

## Code Review 8: Object-Oriented Programming

### 1 Practice Problems

**Problem 1.1** (Object-Oriented Counters).

```
class loud_counter : counter_interface =
  object (this)
    inherit counter as super
    method! bump n =
      super#bump n;
      Printf.printf "State is now %d\n" this#get_state
    end ;;

class type reset_counter_interface =
  object
    inherit counter_interface
    method reset : unit
  end ;;

class loud_reset_counter : reset_counter_interface =
  object (this)
    inherit loud_counter
    method reset =
      this#bump (-this#get_state)
  end ;;
```

**Problem 1.2** (Social Network). "ConnectU" is a social media site for college students. Suppose we want to define a `user` class.

1. Define a class interface for a user `user` that includes the following methods:
  - (a) Get a user's username
  - (b) Get a user's student id (a string)
  - (c) Add a friend to a user's list of friends; note that friendships are mutual, so if Alice is a friend of Bob, then Bob is a friend of Alice.
  - (d) Get a user's friend list
  - (e) Add a post (a string) to a user's list of posts
  - (f) Remove a post
  - (g) Retrieve all the user's posts

2. Define an implementation that satisfies the class interface which takes in a `username` and an `id`.
3. Define a class interface called `student` which has the same functionality as the `user` class but an additional method which outputs the school a student attends.
4. Define an implementation that satisfies the `student` interface which takes in a `username`, `id`, and the `school` the student attends.
5. Define a function `form_friend_group` that takes in a list of `users`, and for each user in the list, sets their friends to be everyone else in the list.
6. Define a list of four `students` and use `form_friend_group` on the `student` list.

### Solution

```
class type user_type =  
  object  
  
    method get_username : string  
  
    method get_id : string  
  
    method add_friend : user_type -> unit  
  
    method get_friends : user_type list  
  
    method add_post : string -> unit  
  
    method remove_post : string -> unit  
  
    method get_posts : string list  
  
  end ;;  
  
class user (username : string) (id : string) : user_type =  
  object (this)  
  
    val mutable friends : user_type list = []  
    val mutable posts : string list = []  
  
    method get_username = username  
  
    method get_id = id  
  
    method add_friend (friend : user_type) : unit =  
      if  
        List.mem friend friends  
      then
```

```

        ()
    else
        (friends <- friend :: friends;
         friend#add_friend (this :> user_type))

    method get_friends = friends

    method add_post post = posts <- post :: posts

    method remove_post post = posts <- List.filter ((<>) post) posts

    method get_posts = posts

end ;;

class type student_type =
object
inherit user_type
method get_school : string

end ;;

class student (username : string) (id : string) (school : string) =
object

inherit user username id
method get_school = school

end ;;

let rec form_friend_group (users : user_type list) : unit =
    match users with
    | [] -> ()
    | head :: tail ->
        List.iter (fun user -> head#add_friend user) tail;
        form_friend_group tail ;;

let jayden = new student "jaydenp" "1" "Harvard" ;;
let gerson = new student "gersonp" "2" "Harvard" ;;
let kwee = new student "kwee" "3" "Harvard" ;;
let victoria = new student "victoria" "4" "Harvard" ;;

let user_list : student list = [jayden; gerson; kwee; victoria] ;;

form_friend_group (user_list :> user_type list) ;;

```

**Problem 1.3** (Polynomial). In this problem, you will define classes that work with (univariate) polynomials.

A polynomial is an expression consisting of coefficients and variables.

We define a class interface `polynomial_type`.

Listing 1: `polynomial_type`

```
1
2 class type polynomial_type =
3   object
4     method get_coefficients : float list (* int list returns the
        coefficients of the polynomial in order from lowest degree to
        highest degree. For example, [5, 3, 2] would represent the
        polynomial  $5 + 3x + 2x^2$ . *)
5
6     method evaluate : float -> float (* evalulates a polynomial  $f(x)$ 
        *)
7
8     method solve : float -> float list option (* solve c returns real
        solutions for x when a polynomial equals c. For example if a
        polynomial is  $5 + 3x + 2x^2$ , polynomial_object#solve 10 returns
        a list of solutions to  $5 + 3x + 2x^2 = 10$  *)
9
10  end
```

Now we define the class definition for a polynomial class.

