Functional Programming
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Overview

Week 3 - Strings

- Summary of Week 2
- OCaml Strings
- L-Strings
- Pictures

Overview

Lists

Syntax

- [] 'nil', the empty list
- :: 'cons', add element
- [1; 2; 3] syntactic sugar

Functions

- Lst.hd first element
- Lst.tl all but first
- Lst.init create list
- Lst.map apply function to list elements
- Lst.fold combine list elements by function

Modules

Using Files

- implementation files (`.ml`)
- signature files (`.mli`)
- ADTs - abstract data types (e.g., Stck)

Inline

- **module** *Imp* = **struct** ... **end**
- **module type** *Sig* = **sig** ... **end**
- **module** *Module* : *Sig* = *Imp*

Modules (cont'd)

Implementation

- type declarations, function definitions, constants
- '**type** *type* = . . . ;;' for types
- '**let** *name* = . . . ;;' for values

Signature

- types, values
- '**type** *type* [= . . .]' for types (possibly abstract)
- '**val** *name* : *type*' for values

Overview

Built-In Type string

Syntax

- constructed using double quotes “”’
- concatenation: (^) : string −> string −> string

Not functional!

Demonstration

Overview

Strng: A String Implementation Using Lists

`strng.ml`

- install type abbreviation **type** t = char list;;
- advantage: all list functions can be used for l-strings
- of_string : string -> t
- to_string : t -> string
- of_int : int -> t
- print : t -> unit

Nice Interpreter Output

Toplevel directives

- always start with # and end with ;;
- #cd "*dir*";; change directory
- #install_printer *name*;; change output function for certain type
- #load "*file.cmo*";; load bytecode
- #quit;; exit the interpreter
- #remove_printer *name*;; remove output function for certain type
- #trace *fun*;; trace computation of function
- #untrace *fun*;; stop tracing of function
- #use "*file*";; execute file content

Nice Interpreter Output (cont'd)

.ocamlinit

```
#cd "_build/";;
#install_printer Strng.toplevel_printer;;
#install_printer Picture.toplevel_printer;;
```

Strng: Implementation

```
type t = char list;;

let of_string s =
 let rec of_string i m s =
  if i = m then [] else String.get s i :: of_string (i + 1) m s
 in of_string 0 (String.length s) s
;;
let to_string xs =
 let rec to_string i s = function
  | [] -> s
  | x :: xs -> String.set s i x; to_string (i + 1) s xs
 in to_string 0 (String.create (Lst.length xs)) xs
;;
let of_int i = of_string (string_of_int i);;
let print s = Format.printf "%s\n" (to_string s);;
let toplevel_printer s =
 Format.printf "\"%s\"" (String.escaped (to_string s))
```

Overview

The Picture Analogon

Picture

- atomic part: pixel
- height and width
- white pixel

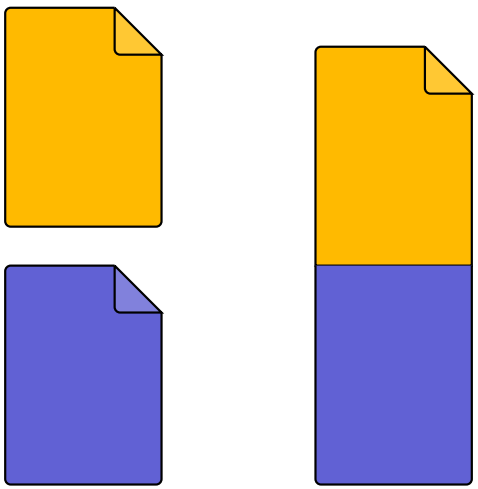
L-String

- atomic part: character
- rows and columns
- blank character (space)

The Type of Pictures

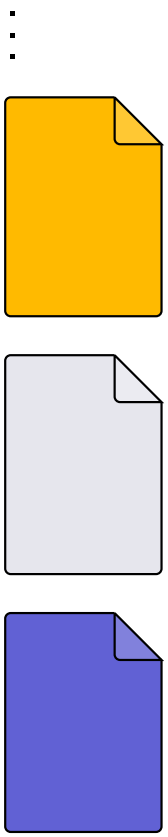
```
type width = int;;
type height = int;;
type t = (width * height * Strng.t list);;
```

