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 process waits for some other process: system hangs.

![Diagram showing a deadlock scenario with locks A and B, and threads 1 and 2 waiting on each other.](attachment:image.png)
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.**
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?).
  – Standard libraries not thread-safe.
  – Kernel calls, window systems not multi-threaded.
  – Few debugging tools (LockLint, debuggers?).

◆ 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.
  - 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 maintain local state** across events (handler must return).

- **No CPU concurrency** (not suitable for scientific apps).

- Event-driven I/O not always well supported (e.g. poor write buffering).
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.