STOCHASTIC PROCESSES

Math36: Solution Sheet Four

Problem 1. Let X be the Markov chain with statespace $I = \{A, B, C\}$ with one-step transition matrix

$$P = \begin{pmatrix} 1/4 & 1/4 & 1/2 \\ 1/3 & 1/3 & 1/3 \\ 2/7 & 4/7 & 1/7 \end{pmatrix}.$$

Recall that T_j denotes the first positive time that the chain reaches state j, for $j \in \{A, B, C\}$.
(a) Give an intuitive argument why $\mathrm{P}_A\{T_C \leq n\} = (\hat{P}^n)_{AC}$ for the one-step transition matrix

$$\hat{P} = \begin{pmatrix} 1/4 & 1/4 & 1/2 \\ 1/3 & 1/3 & 1/3 \\ 0 & 0 & 1 \end{pmatrix}.$$

Solution: The Markov chain $\hat{X}$ is the same as X, except that the moving particle is trapped once it reaches state C. Hence $\hat{X}_n = C$ whenever the chain has reached state C before time n, i.e. if $T_C \leq n$. Hence $\mathrm{P}_A\{T_C \leq n\} = \mathrm{P}_A\{\hat{X}_n = C\} = (\hat{P}^n)_{AC}$. To make this intuitive argument rigorous one has to make the term 'is the same' more precise. We write $\hat{T}_C$ for the first hitting time of C by the chain $\hat{X}$. Then

$$\begin{aligned}
(\hat{P}^n)_{AC} &= \mathrm{P}_A\{\hat{X}_n = C\} = \sum_{j=1}^{n} \mathrm{P}_A\{\hat{T}_C = j\} \\
&= \sum_{j=1}^{n} \sum_{x_1, \ldots, x_{j-1} \neq C} \hat{p}_{Ax_1} \hat{p}_{x_1 x_2} \cdots \hat{p}_{x_{j-2} x_{j-1}} \hat{p}_{x_{j-1} C} \\
&= \sum_{j=1}^{n} \sum_{x_1, \ldots, x_{j-1} \neq C} p_{Ax_1} p_{x_1 x_2} \cdots p_{x_{j-2} x_{j-1}} p_{x_{j-1} C} \\
&= \sum_{j=1}^{n} \mathrm{P}_A\{T_C = j\} = \mathrm{P}_A\{T_C \leq n\}.
\end{aligned}$$

One uses here that the probability $\mathrm{P}_A\{\hat{T}_C = j\}$ can be calculated using only the top two rows of the P-matrix.

(b) For the Markov chain $\hat{X}$, find the probability that the state B is visited, when the chain is started in A. Also find the probability that the state B is visited at least twice!
Solution: Let x_A, x_C be the hitting probabilities of B when the chain starts in A resp. B. Then the first-step method gives

$$x_A = 1/4 x_A + 1/2 x_C + 1/4, x_C = 0,$$

hence $\mathrm{P}_A\{\hat{T}_B < \infty\} = x_A = 1/3$. The probability that B is visited exactly once is

$$\mathrm{P}_A\{\hat{T}_B < \infty\} \mathrm{P}_B\{\hat{T}_B = \infty\} = x_A(1 - x_B).$$

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