Homework 1

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2-5

(a) Write down a recursion for $f^{(n)}(x)$ in terms of $f^{(n-1)}(\cdot)$ and the parameters of the problem.

For any participant, with n more spins, he/she can choose to spin or stop. When choosing **stopping**, he/she will take away the current accumulation of x. We can obtain $f^{(n)}(x) = x$. While choosing **spinning**, it is also easy to know that

$f^{(n)}(x) = \sum_i f^{(n-1)}(x + r_i) \cdot p_i$, where $i = 1, \ldots, m$.

$f^{(n)}(x) = \max\{\sum_i f^{(n-1)}(x + r_i) \cdot p_i,\ x\}$

(b) Solve the problem numerically for the case in which $m = 3, p_i = 1/4$, for $i = 1, 2, 3, r_1 = 1, r_2 = 5, r_3 = 10$, and there are one or two more spins available.

At the beginning, the winning is 0, so must choose to spin.

$$f^{(2)}(0) = \begin{cases} f^{(1)}(1), \text{probability } 1/4 \\ f^{(1)}(5), \text{probability } 1/4 \\ f^{(1)}(10), \text{probability } 1/4 \\ 0 \quad \text{probability } 1/4 \end{cases}$$

$$f^{(1)}(x) = \begin{cases} x+1, \text{probability } 1/4 \\ x+5, \text{probability } 1/4 \\ x+10, \text{probability } 1/4 \\ 0 \quad \text{probability } 1/4 \\ x \quad \text{choose to stop} \end{cases}$$

So when spinning once, the excepted winnings are $1/4 \times (1 + 5 + 10) = 4$. And when spinning twice, $f^{(1)}(x) = 1/4 \times [(x+1) + (x+5) + (x+10)]$. $f^{(2)}(0) = 1/4 \times (f^{(1)}(1) + f^{(1)}(5) + f^{(1)}(10)) = 1/4 \times (4 + 3/4 + 4 + 15/4 + 4 + 30/4) = 6$

In particular, $f^{(0)}(x) = x, f^{(1)}(x) = \max\{3/4x + 4, x\}$. Let $3/4x + 4 = x$, $x = 16$. When $x > 16$, the participant will take away the winnings; when $x < 16$, the participant will spin again. Consequently, the expected total winnings are 16 for this case.

2-6

(a) Write down a recursion for $v(x)$ and use it to find an explicit expression for $v(x)$ in terms of $x, \Phi(x), I(x),$ and α, where $I(x) := E(X - x)^+ = \int_x^\infty (\xi - x)\phi(\xi)d\xi$.

$v(x,n) = v(x, n-1) \cdot \alpha \cdot \Phi(x) + \int_x^\infty \xi\phi(\xi)d\xi$

Let $V = \int_x^\infty \xi\phi(\xi)d\xi$.

$v(x,n) = v(x,1) \cdot [\alpha \cdot \Phi(x)]^{(n-1)} + V[1 + [\alpha \cdot \Phi(x)] + [\alpha \cdot \Phi(x)]^2 + \cdots + [\alpha \cdot \Phi(x)]^{n-2}]$

$v(x,1) = \int_x^\infty \xi\phi(\xi)d\xi = V$

Then we can obtain that $v(x) = V\frac{1-(\alpha\cdot\Phi(x))^n}{1-\alpha\cdot\Phi(x)}$, $\alpha \in (0,1)$. Because this is an infinite period, let $n \to \infty$, so $v(x) = \frac{V}{1-\alpha\cdot\Phi(x)}$.

$I(x) = \int_x^\infty (\xi - x)\phi(\xi)d\xi = \int_x^\infty \xi\phi(\xi)d\xi - x(1-\Phi(x))$

So $V = I(x) + x(1-\Phi(x))$, substitute it in the $v(x)$, we get $v(x) = \frac{I(x)+x(1-\Phi(x))}{1-\alpha\cdot\Phi(x)}$

(b) $\alpha = 0.99$ bids $\sim N(1000, 200)$. x = 1200. So $v(1200) = \frac{I(1200)+1200(1-\Phi(1200))}{1-\alpha\Phi(1200)}$, $I(1200) = 200I_N(1)$, $\Phi(1200) = \Phi_N(1) = 0.841$,$I_N(1) = \phi_N(1) - 1 + \Phi_N(1) = 0.083$.
By calculating, $v(1200) = 1238.9$

2-7

(a) Display Ω.

$\Omega = \{(3,3,1),(2,3,2),(2,2,2),(1,3,2),(2,3,1),(0,3,2),(1,3,1),(1,1,2),(2,2,1),(2,0,2),(3,0,1),(1,0,2),(2,0,1),(1,1,1),(0,0,2)\}$

(b) $S_0 = \{(3,3,1)\}$, $S_1 = \{(2,3,2),(2,2,2),(1,3,2)\}$,
$S_2 = \{(2,3,1)\}$, $S_3 = \{(0,3,2)\}$,
$S_4 = \{(1,3,1)\}$, $S_5 = \{(1,1,2)\}$,
$S_6 = \{(2,2,1)\}$, $S_7 = \{(2,0,2)\}$,
$S_8 = \{(3,0,1)\}$, $S_9 = \{(1,0,2)\}$,
$S_{10} = \{(2,0,1),(1,1,1)\}$, $S_{11} = \{(0,0,2)\}$.

m = 11.

