William Briggs

Uncertainty

The Soul of Modeling, Probability & Statistics

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Uncertainty

To my beautiful and patient wife.
It's about time.

Foreword

Quid est veritas? ("What is truth?") Even if detached from its religious roots, perhaps especially if detached from its religious roots, this is the most serious question a human being can ask. For if we do not have a comprehensible conception of what truth is, then we lack the foundation on which all statements must rest. While it is not the case that we presently speak only cacophony and write only nonsense, if our conceptions of certainty and uncertainty are murky, we then proceed with a disturbing absence of attachment of practice to justification.

And yet, for decades, indeed centuries, the accepted conception of truth has been one of skepticism, a denial that truth exists in more than a probabilistic manner. In this book, William Briggs challenges this accepted wisdom with powerful arguments explained most cogently. With airtight, deep logic, he exposes weaknesses of probability, statistics, causality, modeling, deciding, communicating, and uncertainty—the whole kit and caboodle, "everything to do with evidence."

This is no small claim, and I approached Briggs's work with some skepticism of my own. After all, our conceptions of probability, statistics, and the rest have seemed to work pretty well. Then I read Briggs's book.

Much of the first part of this book, indeed the gist before Briggs gets to work on his positive insights, is refutation of our accepted concepts of probability statistics, evidence, chance, randomness, regression analysis, parameters, hypothesis testing, and a host of other concepts insufficiently questioned until now.

All this sets the stage for Briggs's central point: All truths are known because of the conditions assumed. All probability, like all truth, is conditional. All truths that are known are known because of the conditions assumed.

Briggs brings to his work the widest range of relevant competencies. He has applied his extensive training and research to a wide range of analyses including cryptology, weather forecasting, prediction (and, perhaps most tellingly, the basic failure of prediction), and, more generally, philosophy of science and epistemology.

Briggs's central point is that truth exists, but in a world currently plagued by an over-certainty, which "is already at pandemic levels." It is the failure to understand that all probability is conditional on evidence and resides in the mind, not in objects—probability has no ontological existence—that makes this pandemic possible.

In practice, and in all of science, conditional truths are far more relevant than are necessary truths. While thought could not proceed without necessary truths (P is P and not P is not-P), it is probability and conditional truth that is the launch pad for Briggs's great many original thoughts and the arena that surrounds and binds them.

Uncertainty presupposes, and demonstrates, the existence of truth. Uncertainty must be about something. You cannot be uncertain about nothing. The something implied by uncertainty means that truth exists. Without truth there can be no probability. Since there is probability, there must be truth.

Despite this, probability, and more generally our conception of truth—indeed our conception of anything—must inevitably be anchored in a metaphysical ground. Our understanding of essence and our incomplete and often faulty knowledge of it make this inevitable

Probability is the central issue in this book. Beginning with the traditional definition of logic—the relationship between propositions, and with the separation of the logical from the empirical—Briggs emphasizes and exploits the fact that probability, too, concerns the relationship between propositions. "The rest," he writes, "is mere detail."

Probability is epistemologically conditional. It can be epistemologically true, but it does not exist in ontological reality, but in the epistemology of the mind. Unlike the moon, or the stars, or human beings, probability does not have an existence in reality.

Mathematical proofs depend on premises and chains of premises; proofs found to be incorrect are nearly always found so not on the basis of miscalculation, but of the failure to take into account a necessary constraint. (It is interesting that proofs shown to be incorrect are virtually always demonstrated to be incorrect for this reason and not because their conclusions are incorrect. The conclusions are virtually always shown to be correct by a later proof.)

This book is full of subtle surprises. For example, it is almost universally assumed that deductive proofs are certain, while inductive arguments are uncertain. "But because we know indubitable propositions more surely than any other, induction produces greater certainty than deduction."

As central as are Briggs's methodological insights, equally crucial are their implications for decision-making. Thus, for example, his suggestion that we eliminate hypothesis testing, which serves merely to affirm biases, would go far to improve the decisions resting on probability.

What I have written here is but a glance at the foundation on which Briggs's edifice rests. The deepest satisfaction to the reader of *Uncertainty* resides in following Briggs's thought and logic and the explanation they generate. Anyone who does so will find that this is a marvelous, marvelous book.

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January 2016

Steven Goldberg

Preface

Fellow users of probability, statistics, and computer "learning" algorithms, physics and social science modelers, big data wranglers, philosophers of science, epistemologists, and other respected citizens. We're doing it wrong.

Not completely wrong; not everywhere; not all the time; but far more often, far more pervasively, and in far more areas than you'd imagine.

What are we doing wrong? Probability, statistics, causality, modeling, deciding, communicating, uncertainty. Everything to do with evidence.

