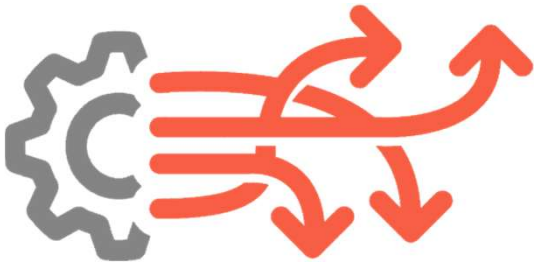
ISTITUTO ITALIANO
DI TECNOLOGIA

Multithreading

in modern C++



Valentina Gaggero

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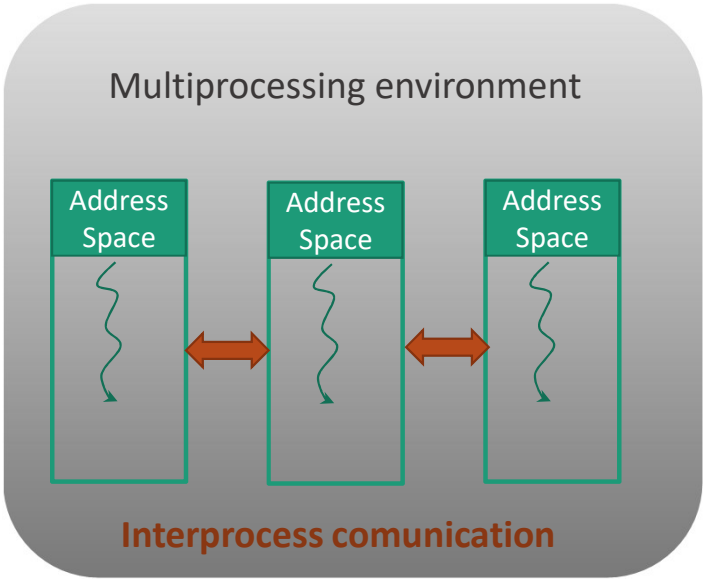
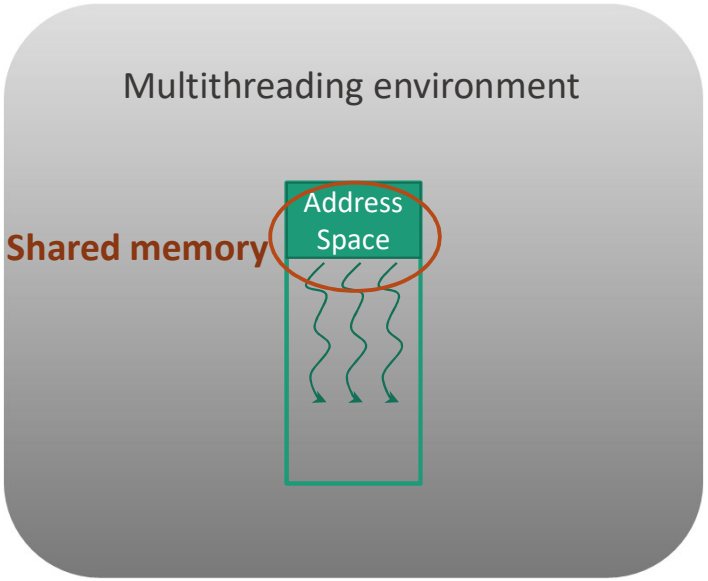
1 – key concepts (1/3)

