# Why Threads Are A Bad Idea (for most purposes)

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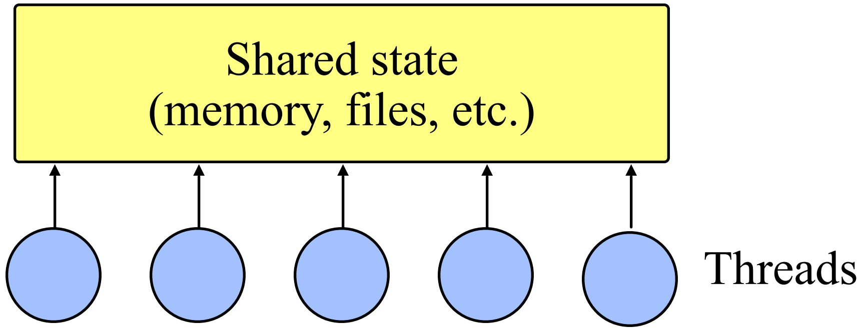
# Introduction

- **Threads:**
  - Grew up in OS world (processes).
  - Evolved into user-level tool.
  - Proposed as solution for a variety of problems.
  - Every programmer should be a threads programmer?
- **Problem: threads are very hard to program.**
- **Alternative: events.**
- **Claims:**
  - For most purposes proposed for threads, events are better.
  - Threads should be used only when true CPU concurrency is needed.

