Modelling and analysis of a cyber-physical system now with monads !!

Practical assignment 2

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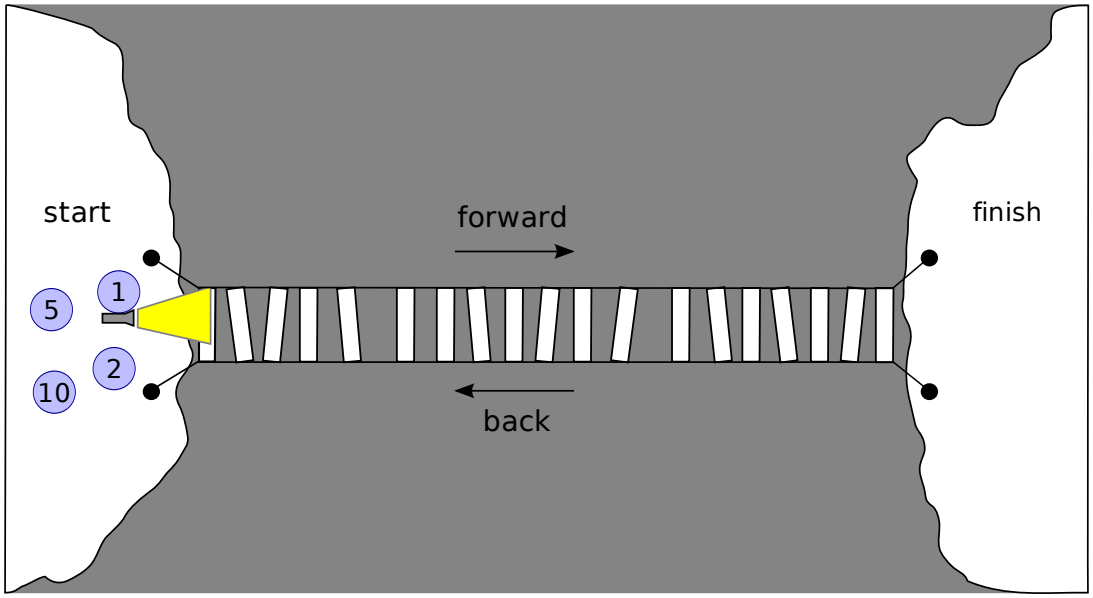
In the middle of the night four adventurers encounter a rope-bridge that spans a deep ravine. For safety reasons, no more than two people cross the bridge at the same time and a flashlight needs to be carried in every crossing. There is only one flashlight. The four adventurers are not equally skilled: crossing the bridge takes them one, two, five, and ten minutes respectively. A pair of adventurers crosses the bridge in an amount of time equal to that of the slowest of the two.



One adventurer claims that they cannot be all on the other side in less than 19 minutes. Another one disagrees and claims that it can be done in 17 minutes.

First task

Your first task is to verify these claims using Haskell[1]. Specifically you will need to,

1. model the system above using what you learned about monads, in particular the duration and non-deterministic ones;
2. show that it is indeed possible for all adventurers to be on the other side in 17 minutes;
3. show that it is impossible for all adventurers to be on the other side in less than 17 minutes.

[1] An animated description of the problem is available here.

You should fulfill this task by completing the code in attachment (`Adventurers.hs`), i.e. by adding a definition to the functions that lack a definition, following the comments present in the code. You are free to add new auxiliary functions.
Some hints to help you get started: Recall the duration monad from the slides and the HASKELL code that was previously provided. Analyse in detail the code concerning the Knight's quest and in particular the monad `LogList`.

Second task

Implement a function that receives a list of valid plays and returns a *distribution* of the resulting states together with the corresponding elapsed time. The function should in particular encompass *probabilistic crossing times*: *i.e.* if the adventurer's crossing time is x then its probabilistic crossing time will now be given by the uniform distribution,

$$\frac{1}{3} \cdot \left(x - \frac{x}{2}\right) + \frac{1}{3} \cdot (x) + \frac{1}{3} \cdot \left(x + \frac{x}{2}\right)$$

In this probabilistic setting, what can you conclude about the adventurer's claims mentioned above? Again you should fulfill this task by completing the code in attachment (`Adventurers.hs`), *i.e.* by adding a definition to the functions that lack a definition, following the comments present in the code. Feel free to add new auxiliary functions.

Third task

Add new functionalities to the code which you think are essential or interesting. For example present the sequence of states respective to the movements of the adventurers from the initial state to the final goal, or make the game more interactive via the IO monad. Imagination is the limit – but of course remind yourself that the focus is the use of monads in programming :-).

What to submit: A single report in PDF for all tasks and the respective source files. Send by email (nevrenato@gmail.com) a unique zip file "`pcf2425-N.zip`", where `N` is your student number. The subject of the email should be "`pcf2425 N`".

Deadline: 10th June 2025 @ 23h59