Your natural reaction will be—this is a prediction based on plentiful observations and simple premises—"Harumph." I can't and shouldn't put a numerical measure to my guess, though. That would lead to over-certainty, which I will prove to you is already at pandemic levels. Nor should I attempt to quantify your *harumphiness*, an act which would surely contribute to scientism, which is when pseudo-numerical values assigned to mental states are taken as scientific.

Now you may well say "Harumph," but consider that there are people who think statistical models prove causality or the truth of "hypotheses," that no probability can be known with certainty until the sound of the last trump, that probabilities can be read from mood rings, that induction is a "problem," that randomness is magic, that chance is real, that parameters exist, that p-values validate or invalidate theories, that computers learn, that models are realer than observations, and that model fit is more important than model performance.

And that is only a sampling of the oddities which beset our field. How did we go awry? Perhaps because our training as "data scientists" (the current buzzword) lacks a proper foundation, a firm philosophical grounding. Our books, especially our introductions, are loaded with a legion of implicit metaphysical presumptions, many of which are false or which contradict one another. The student from the start is plunged into formula and data and never looks back; he is encouraged not to ask too many questions but instead to calculate, calculate, calculate. As a result, he never quite knows where he is or where he's going, but he knows he's in a hurry.

The philosophical concepts which are necessarily present aren't discussed well or openly. This is only somewhat rectified once and if the student progresses to the highest levels, but by that time his interest has been turned either to mathematics or

to solving problems using the tools with which he is familiar, tools which appear "good enough" because everybody else is using them. And when the data scientist (a horrid term) finally and inevitably weighs in on, say, "what models really are," he lacks the proper vocabulary. Points are missed. Falsity is embraced.

So here is a philosophical introduction to uncertainty and the practice of probability, statistics, and modeling of all kinds. The approach is Aristotelian. Truth exists; we can know it, but not always. Uncertainty is in our minds, not in objects, and only sometimes can we measure it, and there are good and bad ways of doing it.

There is not much sparkling new in this presentation except in the way the material is stitched together. The emphasis on necessary versus local or conditional truth and the wealth of insights that brings will be unfamiliar to most. A weakness is that because we have to touch on a large number of topics, many cannot be treated authoritatively or completely. But then the bulk of that work has been done in other places. And a little knowledge on these most important subjects is better than none, the usual condition. Our guiding light is Thomas Aquinas, *ora pro nobis*, who said, "The smallest knowledge that may be obtained of the highest things is more desirable than the most certain knowledge obtained of lesser." It is therefore enough that we form a fair impression of each topic and move onward. The exceptions are in understanding *exactly* what probability is and, as importantly, what it is *not* and in comprehending just what models are and how to tell the good from the bad.

This isn't a recipe book. Except for simple but common examples, this book does not contain the usual lists of algorithms. It's not that I didn't want them, it's more that many proper ones don't yet exist or aren't well understood; and anyway, they can be a distraction. This book is, however, a guide on how to create such recipes and lists, as well as a way to shoehorn (when possible) older methods into the present framework when new algorithms haven't yet been created. This book is thus ideal for students and researchers looking for problems upon which to work. The mathematical requirements are modest: This is not a math book. But then probability is not a mathematical subject, though parts of it are amenable to calculation.

Some will want to know what to call this unfamiliar new theory. Well, it isn't a theory. It is the way things are. The approach taken is surely not frequentist, a method which compounds error upon error, but it is also not Bayesian, not in the usual sense of that term, though it is often close in spirit to objective Bayesianism. There is no subjectivism here. The material here is closely aligned to Keynes's, Stove's, and Jaynes's logical probability. Many elements from the work of these and similar gentlemen are found here, but there are also subtle and important differences. If a name must be given, probability as argument is as good as any, though I prefer simply probability.

If we're doing it wrong, what's right? Return to understanding cause. Models should be used to make probabilistic predictions of observable entities. These predictions can, in turn, be used to make decisions. If the predictions fail, the models fail and should be abandoned. Eliminate all forms of hypothesis testing, Bayesian or frequentist, and forever banish p-values, which only serve to confirm biases. Do not speak of parameters; talk of reality, of observables. This alone will go miles toward eliminating the so-called replication crisis.

Here is the book in brief. All truth is conditional on or with respect to something. There are thus necessary or universal and conditional or local truths. Truth resides in the mind and not in objects except in the sense that objects exist or not. Truth is not relative in the modern sense of that word. Probability aims at truth. We come to know many truths via induction, which is widely misunderstood and is not a "problem"; indeed, it provides the surest form of knowledge. Logic is the study of the relationship *between* propositions and so is probability. All probability, like all truth, is therefore known because of the conditions assumed.

