STA286 Lecture 08

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Last edited: 2017-01-27 10:59

joint distributions

more than one random variable at a time

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Main interest is in statements like:

$$P(X = x, Y = y) \qquad \text{or} \qquad P(a < X < b, c < Y < d)$$

where the "comma" notation is a compact way of writing, say:

$$P(\{X = x\} \cap \{Y = y\})$$

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They also have cdfs:

$$F(x, y) = P(X \leqslant x, Y \leqslant y)$$

but we won't focus much on these.

a joint pmf

A gas distribution company has pipes with diameters 1, 1.5, and 1.75 inches. The pipes are used at pressures of 2, 1, and 0.5 pounds per square inch.

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X and Y might have the following *joint probability mass function*:

	X		
Y	1	1.5	1.75
0.5	0.075	0.100	0.150
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e.g. the probability that a randomly selected pipe has diameter $X = 1.5$ and pressure $Y = 0.5$ is:

$$P(X = 1.5, Y = 0.5) = 0.1$$

joint pmf properties; joint density

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A joint density also must be non-negative and integrate to 1 over all $\mathbb{R}^2$.

joint density example - I

Two electronic components fail at times X and Y according to the following joint density (measured in years):

$$f(x,y) \begin{cases} 2e^{-x-2y} & : x > 0, y > 0 \\ 0 & : \text{otherwise} \end{cases}$$

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Is this actually a valid joint density? It is non-negative, and:

$$\iint_{\mathbb{R}^2} f(x,y)\,dxdy = \int_0^\infty \int_0^\infty 2e^{-x-2y}\,dxdy = \int_0^\infty e^{-x}\,dx \int_0^\infty 2e^{-2y}\,dy = 1$$

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&= \left[-e^{-2y} + \frac{2}{3}e^{-3y}\right]_{y=0}^{\infty}
\end{aligned}
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$$= \frac{1}{3}$$

marginal distributions

A joint distribution contains *all* information about both X and Y together.

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For example, look again at the joint distribution for diameter X and pressure Y of the randomly selected pipe:

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A statement about X alone could be something like $P(X = 1)$, which is just $0.075 + 0.11 + 0.16 = 0.345$

marginal pmf

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Here are the "marginals" for both X and Y in the gas example:

	X			
Y	1	1.5	1.75	Marginal
0.5	0.075	0.100	0.150	0.325
1	0.110	0.080	0.090	0.280
2	0.160	0.140	0.095	0.395
Marginal	0.345	0.320	0.335	1.000

marginal density

Reconstider the two electronic components example:

$$f(x,y)\begin{cases}2e^{-x-2y} & : x>0, y>0\\ 0 & : \text{otherwise}\end{cases}$$

A statement about, say, Y alone might be $P(Y>1)$, which would be the integral on the entire half plane $y>1$:

$$\iint\limits_{y>1} f(x,y)\,dxdy$$

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$$\iint\limits_{y>1} f(x,y)\,dxdy = \int\limits_{1}^{\infty}\int\limits_{0}^{\infty} 2e^{-x-2y}\,dxdy$$

But in the end, the calculation only ever involved $2e^{-2y}$ once x was "integrated out."

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e.g. Consider the following function:

$$f(x, y) = \begin{cases} 2 & : 0 < x < 1,\ 0 < y < 1,\ x + y < 1 \\ 0 & : \text{otherwise} \end{cases}$$

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This is a valid density. Let X and Y have this joint density.

marginal density

The marginal density for X will be 0 outside $x \in (0, 1)$. Otherwise:

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