# Pol Sci 630: Problem Set 2 - Properties of Random Variables

Prepared by: Anh Le (anh.le@duke.edu)

Due Date: Tuesday, September 8, 2015, 10 AM (Beginning of Class)

Note 1: It is absolutely essential that you show all your work, including intermediary steps, and comment on your R code to earn full credit. Showing all steps and commenting on code them will also be required in future problem sets.

Note 2: Please use a *single* PDF file created through knitr to submit your answers. knitr allows you to combine R code and LaTeX code in one document, meaning that you can include both the answers to R programming and math problems. Also submit the source code that generates the PDF file (i.e. either .Rnw or .Rmd files)

Note 3: Make sure that the PDF files you submit do not include any references to your identity. The grading will happen anonymously. You can submit your answer at the following website: `http://ps630-f15.herokuapp.com/`

## 1. Expected Value and Its Properties

### a.

(1 point) (DeGroot, p. 216) Suppose that one word is to be selected at random from the sentence "the girl put on her beautiful red hat''. If $X$ denotes the number of letters in the word that is selected, what is the value of $E(X)$?

### b.

(2 point) (Degroot p. 216) Suppose that one letter is to be selected at random from the 30 letters in the sentence given above. If $Y$ denotes the number of letters in the word in which the selected letter appears, what is the value of $E(Y)$?

Hint: 1a) and 1b) force you to think carefully about the definition of expectation value. For each problem, think about what is your random variable ($X$), which values it takes on ($x \in \{?, ?, ...\}$) and with what probability ($P(X = x) =?$)

### c.

(1 point) (Degroot, p. 224) Suppose that three random variables $X_1$, $X_2$, $X_3$ are uniformly distributed on the interval [0, 1]. They are also independent. Determine the value of $E[(X_1 - 2X_2 + X_3)^2]$.

## 2. Variance and its properties

For this problem, you can use the properties of expected value.

### a.

(1 point) Prove that $Var(aX + b) = a^2 Var(X)$.

### b.

(2 points) Prove that if two random variables are independent, the variance of the sum is the sum of the variance. In other words, if $X_1, X_2$ are independent, then

$$Var(X_1 + X_2) = Var(X_1) + Var(X_2)$$

### c.

(1 point) (Degroot, p. 232) Suppose that one word is selected at random from the sentence 'the girl put on her beautiful red hat'. If $X$ denotes the number of letters in the word that is selected, what is the value of $Var(X)$?

## 3. Binomial distribution (4 points)

(Credit to Jan) This problem is taken from Pitman (1993) Probability

Suppose a fair coin is tossed n times. Find a simple formula in terms of n and k for the following probability: $Pr(k\ heads | k-1\ heads\ or\ k\ heads)$. Please pay close attention to the formula, particularly what event is conditioned on what events. (Ch. 2.1, Problem 10 b) (p. 91)

Hint 1: Use the binomial distribution to model this.

Hint 2: Because those events are mutually exclusive, calculate the following:

$$\frac{Pr(k\ heads)}{Pr(k\ heads) + Pr(k-1\ heads)}$$

This is true because: $Pr(A|B) = \dfrac{Pr(A \cap B)}{Pr(B)}$

The intersection of events A and B in this case, $Pr(k\ heads \cap (k\ heads \cup k-1\ heads))$, reduces to $Pr(k\ heads)$ because the two events are mutually exclusive.

## 4. Plotting distribution (4 points)

For this problem, you'll need to Google some R techniques (e.g. side-by-side / overlapping plot). Also, label the axes and the plots accordingly.

### a.

(1 point) Download a variable you are interested in, using `WDI`. Plot the histogram, density plot, boxplot, and normal quantile plot.

### b.

(1 point) Plot the histogram of that variable for Europe and Asia, 1) side by side (Hint: `par(mfrow=c(?, ?))`), and 2) overlapping in the same plot.

### c.

(1 point) Draw the scatterplot of that variable against another variable of interest. Is the bi-variate relationship as you expected?

### d.

(1 point) Label the point that represents your country (Hint: Tutorial) and color it red (some Googling may be necessary)