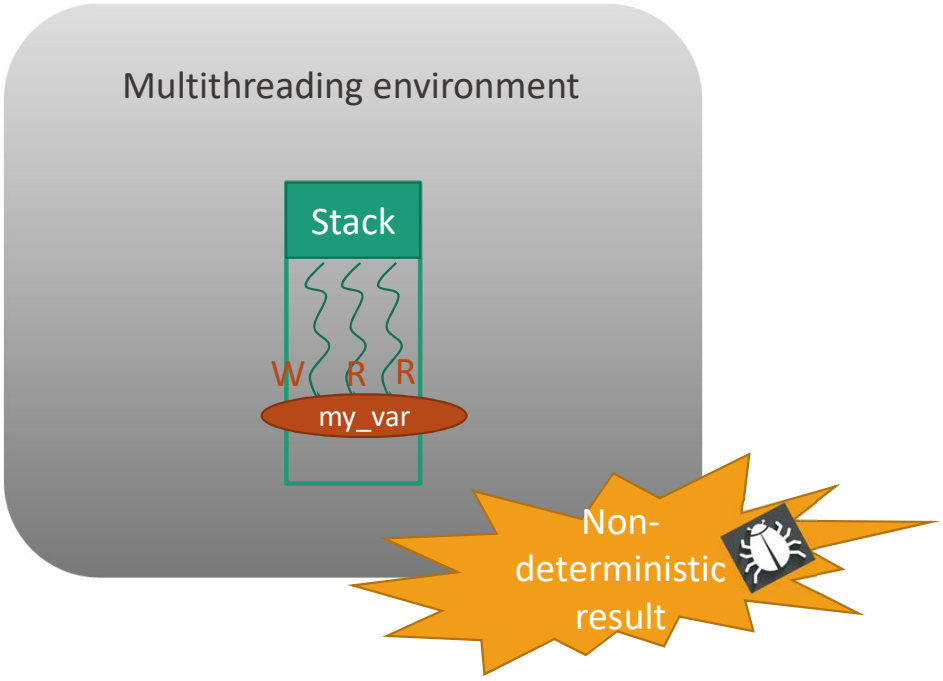
Concept 1: Multiprocessing vs Multithreading





1 – key concepts (2/3)