# What Are Threads?

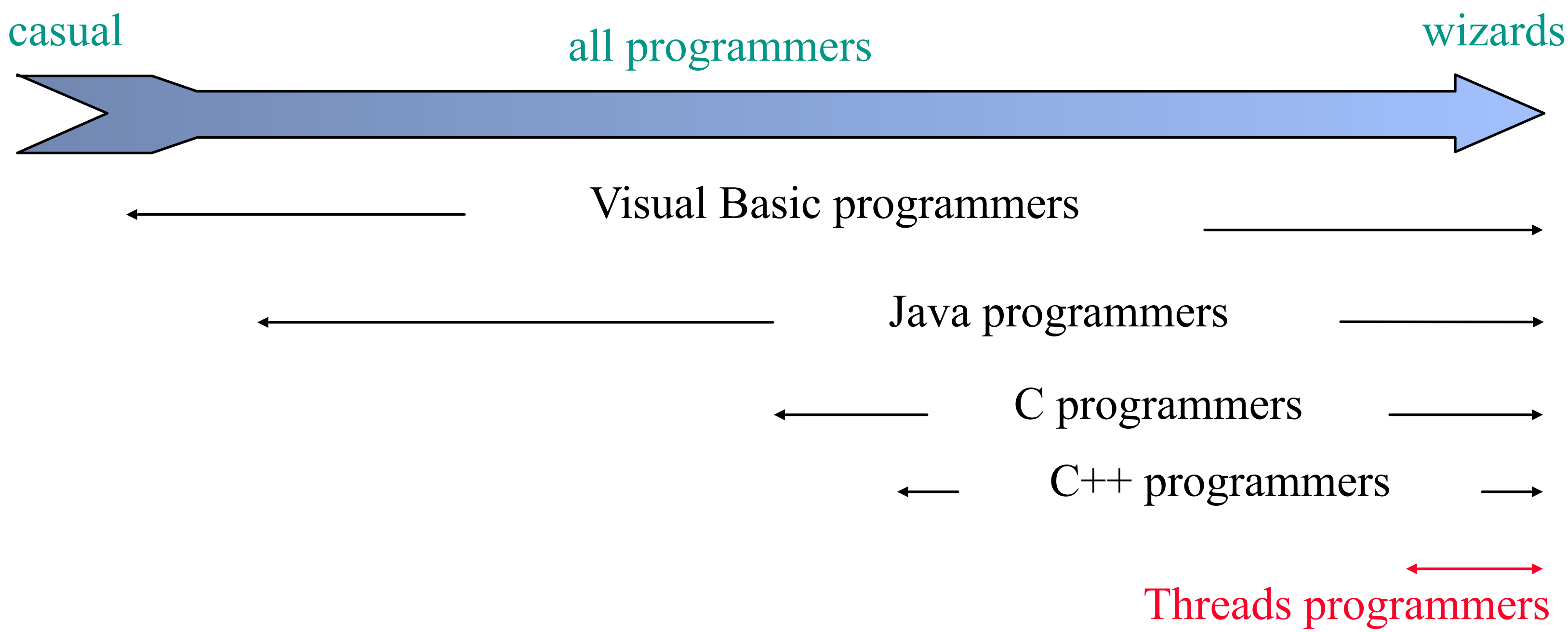



- General-purpose solution for managing concurrency.
- Multiple independent execution streams.
- Shared state.
- Pre-emptive scheduling.
- Synchronization (e.g. locks, conditions).

# What Are Threads Used For?

- **Operating systems:** **one kernel thread for each user process.**
- **Scientific applications:** **one thread per CPU (solve problems more quickly).**
- **Distributed systems:** **process requests concurrently (overlap I/Os).**
- **GUIs:**
  - Threads correspond to user actions;  can service display during long-running computations.
  - Multimedia, animations.

# What's Wrong With Threads?



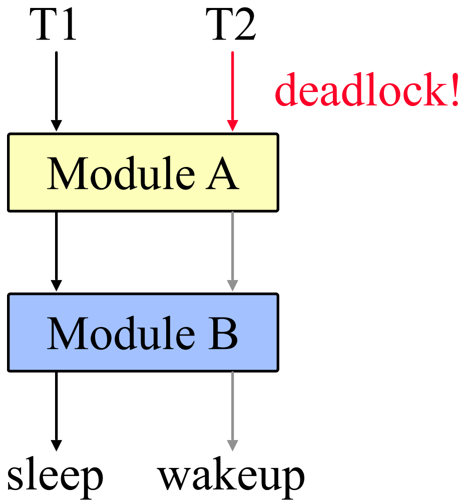

- **Too hard for most programmers to use.**
- **Even for experts, development is painful.**

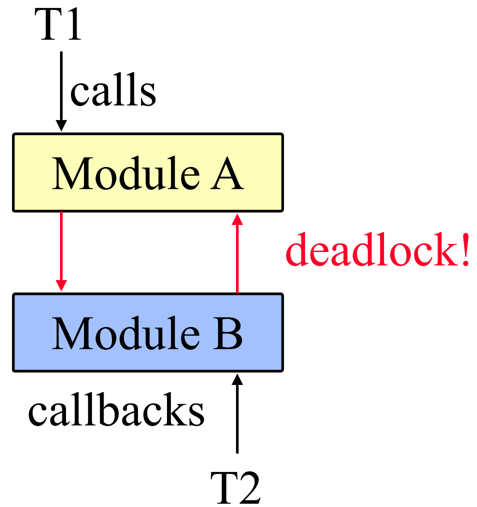
# Why Threads Are Hard

- **Synchronization:**
  - Must coordinate access to shared data with locks.
  - Forget a lock?  Corrupted data.
- **Deadlock:**
  - Circular dependencies among locks.
  - Each thread waits for some other thread: system hangs.

# Why Threads Are Hard, cont'd

- **Hard to debug: data dependencies, timing dependencies.**
- **Threads break abstraction: can't design modules independently.**
- **Callbacks don't work with locks.**



# Common synchronization primitives

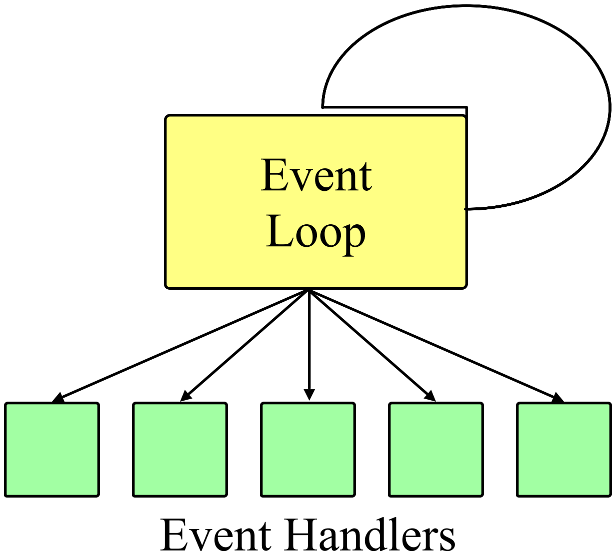
- **Semaphores**
  - Down and up operations
  - Counting semaphore
  - Mutex -- binary semaphore
- **Monitors and Condition variables**
  - Wait and signal operations
- **Spin-locks**
  - Useful in multi-processor settings
  - Dangerous to use in callbacks (e.g. interrupt context) on uniprocessors
- **"Try-lock" variants of the above**
  - Return with error if lock unavailable and caller would block

