section:

Code that runs before entering the critical section to check if the critical section is available. If another thread is using it, the current thread waits.

Release Section:  
Code that runs after leaving the critical section to signal that the critical section is now free for other threads to use.

❖ Race conditions could be prevented with an **access protocol** that enforces **mutual exclusion** for each CS

➤ Before a CS, there should be a **reservation section**

- The reservation code must block (lock out) the P (or T) if another P (or T) is using its CS

➤ After the CS, there should be a **release section**

- The release possibly unlocks another P (or T) which was waiting in the "reservation" code of its CS

Mutex (Mutual Exclusion Object):

A common tool used to implement critical sections. It locks the critical section so that only one thread can access it at a time.

# Access protocol

$T_i$

```

while (TRUE) {
    ...
    reservation code
    Critical Section
    release code
    ...
    non critical section
}
  
```

Non-critical  
Sections: These are parts  
of your code that do not  
access shared resources  
and do not require  
synchronization.

Structure of Critical Section Protection:  
Reservation Code: Check and wait if  
necessary until the critical section is  
free.  
Critical Section Code: The actual code  
that accesses shared resources.  
Release Code: Signal that the critical  
section is now free.

$T_j$

```

while (TRUE) {
    ...
    reservation code
    Critical Section
    release code
    ...
    non critical section
}
  
```

Locks and Unlocks:  
In the reservation code, threads try to acquire  
a lock (using `mutex.lock()`). If the lock is  
already taken, they wait.

In the release code, threads release the lock  
(using `mutex.unlock()`), allowing other waiting  
threads to proceed.

- ❖ Every Critical Section is protected by an
  - Enter code (reservation, or prologue)
  - Exit code (release, or epilogue)
- ❖ Non-critical sections should not be protected
- ❖ OSs provide appropriate primitives