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Creating and removing pthreads

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There’s an old joke...

- *A programmer had a problem, and thought*
  “I know, I’ll solve it with threads!”
- *has Now problems. two programmer the*

- We have already seen similar issues using parallel processes
- They appear perhaps even more easily with threads, because there are no explicit messages in the code that synchronize it

Enabling pthreads

- Unlike MPI, it is not necessary to install any additional software in order to start using pthreads
  - The P stands for “POSIX”
  - “POSIX” stands for “Portable Operating System Interface” (...X?)
  - If your O/S supports them, you already have everything needed
  - If your O/S *doesn’t* support them, it must be a very exotic one
- Your compiler should come with a header file, so that

  #include <pthread.h>

  inserts prototypes for all the functions, and putting

  -pthread

  among the compiler flags handles correct linking

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Creating a function to use

- As we have spoken about, threads are closely related to function calls
  - They have their own call stack, but share everything else
- Spawning a thread basically amounts to writing

  “start this function call in the background, and return immediately”

  ...so we’re going to need a function to call.
- Thread-able functions have this type signature in C:

  void * my_function (void *argument);

  i.e. it accepts a **void *** argument, and returns a **void *** value

Into the void

- 'void' means different things in C, depending on where it appears
  - When it stands in for an argument list it means "exactly zero arguments", as in

    ```
    int make_random_number ( void );  // No input needed
    ```
  - When it stands in for a type, it means "no particular type", as in

    ```
    void just_do_something ( int x );   // No return value needed
    ```
- Pointers-to-void (void *) aren't "pointers to nothing"
  - They **are** pointers to something, but
  - They don't know *what type of value* they point at

Pointers with types

- Connecting a type to a pointer allows a C compiler to check that you're using it correctly
  - If we define

```
void do_something_useful ( int *x );
```

    and call

```
double pi = 3.141593;
do_something_useful ( &pi );
```

    we get a warning that there is probably some mistake

Pointers with types

- Connecting a type to a pointer also defines how to handle arithmetic and dereferencing

If we define

```
int16_t *ten_sixteen_bit_ints = malloc ( 10 * sizeof(int16_t) );
```

then

```
ten_sixteen_bit_ints[7]
```

and

```
*(ten_sixteen_bit_ints+7)
```

both mean *“addr. ‘ten_sixteen_bit_ints’ plus 7 times sizeof(int16_t)”* because the pointer is pointing at 16-bit ints

Pointers without types

- A (void *) is just a memory address that could point at anything
  - We can't do anything directly with it, because it doesn't say anything about how to interpret the data it points at
  - We can't add and subtract with it, because it doesn't say how big an address change "+1" should correspond to
  - We **can** turn any type of pointer into a (void *), just discard the type
  - We can also turn a (void *) into any other type of pointer, just add the desired type
- This basically removes all protections from C's type system
  - On the assumption that you know exactly what you're doing when you explicitly choose to disable them

Case in point:

```
% cat unsafe.c
#include <stdio.h>
#include <stdint.h>

int main () {
    double hello = 1.81630607015975e-310;
    printf ( "%s\n", (char *)(&hello) );
}
% make unsafe
cc -O2 -pipe  unsafe.c  -o unsafe
% ./unsafe
Hello!
%
```

– This program works because the bit pattern of that horrible floating point number coincides with the string "Hello!"
– It *"shouldn't"* work, because it reinterprets the address of a number as the address of some text, and numbers aren't text
– It ***won't*** work (the same way) on a CPU with a different internal floating point representation
– The C compiler just shuts up and generates code when we tell it to

Back to the threads

void * my_function (void *argument);

- This function takes an address to an un-checked thing as its argument
  - The body of this function will have to cast the argument into whatever type of thing it expects to receive
- It also returns an address to some un-checked thing
  - The caller of this function will have to cast the return value into whatever type of thing it expects to get back
- Unexpected events will occur if you pass it the wrong type of argument, or mis-interpret the answer
  - The compiler will be oblivious to what the mistake is

This is a recurring theme

- The whole design of pthreads is permeated by this idea of a *"gentleman's agreement"* between calling functions and called functions:
  - Callers have to ensure that the arguments are correct, threads have to trust that the caller will interpret the answer correctly
  - Threads can't actually prevent each other from entering a critical section, you have to program them so that they all respect the state of a locking mechanism everyone can see
  - Threads can't forcibly exclude each other from overwriting shared values, you have to program them so that they don't try to

Creating a thread
(finally!)