# Why Threads Are Hard, cont'd

- **Achieving good performance is hard:**
  - Simple locking (e.g. monitors) yields low concurrency.
  - Fine-grain locking increases complexity, reduces performance in normal case.
  - OSes limit performance (scheduling, context switches).
- **Threads not well supported:**
  - Hard to port threaded code (PCs?  Macs?).
    - ➔ not anymore
  - Standard libraries not thread-safe. ➔ not anymore
  - Kernel calls, window systems not multi-threaded.
    - ➔ not anymore
  - Few debugging tools
- **Often don't want concurrency anyway (e.g. window events).**

# Event-Driven Programming

- One execution stream: no CPU concurrency.
- Register interest in events (callbacks).
- Event loop waits for events, invokes handlers.
- No preemption of event handlers.
- Handlers generally short-lived.



# What Are Events Used For?

- **Mostly GUIs:**
  - One handler for each event (press button, invoke menu entry, etc.).
  - Handler implements behavior (undo, delete file, etc.).

- **Distributed systems:**
  - One handler for each source of input (socket, etc.).
  - Handler processes incoming request, sends response.
  - Event-driven I/O for I/O overlap.

# Problems With Events

- **Long-running handlers make application non-responsive. Some solutions:**
  - Fork off subprocesses for long-running things (e.g. multimedia), use events to find out when done.
  - Break up handlers (e.g. event-driven I/O).
  - Periodically call event loop in handler (reentrancy adds complexity).
- **Can't (hard to?) maintain local state across events (handler must return).**
- **No CPU concurrency (not suitable for scientific apps).**

# Events vs. Threads

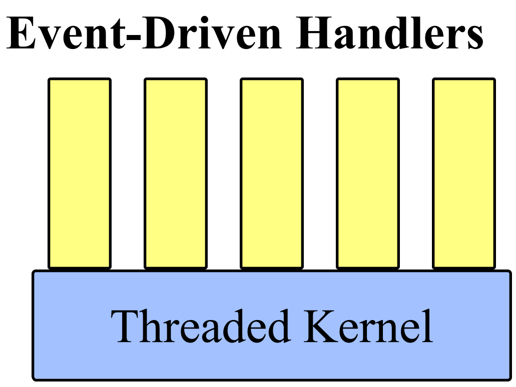
- **Events avoid concurrency as much as possible, threads embrace:**
  - Easy to get started with events: no concurrency, no preemption, no synchronization, no deadlock.
  - Use complicated techniques only for unusual cases.
  - With threads, even the simplest application faces the full complexity.
- **Debugging easier with events:**
  - Timing dependencies only related to events, not to internal scheduling.
  - Problems easier to track down: slow response to button vs. corrupted memory.

# Events vs. Threads, cont'd

- **Events faster than threads on single CPU:**
  - No locking overheads.
  - No context switching.
- **Events more portable than threads.**
- **Threads provide true concurrency:**
  - Can have long-running stateful handlers without freezes.
  - Scalable performance on multiple CPUs.

# Should You Abandon Threads?

- **No: important for high-end servers (e.g. databases).**
- **But, avoid threads wherever possible:**
  - Use events, not threads, for GUIs, distributed systems, low-end servers.
  - Only use threads where true CPU concurrency is needed.
  - Where threads needed, isolate usage in threaded application kernel: keep most of code single-threaded.



# Conclusions

- Concurrency is fundamentally hard;  avoid whenever possible. (??)
- Threads more powerful than events, but power is rarely needed.
- Threads much harder to program than events; for experts only.
- Use events as primary development tool (both GUIs and distributed systems).
- Use threads only for performance-critical kernels.