UNIVERSITÀ DEGLI STUDI DI PALERMO

SISTEMI OPERATIVI

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UNIVERSITÀ DEGLI STUDI DI PALERMO

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Thread programming

Threads Concepts

- Threads, like processes, allows a program to do more than one thing at a time
- As with processes, threads appear to run concurrently; the Linux kernel schedules them asynchronously, interrupting each thread to give others a chance to execute
- Conceptually, a thread exists within a process
- When you invoke a program, Linux creates a new process containing a single thread, which runs the program sequentially
- All threads run the same program in the same process, but each thread may be executing a different part of the program at any given time.

Process VS Thread

- Using fork, the child process is initially running its parent's program, with its parent's virtual memory, file descriptors, and so on copied.
  - The child process can modify its memory without affecting its parent, and vice versa.

- **The creating and the created thread share the same memory space, file descriptors, and other system resources as the original**.
  - If one thread changes the value of a variable, the other thread subsequently will see the modified value.
  - If one thread closes a file descriptor, other threads may not read from or write to that file descriptor.
  - …

P-threads and Linux

- GNU/Linux implements the POSIX standard thread API (known as pthreads – p(osix)threads)
- All thread functions and data types are declared in the header file **<pthread.h>**
- The pthread functions are not included in the standard C library, instead, they are in **libpthread**
- You should add **-lpthread** to the command line when you link your program

Thread creation

- Each thread in a process is identified by a *thread ID*.
- In C/C++ the type **pthread_t** is used to refer to thread IDs
- Upon creation, each thread executes a *thread function* containing the code that the thread should run
- When the *thread function* returns, the thread exits
- On GNU/Linux, thread functions take a single generic pointer `void*` parameter called *thread argument*, and have a `void*` return type
- Programs use:
  - *thread argument* to pass data to a new thread
  - the *return value* to pass data from an exiting thread back to its creator

Thread creation

```
#include <pthread.h>

int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine) (void *),
                   void *arg);
```

Thread creation

```
#include <pthread.h>

int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine) (void *),
                   void *arg);
```

A pointer to a pthread_t variable, in which the ID of the new thread is stored

Thread creation

```
#include <pthread.h>

int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine) (void *),
                   void *arg);
```

A pointer to a thread attribute object that controls details of how the thread interacts with the rest of the program (NULL = default attributes)

Thread creation

```
#include <pthread.h>

int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine) (void *),
                   void *arg);
```

A pointer to the thread function

Thread creation

```
#include <pthread.h>

int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine) (void *),
                   void *arg);
```

The argument passed to the thread function when the thread begins executing

Thread creation

```
#include <pthread.h>

int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine) (void *),
                   void *arg);
```

- A call to `pthread_create` returns immediately, and the original thread continues executing the instructions following the call.
- Meanwhile, the new thread begins executing the thread function.
- Linux schedules both threads asynchronously, and your program must not rely on the relative order in which instructions are executed in the two threads.

thread-create.c

```c
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>

/* Prints -'s to stderr.  The parameter is unused.  Does not return.  */
void* print_X (void* unused) {
  while (1) {
    printf("-\n");
    fflush(stdout); // stdout stream is buffered, so we need
                    // to force it for showing its content

    sleep(1);       // sleep in seconds
  }
  return NULL;
}

/* The main program.  */
int main () {
  pthread_t thread_id;
  // thread id, NULL (default attributes), thrd function, args della thrd function
  pthread_create (&thread_id, NULL, &print_X, NULL);

  /* Print o's continuously */
  while (1) {
    printf("o\n");
    fflush(stdout);
    sleep(1);
  }
  return 0;
}
```

gcc -o thread-create thread-create.c -lpthread

ubuntu1804 [Running]

Attività Terminale ven 16:32

Apri thread-create.c ~/Scrivania/thread Salva

```c
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>

/* Prints -'s to stderr.  The parameter is unused.  Does not return.  */
void* print_X (void* unused) {
  while (1) {
    printf("-\n");
    fflush(stdout); // stdout stream is buffered, so we need
                    // to force it for showing its content

    sleep(1);       // sleep in seconds
  }
  return NULL;
}

/* The main program.  */
int main () {

  pthread_t thread_id;

  // thread id - NULL (default attributes) - th funct
  pthread_create(&thread_id, NULL, &print_X, NULL);

  /* Print o's continuously */
  while (1) {
    printf("o\n");
    fflush(stdout);
    sleep(1);
  }
  return 0;

}
```

marco@marco-VirtualBox: ~/Scrivania/thread

File Modifica Visualizza Cerca Terminale Aiuto

```
marco@marco-VirtualBox:~/Scrivania/thread$ gcc -o thread-create thread-create.c
 -lpthread
marco@marco-VirtualBox:~/Scrivania/thread$ ./thread-create
o
-
o
-
o
-
o
-
o
-
o
-
o
-
o
-
```

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gcc -o thread-create thread-create.c -lpthread

ubuntu1804 [Running]

