Math 312 Lecture Notes
Markov Chains

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Markov Chains

A (finite) Markov chain is a process with a finite number of states (or outcomes, or events) in which the probability of being in a particular state at step $n + 1$ depends only on the state occupied at step n.

Let $S = \{S_1, S_2, \ldots, S_r\}$ be the possible states. Let

$$\mathbf{p}_n = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_r \end{bmatrix} \tag{1}$$

be the vector of probabilities of each state at step n. That is, the ith entry of $\mathbf{p}_n$ is the probability that the process is in state S_i at step n. For such a probability vector, $p_1 + p_2 + \cdots + p_r = 1$.

Let

$$p_{ij} = \text{Prob}(\text{ State } n + 1 \text{ is } S_i \mid \text{State } n \text{ is } S_j). \tag{2}$$

and let

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1r} \\ p_{21} & p_{22} & \cdots & p_{2r} \\ \vdots & & \ddots & \\ p_{r1} & & & p_{rr} \end{bmatrix} \tag{3}$$

That is, p_{ij} is the (conditional) probability of being in state S_i at step $n + 1$ given that the process was in state S_j at step n. P is called the *transition matrix*. P contains all the conditional probabilities of the Markov chain. It can be useful to label the rows and columns of P with the states, as in this example with three states:

$$\text{State } n + 1 \left\{ \begin{matrix} & \overbrace{\begin{matrix} S_1 & S_2 & S_3 \end{matrix}}^{\text{State } n} \\ \begin{matrix} S_1 \\ S_2 \\ S_3 \end{matrix} & \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix} \end{matrix} \right.$$

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