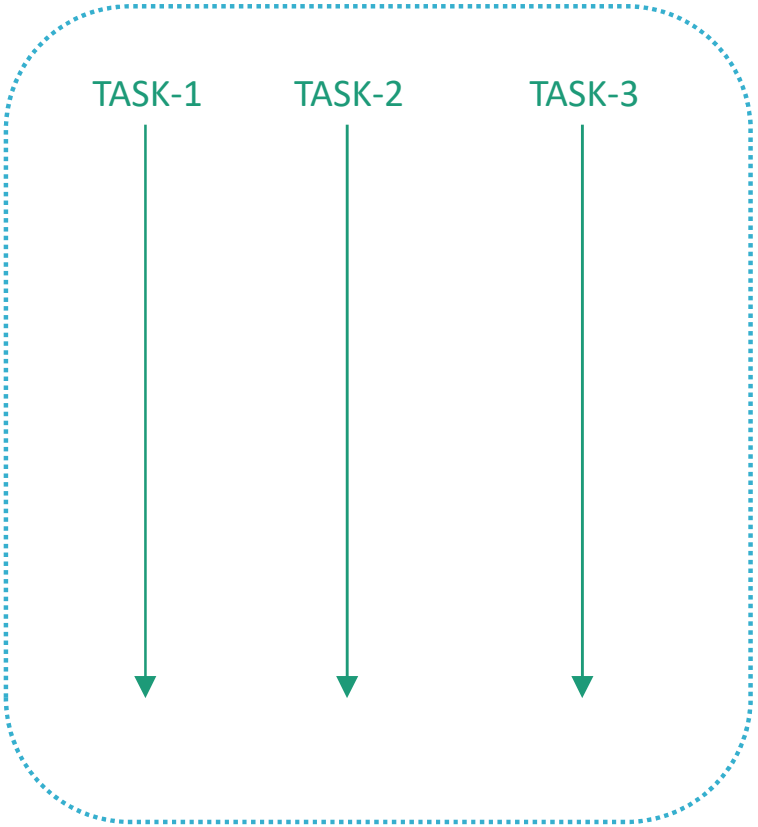
Concept 2: Data race

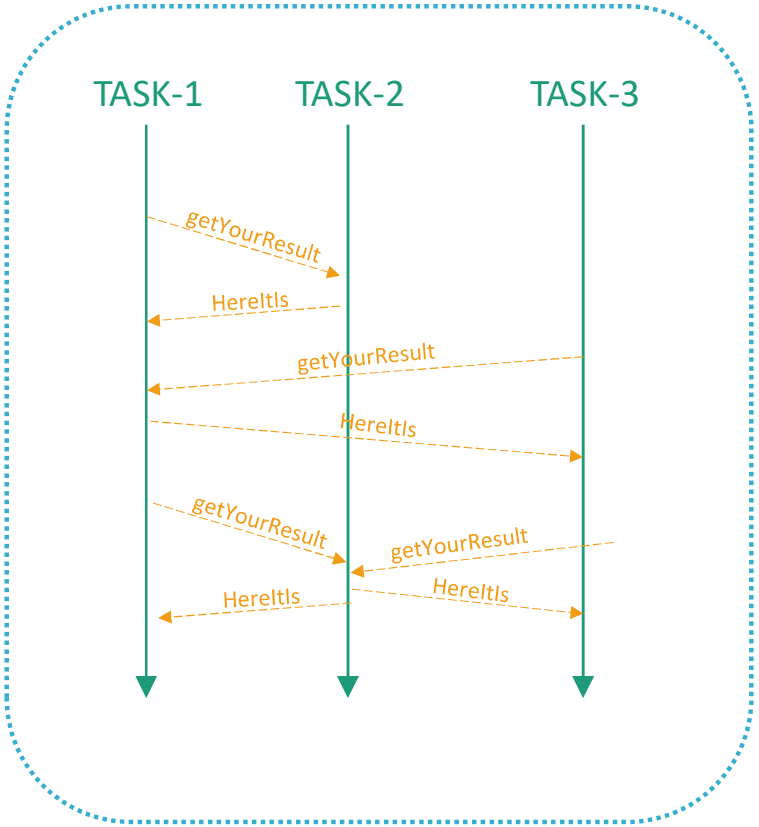


A multi-thread program has a data race if all of these conditions are true:

1. Multiple threads access the same memory location
2. At least one operation is a write access
3. Memory operations don't follow sorting rules, as "Do X before Y"

Concept 3: parallelism vs concurrency





2 – Threads (1/4)

```
int main ()
{
    DoSomething();
    return 0;
}
```

→ Create a thread that executes the main

If we need to perform other tasks → We need to create a thread per task

std::thread

- ✓ Represents a single thread of execution
- ✓ Its execution starts immediately after its creation

```
#include <thread>
std::thread my_th(myTaskFunction);
```

Which type of task?

2 – Threads (2/4)

Type of task we can create

Do something and the main thread waits the result

```
#include <thread>
use namespace std;
int main ()
{
    DoSomething();
    thread my_th (myTaskFunction);
    DoSomethingElse();
    my_th.join();
return 0;
}
```

The main thread "waits" the my_th accomplishes its task

The main thread is not interested in the result of the task (background task)

```
#include <thread>
use namespace std;
int main ()
{
    DoSomething();
    thread my_th(myTaskFunction);
    my_th.detach();
    DoSomethingElse();
    return 0;
}
```

The main thread continues its works, while the detached thread is running.

If you don't call *join()* or *detach ()* before the std::thread object is destroyed, then your program is terminated.
The std::thread destructor calls std::terminate().

2 – Threads (3/4)

How to pass arguments to a thread

```
void retrieveData(uint32_t num, myObject_t obj);

int main()
{
uint32_t mynum = 3;
myObject_t myobj;
……

thread my_th (retrieveData, mynum, myobj);
…
}
```

by default the arguments are *copied*

```
void stringManipulation(uint32_t num, std::string const &str);

void myfunction()
{
uint32_t mynum = 15;
char buffer[100];
……
                                        std::string(buffer)
thread my_th (stringManipulation, mynum, buffer);
my_th.detach();
}
```

the std::thread constructor copies the supplied values as is, without converting to the expected argument type.

