Example: Launching Fifteen Threads

07/fifteen-threads.c

```c
#include <pthread.h>

const int num_threads = 15;

void *thread_start(void *ptr) {
  int id = *((int *)ptr);
  printf("Thread %d running...\n", id);
  return NULL;
}

int main(int argc, char *argv[]) {
  // Create threads:
  int i;
  pthread_t tid[num_threads];
  for (i = 0; i < num_threads; i++) {
    pthread_create(&tid[i], NULL,
                                thread_start, (void *)&i);
  }

  printf("Done!\n");
  return 0;
}
```

Creating Additional Threads in C

The pthread library is the POSIX thread library allowing you to create additional threads beyond the initial **main** thread.

Creating a new thread is a complex call with four arguments:

```c
int pthread_create(
  pthread_t *thread,               /* thread struct */
  const pthread_attr_t *attr,      /* usually NULL  */
  void *(*start_routine) (void *), /* start func    */
  void *arg                        /* thread start arg  */
);
```

The `start_routine` of `pthread_create` has a very interesting type signature:

```c
void *(*start_routine) (void *)
```

This signature is a **function pointer** ("functor") and is the syntax we can use to pass a pointer to a function. Therefore, the third argument into pthread_create must be a function with the following prototype:

```c
void *__________(void *ptr);
```

...you can use any name for the function name.

Q1: What is the expected output of the `fifteen-threads.c` program?

Q2: What actually happens?

Q3: What do we know about threads in C?

Five-State Thread Model

When the operating system has control over the CPU and needs to decide what program to run, it must maintain a model of all threads within the CPU.

We commonly refer to the "state" of a thread as part of the five-state model:

08/fifteen-join.c

```
13 int main(int argc, char *argv[]) {
14   // Create threads:
15   int i;
16   pthread_t tid[num_threads];
17   for (i = 0; i < num_threads; i++) {
18     int *val = malloc(sizeof(int));
19     *val = i;
20     pthread_create(&tid[i], NULL,
                                thread_start, (void *)val);
21   }
22
23   // Joining Threads
24   for (i = 0; i < num_threads; i++) {
25     pthread_join(tid[i], NULL);
26   }
27
28   printf("Done!\n");
29   return 0;
30 }
```

pthread_join – In the above program, we use **pthread_join**. This call will _____ from running the program further until the specified thread has **finished and returned**.

Q1: What happens in this program?

Q2: Does the order vary each time we run it? What is happening?

Q3: What can we say about the relationship between "Done" and "Thread %d running..." lines?

Counting with Threads

Here's a new program using multiple threads, which we will compile as the executable **count** (`gcc count.c -lpthread -o count`):

08/count.c

```
 5 int ct = 0;
 6
 7 void *thread_start(void *ptr) {
 8   int countTo = *((int *)ptr);
 9
10   int i;
11   for (i = 0; i < countTo; i++) {
12     ct = ct + 1;
13   }
14
15   return NULL;
16 }
17
18 int main(int argc, char *argv[]) {
 …   /* [...check argv size...] */
24
25   const int countTo = atoi(argv[1]);
 …   /* [...error checking...] */
28   const int thread_ct = atoi(argv[2]);
 …   /* [...error checking...] */
30
31   // Create threads:
32   int i;
33   pthread_t tid[thread_ct];
34   for (i = 0; i < thread_ct; i++) {
35     pthread_create(&tid[i], NULL,
          thread_start, (void *)&countTo);
36   }
37
38   // Join threads:
39   for (i = 0; i < thread_ct; i++) {
40     pthread_join(tid[i], NULL);
41   }
42
43   // Display result:
44   printf("Final Result: %d\n", ct);
45   return 0;
46 }
```

Q1: What do we expect when we run this program?

Q2: What is the output of running: `./count 100 2`

Q3: What is the output of running: `./count 100 16`

Q4: What is the output of running:: `./count 10000000 2`

Q5: What is the output of running:: `./count 10000000 16`

Q6: What is going on???