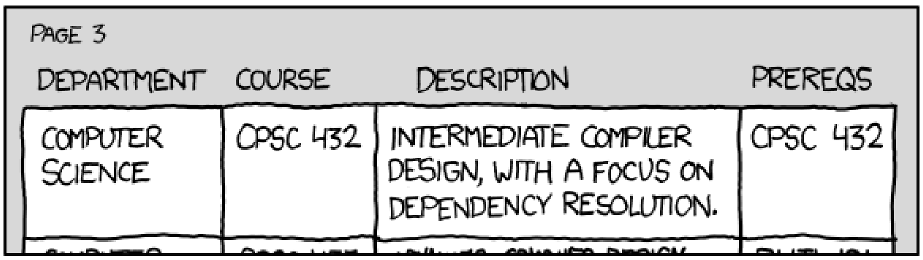
Assignment 8: Recursion

ETH Zurich

Hand-out: 12. November 2012
Due: 21. November 2012



Dependencies © Randall Munroe (http://xkcd.com/754/)

Goals

- Test your understanding of recursion.
- Implement recursive algorithms.

1 An infectious task

You are the boss of a company concerned about health of your employees (especially in winter - the time of flu epidemics). To take a better decision about the company's health policy, you decide to simulate the spreading of the flu in a program. For this you assume the following model: if a person has a flu, he spreads the infection to only one coworker, who then spreads it to another coworker, and so on.

The following class *PERSON* models coworkers. The class *APPLICATION* creates *PERSON* objects and sets up the coworker structure.

Listing 1: Class *PERSON*

```
class
  PERSON

create
  make

feature -- Initialization
  make (a_name: STRING)
      -- Create a person named 'a_name'.
```

```
    require
      a_name_valid: a_name /= Void and then not a_name.is_empty
    do
      name := a_name
    ensure
      name_set: name = a_name
    end

feature -- Access
  name: STRING

  coworker: PERSON

  has_flu: BOOLEAN

feature -- Element change
  set_coworker (p: PERSON)
      -- Set ‘coworker’ to ‘p’.
    require
      p_exists: p /= Void
      p_different: p /= Current
    do
      coworker := p
    ensure
      coworker_set: coworker = p
    end

  set_flu
      -- Set ‘has_flu’ to True.
    do
      has_flu := True
    ensure
      has_flu: has_flu
    end

invariant
  name_valid: name /= Void and then not name.is_empty
end
```

Listing 2: Class *APPLICATION*

```
class
  APPLICATION

create
  make

feature -- Initialization
  make
      -- Simulate flu epidemic.
    local
      joe, mary, tim, sarah, bill, cara, adam: PERSON
    do
```

```
        create joe.make ("Joe")
        create mary.make ("Mary")
        create tim.make ("Tim")
        create sarah.make ("Sarah")
        create bill.make ("Bill")
        create cara.make ("Cara")
        create adam.make ("Adam")
        joe.set_coworker (sarah)
        adam.set_coworker (joe)
        tim.set_coworker (sarah)
        sarah.set_coworker (cara)
        bill.set_coworker (tim)
        cara.set_coworker (mary)
        mary.set_coworker (bill)
        infect (bill)
    end
end
```

Table 1 shows four different implementations of feature *infect*, which is supposed to infect a person p and all people reachable from p through the coworker relation.

To do

1. For each version of *infect* answer the following questions:
   - Does it do what it is supposed to do?
   - If yes, how? (One to two sentences.)
   - If no, why? (One to two sentences.)

   Note: this is a pen-and-paper task; you are not supposed to use EiffelStudio.

2. The class *PERSON* above assumes that each employee can only infect one coworker. This is unfortunately too optimistic. Rewrite the class *PERSON* in such a way that an employee can have (and infect) an arbitrary number of coworkers. Implement a correct recursive feature *infect* for this new setting. Note: you may use a loop to iterate through the list of coworkers.

3. **Optional.** The coworker structure with at most one coworker forms a (possibly circular) linked list. Which data structure is formed by a coworker structure with multiple coworkers? What kind of traversal do you apply to traverse this structure in the feature *infect*?

To hand in

Hand in your answers to the tasks 1 and 3 and the code of class *PERSON* and feature *infect* for the task 2.