Avoids dangling pointers

2 – Threads (4/4)

How to pass arguments to a thread by reference

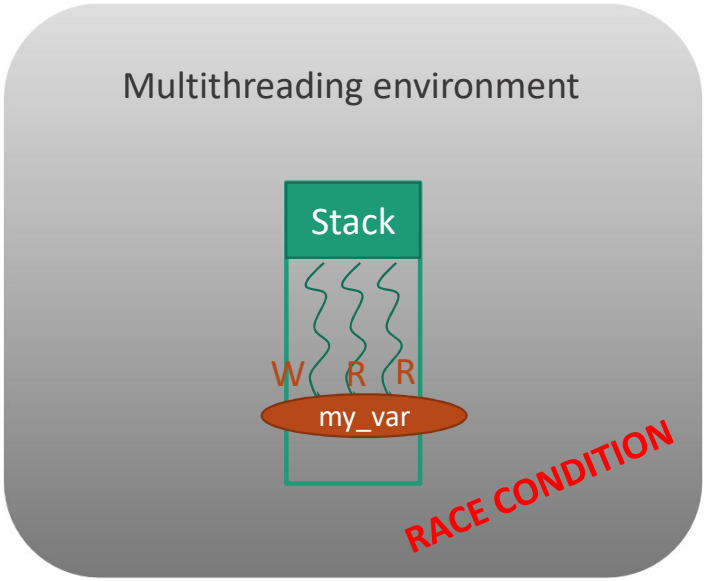
```
void retrieveData(uint32_t num, myObject_t &obj);

int main()
{
   uint32_t mynum = 1000;
   myObject_t myobj;
   ……
                                    std::ref(myobj)
   thread my_th (retrieveData, mynum, myobj);
   …
   my_th.join();
   myobj.getComputedData();

}
```

will be correctly passed a reference to data rather than a reference to a *copy* of data.

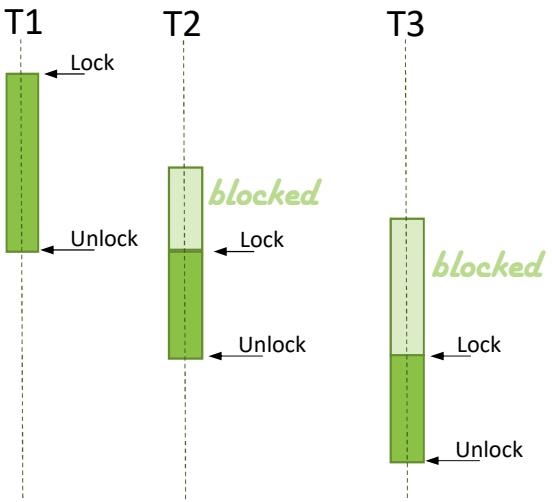
Will I have the updated data in the myobj?

NO!!!

3 – sharing data between threads (1/5)



SOLUTION:
MUTEX (MUTal EXclusion)



3 – sharing data between threads (2/5)

Mutex downsides (1/3)

```
std::mutex mymutex;


void thisIsAFunction()
{
   mymutex.lock();
   //inside the critical section
   bool someError = doSomething();
   if(someError)
     return;
   …..
   mymutex.unlock();
   //end critical section

}
```

Forget to unlock
(also when an exception has been thrown)

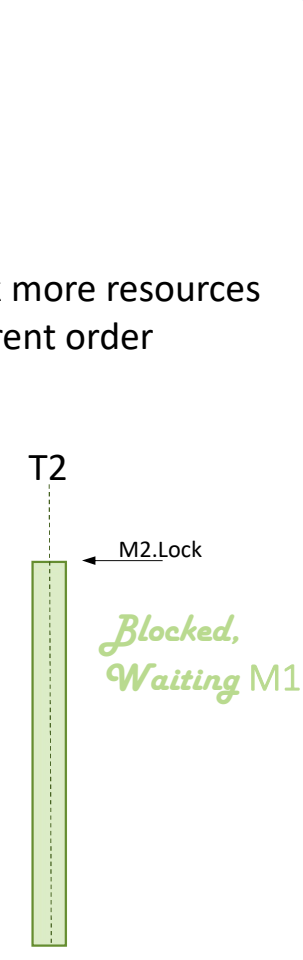
Automatic Lock/unlock by RAII
lock_guard or **unique_lock**

```
std::mutex mymutex;


void thisIsAFunction()
{
   std::lock_guard<std::mutex> guard(mymutex);
   //inside the critical section
   bool someError = doSomething();
   if(someError)
     return;
   …..
} //end critical section
```

```
std::mutex mymutex;


void thisIsAFunction()
{
  std::unique_lock<std::mutex> ul(mymutex);
  //inside the critical section
  bool someError = doSomething();
  if(someError)
    return;
  …..
  mymutex.unlock();
  …. //end critical section
  ….
}
```

