Assignment #1: ML Introduction #1

Note: Your solution must be submitted in a file named hw1.sml.

Overview

This assignment is the first of a pair of assignments intended to serve as an introduction to the ML programming language. These assignments are not meant to cover the entire language, but should prepare you for the remaining programming assignments.

Note: Though each part asks that you “write a function”, you are always allowed to write additional helper/utility functions to simplify the implementation of the required function. This is good design in most languages, and is extremely important in this language where you will often write recursive solutions.

Mutation

Your solutions may not use mutation. This means that your solution cannot have variables of reference type, nor can it use data structures provided by the ML libraries that use mutation. This will be the case for all assignments in this course unless explicitly stated otherwise.

The purpose of this exercise is for you to familiarize yourself with the language, not to program in Java using the ML syntax.

Part of the programming experience in this course will, for most, be working in a new style. While you could write code in ML using a style more similar to the imperative background with which you are already familiar, doing so would be somewhat unnatural for the language and, more importantly, in so doing you would cheat yourself of an opportunity to think differently about programming and to develop new and very useful skills.

Part 1

intToString: int → string

Write a function named `intToString` that takes an integer and returns the string representation of the integer. You may use the built-in `Int.toString` function, but for negative integers your solution must return strings with '-' instead of '∼' (used by ML) as the negation operator.

For example,
- `intToString 99; val it = "99" : string`
- `intToString ~1; val it = "-1" : string`

Part 2

twin: 'a list → ('a * 'a) list

Write a function named `twin` that takes a list of values and returns a list of pairs. The returned list duplicates each element of the input list into a pair.

For example,
- `twin [1,2,3]; [(1,1),(2,2),(3,3)]`

Part 3

memberRec: "a list * "a → bool

memberExists: "a list * "a → bool

You may ignore the inevitable “calling polyEqual” warning.

For this problem you will write the same function in two forms. This function implements a list membership test. Given a pair of a list of values and a singular value, the function must return true if the value appears in the list and false otherwise.

• Write a function named `memberRec` that implements this membership test. This function must be written using explicit recursion (i.e., as a traditional recursive function).
Write a function named `memberExists` that implements this membership test. This function must be written using a single call to `List.exists` (familiarity with higher-order functions is a valuable skill).

For example,
- `memberRec ([1,2,3], 2);`
  val it = true : bool
- `memberRec ([1,2,3], 4);`
  val it = false : bool
- `memberExists ([1,2,3], 2);`
  val it = true : bool
- `memberExists ([1,2,3], 4);`
  val it = false : bool

Part 4

`both`: `(('a ⇒ bool) * ('a ⇒ bool)) ⇒ 'a ⇒ bool`

Write a function named `both` that takes a pair of predicates and a value, \( v \), of any type, and that returns `true` if \( v \) satisfies both predicates.

For example,
- `both (fn x => x > 0, fn x => x < 20) 10;`
  val it = true : bool
- `both (fn x => x > 0, fn x => x < 20) 100;`
  val it = false : bool

Part 5

`satisfiesAll`: `('a ⇒ bool) list * 'a ⇒ bool`

Write a function named `satisfiesAll` that takes a list of predicates and a value, \( v \), of any type, and that returns `true` if \( v \) satisfies every predicate in the list.

For example,
- `satisfiesAll ([], 10);`
  val it = true : bool
- `satisfiesAll ([fn x => x > 0, fn x => x < 20], 10);`
  val it = true : bool
- `satisfiesAll ([fn x => x > 0, fn x => x < 20], 100);`
  val it = false : bool
- `satisfiesAll ([fn x => x > 0, fn x => x < 20, fn x => x mod 2 = 0], 10);`
  val it = true : bool
- `satisfiesAll ([fn x => x > 0, fn x => x < 20, fn x => x mod 2 = 0], 11);`
  val it = false : bool

Part 6

`mapSome`: `('a ⇒ 'b option) ⇒ 'a list ⇒ 'b list`

Write a function named `mapSome` that takes a function, \( f \), and a list. The `mapSome` function returns a list of values extracted from the `SOME` options returned by \( f \) applied to the elements of the input list. In the case that \( f \) applied to an element results in `NONE`, that element does not generate a corresponding value in the result list.

Note: no credit will be earned for solutions that use `List.mapPartial` since you are being asked to implement the same function.

For example,
- `mapSome (fn x => if x > 0 then SOME x else NONE) [1, 2, ~3, 4, ~55];`
  val it = [1,2,4] : int list
- `mapSome (fn x => if x > 0 then SOME (Int.toString x) else NONE) [1, 2, ~3, 4, ~55];`
  val it = ["1","2","4"] : string list
Part 7

prefixBy: ('a → bool) * 'a list → 'a list * 'a list

Write a function named `prefixBy` that takes, as a tuple, a predicate and a list. This function must return a pair of lists representing a split of the original list into a prefix and a suffix (i.e., the concatenation of the resulting lists will match the original list). This split is based on the provided predicate; all values that satisfy the predicate, prior to the first failure, must be placed in the first result list and all remaining values are placed in the second result list.