Attività Terminale ven 16:50

Apri thread-create.c ~/Scrivania/thread Salva

```c
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>

/* Prints -'s to stderr.  The parameter is unused.  Does not return.  */
void* print_X (void* unused) {
  while (1) {
    printf("-\n");
    fflush(stdout); // stdout stream is buffered, so we need
                    // to force it for showing its content

    sleep(2);       // sleep in seconds
  }
  return NULL;
}

/* The main program.  */
int main () {

  pthread_t thread_id;

  // thread id - NULL (default attributes) - th funct
  pthread_create(&thread_id, NULL, &print_X, NULL);

  /* Print o's continuously */
  while (1) {
    printf("o\n");
    fflush(stdout);
    sleep(1);
  }
  return 0;

}
```

marco@marco-VirtualBox: ~/Scrivania/thread

File Modifica Visualizza Cerca Terminale Aiuto

```
marco@marco-VirtualBox:~/Scrivania/thread$ gcc -o thread-create thread-create.c
 -lpthread
marco@marco-VirtualBox:~/Scrivania/thread$ ./thread-create
o
-
o
o
-
o
o
-
o
-
o
o
o
-
o
```

Left ⌘

See running threads

```
ps -e -o pid,cmd
```

```
marco@marco-VirtualBox: ~
File  Modifica  Visualizza  Cerca  Terminale  Aiuto
 3020 [jfsSync]
 3466 /usr/lib/gvfs/gvfsd-network --spawner :1.13 /org/gtk/gvfs/exec_spaw/1
 3488 /usr/lib/gvfs/gvfsd-smb-browse --spawner :1.13 /org/gtk/gvfs/exec_spaw/6
 3501 /usr/lib/gvfs/gvfsd-dnssd --spawner :1.13 /org/gtk/gvfs/exec_spaw/7
 3909 [kworker/0:2]
 7253 /usr/lib/gnome-terminal/gnome-terminal-server
 7263 bash
 9692 [kworker/u2:1]
 9968 [kworker/u2:0]
10017 /sbin/dhclient -d -q -sf /usr
10171 ./thread-create
10184 bash
10268 [kworker/u2:4]
10269 /usr/sbin/cupsd -l
```

```
top -H -p pid
```

```
marco@marco-VirtualBox: ~
File  Modifica  Visualizza  Cerca  Terminale  Aiuto
top - 11:20:30 up  4:42,  1 user,  load average: 0,01, 0,03, 0,02
Threads:   2 total,   0 running,   2 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0,0 us,  0,0 sy,  0,0 ni,100,0 id,  0,0 wa,  0,0 hi,  0,0 si,  0,0 st
KiB Mem :  1009088 total,    76544 free,   573696 used,   358848 buff/cache
KiB Swap:   483800 total,    28724 free,   455076 used.   213856 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S %CPU %MEM     TIME+ COMMAND
10171 marco     20   0   14888    936    856 S  0,0  0,1   0:00.03 thread-crea+
10172 marco     20   0   14888    936    856 S  0,0  0,1   0:00.01 thread-crea+
```

```
marco@marco-VirtualBox: ~
File  Modifica  Visualizza  Cerca  Terminale  Aiu
marco@marco-VirtualBox:~$ ps -T -p 101
  PID  SPID TTY          TIME CMD
10171 10171 pts/0    00:00:00 thread-c
10171 10172 pts/0    00:00:00 thread-c
marco@marco-VirtualBox:~$
```

2 thread, di cui uno è il main

```
ps -T -p pid
```

Passing Data to Threads

```
int pthread_create(pthread_t *thread,
                   const pthread_attr_t *attr,
                   void *(*start_routine) (void *),
                   void *arg);
```

- Because the type of the argument is `void*`, this element is used to pass a pointer to some structure or array of data
- One common technique is to define a structure for each thread function, which contains the “parameters” that the thread function expects

thread-create2.c

```c
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>

struct print_params {
  char character;
  int times;
};

int main () {
  pthread_t thread1_id;
  pthread_t thread2_id;

  struct print_params thread1_args;
  struct print_params thread2_args;

  thread1_args.character = 'X';
  thread1_args.times = 20;

  thread2_args.character = 'o';
  thread2_args.times = 30;

  pthread_create (&thread1_id, NULL, &print_char, &thread1_args);
  pthread_create (&thread2_id, NULL, &print_char, &thread2_args);




  return 0;
}
```

```c
void* print_char (void* parameters)
{
  struct print_params* pp = (struct
print_params*) parameters;

  for (int i=0; i<= pp->times; i++) {
    printf("%c",pp->character);
    fflush(stdout);
    sleep(1);
  }
  return NULL;
}
```