Mutex downsides (2/3)

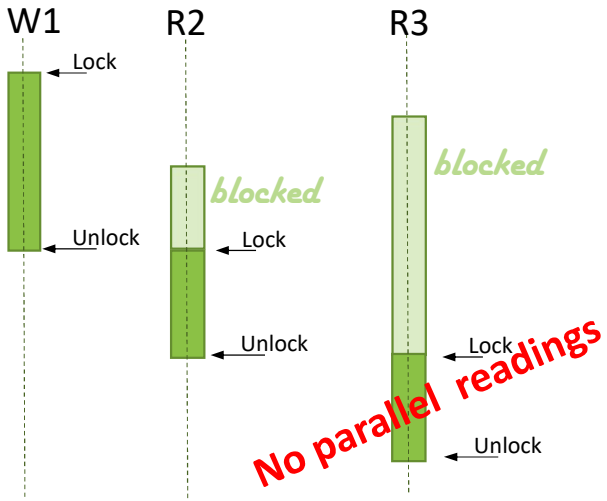
Deadlock
- T1 and T2 need to lock more resources
- T1 and T2 lock in different order



Multiple lock: all-or-nothing by RAII
scoped_lock

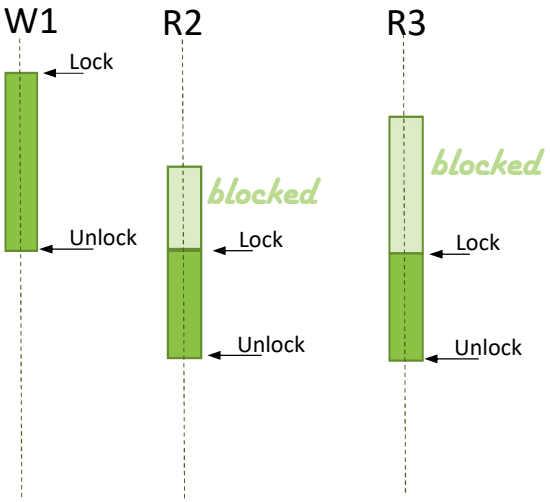
```
std::mutex mymutex1, mymutex2;


void thisIsAFunction()
{
   std::scoped_lock<std::mutex> sl(mymutex1, mymutex2);
   //insiede the critical section
   bool someError = doSomething();
   if(someError)
   return;
   //end critical section
}
```

Mutex downsides (3/3)



3 – sharing data between threads (4/4)

Mutex downsides (3/3)



shared locks:
std::shared_mutex + (**uinique_lock** or **shared_lock**)

```
std::shared_mutex sh_mutex;

void theWriter()
{
      std::unique_lock<std::shared_mutex> ul(sh_mutex);
      //insiede the critical section
      writeData();
      //end critical section

}

void theReader()
{
      std::shared_lock<std::shared_mutex> sl(sh_mutex);
      //insiede the critical section
      readData();
      //end critical section

}
```