3-4

(a) Write down a recursion for $f^n(x|S)$.

$f^{(n)}(x|S) = \sum_i f^{(n-1)}(x + r_i|S) \cdot p_i$.

$$f^{(n)}(x|S) = \begin{cases} \sum_i f^{(n-1)}(x + r_i|S) \cdot p_i, \text{ spin or } x < S. \\ x \quad \text{, stop.} \end{cases}$$

(b) Being indifferent means $\sum_i f^{(n-1)}(S + r_i|S) \cdot p_i = S = f^{(n)}(S|S) \Rightarrow \sum_i^m (S^* + r_i)p_i = S^* \Rightarrow S^* = \frac{\mu}{p}$.

3-5

(a) Write a recursion for f_n in terms of f_{n-1}

$f_n = f_{n-1} \cdot \alpha \cdot \Phi(\alpha f_{n-1}) + \int_{\alpha f_{n-1}}^{\infty} \xi\phi(\xi)d\xi$

Let $V = \int_{\alpha x}^{\infty} \xi\phi(\xi)d\xi = I(\alpha x) + \alpha x(1 - \Phi(\alpha x))$.

(b) Calculate f_n. $I_N(-0.05) = \phi_N(-0.05) - 1 + \Phi_N(-0.05) = 0.398 - 1 + 0.48 = -0.122$,

$V = I(990) + 990(1 - \Phi(990)) = 200 I_N(-0.05) + 990(1 - \Phi_N(-0.05)) = 200 \times (-0.12) + 990(1 - 0.48) = 490.5$

$f_2 = \alpha\mu\Phi(\alpha\mu) + \int_{\alpha\mu}^{\infty} \xi\phi(\xi)d\xi = 0.48 * 0.99 * 1000 + 490.5 = 965.7$

$f_3 = \alpha\Phi(\alpha f_2)f_2 + \int_{\alpha f_2}^{\infty} \xi\phi(\xi)d\xi = 916.5$

$f_4 = \alpha\Phi(\alpha x)f_3 + \int_{\alpha x}^{\infty} \xi\phi(\xi)d\xi = 843.3$

(c) Let $f_n = f_{n-1}$, we can obtain that $f_n = \alpha f_n \Phi(\alpha f_n) + I(\alpha f_n) + \alpha f_n(1 - \Phi(\alpha f_n))$. Obviously, we can obtain that $f_n = \frac{I(\alpha f_n)}{1-\alpha}$.

3-6

(a) Because there is a discount factor which is less than 1, when you wait it for a long period, your profit will be very low as time went by. So, it is obvious that we don't need to wait for all bids to be received.

(b)

$$f_n(x) = \begin{cases} \alpha f_{n-1}(x/\alpha), \text{not accept this period.} \\ \alpha^t x \quad \text{, accept.} \end{cases}$$

$f_n(x) = \alpha f_{n-1}(x/\alpha) \int_{x/\alpha}^{\infty} \phi(\xi) d\xi + \alpha^t x \Phi(x/\alpha)$

To be honest, I'm confused by this question....

4-4

The original formulation is $v(x,S) = \begin{cases} c & \text{if } x = 0 \\ px + qv(x-1,S) & \text{if } 1 \le x \le S \\ v(S,S) & \text{if } S < x \end{cases}$, for this case, we can continue drive until we find an unoccupied space. So define a function $F(x), f(x,i)$, where $x < 0$.

$F(x) = pf(x,0) + qf(x,1)$ and

$f(x,i) = \begin{cases} -x & \text{if } i = 0 \\ F(x-1) & \text{if } i = 1 \end{cases}$

$i = 0$ means the space isn't occupied, only choose to park here. Now, we can obtain $F(x) = p(-x) + qF(x-1) = p(\sum_{i=-x}^{n-x-1} iq^{i+x}) = \frac{q[1+(n-1)q^n - nq^{n-1}]}{(1-q)^2} - x\frac{1-q^n}{1-q}, x < 0$, let $n = \infty, F(-1) = \frac{1}{(1-q)^2}$

Let $v(0,S) = F(-1)$, we can obtain the formulation for this question:

$$v(x,S) = \begin{cases} v(0,S) = \frac{1}{(1-q)^2} & \text{if } x = 0 \\ px + qv(x-1,S) & \text{if } 1 \le x \le S \\ v(S,S) & \text{if } S < x \end{cases}$$

Consequently, $v(S,S) = p\sum_{i=0}^{S} q^i(S-i) + q^S \frac{1}{(1-q)^2} = S - \frac{q(1-q^S)}{p} + q^S \frac{1}{(1-q)^2}$.

4-5

Define $G^n(x) = -x + \sum_i^m f^{n-1}(x + r_i)p_i$.

The derivative of $G^n(x)$ equals $(-1 + \sum_i^m f'^{n-1}(x + r_i)p_i)$, because $f^{n-1}(x + r_i)$ is a linear function of x, and the coefficient of x is 1. So $\sum_i^m f'^{n-1}(x + r_i)p_i = \sum_i^m p_i = 1 - p < 1$. So the derivative of $G^n(x)$ is less than 0. Therefore, $G^n(x) < G^n(x + 1)$. According to Exercise 3.4, the decision rule we decided is indeed optimal.