Combining Pictures - Stack Above Each Other



```
let rec above (w1, h1, p1) (w2, h2, p2) =
 if w1 = w2 then
  (w1, h1 + h2, p1 @ p2)
 else
  failwith "Picture.above: different widths"
;;
```

Combining Pictures - Stack Above Each Other (cont'd)



```
let stack ps = Lst.fold1 above ps;;
```

Fold Lists Containing At Least One Element

Type

Lst.fold1 : ('a -> 'a -> 'a) -> 'a list -> 'a

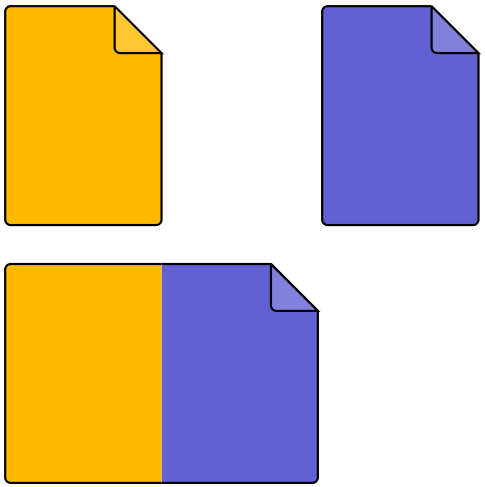
$$\text{Lst.fold1} \circ [x_1; \ldots; x_{n-1}; x_n] = (x_1 \circ (\cdots (x_{n-1} \circ x_n) \cdots))$$

Example

$$\text{fold1 } (+) \text{ [1; 2; 3]} = 1 + 2 + 3 = 6$$

$$\text{fold1 } (\hat{}) \text{ ["Hello"; ", World!"]} = \text{"Hello"} \hat{} \text{ ", World!"} = \text{"Hello, World!"}$$

Combining Pictures - Spread Side By Side



```
let rec beside (w1, h1, p1) (w2, h2, p2) =
 if h1 = h2 then
  (w1 + w2, h1, Lst.zip2_with (@) p1 p2)
 else
  failwith "Picture.beside: different heights"
;;
```

Combine Two Lists Via Function

Type

zip2_with : ('a -> 'b -> 'c) -> 'a list -> 'b list -> 'c list

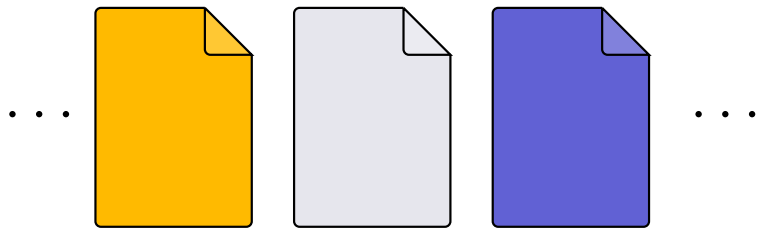
Lst.zip2_with $\circ$ $[x_1; \ldots; x_m]$ $[y_1; \ldots; y_n] = [x_1 \circ y_1; \ldots; x_{\min\{m,n\}} \circ y_{\min\{m,n\}}]$

Example

zip2_with ($*$) [1; 2] [3; 4; 5] = [1 $*$ 3; 2 $*$ 4] = [3; 8]

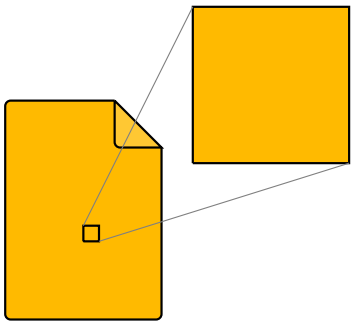
zip2_with drop [1; 0] [['a']; ['b']] = [drop 1 ['a']; drop 0 ['b']] = [[]; ['b']]