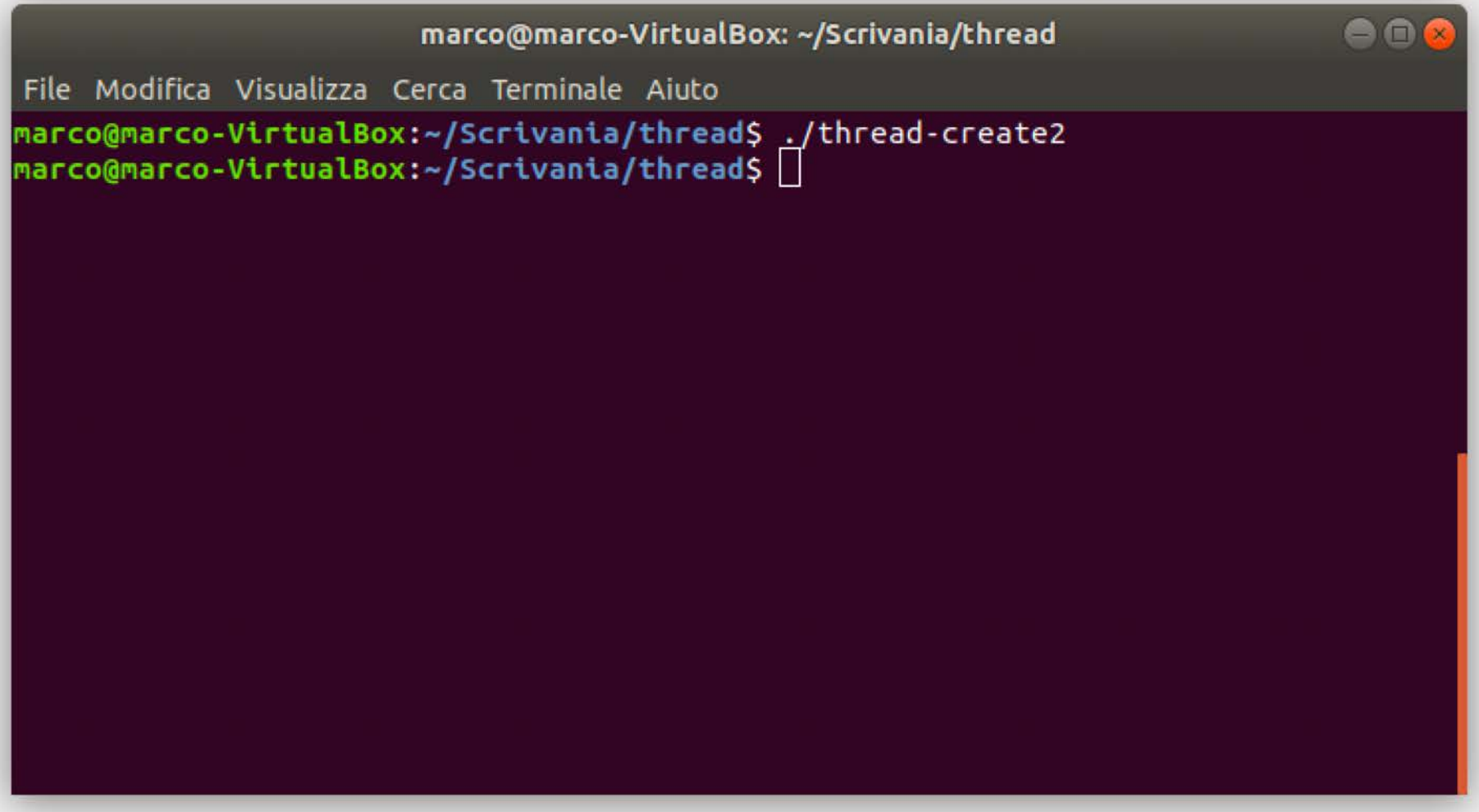
thread-create2.c

```c
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>

struct print_params {
  char character;
  int times;
};

int main () {
  pthread_t thread1_id;
  pthread_t thread2_id;

  struct print_params thread1_args;
  struct print_params thread2_args;

  thread1_args.character = 'X';
  thread1_args.times = 20;

  thread2_args.character = 'o';
  thread2_args.times = 30;

  pthread_create (&thread1_id, NULL, &print_char, &thread1_args);
  pthread_create (&thread2_id, NULL, &print_char, &thread2_args);



  return 0;
}
```

```c
void* print_char (void* parameters)
{
  struct print_params* pp = (struct
print_params*) parameters;

  for (int i=0; i<= pp->times; i++) {
    printf("%c",pp->character);
    fflush(stdout);
    sleep(1);
  }
  return NULL;
}
```

Cosa succede ai due thread se nel frattempo
il main viene schedulato, eseguito e terminato?

