

# Threads

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## Thread definition

Thread: set of operations executed sequentially

Traditionally, all operations in a program are executed in one single thread, but:

- The optimization of the processor capabilities can require the execution of more threads at one time.
- Two possible ways of executing more threads:
  - the threads are executed on the same processor,
  - the threads actually share the time.
- Multi-core processors and multi-processor computers allow the actual execution of more operations at the same time.

## Threads in C++

### C++11 only

The simplest instruction to execute a function in a separate thread is the instantiation of a `std::thread` object.  
To use it an `#include <thread>` is required.

```
#include <thread>
void f(...);
...
std::thread t(f, ...); // start a thread
...
t.join(); // wait for thread completion
... // if not yet finished
```

In the compilation with `gcc`  
the optional argument `-pthread` must be given.

## Thread arguments

Several objects can be used to start a thread:

- a global function,
- a “lambda” function, i.e. a function coded inside the instruction referring to it (in this case the thread creation),
- a functor, i.e. the instance of a class with the `()` operator.

### Function arguments

The arguments required by the function (or functor) are to be listed after the function (or functor) name in the thread instantiation.

## Access to data

More than one thread can access to the same variable or object, at the same time or at different times.

- The compiler can be not aware that a variable is modified by another thread, and produce wrong code in optimization attempt: `volatile` keyword prevents this.
- A resource can be accessible by one thread only at a time, multiple access can be prevented by mean of locks.

```
volatile int i; // "i" is accessed by
                // other threads

int j=100;
while(j-->0) {
    i=10; // "i" must be set at 10 at each
    ...  // iteration, even if not changed
}
```

## Data race

When more than one thread accesses one variable  
a “data race” occurs.

```
...  
i=12;  
j=25;  
int k=i+j; // "k" may differ from 37
```

## Locks

A “mutually exclusive lock” is an object the control of which can be taken by at most one thread at a time.

```
std::mutex m;  
...  
m.lock();  
...// this code can be executed by  
...// only one thread at a time  
m.unlock();
```

## Threads returning a value

- A thread producing a result can put it in a `std::promise` object.
- The result can be retrieved through an associated `std::future` object.
- The progress status can be inspected.
- When the `std::future` object is queried the execution wait for the completion of the thread setting it.

## Status inspection and result retrieve

```
#include <future>
void func(..., std::promise<int> i) {
    ...
    i.set(...);
}
...
std::promise<int> pi;
std::future <int> fi=pi.get_future();
std::thread t(func, ..., std::move(pi));
...
while(fi.wait_for(std::chrono::seconds(1)))
    cout<<"waiting..."<<endl;
int i=fi.get();
```

## Direct `std::future` retrieval

An explicit `std::promise` set can be avoided using a `std::packaged_task` object.

```
#include <future>
int func(...) {
    ...
    return ...;
}

...
std::packaged_task<int (...)> pt(func);
std::future<int> fi=pt.get_future();
std::thread t(std::move(pt), ...);
...
int i=fi.get();
```

## Single instruction start

The thread can be started and the associated `future` retrieved with a single call to `std::async`.

```
#include <future>
int func(...) {
    ...
    return ...;
}
...
std::future<int> fi=
    std::async(std::launch::async, func, ...);
...
int i=fi.get();
```