- When you have defined your

```
void * my_function ( void *arg );
```

it can be launched in a thread like this:

```
thread_t my_thread;
pthread_create ( &my_thread, NULL, &my_function, NULL );
```

Thread handle — Thread attributes — Pointer to function — (void *) to the argument

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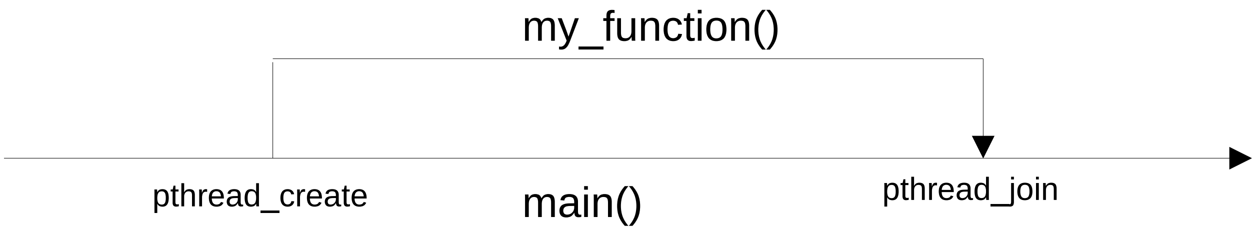
Waiting for a thread to finish

- When we need that thread to finish its work, we can wait for it like this:

```
pthread_join ( my_thread, NULL );
```

- Those were a lot of NULLs, we'll get back to them momentarily
- What we did so far was to make control flow split and merge over time:



(time goes from left to right)

Arguments and return values

(two of those NULLs)

- We can now try it out with passing arguments and obtaining return values
  - Today's example archive subdirectory '01_hello_world' contains a program 'arguments_and_return.c' which utilizes the in/out arguments of pthread_{create/join} to pass some values
  - It's a little redundant to return the result-pointer when there is only one value it could ever have, but we can imagine a function that chooses between several places to put the answer
  - It serves mostly as an illustration, anyway

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The last of the NULLs

- The second argument to pthread_create is a pointer to a struct that has the type `phtread_attr_t`
- Such structs can be created and deleted with pthread_attr_init and pthread_attr_destroy
- It lets you control O/S-dependent info about the thread
  - Maximal lifetime
  - Size of its stack
  - Scheduling priority
  - *etc.*
- The defaults we get by not using this will suffice

Now you've seen it

- The arguments/return thing is important for programs that aim to be modular
  - Pthreads were originally introduced for *concurrent* programs
  - *e.g.* programs that spawn lots of threads with separate tasks, and mostly wait around for something to do
- Most parallel HPC programs have a different purpose
  - We usually don't want more threads than we have CPU cores
  - All the threads tend to do the same thing
  - They tend to do it to large amounts of shared data, making it impractical/pointless to pass copies of every value in and out of function calls

HPC-style pthreads

- As with MPI programs, most of our needs are covered if we can
  - Work on some huge, global problem
  - Give each thread a unique index among the total number of threads
  - Calculate its part of the global problem from those two numbers
- A very common trick is to use the (void *) argument as an integer instead
  - We can store the total number of threads in a global variable
  - We don’t need the argument to represent a memory address, so we can just use the fact that a memory address is an integer

This is terrible software design

- I know, right?
- The variables don’t have descriptive names
  - The argument pointer isn’t a pointer, and it doesn’t point at any arguments
- The whole program state is global
  - That’s where the threads can access it directly
  - Individual blocks of local work-shares would double the total memory requirement, and require a lot of copying
- I didn’t invent this pattern, you will find that our book uses it as well

Hello, threads

- In the same example directory, there is also a program called ‘hello_pthreads.c’
- It works in pretty much the same way as our MPI hello world program, except that
  - The collective isn’t there from the start, the main function has to launch every co-worker
  - They don’t all last until the end of the program, threads disappear when they are joined on completion
  - Threads that don’t join before the program exits will just vanish without a trace

We have been here before

- We now have the tools to parallelize the same kind of tasks that we could handle with only

  MPI_{ Init, Finalize, Comm_rank, Comm_size }

  - *Embarrassingly parallel* problems don't need the threads to synchronize/communicate
  - If a sub-problem is only a function of a worker's index, it can be handled with just pthread_{ create, join }

- Next lecture, we will look at synchronization and communication, and solve a problem that requires it

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