Probability Basics

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Probability Background

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- you talk of the probability of a particular feature value: $P(X = a)$
- standard frequentist interpretation is that the systems can be observed over and over again, and that the relative frequency of $X = a$ in all the observations tends to a stable fixed value as the number of observations tends to infinity. $P(X = a)$ is this limit

$$P(X = a) = \lim_{N \to \infty} freq(X = a)/N$$

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- for example, the 'event' of dice throw being even can be described as $(X = 2 \vee X = 4 \vee X = 6)$
- the relative freq. of (2 *or* 4 *or* 6) is by definition the same as the $(rel.freq\ 2) + (rel.freq.\ 4) + (rel.freq.\ 6)$. So its not surprising that by definition the probability of an 'event' is the sum of the mutually exclusive atomic possibilities that are contained within it (ie. ways for it to happen) so

$$P(X = 2 \vee X = 4 \vee X = 6) = P(X = 2) + P(X = 4) + P(X = 6)$$

Independence of two events

- suppose two 'events' A and B . If the probability of $A \wedge B$ occuring is just the probability A occuring times the probability of B occuring, you say the events A and B are independent

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- This is defined to be

Conditional Prob

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- since $P(A|B)P(B) = P(B|A)P(A)$, you also get the famous

Bayesian Inversion

$$P(A|B) = \frac{P(A \wedge B)}{P(B)} = \frac{P(B|A)P(A)}{P(B)}$$

Alternative expressions of independence

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NOTE: each of these *on its own* is equivalent to $P(A \wedge B) = P(A) \times P(B)$

- Suppose > 1 feature/attribute of your system/situation eg. rolling a red & a green dice. Using X for red & Y for green can specify events with their values and their probs with expressions such as:[1]

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- can wish to consider the probs of events specified by the value on just one feature (eg. those where X=1) and the probs. of these are called marginal probabilities and are obtained by summing the joints with all possible values of the other feature

$$P(X = 1) = \sum_{b \in B} P(X = 1, Y = b)$$

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- the conditional probability function for two features X and Y is

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  so for any pair of values a for X and b for Y, the value of this function is $P(X=a, Y=b)/P(Y=b)$
- you say $P(X|Y) = P(X)$ and the features X and Y are independent in case for every value a for X and b for Y you have

$$\frac{P(X=a, Y=b)}{P(Y=b)} = P(X=a)$$

Chain Rule

- generalising to more variables, you can derive the indispensable

chain rule

$$P(X, Y, Z) = P(Z|(X, Y)) \times P(X, Y) = P(Z|(X, Y)) \times P(Y|X) \times P(X)$$

$$P(X_1 \ldots X_n) = P(X_n|(X_1 \ldots X_{n-1})) \times \ldots \times P(X_2|X_1) \times P(X_1)$$

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Notation: typically $P(Z|(X, Y))$ is written as $P(Z|X, Y)$

Conditional Independence

- there is a notion of conditional independence. It may be that two variables X and Y are not in general independent, but given a value for a third variable Z, X and Y become independent.

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- Real-life cases of this arise where Z describes a *cause*, which manifests itself into two *effects* X and Y, which though very dependent on Z, do not directly influence each other
- The theories behind Speech Recognition and Machine Translation typically make a lot of *conditional independence* assumptions