CS 3110

# Promises

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Today's scene: Ithaca Farmer's Market

## Review

**New unit:** Advanced functional programming

**Today:**

- Promises: a data structure and (functional) programming paradigm for concurrency

**Coming up:**

- Monads
- Streams
- Laziness

## Concurrency

- Networks have multiple computers
- Computers have multiple processors
- Processors have multiple cores

...all working semi-independently
...all sharing resources

sequential: non-overlapping in duration
concurrent: overlapping in duration

- parallel: happening at the same time
- interleaved: rapidly switching between

## Concurrency

At any given time, my laptop is...

- Streaming music
- Running a web server
- Syncing with web services
- Running Ocaml
- Running Zoom (let's be honest)

The OS plays a big role in making it look like those all happen simultaneously

## Concurrency

Applications might also want concurrency:

- Web server that handles many clients at once
- Scientific calculations that exploit parallel architecture to get speedup
- GUIs that want to respond to users while doing computation (e.g., rendering) in the background

## Programming models for concurrency

Threads: procedures executed concurrently

- CS 2110: **`java.lang.Thread`**
- Others:
  - OCaml **`Thread`**
  - pthreads
  - OpenMP

## Programming models for concurrency

Promises: values computed concurrently

- CS 3110: OCaml **`Lwt`**
- Others:
  - **`async`**/**`await`** in JavaScript and .NET
  - **`java.util.concurrent.Future`**
  - OCaml **`Async`**

(and many other models)

## PART II: PROMISES

## Promises

Computation that promises to produce a value sometime in the future

Aka:

- future
- delayed
- deferred

**`Lwt:`** OCaml library for promises

## Promises

A promise – `'a Lwt.t` – is like a box:

- It starts out empty
- At some point in the future, it could be filled with a value of type `'a`
- Once it's filled, the box's contents can never be changed ("write once")