thread-create2.c



Joining Threads

- Prevent Linux from scheduling threads in such a way that main finishes executing before the other threads are done

```
#include <pthread.h>
int pthread_join(pthread_t thread, void **value_ptr);
```

the thread ID of the thread to wait for

a pointer to a void* variable that will receive the finished thread's return value

thread-create2.c

```c
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>

struct print_params {
  char character;
  int times;
};

int main () {
  pthread_t thread1_id;
  pthread_t thread2_id;

  struct print_params thread1_args;
  struct print_params thread2_args;

  thread1_args.character = 'X';
  thread1_args.times = 20;

  thread2_args.character = 'o';
  thread2_args.times = 30;

  pthread_create (&thread1_id, NULL, &print_char, &thread1_args);
  pthread_create (&thread2_id, NULL, &print_char, &thread2_args);

  pthread_join(thread1_id,NULL);
  pthread_join(thread2_id,NULL);

  return 0;
}
```

```c
void* print_char (void* parameters)
{
  struct print_params* pp = (struct
print_params*) parameters;

  for (int i=0; i<= pp->times; i++) {
    printf("%c",pp->character);
    fflush(stdout);
    sleep(1);
  }
  return NULL;
}
```

Il secondo argomento è un puntatore al valore di ritorno del thread, se non esiste si usa NULL

ubuntu1804 [Running]

Attività Terminale ven 17:06

Apri thread-create2.c ~/Scrivania/thread Salva

```c
struct print_params {
  char character;
  int times;
};

void* print_char (void* parameters) {
  struct print_params* pp = (struct print_params*) parameters;

  for (int i=0; i<= pp->times; i++) {
    printf("%c",pp->character);
    fflush(stdout);
    sleep(1);
  }
  return NULL;
}

int main () {
  pthread_t thread1_id;
  pthread_t thread2_id;

  struct print_params thread1_args;
  struct print_params thread2_args;

  thread1_args.character = 'X';
  thread1_args.times = 20;
  thread2_args.character = 'o';
  thread2_args.times = 30;

  pthread_create (&thread1_id, NULL, &print_char,&thr
  pthread_create (&thread2_id, NULL, &print_char,&thr

  pthread_join(thread1_id,NULL);
  pthread_join(thread2_id,NULL);

  return 0;
}
```

marco@marco-VirtualBox: ~/Scrivania/thread

File Modifica Visualizza Cerca Terminale Aiuto

```
marco@marco-VirtualBox:~/Scrivania/thread$ ./thread-create2
oXoXoXoXoXoXoXoXoXoXoXoXoXoXoXoXoXoXoXoXXooXoooooooo
```

Left ⌘

See running threads

```
marco@marco-VirtualBox: ~
File  Modifica  Visualizza  Cerca  Terminale  Aiuto
top - 11:26:25 up  4:48,  1 user,  load average: 0,03, 0,01, 0,00
Threads:   3 total,   0 running,   3 sleeping,   0 stopped,   0 zombie
%Cpu(s):  1,3 us,  0,0 sy,  0,0 ni, 98,7 id,  0,0 wa,  0,0 hi,  0,0 si,  0,0 st
KiB Mem :  1009088 total,    73788 free,   575524 used,   359776 buff/cache
KiB Swap:   483800 total,    28724 free,   455076 used.   211960 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S %CPU %MEM     TIME+ COMMAND
10463 marco     20   0   88620    812    732 S  0,0  0,1   0:00.00 thread-crea+
10464 marco     20   0   88620    812    732 S  0,0  0,1   0:00.00 thread-crea+
10465 marco     20   0   88620    812    732 S  0,0  0,1   0:00.00 thread-crea+
```

3 thread, di cui uno è il main

Thread Return Values

- If the second argument you pass to `pthread_join` is non-null, the thread's return value will be placed in the location pointed to by that argument

