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CS 4300 - 001

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Assignment A1: Random Actions in Wumpus World

1. INTRODUCTION: CONAN

A Wumpus World is a simulated environment where an agent must reach a goal without being caught by a Wumpus. In the environment, a Wumpus World consists of a 4x4 board with an agent, a variable number of pits, a Wumpus, and a goal which is represented by gold. This system allows to test the rigour of an agent that performs random actions. The purpose of this paper is to provide a mathematical and experimental analysis of the probabilities for a random agent to reach the goal on a solvable board. Some questions we seek to answer are: What are the percentages of solvable boards for 4x4 boards with 0, 1 and 14 pits? What is the estimated mean, variance, and 95% confidence interval for solvable boards with 0 to 14 pits? What is the estimated mean, variance, and 95% confidence interval for the number of steps a random agent survives with a predetermined board?

The algorithm used for this agent is based on random actions from the set of:

$$A = \{FORWARD, RIGHT, LEFT\}$$

Where *FORWARD* is moving forward, *RIGHT* is turning right, and *LEFT* is turning left. Actions are determined randomly by MATLAB's rand function. The robustness of this agent can be tested with multiple simulations to determine how effective it is as rudimentary artificial intelligence

2. METHOD: RAJUL

The method for this experiment was to create a program that can run a large number of data samples. The program was created to check the percentage of solvable boards while varying the number of pits, thereby randomly generating a board every time. For each selected number of pits, 1,000 boards were checked to observe close to all possible boards.

To test the an agent that picked an action at random to move around in the world, the board was kept to a constant configuration. This agent was then run against 2000 trials to observe the number of steps taken and whether or not it reached the gold so that we could calculate the estimated mean, variance, and 95% confidence interval for each value.

3. VERIFICATION OF PROGRAM: CONAN

To verify the program, three special cases are considered to confirm that the program is correct. The case where the board has 0 pits, the case where the board has 1 pit, and the case where the board has 14 pits.

For 0 pits, the only unsolvable boards are where the Wumpus placed on the agent. However, the gold can still spawn on the remaining 15 spaces, making the total number of unsolvable boards 15. The total number of boards that can be generated with 0 pits is given by:

$$P(n, r) = P(16, 2) = 240 \text{ boards}$$

Denoting 16 board spaces and a generation of ordered subset of 2 elements. Thus the percentage of solvable boards is given by:

$$240-15 = 225/240 = \mathbf{93.75\%}$$

For 1 pit, there are three cases where the board is unsolvable. The first case is when the agent is placed at the same position as a Wumpus. However, the positions of the pit and gold can still vary. Therefore, while varying the pit and gold, the number of unsolvable boards is given by:

$$P(n, r) = P(15, 2) = 15*14 = 210 \text{ unsolvable boards}$$

Further, to calculate the number of boards while the agent is placed at the same position as the Pit, the same number of possibilities exist. Therefore:

$$210*2 = 420 \text{ Total unsolvable boards}$$

The second case is when the agent, at start position, is surrounded (above and to the right) by a wupus and pit. For all unsolvable boards the Wumpus and pit will always be at (2,1) and (1,2) blocking any movement from start position. Therefore, there are 13 other positions for gold. Taking into

consideration both positions for the Wumpus and pit number of unsolvable boards for this case is given by:

$$(13*2) = 26 \text{ boards}$$

The third case is when the Wumpus and pit block all possible paths to the gold.

This case occurs like the previous case, but the pit and Wumpus block the gold instead of the agent in the other three corners of the board.