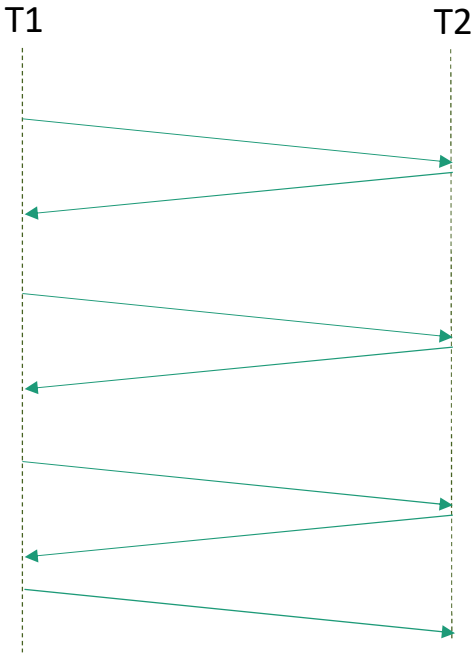
3 – sharing data between threads (4/5)

Mutex - summary

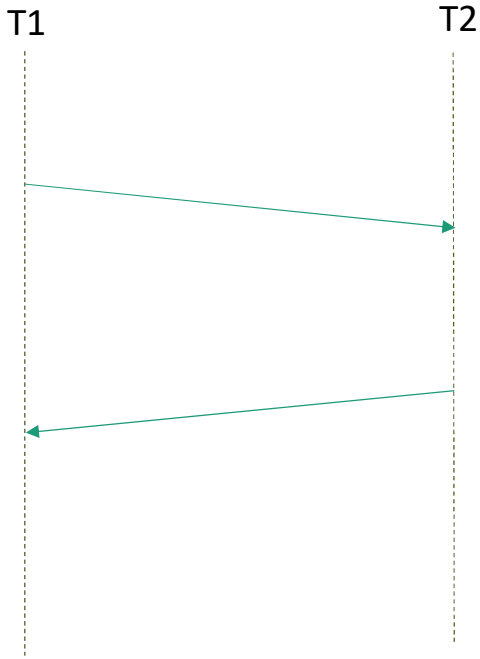
Type	Info
std::mutex	- Lock/unlock API - Need to remember to unlock (also in exception case)
std::lock_guard	- Locking with RAII - No need to remember to unlock - Just declare and use
std::unique_lock	Like std::lock_guard + lock/unlock API
std::shared_mutex	std::unique_lock + std::shared_lock (1 write, more readers)
std::scoped_lock	Like std::lock_guard, but for multiple mutex (to avoid deadlock)

4 –threads synchronization (1/6)

