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1  (*
2           CS51 Lab 3
3           Polymorphism and record types
4  *)
5
6
7  (*=====
8  Readings:
9
10  This lab builds on material from Chapters 7.4 and 9-9.5 of the
11  textbook <http://book.cs51.io>, which should be read before the lab
12  session.
13
14  Objective:
15
16  In this lab, you'll exercise your understanding of polymorphism and
17  record types. Some of the problems extend those from Lab 2, but we'll
18  provide the necessary background code from that lab.
19  =====)
20
21  (*=====
22  Part 1: Records and tuples
23
24  Records and tuples provide two different ways to package together
25  data. They differ in whether their components are selected by *name*
26  or by *position*, respectively.
27
28  Consider a point in Cartesian (x-y) coordinates. A point is specified
29  by its x and y values, which we'll take to be ints. We can package
30  these together as a pair (a 2-tuple), as in the following data type
31  definition: *)
32
33  type point_pair = int * int ;;
34
35  (* Then, we can add two points (summing their x and y coordinates
36  separately) with the following function:
37
38  let add_point_pair (p1 : point_pair) (p2 : point_pair) : point_pair =
39      let x1, y1 = p1 in
40      let x2, y2 = p2 in
41      (x1 + x2, y1 + y2) ;;
42
43  .....
44  Exercise 1:

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45
46 It might be nicer to deconstruct the points in a single match, rather
47 than the two separate matches in the two `let` expressions. Reimplement
48 `add_point_pair` to use a single pattern match in a single `let`
49 expression.
50 .....*)
51
52 let add_point_pair (p1 : point_pair) (p2 : point_pair) : point_pair =
53   failwith "add_point_pair not implemented" ;;
54
55 (* Analogously, we can define a point by using a record to package up
56 the x and y coordinates. *)
57
58 type point_recd = {x : int; y : int} ;;
59
60 let example_point_recd = {x = 1; y = 3} ;;
61
62 (*.....
63 Exercise 2A:
64
65 Replace the two lines below with a single top-level `let` expression
66 that extracts the x and y coordinate values from `example_point_recd`
67 above into global variables `x1` and `y1`, respectively.
68 .....*)
69
70 let x1 = 0 ;;
71 let y1 = 0 ;;
72
73 (*.....
74 Exercise 2B:
75
76 Implement a function `add_point_recd` to add two points of type
77 `point_recd` and returning a `point_recd` as well.
78 .....*)
79
80 let add_point_recd =
81   fun _ -> failwith "add_point_recd not implemented" ;;
82
83 (* Recall the dot product from Lab 2. The dot product of two points
84 `x1, y1` and `x2, y2` is the sum of the products of their x and y
85 coordinates.
86
87 .....
88 Exercise 3: Write a function `dot_product_pair` to compute the dot
89 product for points encoded as the `point_pair` type.
90 .....*)

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137             course : string } ;;
138
139 (* Here's an example of a list of enrollments. *)
140
141 let college =
142   [ { name = "Pat"; id = 603858772; course = "cs51" };
143     { name = "Pat"; id = 603858772; course = "expos20" };
144     { name = "Kim"; id = 482958285; course = "expos20" };
145     { name = "Kim"; id = 482958285; course = "cs20" };
146     { name = "Sandy"; id = 993855891; course = "ls1b" };
147     { name = "Pat"; id = 603858772; course = "ec10b" };
148     { name = "Sandy"; id = 993855891; course = "cs51" };
149     { name = "Sandy"; id = 482958285; course = "ec10b" }
150   ] ;;
151
152 (* In the following exercises, you'll want to avail yourself of the
153 'List' module functions, writing the requested functions in
154 higher-order style rather than handling the recursion yourself.
155
156 .....
157 Exercise 7: Define a function called 'transcript' that takes an
158 'enrollment list' and returns a list of all the enrollments for a given
159 student as specified by the student's ID.
160
161 For example:
162
163   # transcript college 993855891 ;;
164   - : enrollment list =
165   [{name = "Sandy"; id = 993855891; course = "ls1b"};
166   {name = "Sandy"; id = 993855891; course = "cs51"}]
167   .....
168
169 let transcript (enrollments : enrollment list)
170   (student : int)
171   : enrollment list =
172   failwith "transcript not implemented" ;;
173
174 (*.....
175 Exercise 8: Define a function called 'ids' that takes an 'enrollment
176 list' and returns a list of all the ID numbers in that list,
177 eliminating any duplicates. Hint: The 'map' and 'sort_uniq' functions
178 from the 'List' module and the 'compare' function from the 'Stdlib'
179 module may be useful here.
180
181 For example:
182
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183     # ids college ;;
184     - : int list = [482958285; 603858772; 993855891]
185     .....(*)
186
187 let ids (enrollments: enrollment list) : int list =
188   failwith "ids not implemented" ;;
189
190 (* There's a big problem with this database design: nothing guarantees
191    that a given student ID is associated with a single name. The right
192    thing to do is to use a different database design where this kind of
193    thing can't happen; that would be an application of the *edict of
194    prevention*. But for the purpose of this lab, you'll just write a
195    function to verify that this problem doesn't occur.
196
197 ....
198 Exercise 9: Define a function `verify` that determines whether all the
199 entries in an enrollment list for each of the ids appearing in the
200 list have the same name associated. Hint: You may want to use
201 functions from the `List` module such as `map`, `for_all`,
202 `sort_uniq`.
203
204 For example:
205
206     # verify college ;;
207     - : bool = false
208
209 (Do you see why it's false?)
210 ....(*)
211
212 let verify (enrollments : enrollment list) : bool =
213   failwith "verify not implemented" ;;
214
215 =====
216 Part 3: Polymorphism
217
218 .....
219 Exercise 10: In Lab 2, you implemented a function `zip` that takes two
220 lists and "zips" them together into a list of pairs. Here's a possible
221 implementation of `zip`:
222
223 let rec zip (x : int list) (y : int list) : (int * int) list =
224   match x, y with
225   | [], [] -> []
226   | xhd :: xtl, yhd :: ytl -> (xhd, yhd) :: (zip xtl ytl) ;;
227
228 As implemented, this function works only on integer lists. Revise your