For the 3 possible corners of the board the 2 permutations of the Wumpus and pit is given by:

$$(2*3) = 6 \text{ boards}$$

In conclusion, the total unsolvable boards is given by: $420+26+6 = 452$

All possibilities of board permutations with 1 pit is given by:

$$P(n, r) = P(16, 3) (16*15*14) = 3360$$

By considering the variations of the positions of Gold, Wumpus, and 1 pit total solvable boards is given

by subtracting unsolvable boards from total boards: $3360 - 452 = 2908 \text{ boards}$

Therefore, The percentage of solvable boards is:

$$2908/3360 = \mathbf{86.5476\%}$$

For 14 pits, the only solvable boards are when the gold is positioned at the start position. However, the Wumpus can still spawn on the remaining 15 spaces, making the total number of solvable boards 15. The

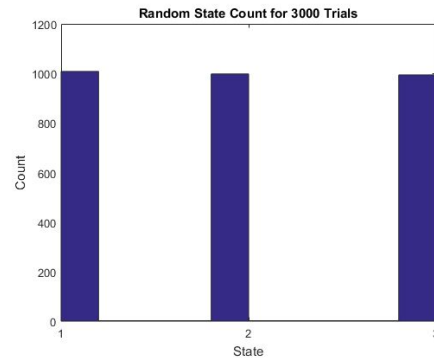
total number of boards that can be generated with 14 pits is given by:

$$P(n, r) = P(16, 2) = 240 \text{ boards}$$

Denoting 16 board spaces and generation of an ordered subset of two elements. Thus, the percentage of solvable boards is given by:

$$15/240 = 1/16 = \mathbf{6.25\%}$$

Finally, we also verify that the agent produces FORWARD, RIGHT and LEFT actions an equal amount of the time by testing the state generator we use over 3000 trials.



4. DATA AND ANALYSIS: RAJUL

4.1 Solvable Board Data

The table below shows the mean, variance and 95% confidence interval of solvable boards for each $0 \leq p \leq 14$. The data was collected for 1000 boards for each value of p .

Data for 1000 Generated Boards				
Pit Count	Mean	Variance	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
0	0.938	0.0582	0.9254	0.9506
1	0.882	0.1042	0.8652	0.8988
2	0.769	0.1778	0.7471	0.7909
3	0.656	0.2259	0.6313	0.6807
4	0.54	0.2486	0.5141	0.5659
5	0.384	0.2368	0.3587	0.4093
6	0.288	0.2053	0.2644	0.3116
7	0.214	0.1684	0.1927	0.2353
8	0.194	0.1565	0.1734	0.2146
9	0.136	0.1176	0.1182	0.1538
10	0.111	0.0988	0.0947	0.1273
11	0.103	0.0925	0.0872	0.1188
12	0.072	0.0669	0.0585	0.0855
13	0.065	0.0608	0.0522	0.0778
14	0.062	0.0582	0.0494	0.0746

Figure 1: Data for 1000 Generated Boards

Seen above in Fig 1., the mean value for number of pits of 0,1 and 14 are very close to the manual calculation provided in section 3. Further, for the 95% confidence intervals, it is observed that for the 1000 boards generated for 0 pits, between 92.5% and 95% of the boards were solved. Similarly, the data for 1

and 14 pits can be seen above. It is also observed that the mean number of solved Boards decreases when pits increase, as expected.