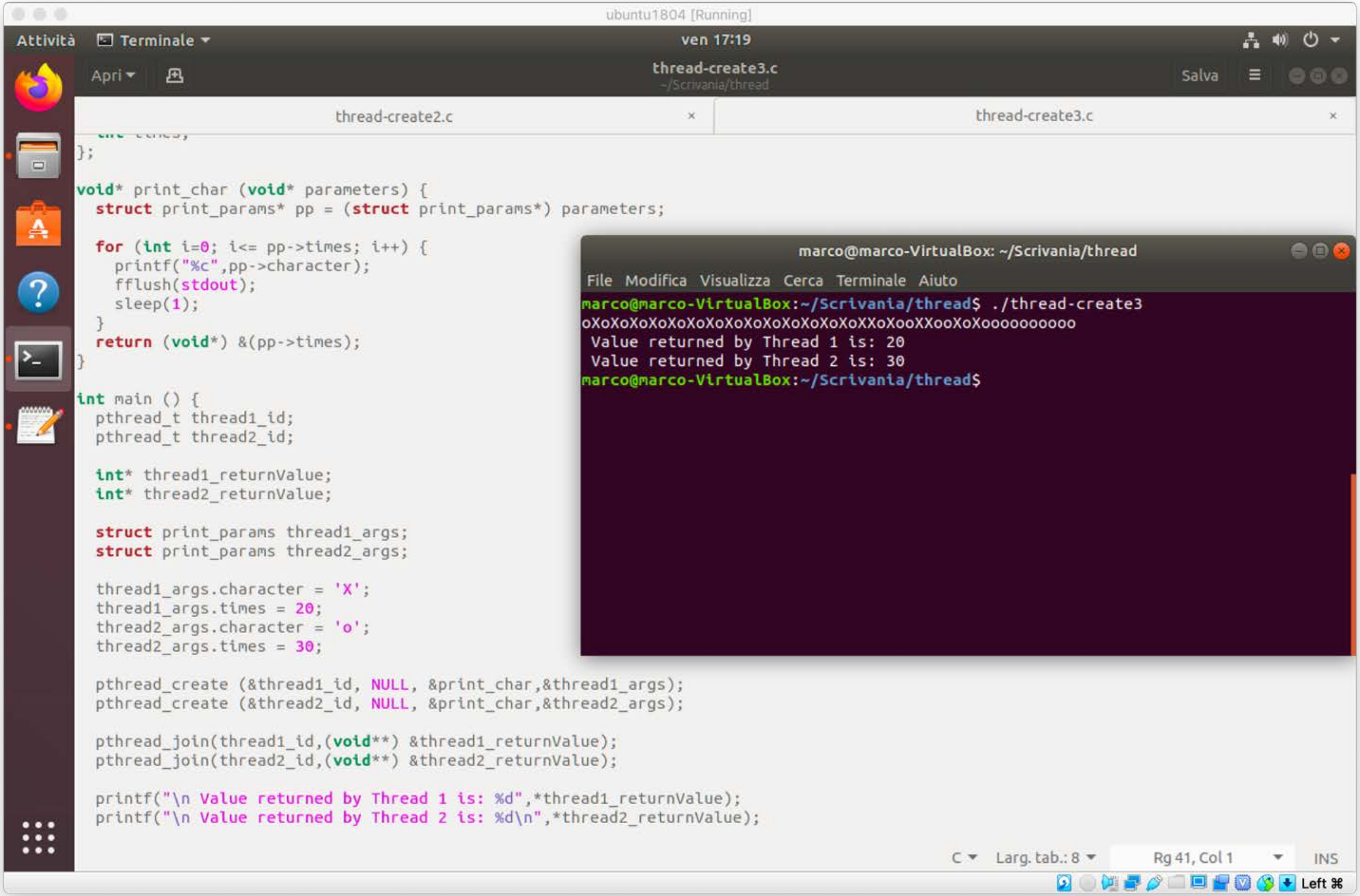
- The thread return value, like the thread argument, is of type void*

- If you want to pass back a single int or other small number, you can do this by *casting the value to void* and then casting back* to the appropriate type after calling `pthread_join`

thread-create3.c

```c
#include <pthread.h>
#include <stdio.h>
#include <unistd.h>

struct print_params {
  char character;
  int times;
};

int main () {
  pthread_t thread1_id;
  pthread_t thread2_id;

  int* thread1_returnValue;
  int* thread2_returnValue;

  struct print_params thread1_args;
  struct print_params thread2_args;

  thread1_args.character = 'X';
  thread1_args.times = 20;
  thread2_args.character = 'o';
  thread2_args.times = 30;

  pthread_create (&thread1_id, NULL, &print_char, &thread1_args);
  pthread_create (&thread2_id, NULL, &print_char, &thread2_args);

  pthread_join(thread1_id, (void**) &thread1_returnValue);
  pthread_join(thread2_id, (void**) &thread2_returnValue);

  printf("\n Value returned by Thread 1 is: %d",*thread1_returnValue);
  printf("\n Value returned by Thread 2 is: %d\n",*thread2_returnValue);
  return 0;
}
```

```c
void* print_char (void* parameters)
{
  struct print_params* pp = (struct
print_params*) parameters;

  for (int i=0; i<= pp->times; i++) {
    printf("%c",pp->character);
    fflush(stdout);
    sleep(1);
  }
  return (void*) &(pp->times);
}
```



```c
};

void* print_char (void* parameters) {
  struct print_params* pp = (struct print_params*) parameters;

  for (int i=0; i<= pp->times; i++) {
    printf("%c",pp->character);
    fflush(stdout);
    sleep(1);
  }
  return (void*) &(pp->times);
}

int main () {
  pthread_t thread1_id;
  pthread_t thread2_id;

  int* thread1_returnValue;
  int* thread2_returnValue;

  struct print_params thread1_args;
  struct print_params thread2_args;

  thread1_args.character = 'X';
  thread1_args.times = 20;
  thread2_args.character = 'o';
  thread2_args.times = 30;

  pthread_create (&thread1_id, NULL, &print_char,&thread1_args);
  pthread_create (&thread2_id, NULL, &print_char,&thread2_args);

  pthread_join(thread1_id,(void**) &thread1_returnValue);
  pthread_join(thread2_id,(void**) &thread2_returnValue);

  printf("\n Value returned by Thread 1 is: %d",*thread1_returnValue);
  printf("\n Value returned by Thread 2 is: %d\n",*thread2_returnValue);
```

```
marco@marco-VirtualBox:~/Scrivania/thread$ ./thread-create3
oXoXoXoXoXoXoXoXoXoXoXoXoXoXoXXoXooXXooXoXoooooooooo
 Value returned by Thread 1 is: 20
 Value returned by Thread 2 is: 30
marco@marco-VirtualBox:~/Scrivania/thread$
```

