What sets Bayes apart?

ESS 575 Models for Ecological Data

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January 23, 2019

Graduate Degree Program in Ecology
Department of Ecosystem Science and Sustainability
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Today

- A high elevation view of approaches for statistical inference
- Some motivation for learning
- The basic ideas of Bayesian inference

Exercise

What sets statements of scientists apart from statements made by journalists, lawyers, and logicians?

Exercise

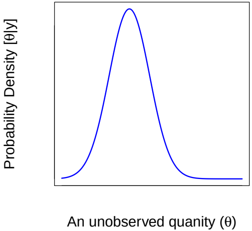
Write out the definition of a frequentist, 95% confidence interval on a parameter of interest, θ.

Frequentist confidence interval

1. In frequentist statistics, a 95% confidence interval represents an interval such that if the experiment were repeated 100 times, 95% of the resulting confidence intervals (e.g.. average + or - 1.96 * standard error) would contain the true parameter value.
2. In a narrower sense, a CI for a population parameter is an interval with an associated proportion p that is generated from a random sample of an underlying population such that if the sampling was (sic) repeated numerous times and the confidence interval recalculated from each sample according to the same method, a proportion p of the confidence intervals would contain the population parameter in question.

Exercise

Describe how Bayesian analysis differs from other types of statistical analysis.



- All unobserved quantities are treated as *random variables*.
- A random variable is a quantity whose behavior is governed by chance.
- Probability distributions are mathematical abstractions of "governed by chance."
- We seek to understand the characteristics of these probability distributions.

Some notation

- y data
- $\boldsymbol{\theta}$ a parameter or other unknown quantity of interest
- $[y|\boldsymbol{\theta}]$ The probability distribution of y conditional on $\boldsymbol{\theta}$
- $[\boldsymbol{\theta}|y]$ The probability distribution of $\boldsymbol{\theta}$ conditional on y
- $[y|\boldsymbol{\theta}] = P(y|\boldsymbol{\theta}) = p\,(y|\boldsymbol{\theta}) = f\,(y|\boldsymbol{\theta}) = f\,(y, \boldsymbol{\theta})$, different notation that means the same thing.

Board work on confidence envelopes

Define a confidence interval

Prior data on the exercise from faculty, researchers, and graduate students at:

- Swedish Agricultural University
- University of Alaska Anchorage
- Woods Hole Research Institute
- Conservation Science Partners
- ESS 575 2017

Cut to R to illustrate updating with today's data.

What sets Bayes apart?

- We divide the world into things that are observed (y) and things that unobserved (θ).
- The unobserved quantities (θ) are *random variables.* The data are random variables before they are observed and fixed after they have been observed.
- We seek to understand the probability distribution of θ using fixed observations, i.e., $[\theta|y]$.
- Those distributions quantify our uncertainty about θ.

What sets Bayes apart?

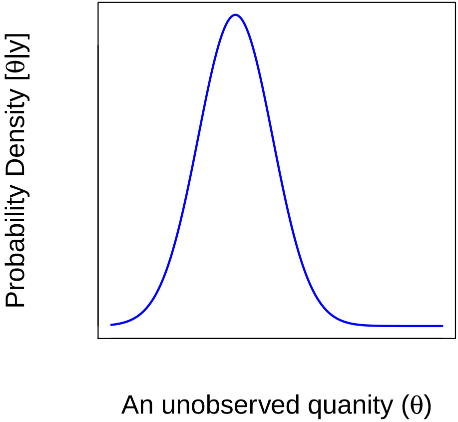
Treating unobserved quantities as random variables is profound.

What sets Bayes apart?

All unobserved quantities are treated in exactly the same way.

- Parameters
- Latent states
- Missing data
- Censored data
- Predictions
- Forecasts

What sets Bayes apart?



Current knowledge → New data → Updated knowledge

You can understand it.

