**Problem 2.1** Explain the difference between agent function and agent program. How many agent programs can there be for a given agent function?

**Answer:**

An **agent** can perceive its environment through sensors and act upon that environment through actuators. However, the agent’s perceptual inputs at any given instant are known as **percept,** whereas the complete history of everything the agent has ever perceived is called the agent’s **percept sequence**. To understand the whole scenario of an agent, we need to know about the agent function and agent program. The difference between the agent function and the agent program is given below,

**Agent function:** The agent function is an abstract mathematical description that maps any given percept sequence to an action. An agent’s behavior is described by the agent function. The agent function for an artificial agent will be implemented by an agent program.

**Agent program:**An agent program is a concrete implementation running within some physical system. This is assumed that agent program will run on some sort of computing device with physical sensors and actuators, which is called architecture. Therefore, agent = architecture + program.

There can be more than one agent program that implements a given agent function since the agent function is the purpose, and the agent program is the code for its implementation. If the agent function has multiple options, then there must be more than one agent program. For example, given an architecture with n bits of storage, there are 2n agent programs possible.

**Problem 2.2** Explain the commonalities of and the differences between the performance measure and the utility function.

**Answer:**

The performance measure is used by an external observer to determine how efficient and successful an agent is. Whereas the utility function is used by an agent itself to evaluate how desirable states or histories are.

The core commonality of performance measure and utility function is that both are used to evaluate the success of an agent. However, an agent’s utility function is essentially an internalization of the performance measure. If the internal utility function and the external performance measure are in agreement, then an agent that chooses actions to maximize its utility will be rational according to the external performance measure.

The core difference between the performance measure and the utility function is that the performance measure of an agent is observed by an external observer, whereas the utility function is used by the agent itself. The utility function may not be the same as the performance measure. Furthermore, an agent may have no explicit utility function at all, whereas there is always a performance measure.

**Problem 2.3.2** Complexity analysis of the Tower of Hanoi algorithm

**Answer:**

**Time Complexity Analysis:**

Let,

the time required for disks is

moving a disk from source to destination is a constant time operation, let it be 1

Now according to the recursive solution of Tower of Hanoi,

(1)

Then,

(2)

(3)

Using the substitution law between equation (2) and (3),

(4)

Again, using the substitution law between equation (1) and (4),

(5)

After the generalization of equation (5),

For the base case, , then , so

Therefore,

(6)

Equation (6) is a geometric series, where

First term,

Common ratio,

Number of terms,

So equation (6),

Therefore, the time complexity of the Tower of Hanoi algorithm, , which is exponential.

**Space Complexity Analysis:**

Let,

the space required for disk is

space needed for each call is independent of which is constant, let it be 1

Since, there are two recursive call and among them 2nd recursive call is invoked after 1st recursive call is over, we can reuse the space of 1st recursive call for 2nd recursive call. Therefore,

(For base case, constant space is needed)

Then,

and so on

So, by looking into the , and so on, the required space is linearly increasing depending on the disk size. Therefore, the space complexity of the Tower of Hanoi algorithm, .

**Summary:** Complexity of the Tower of Hanoi algorithm for disk is as follows,

|  |  |  |
| --- | --- | --- |
| **Complexity Category** | **Complexity Function (for Disk)** | **Complexity Class** |
| Time |  | exponential |
| Space |  | linear |

**Problem 2.4** Mathematical Notation

**Answer:**

Consider 0 as a natural number, hence

1. The set containing all natural numbers,
2. The set containing the set of natural numbers,
3. The set containing all square numbers,
4. The set containing all even natural numbers,

, or

1. The set containing all even square numbers,
2. The 3-tuple of 0, 1, and 2, which is triplet,
3. The n-tuple of all numbers from 0 to n – 1,
4. The set of pairs of natural numbers and their squares,
5. The pair of sets of natural numbers and square numbers,
6. Algebraic structure is monoid, as the identity element

So, the monoid of natural numbers under addition,

1. Algebraic structure and are monoid, as the identity element and respectively. So, the pair of monoids of the natural numbers under addition and under multiplication, .
2. The set of the monoids of the natural numbers under addition and under multiplication,
3. Given a monoid , the set of elements that are not the neutral element,
4. Given a monoid , the monoid in which the operation is flipped,

are new monoid, where the identity element and