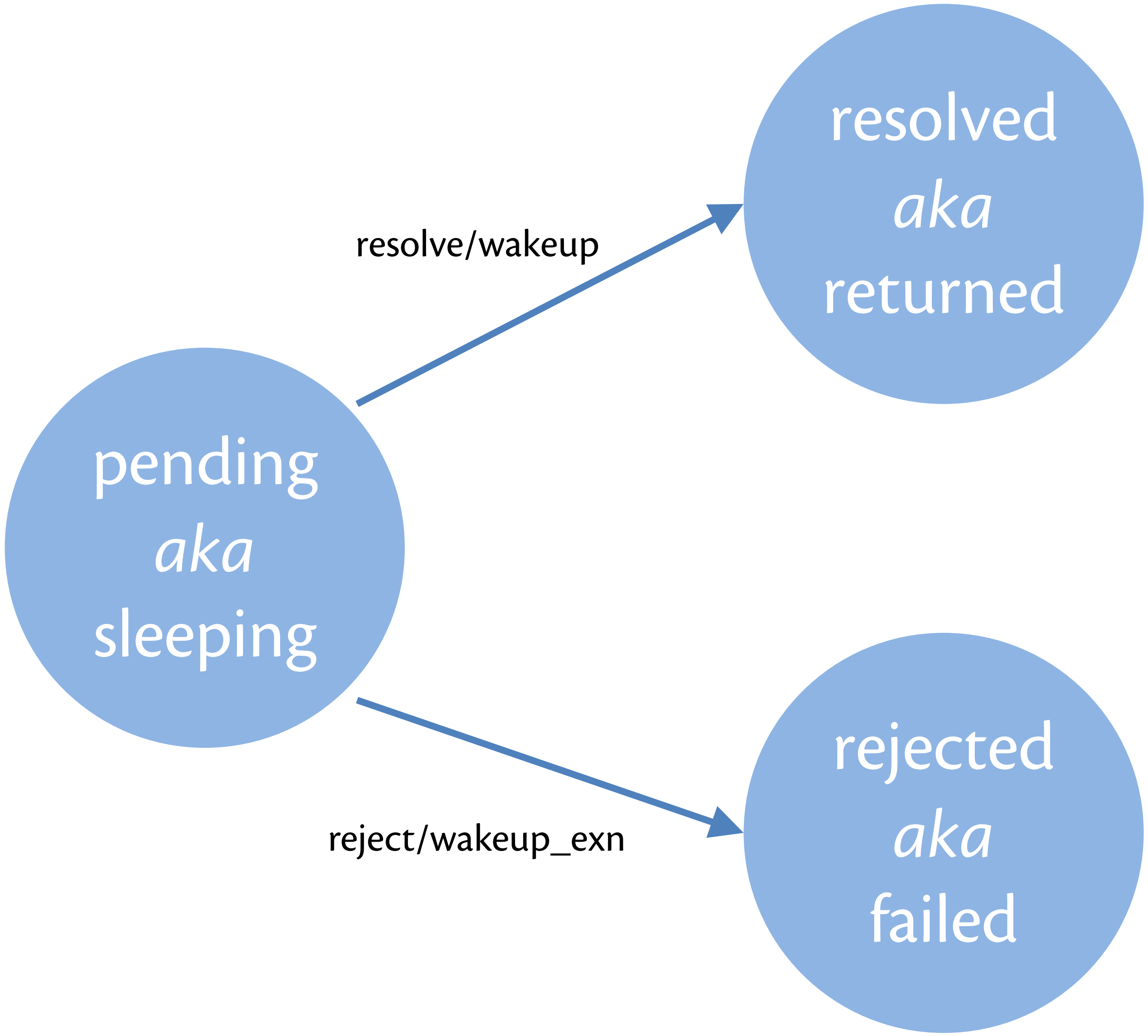
# Resolver

A resolver – `'a Lwt.u` – is what fills the box

Terminology:

- promise is pending aka sleeping: box is empty
- promise is resolved aka returned: box is full
- promise is rejected aka failed: box contains exn

Demo


resolved
*aka*
returned
resolve/wakeup
pending
*aka*
sleeping
reject/wakeup_exn
rejected
*aka*
failed

## Promise signature

```
(** A signature for Lwt-style promises,
    with better names *)
module type Promise = sig

  type 'a promise
  type 'a resolver

  type 'a state =
    Pending | Resolved of 'a | Rejected of exn

  (** [state p] is the state of the promise *)
  val state : 'a promise -> 'a state
```

## Promise signature

```
(** [resolve r x] resolves the promise
    [p] associated with [r] with value [x].
    Requires: [p] is pending. *)
val resolve : 'a resolver -> 'a -> unit

(** [reject r x] rejects the promise [p]
    associated with [r] with exception [x].
    Requires: [p] is pending. *)
val reject : 'a resolver -> exn -> unit
```

## Promise signature

```
  (** [make ()] is a new promise and
      resolver. The promise is pending. *)
  val make : unit -> 'a promise * 'a resolver


  (** [return x] is a new promise that is
      already resolved with value [x]. *)
  val return : 'a -> 'a promise

end
```

Demo

# Digression on Cornell history

- ivars = promises+resolvers
- Used for parallel computing in language called Id
  - [Arvind, Nikhil, and Pingali 1986]
  - Keshav Pingali, Cornell CS prof 1986-2006
- Implemented in *Concurrent ML* by John Reppy (Cornell PhD 1992)

## Lwt

Typical use of library is to do asynchronous I/O

- Launch an I/O operation as a promise
- OS helps to resolve promise

Source of parallelism: OS, not OCaml

Demo

call me maybe?

## PART III: CALLBACKS

## Managing Promises

What if program has many promises "in flight"?

- Web server handling many client
- Spreadsheet updating many cells
- Game updating many enemies

Need a way to manage dependencies of computations upon promises...

Demo

```
bind promise callback

bind :
'a Lwt.t
-> ('a -> 'b Lwt.t)
-> 'b Lwt.t
```

```
promise >>= callback

(>>=) :
'a Lwt.t
-> ('a -> 'b Lwt.t)
-> 'b Lwt.t
```

Demo

## Implementing bind

- Store a list of callbacks with each promise
- After promise is resolved, Lwt runs callbacks
- If promise never resolved (or fails), no callback

# Callback execution

- Single-threaded: only one callback running at a time
- Cooperative: callbacks run to completion
- Nondeterministic: unspecified which runs first

## Upcoming events

- [Friday] MS1 due
- [next Monday] R7 due
- [next Tuesday/Wednesday] MS1 Demos!
- [next Thursday] MS1 Report

*This is resolved.*

**THIS IS 3110**