4.11 Java Multithreading Case Study, Part I: Introduction to Java Threads

- Java allows the application programmer to create threads that can port to many computing platforms
- Threads
  - Created by class `Thread`
  - Execute code specified in a `Runnable` object's `run` method
- Java supports operations such as naming, starting and joining threads

Thread creation in Java (`ThreadTester.java`)

```
public class ThreadTester {

        public static void main(String [] args) {

                //creiamo 3 thread
                PrintThread thread1 = new PrintThread("thread 1");
                PrintThread thread2 = new PrintThread("thread 2");
                PrintThread thread3 = new PrintThread("thread 3");

                System.err.println("Starting threads");

                // start, place the thread in ready state
                thread1.start();
                thread2.start();
                thread3.start();

                System.err.println("Threads started, main ends\n");

        }

}
```

Thread creation in Java (`ThreadTester.java`)

```
class PrintThread extends Thread {

        private int sleepTime;

        // costruttore
        public PrintThread(String name) {
                super(name);
                // sleep 0-5 secondi
                sleepTime = (int) (Math.random() * 5001);
        }

        public void run() {
                try {
                        System.err.println(getName() + " going to
                        sleep for " +  sleepTime + "milliseconds");
                        Thread.sleep(sleepTime);
                } catch (InterruptedException e) {
                        e.printStackTrace();
                }
                System.err.println(getName() + " done sleeping");
        }
}
```

ubuntu1804 [Running]

Attività Terminale ven 17:26

Apri ThreadTester.java ~/Scrivania/thread Salva

```java
        public static void main(String [] args) {

                //creiamo 3 thread
                PrintThread thread1 = new PrintThread("thread 1");
                PrintThread thread2 = new PrintThread("thread 2");
                PrintThread thread3 = new PrintThread("thread 3");

                System.err.println("Starting threads"

                // start, place the thread in ready s
                thread1.start();
                thread2.start();
                thread3.start();

                System.err.println("Threads started,
        }
}

class PrintThread extends Thread {
        private int sleepTime;

        // costruttore
        public PrintThread(String name) {
                super(name);
                // sleep 0-5 secondi
                sleepTime = (int) (Math.random() * 50
        }

        public void run() {
                try {
                        System.err.println(getName() + " going to sleep for " + sleepTime + " milliseconds");
                        Thread.sleep(sleepTime);
                } catch (InterruptedException e) {
                        e.printStackTrace();
                }

                System.err.println(getName() + " done sleeping");
        }
}
```

Java Larg. tab.: 8 Rg 33, Col 95 INS

marco@marco-VirtualBox: ~/Scrivania/thread

File Modifica Visualizza Cerca Terminale Aiuto

```
marco@marco-VirtualBox:~/Scrivania/thread$ javac ThreadTester.java
marco@marco-VirtualBox:~/Scrivania/thread$ java ThreadTester
Starting threads
Threads started, main ends

thread 3 going to sleep for 1158 milliseconds
thread 1 going to sleep for 3296 milliseconds
thread 2 going to sleep for 4124 milliseconds
thread 3 done sleeping
thread 1 done sleeping
thread 2 done sleeping
marco@marco-VirtualBox:~/Scrivania/thread$
```

Left ⌘

marco@marco-VirtualBox: ~

File Modifica Visualizza Cerca Terminale Aiuto

```
marco@marco-VirtualBox:~$ ps -T -p 11123
  PID  SPID TTY          TIME CMD
11123 11123 pts/0    00:00:00 java
11123 11124 pts/0    00:00:00 java
11123 11125 pts/0    00:00:00 VM Thread
11123 11126 pts/0    00:00:00 Reference Handl
11123 11127 pts/0    00:00:00 Finalizer
11123 11128 pts/0    00:00:00 Signal Dispatch
11123 11129 pts/0    00:00:00 C2 CompilerThre
11123 11130 pts/0    00:00:00 C1 CompilerThre
11123 11131 pts/0    00:00:00 Sweeper thread
11123 11132 pts/0    00:00:00 Service Thread
11123 11133 pts/0    00:00:00 Common-Cleaner
11123 11134 pts/0    00:00:00 VM Periodic Tas
11123 11135 pts/0    00:00:00 thread 1
11123 11136 pts/0    00:00:00 thread 2
11123 11137 pts/0    00:00:00 thread 3
marco@marco-VirtualBox:~$
```