Listing 2: polynomial

```
1
2 class polynomial (coefficients : float list) : polynomial_type =
3   object
4     method get_coefficients : float list = coefficients
5
6     method evaluate (x : float) : float = failwith "not yet implemented"
7
8     method solve (c : float) : float list option = None
9   end ;;
```

1. Implement the `evaluate` method for the polynomial class. For example, for a polynomial  $5 + 3x + 2x^2$  with coefficients `[5.0, 3.0, 2.0]`, the `evaluate` method called on 5 should return  $5 + 3(5) + 2(5)^2 = 70$ .
2. Implement a `linear_polynomial` class satisfying the `polynomial_type` class interface. A linear polynomial is an expression that has **at most two coefficients**. For example,  $5x + 2$  (with coefficients as `[2.0, 5.0]`),  $3x$  (`[0., 3.]`), and  $11$  (`[11.]`) are all polynomial functions. *Hint*: You may define a type so that users can only define at most two coefficients.

For a constant polynomial  $c$ , `solve a` should return `[Float.infinity]` if  $c = a$ , `None` otherwise.

3. Implement a `quadratic_polynomial` class satisfying the `polynomial_type` class interface.

Quadratic polynomials have at most three coefficients. To solve quadratic polynomials, we can use the quadratic formula.

The solutions to a quadratic  $ax^2 + bx + c = 0$  is given by the formula:  $\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ .

Remember to properly handle cases when there are no real solutions or infinitely many solutions.

### Solution

```
class type polynomial_type =
  object

    (* returns the coefficients of the polynomial in order from lowest
       degree to highest
       degree *)
    method get_coefficients : float list

    (* 'evaluate' x evaluates a polynomial f at x, i.e. computes f(x) *)
    method evaluate : float -> float
```

```

(* solve c returns real solutions for x when a polynomial equals c.
   In other words,
   it should return the real solution solutions x such that f(x) =
   c *)
method solve : float -> float list option

end ;;

class polynomial (coefficients : float list) : polynomial_type =
object
  method get_coefficients : float list = coefficients

  method evaluate (x : float) : float =
    List.fold_right (fun coeff acc -> x *. acc +. coeff)
      coefficients 0.0

  method solve (c : float) : float list option = None
end ;;

type linear_coefficients =
| Constant of float
| Linear of float * float (* first element of constructor should be
   intercept, second should be slope *)

let rec extract_linear_coeffs (coeffs : linear_coefficients) =
  match coeffs with
  | Constant c -> [c]
  | Linear (intercept, slope) -> if slope = 0. then
    extract_linear_coeffs (Constant intercept) else [intercept;
    slope]

class linear_polynomial (coefficients : linear_coefficients) :
  polynomial_type =
  object (this)

    inherit polynomial (extract_linear_coeffs coefficients)

  method! solve (c : float) : float list option =
    let coeffs = this#get_coefficients in
    match coeffs with
    | [constant] -> if c = constant then Some [Float.infinity] else
      None
    | [intercept; slope] -> Some [(c -. intercept) /. slope]
    | _ -> failwith "solve: Invalid linear polynomial"

  end ;;

```

```

type quadratic_coeffs =
| Constant of float
| Linear of float * float (* first element is intercept, second is
    slope *)
| Quadratic of float * float * float (* Quadratic (c, b, a)
    corresponds to  $ax^2 + bx + c$  *)

let rec extract_quad_coeffs (coeffs: quadratic_coeffs) =
  match coeffs with
  | Constant c -> [c]
  | Linear (intercept, slope) -> if slope = 0. then
      extract_quad_coeffs (Constant intercept) else [intercept; slope]
  | Quadratic (c, b, a) -> if a = 0. then extract_quad_coeffs (Linear
      (b, c)) else [c; b; a] ;;

class quadratic_polynomial (coefficients: quadratic_coeffs) :
  polynomial =
  object (this)
  inherit polynomial (extract_quad_coeffs coefficients)

  method !solve (c : float) : float list option =
    let coeffs = this#get_coefficients in
    match coeffs with
    | [constant] -> if c = constant then Some [Float.infinity] else
        None
    | [intercept; slope] -> Some [(c -. intercept) /. slope]
    | [c_prime; b; a] ->
        let inner = b ** 2. -. 4. *. a *. (c_prime -. c) in
        if
          inner < 0.
        then None
        else
          let root = sqrt inner in
          let left = (-.b -. root) /. (2. *. a) in
          let right = (-.b +. root) /. (2. *. a) in
          if left = right then Some [left]
          else Some [left; right]
    | _ -> failwith "solve: Invalid quadratic polynomial"
  end ;;

```