4.2 Random Agent Data

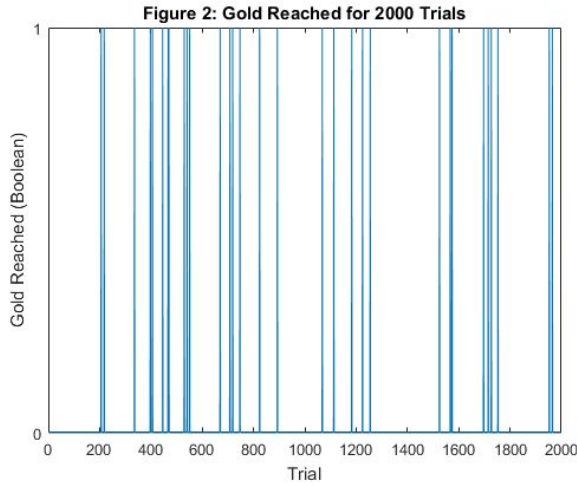


Figure 2: Reaching the gold

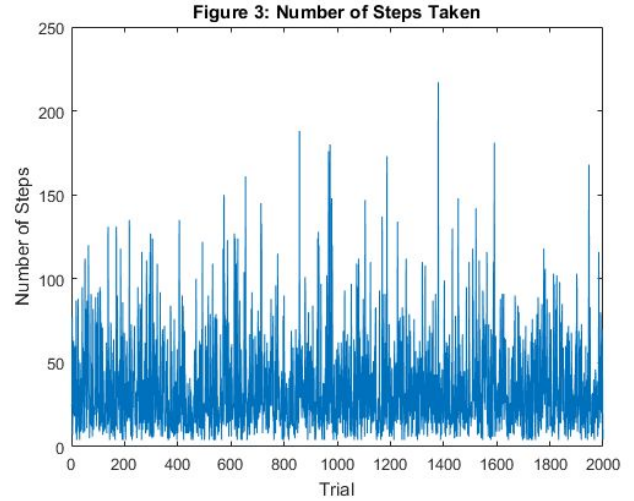


Figure 3: Number of steps

The data in the above graphs [Figure 2 & 3] represent the behavior of the random agent. The agent was tested for 2000 trials against the given board [Figure 4]. The graph for the number of steps shows the random nature of the agent due to the highly varying number of steps for the trials.

Statistics for Random Agent using 2000 Trials		
Values	Gold Reached	Steps Taken
Mean	0.0150	34.4570
Variance	0.0148	700.0362
95% Confidence Interval Lower Bound	0.0105	33.4838
95% Confidence Interval Upper Bound	0.0195	35.4302

Figure 4: Random Agent Statistics

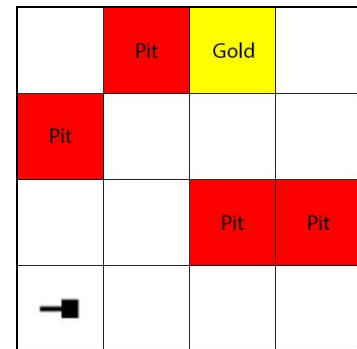


Figure 5: Board Layout

5. INTERPRETATION: CONAN

As verified in Section 3, the percentage of solvable boards with 0 pits is 93.75%, with 1 pit is 86.5476%, and with 14 pits is 6.25%. In table for Random Agent Statistics [Figure 4], it is observed that the random agent reaches the gold with a mean of 1.5% of the time, a variance of 1.48%, and a 95% confidence interval of 1.05% - 1.95%. The Wumpus also survives with a mean of 34.457 steps, a variance of 700.0362, and a 95% confidence interval of 33.4838 - 35.4302. The variance in number of steps can explain some of the spikes in the graph for Number of Steps Taken [Figure 3], but it also lies outside of the lower and upper bounds for our 95% confidence interval, which implies the random agent is not an effective program to find the goal in the given board [Figure 5]. A 1.5% chance of success can also be seen in the graph for Gold Reached [Figure 2], where there are large gaps between successful trials.

6. CRITIQUE: RAJUL

While writing the simulation code, it was very important to take into consideration the simulation concept of trials. Calculating the statistical data became more accurate when averaged over number of trials to produce all possibilities of the experiment.

As for the Agent, with the limited requirements of randomized movement and limited capabilities, the agent was not necessarily reactive to its surrounding in any way. The problem is that the agent currently ignores the raw data and percept provided. This becomes the cause for a very wide range of random data. The suggestion to this would be to develop an agent that reacts to percept. This data would then help narrow down to an Agent that will in turn use the most effective way(which in this case, was number of steps) to get to the gold.

7. LOG: RAJUL & CONAN

Rajul: I spent 3 hours on Part 1 and 2.5 hours on Part 2 and 5.5 hours on the Lab Report.

Conan: I spent 3 hours on Part 1, 2.5 hours on Part 2 and 5.5 hours on the Lab Report.