Combining Pictures - Spread Side By Side (cont'd)



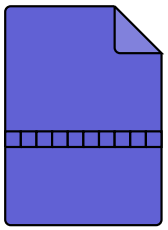
```
let spread ps = Lst.fold1 beside ps;;
```

Creating Pictures - Pixels, Rows, and Empty Pictures



Pixel

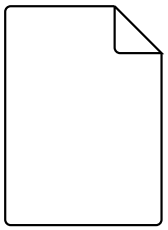
```
let pixel c = (1, 1, [[c]]);;
```



Row

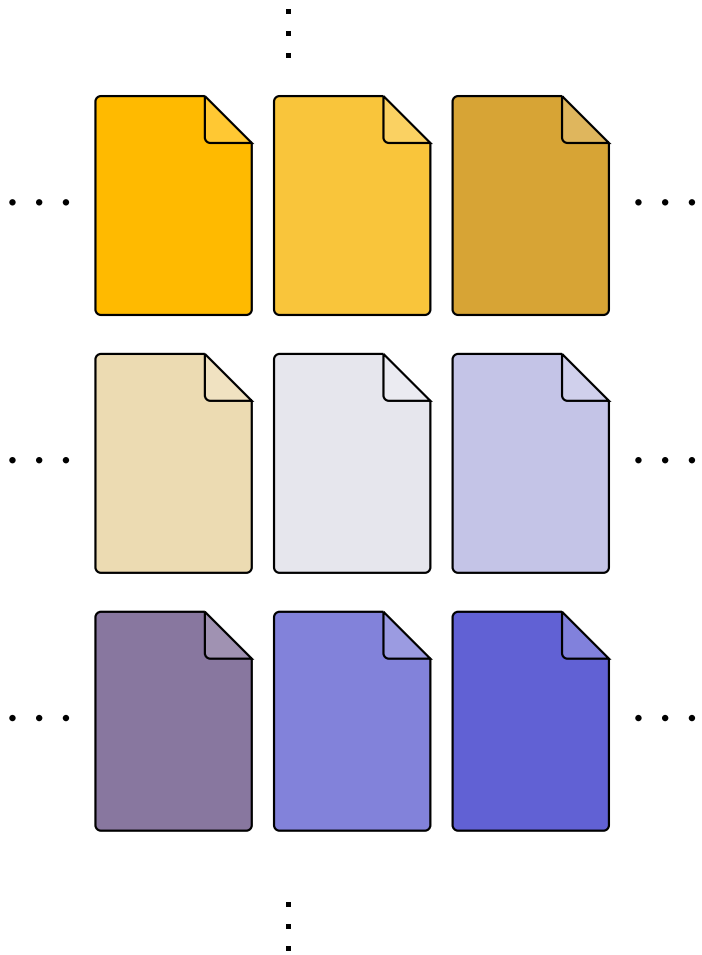
```
let row s = spread (Lst.map pixel s);;
```

Empty



```
let empty w h =
  let line = Lst.init ' ' w in
  let rows = Lst.init line h in
  stack (Lst.map row rows)
;;
```

Combining Pictures - Tile



```
let tile pss = stack (Lst.map spread pss);;
```

Margins

Signatures

- stack_with : height -> t list
- spread_with : width -> t list
- tile_with : height -> width -> t list list

Functions

```
let stack_with h ps =
 Lst.fold1 (fun p q -> above (above p (empty (width q) h)) q) ps
;;

let spread_with w ps =
 Lst.fold1 (fun p q -> beside (beside p (empty w (height q))) q) ps
;;

let tile_with w h pss = stack_with h (Lst.map (spread_with w) pss);;
```

Printing Pictures

Idea

- convert to Strng.t
- use Strng.print

Realization

- Picture:

```
let to_strng (_, _, p) = Strng.join ['\n'] p;;
```

- Strng:

```
;;
let join s xs =
 Lst.fold1 (fun xs ys -> xs @ s @ ys) xs
```