KEY TO STATISTICAL METHODS

	Design or Purpose	Measurement Variables	Ranked Variables	Attributes
1 variable 1 sample	Examination of a single sample	Procedure for grouping a frequency distribution, Box 2.1; stem-and-leaf display, Section 2.5; testing for outliers, Section 13.4 Computing median of frequency distribution, Box 4.1 Computing arithmetic mean: unordered sample, Box 4.2; frequency distribution, Box 4.3 Computing standard deviation: unordered sample, Box 4.2; frequency distribution, Box 4.3 Setting confidence limits: mean, Box 7.2; variance, Box 7.3 Computing g_1 and g_2, Box 6.2		Confidence limits for a percentage, Section 17.1 Runs test for randomness in dichotomized data, Box 18.3
	Comparison of a single sample with an expected frequency distribution	Normal expected frequencies, Box 6.1 Goodness of fit tests: parameters from an extrinsic hypothesis, Box 17.1; from an intrinsic hypothesis, Box 17.2 Kolmogorov–Smirnov test of goodness of fit, Box 17.3 Graphic "tests" for normality: large sample sizes, Box 6.3; small sample sizes (rankit test), Box 6.4 Test of sample statistic against expected value, Box 7.4		Binomial expected frequencies, Box 5.1 Poisson expected frequencies, Box 5.2 Goodness of fit tests: parameters from an extrinsic hypothesis, Box 17.1; from an intrinsic hypothesis, Box 17.2
1 variable ⩾2 samples	Single classification	Single classification anova: unequal sample sizes, Box 9.1; equal sample sizes, Box 9.4 Planned comparison of means in anova, Box 9.8; single degree of freedom comparisons of means, Box 14.10 Unplanned comparison of means: T-method, equal sample sizes, Box 9.9; T′, GT2, and Tukey–Kramer, unequal sample sizes, Box 9.10; Welsch step-up, Box 9.11; STP test, Section 9.7; contrasts using Scheffé, T, and GT2, Box 9.12; multiple confidence limits, Section 14.10 Estimate variance components: unequal sample sizes, Box 9.2; equal sample sizes, Box 9.3 Setting confidence limits to a variance component, Box 9.3 Tests of homogeneity of variances, Box 13.1 Tests of equality of means when variances are heterogeneous, Box 13.2	Kruskal–Wallis test, Box 13.5 Unplanned comparison of means by a nonparametric STP, Box 17.5	*G*-test for homogeneity of percentages, Boxes 17.5 and 17.8 Comparison of several samples with an expected frequency distribution, Box 17.4; unplanned analysis of replicated tests of goodness of fit, Box 17.5
	Nested classification	Two-level nested anova: equal sample sizes, Box 10.1; unequal sample sizes, Box 10.4 Three-level nested anova: equal sample sizes, Box 10.3; unequal sample sizes, Box 10.5		
	Two-way or multi-way classification	Two-way anova: with replication, Box 11.1; without replication, Box 11.2; unequal but proportional subclass sizes, Box 11.4; with a single missing observation, Box 11.5 Three-way anova, Box 12.1 More-than-three-way classification, Section 12.3 and Box 12.2 Test for nonadditivity in a two-way anova, Box 13.4	Friedman's method for randomized blocks, Box 13.9	Three-way log-linear model, Box 17.9 Randomized blocks for frequency data (repeated testing of the same individuals), Box 17.11

You can understand it.

P value :

A number that shows the likelyhood that a value is the same as another

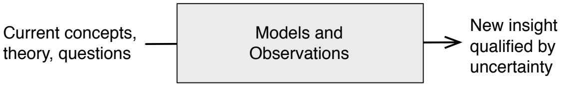
Confidence Interval - ~~shows~~ A range of values that we have a certain level of confidence our value of interest falls in.

1) Definition of Pvalue
The probability of the significant difference between measured (observed) value & other measured values

2) What is confidence Interval?
The range of measured (observed) value
true population mean can occur within it

You can understand it.

- Rules of probability
  - Conditioning and independence
  - Law of total probability
  - Factoring joint probabilities
- Distribution theory
- Markov chain Monte Carlo



One approach applies to many problems

- An unobservable state of interest, z
- A deterministic model of a process, $g\left(\boldsymbol{\theta}, x\right)$, controlling the state.
- A model of the data
- Models of parameters