Use case 1: collaborative threads



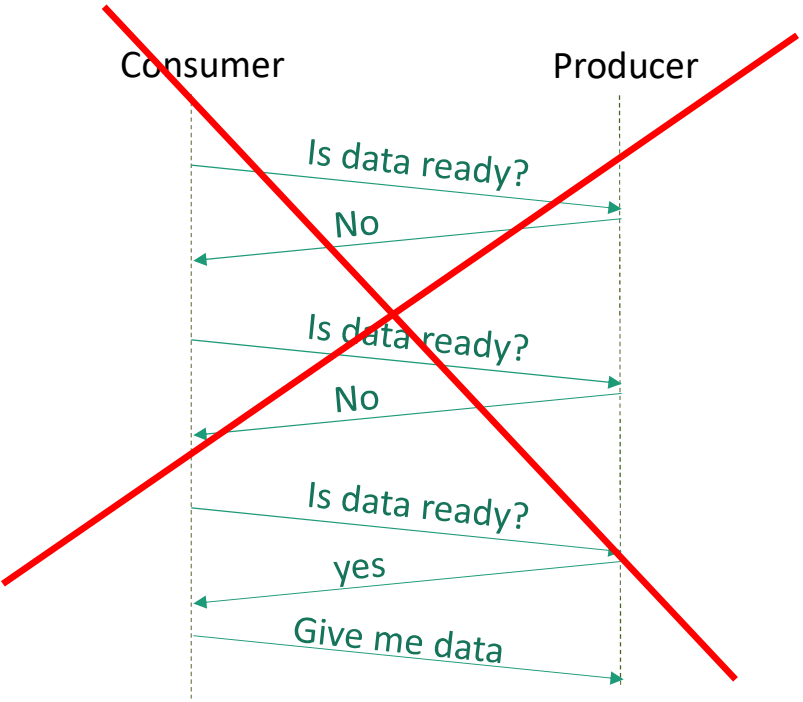
Use case 2: one-off interaction

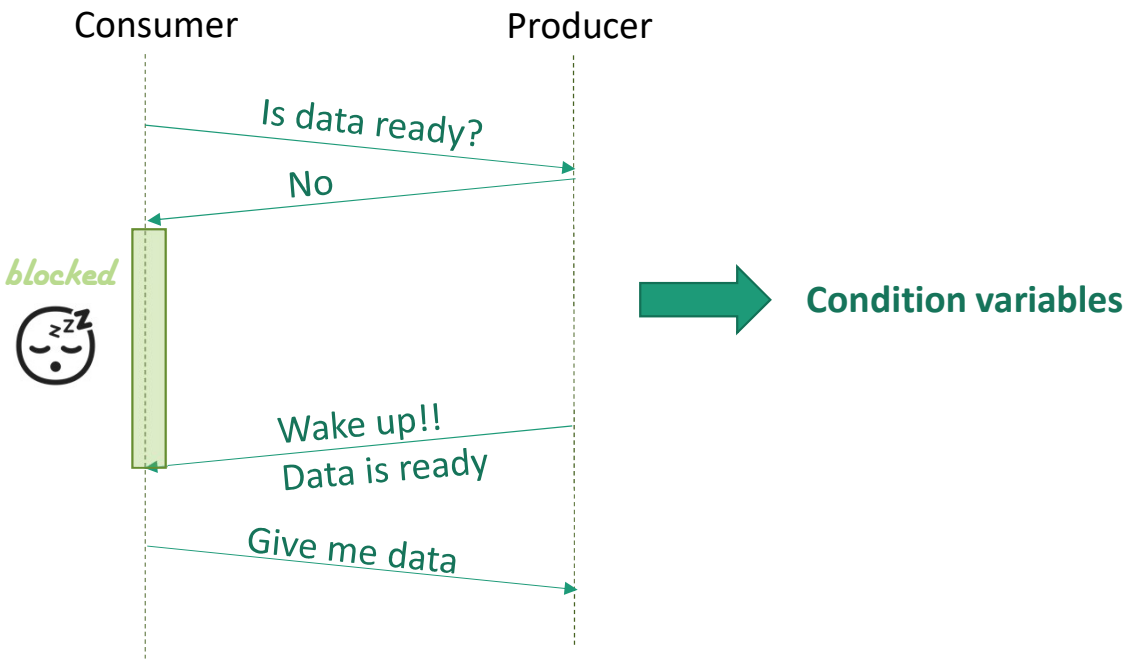


4 –threads synchronization (2/6)