For example,

- `prefixBy (fn n => n < 10, [1,4,5,9,10,3,4,21]);`
  val it = ([1,4,5,9],[10,3,4,21])
- `prefixBy (fn c => Char.isAlpha c, explode "abc123def");`
  val it = (["a","b","c"],["1","2","3","d","e","f"])
- `prefixBy (fn n => n < 10, [1,4,5,9]);`
  val it = ([1,4,5,9],[]) : int list * int list
- `prefixBy (fn n => n < 10, [10,4,5,9]);`
  val it = ([],[10,4,5,9]) : int list * int list

Part 8

groupAscending: int list → int list list

Write a function named `groupAscending` that takes a list of integers as an argument and returns a list of integer lists as its result. This function must group ascending (contiguous) sequences of integers in the original list into sublists in the result. More specifically, each sublist in the result represents an ascending sequence in the input list with the elements in the same relative order and the sublists in the same relative order (i.e., for two consecutive sublists, the elements of the second immediately followed the elements of the first in the original list).

For example,

- `groupAscending [];
  val it = [] : int list list`
- `groupAscending [1];
  val it = [[1]] : int list list`
- `groupAscending [1,2,3];
  val it = [[1,2,3]] : int list list`
- `groupAscending [1,2,3,2,3];
  val it = [[1,2,3],[2,3]] : int list list`
- `groupAscending [4,7,10,2,3,1,99,45,122,123,122,47,46,46,49];
  val it = [[4,7,10],[2,3],[1,99],[45,122,123],[122],[47],[46],[46,49]] : int list list`

Part 9

reachable: (int * int list) list → int → int list

Consider a representation of “memory” as a mapping of address to lists of addresses. For instance, each address might correspond to an object that itself references additional objects at other addresses (the list). As an example, `[(1, [2,3]), (2, [1]), (3, [])]` might represent three objects: the object at address 1 references both of the other objects; the other objects do not reference anything else.

Write a function named `reachable` that takes, as a pair, a list of pairs (each containing, in this order, an integer and a list of integers) and an integer. This list is meant to model “memory” and the integer is meant to represent a start address.

This function must return (in ascending order) the list of all “addresses” reachable from the initial address. An address is included in the list only if it appears in “memory” (i.e., is allocated). The resulting list may include duplicates (do not remove them). Your function need not account for cycles in the memory (e.g., `[(1, [2]), (2, [1])]` creates a cycle wherein the object at address 1 refers to the object at address 2, which refers back to address 1).

Consider the use of the following functions: `ListMergeSort.sort`, `List.find`, and `List.concat`.

For example,
Part 10

simplifyEscapes: string → string

It is very common in programming languages to specify special characters in strings using escape sequences (e.g., the ubiquitous $\texttt{\textbackslash n}$). These escape sequences, before being processed, are actually just two characters: a backslash ($\texttt{\textbackslash}$) followed by a character indicating the sequence.

Write a function named \texttt{simplifyEscapes} that takes a string as its only argument. This function must return a string with the same characters as the argument string but with all valid escape sequences reduced to their corresponding single character complements. If an invalid escape sequence is found, then the function must raise an \texttt{InvalidEscapeSequence} exception, with the offending character (if there is one) as an argument, or an \texttt{InvalidEscapeMissing} exception, as appropriate. (Copy the exception definitions given below into your source file.)

```ml
exception InvalidEscapeSequence of char;
exception InvalidEscapeMissing;
```

For this problem, the only valid escape sequences are those that consist of a $\texttt{\textbackslash}$ immediately followed one of $\texttt{", \textbackslash, n, and t}$ (these sequences map to the single characters that you should expect from experience with C, Java, etc.).

\textbf{Note} that you may not use any functions provided by the ML library to do this conversion for you (e.g., \texttt{String.fromString}). You can, however, convert between strings and lists with \texttt{explode} and \texttt{implode}.

For example,

- \texttt{simplifyEscapes "abc"};
  val it = "abc" : string
- \texttt{simplifyEscapes "ab \t c \" " \\
val it = "ab \t c \" " \\
- \texttt{simplifyEscapes "ab\bc" handle InvalidEscapeSequence c =>
  "invalid escape \" " - str c;
  val it = "invalid escape \b" : string
- \texttt{simplifyEscapes "ab\\" handle InvalidEscapeMissing =>
  "escape sequence missing character";
  val it = "escape sequence missing character" : string

Logistics

- Strive for simplicity in your programming. Write short helper functions.
- Grading will be divided as follows.
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