1 Foundations of Computer Science (LCP)

A one-person game (such as Rubik’s cube, or peg solitaire) has a finite number of possible states, some of which count as winning. A move is a step from one state to another. From each given state, the player can choose from a set of (zero or more) possible next moves. We call a state winnable if a winning state can be reached from it in zero or more moves.

For simplicity, assume that states are coded as integers. Also assume that we are given functions \( \text{winning}(x) \) returning true or false and \( \text{next}(x) \) returning the list of states that can be reached in one move from state \( x \).

(a) The following code is an attempt to implement the notion of winnable:

\[
\begin{align*}
\text{fun exists } p \ [\ ] &= \text{false} \\
| \text{exists } p \ (x::xs) &= p x \text{ orelse exists } p \ xs;
\end{align*}
\]

\[
\text{fun winnable } x = \text{winning } x \text{ orelse exists } \text{winnable} \ (\text{next } x);
\]

Briefly explain how this code works. Also describe its main limitation: how it can fail to find a winning state that is only a few moves away. Illustrate this point by giving specific definitions of \( \text{winning} \) and \( \text{next} \). [5 marks]

(b) Modify the code above to yield the function \( \text{winpath} \ x \), which returns the list of states from \( x \) to the winning state found or, alternatively, the empty list to indicate that no winning state was found. [4 marks]

(c) Sometimes we are only interested in a winnable state if it is only a few moves away from the current state. Modify your solution from part (b) to obtain the function \( \text{bounded_winpath} \ n \ x \), which looks for winning states that are at most \( n \) moves away from \( x \). [3 marks]

(d) Use your solution from part (c) to obtain the function \( \text{new_winpath} \ x \), which has the same objective as \( \text{winpath} \ x \), but without the limitation mentioned in part (a). Briefly explain why the limitation no longer applies and the price that has been paid for this. [5 marks]

(e) Briefly outline an alternative approach to correcting the limitation mentioned in part (a), using the notion of a queue. What are the advantages and drawbacks of this approach? [3 marks]

For full credit, code should be concise and clear. Exceptions may be useful in this but are not required.