

HOMEWORK ASSIGNMENT 3

SIYUAN YAO, ZHENGFEI CHEN, KAI YAN

(1) Problem 1

See code.

(2) Problem 2

$$r = 3, p = 0.4$$

$$EN = r \cdot \frac{1}{p} = 7.5$$

$$Var(N) = r \cdot \frac{1-p}{p^2} = 11.25$$

$$\text{Standard Deviation of } B = \sqrt{Var(N)} = 3.35$$

$$pN(k) = \binom{k-1}{r-1} \cdot (1-p)^{k-r} \cdot p^r$$

$$skewness = E[(N - 7.5)^3 / 3.35^3] = E[(N - 7.5)^3 / 37.73]$$

$$= \sum_{N=3}^{\infty} [((N - 7.5)^3 / 37.73) \cdot (0.4^3) \cdot (0.6^{N-3})] = 1.1925$$

(3) Problem 3

(a) long run average number of rolls between wins

Let's call the number of rolls between wins M . We are to find $E(M)$; if there are M rolls between consecutive wins, then in long run, every $(M + 1)$ rolls contain a win;

let $Avg(R)$ denotes the average of all the rolls we got between one win and another;

$$E(M + 1) = E\left(\frac{8}{Avg(R)} + 1\right) = \frac{E(8)}{E(Avg(R))} + 1$$

the expected value of $Avg(R)$ is just ER , which is 3.5 according to textbook;

$$\text{so } E(M) = E(M + 1) - 1 = \frac{E(8)}{ER} - 1 = 8/3.5 - 1 = 2.2857 - 1 = 1.2857$$

(b) long run value of total winnings per turn.

this should be equal to $\sum_{i=0}^5 P(\text{land on } i \text{ and win})(i + 1)$

$$P(\text{land on } i \text{ and win}) = P(\text{land on } i) \cdot P(\text{win} \mid \text{land on } i)$$

$P(\text{land on } i)$ for all i should be equal, which will be $1/8$.

$$P(\text{land on } 0 \text{ and win}) = (1/8) \cdot (1)$$

$$P(\text{land on } 1 \text{ and win}) = (1/8) \cdot (5/6)$$

$$P(\text{land on } 2 \text{ and win}) = (1/8) \cdot (4/6)$$

$$P(\text{land on } 3 \text{ and win}) = (1/8) \cdot (3/6)$$

$$P(\text{land on 4 and win}) = (1/8) \cdot (2/6)$$

$$P(\text{land on 5 and win}) = (1/8) \cdot (1/6)$$

$$\begin{aligned} & \sum_{i=0}^5 P(\text{land on } i \text{ and win})(i+1) \\ &= 1 \cdot (1/8) \cdot 1 + 2 \cdot (1/8) \cdot (5/6) + 3 \cdot (1/8) \cdot (4/6) + 4 \cdot (1/8) \cdot (3/6) + 5 \cdot \\ & \quad (1/8) \cdot (2/6) + 6 \cdot (1/8) \cdot (1/6) \\ &= 1.666667 \end{aligned}$$

so the value should be 1.666667

(c) ET_j :

if we start at square j , we need to get a total number of $(8-j)$ to win;
let S_i denotes the total squares we've advanced given i rolls; for example, if we rolled a 1, then a 2, then $S_2 = 1+2 = 3$;

$$P(T_j = N) = P[(S_n - 1 < (8-j)) \text{ and } (S_n \geq (8-j))]$$

for ET_7 : we definitely will win in 1 roll, so $ET_7 = 1$;

for ET_6 : we have $5/6$ chance to win in 1 roll, and $1/6$ chance that we roll a 1 first, then roll anything to win

$$\text{so } ET_6 = 1 \cdot 5/6 + 2 \cdot 1/6 = 1.16666$$

for ET_5 : we have $4/6$ chance to win in 1 roll, and $1/6$ chance that we enter a situation which is exactly the same as ET_6 , and $1/6$ chance we enter a situation that's exactly like ET_7 ;

$$\text{so } ET_5 = 1 \cdot 4/6 + (1 + ET_6) \cdot 1/6 + (1 + ET_7) \cdot 1/6 = 1.36111$$

so we see the pattern here: if we don't make it to win from our original state, we are entering one of the other states: for example, if we start out at position 5 and didn't win, we are either entering position 6 or 7, and thus we can use the ET of those state, except that we take one more steps to arrive, so we can do $(1 + ET_i) \cdot P(j \rightarrow i)$ where j is our original state and i is the expected new state.

consequently:

$$ET_4 = 1 \cdot 3/6 + (1 + ET_5) \cdot 1/6 + (1 + ET_6) \cdot 1/6 + (1 + ET_7) \cdot 1/6 = 1.58796$$

$$ET_3 = 1 \cdot 2/6 + (1 + ET_4) \cdot 1/6 + (1 + ET_5) \cdot 1/6 + (1 + ET_6) \cdot 1/6 + (1 + ET_7) \cdot 1/6 = 1.85262$$

$$ET_2 = 1 \cdot 1/6 + (1 + ET_3) \cdot 1/6 + (1 + ET_4) \cdot 1/6 + (1 + ET_5) \cdot 1/6 + (1 + ET_6) \cdot 1/6 + (1 + ET_7) \cdot 1/6 = 2.16139$$

$$ET_1 = (1 + ET_2) \cdot 1/6 + (1 + ET_3) \cdot 1/6 + (1 + ET_4) \cdot 1/6 + (1 + ET_5) \cdot 1/6 + (1 + ET_6) \cdot 1/6 + (1 + ET_7) \cdot 1/6 = 2.52162$$

$$ET_0 = (1 + ET_1) \cdot 1/6 + (1 + ET_2) \cdot 1/6 + (1 + ET_3) \cdot 1/6 + (1 + ET_4) \cdot 1/6 + (1 + ET_5) \cdot 1/6 + (1 + ET_6) \cdot 1/6 = 2.77523$$