2 Short trips

In Zurich you can buy a cheaper public transportation ticket if you are doing a short trip (Kurzstrecke). In this task you will develop an application that helps customers decide what type of ticket they need, by visualizing the short-trip range of a given station. We consider a trip short if it takes two minutes or less.

Table 1: Different versions of feature *infect*

Version 1

```
infect (p: PERSON)
        -- Infect 'p' and coworkers.
    require
        p_exists: p /= Void
    do
        if p.coworker /= Void and then
                not p.coworker.has_flu then
            p.coworker.set_flu
            infect (p.coworker)
        end
        p.set_flu
    end
```

Version 2

```
infect (p: PERSON)
        -- Infect 'p' and coworkers.
    require
        p_exists: p /= Void
    do
        if p.coworker /= Void and then not
                p.coworker.has_flu then
            infect (p.coworker)
            p.coworker.set_flu
        end
        p.set_flu
    end
```

Version 3

```
infect (p: PERSON)
        -- Infect 'p' and coworkers.
    require
        p_exists: p /= Void
    local
        q: PERSON
    do
        from
            q := p.coworker
            p.set_flu
        until
            q = Void
        loop
            if not q.has_flu then
                q.set_flu
            end
            q := q.coworker
        end
    end
```

Version 4

```
infect (p: PERSON)
        -- Infect 'p' and coworkers.
    require
        p_exists: p /= Void
    do
        p.set_flu
        if p.coworker /= Void and then not
                p.coworker.has_flu then
            infect (p.coworker)
        end
    end
```

To do

1. Download `http://se.inf.ethz.ch/courses/2012b_fall/eprog/assignments/08/traffic.zip` unzip it and open `assignment_8.ecf`. Open class *SHORT_TRIPS*.
2. Implement a recursive feature *highlight_reachable* that takes two arguments: a station *s* of type *STATION* and a time interval *t* of type *REAL_64*. The feature should highlight all stations that are reachable from *s* in *t* seconds or less. You may use a loop to traverse the lines passing through a given station (accessible through the query *lines*); however you are not allowed to use a loop that traverses all the stations in the city.

   Hint. We assume that the segment of a public transportation line between any two adjacent stations is always straight. For that reason you can compute the time it takes to go from a station to the next one, by simply dividing the distance between the station positions by the speed of the line.

3. To test *highlight_reachable*, invoke it from the feature *highlight_short_distance* with the time interval of two minutes. The application is programmed to call *highlight_short_distance*, whenever you left-click a station on the map.

To hand in

Hand in the code of *SHORT_TRIPS*.

3 N Queens

The N-queens problem is the problem of positioning N queens on an $N \times N$ chess board such that no queen attacks another (i.e., they do not share the same row, column, or diagonal).

The problem can be solved recursively. For example, Figure 1 shows how a partial solution for the first 4 rows of the board is being extended to the 5^{th} row. The main idea is that if the partial solution is not yet complete, then for each safe location in the current row[1], you can add the location to the solution and use this new solution to solve the problem for the next row.

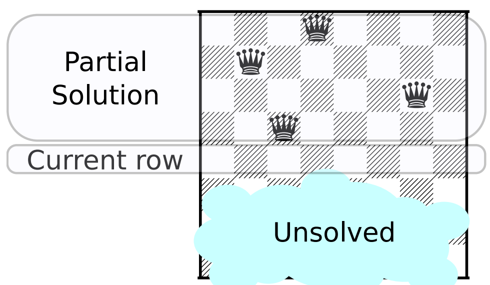


Figure 1: An example of a partial solution

To do

1. Download `http://se.inf.ethz.ch/courses/2012b_fall/eprog/assignments/08/n_queens.zip` unzip it and open `n_queens.ecf`. Open class *PUZZLE*.

2. Implement a recursive procedure *complete*, which completes a given partial solution. You can make use of a given function *under_attack*, which determines if a particular position in the current row is safe; for this function to work correctly you need to implement the helper function *attack_each_other*.

3. Add a call to *complete* from *solve*, in such a way that after calling *solve* (n) the list *solutions* contains all solutions for the board of size n.

4. Run the program: this will test you implementation on board sizes from 1 to 10. If any of the tests fail, revise your implementation until they pass.

To hand in

Hand in the code of *PUZZLE*.

[1] A location is safe if it is not attacked by any of the currently placed queens.