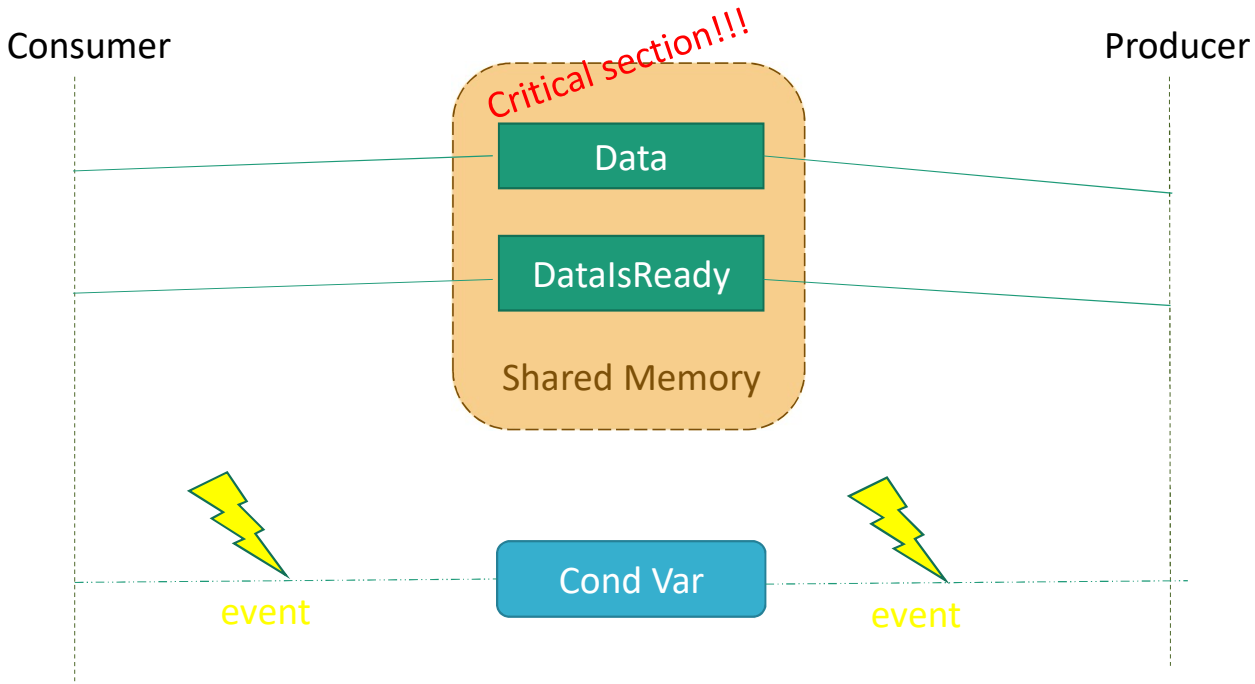
Use case 1: collaborative threads

One thread waits an event triggered by another thread. *Example: producer/consumer use case*





Condition Variables



Hands-on example

4 –threads synchronization (4/4)

Use case 2: one-off interaction – get the result of a thread

```
#include <thread>
use namespace std;
int main ()
{
    DoSomething();
    thread my_th (myTaskFunction);
    my_th.detach();
    return 0;
}
```

How I retrieve the result of the detached thread?

~~my_th.get()~~ ????

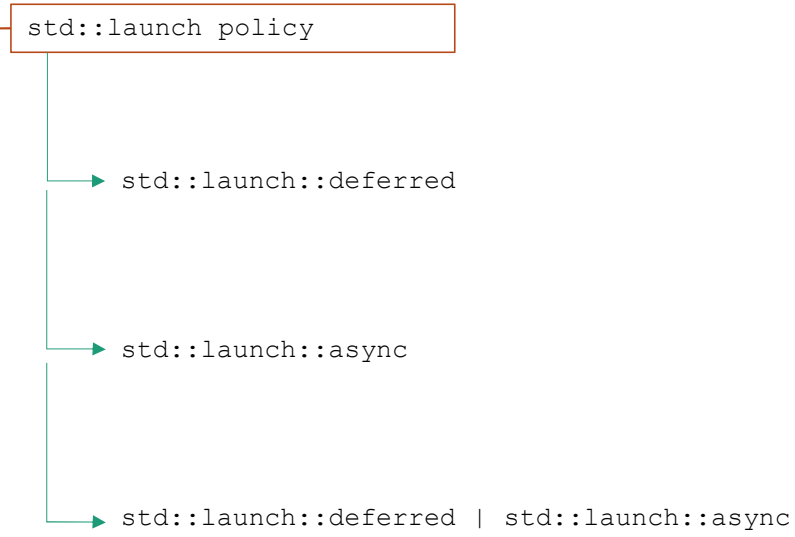
```
#include <feature>
use namespace std;
int main ()
{
    DoSomething();
    future f = async(calculateSomething);
    DoOtherstuff();
    cout << "the result is " << f.get() << endl;
    return 0;
}
```

std::async function template

4 –threads synchronization (5/6)

Where does *calculateSomething* run?

```
#include <feature>
use namespace std;
int main ()
{
    DoSomething();
    future f = async(calculateSomething);
    DoOtherstuff();
    cout << "the result is " << f.get() << endl;
    return 0;
}
```



4 –threads synchronization (6/6)

Use case 2: one-off interaction – future & promise

Hands - on exercise

Thank you !!!