marco@marco-VirtualBox: ~

File Modifica Visualizza Cerca Terminale Aiuto

```
top - 14:55:06 up  8:16,  1 user,  load average: 0,07, 0,08, 0,03
Threads:  15 total,   1 running,  14 sleeping,   0 stopped,   0 zombie
%Cpu(s):  0,0 us,  0,0 sy,  0,0 ni, 99,7 id,  0,3 wa,  0,0 hi,  0,0 si,  0,0 st
KiB Mem :  1009088 total,    97476 free,   620296 used,   291316 buff/cache
KiB Swap:   483800 total,    48604 free,   435196 used.   184644 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S %CPU %MEM     TIME+ COMMAND
11162 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 java
11163 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.05 java
11164 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 VM Thread
11165 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 Reference H+
11166 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 Finalizer
11167 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 Signal Disp+
11168 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.02 C2 Compiler+
11169 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.03 C1 Compiler+
11170 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 Sweeper thr+
11171 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 Service Thr+
11172 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.00 Common-Clea+
11173 marco     20   0 2354356  32996  18032 R  0,0  3,3   0:00.00 VM Periodic+
11174 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.01 thread 1
11175 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.01 thread 2
11176 marco     20   0 2354356  32996  18032 S  0,0  3,3   0:00.01 thread 3
```

jstack <pid>

Print Java stack traces of Java threads for a specified Java process

```
`Full thread dump Java HotSpot(TM) 64-Bit Server VM (10.0.1+10 mixed mode):

Threads class SMR info:
_java_thread_list=0x00007f1370007660, length=13, elements={
0x00007f13a008a800, 0x00007f13a008c800, 0x00007f13a00a0000, 0x00007f13a00a2000,
0x00007f13a00a4000, 0x00007f13a00a6000, 0x00007f13a0127000, 0x00007f13a00c7000,
0x00007f13a0142800, 0x00007f13a0144000, 0x00007f13a0145800, 0x00007f13a0011000,
0x00007f1370006000
}

"Reference Handler" #2 daemon prio=10 os_prio=0 tid=0x00007f13a008a800 nid=0x2c7d waiting on condition  [0x00007f13a4759000]
   java.lang.Thread.State: RUNNABLE
                        at java.lang.ref.Reference.waitForReferencePendingList(java.base@10.0.1/Native Method)
                        at java.lang.ref.Reference.processPendingReferences(java.base@10.0.1/Reference.java:174)
                        at java.lang.ref.Reference.access$000(java.base@10.0.1/Reference.java:44)
                        at java.lang.ref.Reference$ReferenceHandler.run(java.base@10.0.1/Reference.java:138)

"Finalizer" #3 daemon prio=8 os_prio=0 tid=0x00007f13a008c800 nid=0x2c7e in Object.wait()  [0x00007f13a4658000]
   java.lang.Thread.State: WAITING (on object monitor)
                        at java.lang.Object.wait(java.base@10.0.1/Native Method)
                        - waiting on <0x00000000f0809480> (a java.lang.ref.ReferenceQueue$Lock)
                        at java.lang.ref.ReferenceQueue.remove(java.base@10.0.1/ReferenceQueue.java:151)
                        - waiting to re-lock in wait() <0x00000000f0809480> (a java.lang.ref.ReferenceQueue$Lock)
                        at java.lang.ref.ReferenceQueue.remove(java.base@10.0.1/ReferenceQueue.java:172)
                        at java.lang.ref.Finalizer$FinalizerThread.run(java.base@10.0.1/Finalizer.java:216)

"Signal Dispatcher" #4 daemon prio=9 os_prio=0 tid=0x00007f13a00a0000 nid=0x2c7f runnable  [0x0000000000000000]
   java.lang.Thread.State: RUNNABLE

"C2 CompilerThread0" #5 daemon prio=9 os_prio=0 tid=0x00007f13a00a2000 nid=0x2c80 waiting on condition  [0x0000000000000000]
   java.lang.Thread.State: RUNNABLE
   No compile task

"C1 CompilerThread1" #6 daemon prio=9 os_prio=0 tid=0x00007f13a00a4000 nid=0x2c81 waiting on condition  [0x0000000000000000]
   java.lang.Thread.State: RUNNABLE
   No compile task

"Sweeper thread" #7 daemon prio=9 os_prio=0 tid=0x00007f13a00a6000 nid=0x2c82 runnable  [0x0000000000000000]
   java.lang.Thread.State: RUNNABLE

"Service Thread" #8 daemon prio=9 os_prio=0 tid=0x00007f13a0127000 nid=0x2c83 runnable  [0x0000000000000000]
   java.lang.Thread.State: RUNNABLE

"Common-Cleaner" #9 daemon prio=8 os_prio=0 tid=0x00007f13a00c7000 nid=0x2c84 in Object.wait()  [0x00007f138526a000]
   java.lang.Thread.State: TIMED_WAITING (on object monitor)
                        at java.lang.Object.wait(java.base@10.0.1/Native Method)
                        - waiting on <0x00000000f08d81d8> (a java.lang.ref.ReferenceQueue$Lock)
                        at java.lang.ref.ReferenceQueue.remove(java.base@10.0.1/ReferenceQueue.java:151)
                        - waiting to re-lock in wait() <0x00000000f08d81d8> (a java.lang.ref.ReferenceQueue$Lock)
                        at jdk.internal.ref.CleanerImpl.run(java.base@10.0.1/CleanerImpl.java:148)
                        at java.lang.Thread.run(java.base@10.0.1/Thread.java:844)
                        at jdk.internal.misc.InnocuousThread.run(java.base@10.0.1/InnocuousThread.java:134)

"thread 1" #10 prio=5 os_prio=0 tid=0x00007f13a0142800 nid=0x2c86 waiting on condition  [0x00007f1384c3f000]
   java.lang.Thread.State: TIMED_WAITING (sleeping)
                        at java.lang.Thread.sleep(java.base@10.0.1/Native Method)
                        at PrintThread.run(ThreadTester.java:34)

"thread 2" #11 prio=5 os_prio=0 tid=0x00007f13a0144000 nid=0x2c87 waiting on condition  [0x00007f1384b3e000]
   java.lang.Thread.State: TIMED_WAITING (sleeping)
                        at java.lang.Thread.sleep(java.base@10.0.1/Native Method)
                        at PrintThread.run(ThreadTester.java:34)

"thread 3" #12 prio=5 os_prio=0 tid=0x00007f13a0145800 nid=0x2c88 waiting on condition  [0x00007f1384a3d000]
   java.lang.Thread.State: TIMED_WAITING (sleeping)
                        at java.lang.Thread.sleep(java.base@10.0.1/Native Method)
                        at PrintThread.run(ThreadTester.java:34)

"DestroyJavaVM" #13 prio=5 os_prio=0 tid=0x00007f13a0011000 nid=0x2c7b waiting on condition  [0x0000000000000000]
   java.lang.Thread.State: RUNNABLE

"Attach Listener" #14 daemon prio=9 os_prio=0 tid=0x00007f1370006000 nid=0x2c99 runnable  [0x0000000000000000]
   java.lang.Thread.State: RUNNABLE

"VM Thread" os_prio=0 tid=0x00007f13a0080800 nid=0x2c7c runnable

"VM Periodic Task Thread" os_prio=0 tid=0x00007f13a00c8800 nid=0x2c85 waiting on condition

JNI global references: 3
```