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229 solution to operate polymorphically on lists of any type. What is the
230 type of the result? Did you provide full typing information in the
231 first line of the definition? (As usual, for the time being, don't
232 worry about explicitly handling the anomalous case when the two lists
233 are of different lengths.)
234 .....*)
235
236 let zip =
237   fun _ -> failwith "zip not implemented" ;;
238
239 (*.....
240 Exercise 11: Partitioning a list -- Given a function returning a
241 boolean, for instance
242
243   fun x -> x mod 3 = 0
244
245 and a list of elements, for instance
246
247   [3; 4; 5; 10; 11; 12; 1]
248
249 we can partition the list into two lists, the list of elements
250 satisfying the boolean function `([3; 12])` and the list of elements
251 that don't `([4; 5; 10; 11; 1])`.
252
253 The library function `List.partition` partitions its list argument in
254 just this way, returning a pair of lists. Here's an example:
255
256   # List.partition (fun x -> x mod 3 = 0) [3; 4; 5; 10; 11; 12; 1] ;;
257   - : int list * int list = ([3; 12], [4; 5; 10; 11; 1])
258
259 What is the type of the `partition` function, keeping in mind that it
260 should be as polymorphic as possible?
261
262 Now implement the function yourself (without using `List.partition` of
263 course, though other `List` module functions may be useful).
264 .....*)
265
266 let partition =
267   fun _ -> failwith "partition not implemented" ;;
268
269 =====
270 Part 4: Implementing polymorphic application, currying, and uncurrying
271
272 .....
273 Exercise 12: We can think of function application itself as a
274 polymorphic higher-order function (:exploding_head:). It takes two

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275 arguments -- a function and its argument -- and returns the value
276 obtained by applying the function to its argument. In this exercise,
277 you'll write this function, called `apply`. You might use it as in the
278 following examples:
279
280     # apply pred 42 ;;
281     - : int = 41
282     # apply (fun x -> x ** 2.) 3.14159 ;;
283     - : float = 9.8695877280999907
284     # apply int_of_float 3.14159 ;;
285     - : int = 3
286
287     An aside: You may think such a function isn't useful, since we
288     already have an even more elegant notation for function
289     application, as in
290
291     # pred 42 ;;
292     - : int = 41
293     # (fun x -> x ** 2.) 3.14159 ;;
294     - : float = 9.8695877280999907
295     # int_of_float 3.14159 ;;
296     - : int = 3
297
298     But we'll see a quite useful operator that works similarly --
299     the backwards application operator -- in Chapter 11 of the
300     textbook.
301
302 Start by thinking about the type of the function. We'll assume it
303 takes its two arguments curried, that is, one at a time.
304
305 1. What is the most general (polymorphic) type for its first argument
306     (the function to be applied)?
307
308 2. What is the most general type for its second argument (the argument
309     to apply it to)?
310
311 3. What is the type of its result?
312
313 4. Given the above, what should the type of the function `apply` be?
314
315 Now write the function.
316
317 Can you think of a reason that the `apply` function might in fact be
318     useful?
319 .....*)
```


