

Programming Languages (4)  
Parametric Polymorphism (aka Generic  
Types/Functions)

Kenjiro Taura

# Motivation

say want to write ...

- ▶ a function that *sorts arrays of various types* (e.g., ints, floats, strings, structs, ...)
- ▶ a function that *extracts elements from a list satisfying  $p(x)$*
- ▶ *stacks, queues, trees, graphs, hashtables, etc.*
- ▶ variety of *graph algorithms* (*breadth-first search, depth-first search, connected components, partitioning, etc.*) that can/should work regardless of the exact data type of each node
- ▶ ...

*without duplicating code* for each underlying type

## A trivial example (generic function)

write a function

$$f(a) = a[0]$$

in your language (an element of an array, let's say)

Questions:

- ▶ do you have to specify the type of  $a$ ?
- ▶ if so, how you can say “*a must be an array but whose element can be any type*”
- ▶ if not, can it automatically apply to any array?
  - ▶ *does it type-check statically* (i.e., what if you pass something not an array)?

# Type expressions

- ▶ things are conceptually straightforward
- ▶ but pains are around *spelling out types*
- ▶ master the syntax of *type expressions, parameterized types/functions, and instantiation thereof*

# Type expressions for functions

ex. a type of *functions taking an integer and returning a float*

- ▶ Go : `func (int64) float64`
- ▶ Julia : `Function`
  - ▶ cannot specify input/output types
  - ▶ you normally don't write it
- ▶ OCaml : `int -> float`
  - ▶ you normally don't have to write it
- ▶ Rust : `fn (i64) -> f64`

# Type expressions for array-like data

ex. (one-dimensional) array (or likes) of 64-bit floating point numbers

- ▶ Go :
  - ▶ *n*-element array: `[n]float64`
  - ▶ slice: `[]float64`
- ▶ Julia : `Vector{Float64}`
- ▶ OCaml : `float array`
- ▶ Rust :
  - ▶ *n*-element array : `[f64; n]`
  - ▶ vector : `Vec<f64>`
  - ▶ slice: `[f64]`

## Defining parameterized types

ex. data type `node`, parameterized by *any type* `T` or `'a`

- ▶ Go : `type Node [T any] struct { ... }`
- ▶ Julia : `struct Node{T} ... end`
- ▶ OCaml : `class ['a] node ... = object ... end`
- ▶ Rust : `struct Node<T> { ... }`

and a version parameterized by *any subtype of* `S`

- ▶ Go : `type Node [T S] struct { ... }`
- ▶ Julia : `struct Node{T<:S} ... end`
- ▶ OCaml : not possible
- ▶ Rust : `struct Node<T:S> { ... }`

# Instantiating parameterized types

ex. Node of 64-bit integers

- ▶ Go : Node[`int64`]
- ▶ Julia : Node{`Int64`}
- ▶ OCaml : `int node`
- ▶ Rust : `Node::<i64>`



## Defining parameterized functions

ex. a function `bfs`, which can work for *any type*

- ▶ Go : `func bfs [T any] (...) { ... }`
- ▶ Julia : `function bfs(...) where T ... end`
- ▶ OCaml : `let bfs ... =` (nothing special)
- ▶ Rust : `fn bfs<T>(...) { ... }`

and a version that can work for *any subtype of S*

- ▶ Go : `func bfs [T S] (...) { ... }`
- ▶ Julia : `function bfs(...) where {T<:S} ... end`
- ▶ OCaml : not possible
- ▶ Rust : `fn bfs<T:S>(...) { ... }`

# Instantiating parameterized functions

- ▶ Go : `func bfs[int64](...)`
- ▶ Julia : `function bfs(...)`
- ▶ OCaml : `bfs ...` (nothing special)
- ▶ Rust : `fn bfs::<T>(...) { ... }`