Thread joining in Java (`Thread4Max.java`)

```
public class Thread4Max extends Thread {

  private int[] values;
  private int a,b;
  private int max;



  public static void main(String[] args) throws InterruptedException
  {

     int[] arr = new int[100];

     for (int i=0; i<arr.length; i++) {
          arr[i] = (int) (Math.random() * 1001); //oppure = i;
     }

     int max = getMax(arr);
     System.out.println("Massimo = " + max);
  }
```

Thread joining in Java (`Thread4Max.java`)

```
public static int getMax(int[] values) throws InterruptedException {
          int len = values.length;
          int max;

          // creiamo 2 thread
          Thread4Max thread1 = new Thread4Max(values, 0, len/2);
          System.out.println("Il thread 1 calcola il massimo dei valori in
                              posizione da 1 a " + len/2 );

          Thread4Max thread2 = new Thread4Max(values, len/2, len);
          System.out.println("Il thread 2 calcola il massimo dei valori in
                              posizione da " + len/2 + " a " + len );

          thread1.start();
          thread2.start();

}
```

Thread joining in Java (`Thread4Max.java`)

```
public Thread4Max(int[] values, int a, int b ) {
      this.a = a;
      this.b = b;
      this.values = values;
}

public void run() {
      max = values[a];

      for(int i=a+1; i<b; i++) {
        if(values[i]>max) {
          max = values[i];
        }
      }
}
```

Thread joining in Java (`Thread4Max.java`)

```
public static int getMax(int[] values) throws InterruptedException {
          int len = values.length;
          int max;

          // creiamo 2 thread
          Thread4Max thread1 = new Thread4Max(values, 0, len/2);
          System.out.println("Il thread 1 calcola il massimo dei valori in
                              posizione da 1 a " + len/2 );

          Thread4Max thread2 = new Thread4Max(values, len/2, len);
          System.out.println("Il thread 2 calcola il massimo dei valori in
                              posizione da " + len/2 + " a " + len );

          thread1.start();
          thread2.start();

          // aspettiamo il completamento e calcoliamo il max
          thread1.join();
          thread2.join();

          System.out.println("Massimo thread1 = " + thread1.max);
          System.out.println("Massimo thread2 = " + thread2.max);

          if(thread1.max > thread2.max) {
            max = thread1.max;
          } else {
            max = thread2.max;
          }
          return max;
}
```

Thread joining in Java (`Thread4Max.java`)

```
marco@marco-VirtualBox: ~/Scrivania/thread
File  Modifica  Visualizza  Cerca  Terminale  Aiuto
marco@marco-VirtualBox:~/Scrivania/thread$ java Thread4Max
Il thread 1 calcola il massimo dei valori in posizione da 1 a 50
Il thread 2 calcola il massimo dei valori in posizione da 50 a 100
Massimo thread1 = 987
Massimo thread2 = 977
Massimo = 987
marco@marco-VirtualBox:~/Scrivania/thread$
```