Most probabilities are not quantifiable, but some are. Probability is not subjective, and limiting relative frequency is of no use to man or beast. Chance and randomness are not mystical entities or causes; they are only other words for ignorance. Science is of the empirical. Models—whether quantum mechanical, medical, or sociological—are either causal or explanative. Causal models, which are in reality as rare as perfect games (baseball, of course), provide certainty, and explanative models state uncertainty. Probabilistic models are thus not causal (though they may have causal elements).

Bayes is not what you think. Hypothesis testing should immediately and forever be tossed onto the scrap heap of intellectual history and certainly never taught to the vulnerable. Probability is not decision. The parameter-centric, even parameter-obsessed, way of thinking about models must also be abandoned; its use has led to widespread, enormous over-certainty and caused more than one soul to be lost to scientism. Its replacement? If somebody asks, "How does changing X change my uncertainty in Y" *tell them that* and nothing else. Models, which provide the basis of these statements, are and must be checked against reality. The best way to check against reality is conditional on the decisions to which models are put. The most common, widespread errors that come in failing to not treating probability logically are shown, including the common mistakes made in regression, risk measures, the overreliance on questionnaires, and so on.

The language used in this book will not be familiar to regular users of probability and statistics. But that is rather the point. It ought to be. Along the way we'll solve things like induction, Gettier "problems," Grue, the Doomsday Argument, so-called paradoxes in probability assignment, the reproducibility crisis, and much more.

How working statisticians and probabilists should read this book. Start with Chap. 6 "Chance and Randomness," and then read the four successive chapters "Causality," "Probability Models," "Statistical and Physical Models," and "Modeling Strategy and Mistakes." After this, return to the beginning for the proofs of the assumptions made in those chapters.

Everybody else, and in particular students, should start at the beginning.

Manhattan Island, New York City, NY, USA William Briggs
December 2015

Acknowledgments

Pretium non pro veritate.

The motivation behind the tone and structure of this book can be summarized in the old saying (slightly modified), "The love of theory is the root of all evil." The text itself is owed to four men whom I have never met: Aristotle, St. Thomas Aquinas, David Stove, and E.T. Jaynes. My task has been to take what these geniuses have provided and to synthesize out of it a philosophy of uncertainty for an age over-devoted to the appearance of certainty. As for originality, my book stands in the same class as Jeeves's suggested work *The Children's Book of American Birds*, which he had, through an unknown impecunious author in the name of a certain Corky, dedicated to one Alexander Worple, so that Bertie Wooster's pal Corky, who was the nephew of this Worple and who was on a tight allowance controlled by his uncle, could ingratiate himself to Worple, the selfsame Alexander Worple who was the author of the acclaimed *American Birds* and *More American Birds*.

I thank Russell Zaretzki, with whom I discussed and developed some of the material in Chap. 8 on the problem and origin of parameters. Thanks also to Christopher Monckton, 3rd Viscount Monckton of Brenchley, Willie Soon, and David Legates, all of whom have contributed to the material on time series in the final chapter. I thank Samuel Bacharach at Cornell University for providing me employment while writing. John Watkins read through the manuscript and provided helpful comments. Finally, I thank the dedicated readers of my blog, who have encouraged me and sharpened my thinking over the years. A book page at my site is available for updates, homework, and so forth: Go to wmbriggs.com/book.

Steven Goldberg is credited with the book's title. I had run through dozens of possibilities, all of them clunky and cumbersome or narrow and misleading.

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Chapter 1
Truth, Argument, Realism

"Quid est veritas?"

The answer to the above, perhaps the most infamous of all questions, was so obvious that Pilate's interlocutor did not bother to state it. Truth was there, in the flesh, as it were, and utterly undeniable. Everyone knows the sequel. Since that occasion, at which the answer was painfully obvious, the question has been re-asked many times, with answers becoming increasingly skeptical, tortured, and incredulous. The reasons for this are many, not the least of which is that denial of truth leads to interesting, intellectually pleasing, unsolvable but publishable puzzles.

Skepticism about truth is seen as sophistication; works transgressive to truth are rewarded, so much so that finding an audience accepting of truth is increasingly difficult. More than sixty years ago Donald Williams [224], exasperated over the pretended academic puzzlement over the certainty of truth, said the academy

> in its dread of superstition and dogmatic reaction, has been oriented purposely toward skepticism: that a conclusion is admired in proportion as it is skeptical; that a jejune argument for skepticism will be admitted where a scrupulous defense of knowledge is derided or ignored; that an affirmative theory is a mere annoyance to be stamped down as quickly as possible to a normal level of denial and defeat.

Yet truth is our goal, the only destination worth seeking. So we must understand it. There are two kinds of truth: ontological and epistemological, comprising existence and our understanding of existence. Tremendous disservice has been done by ignoring this distinction. There are two modes of truth: necessary and local or conditional. From this seemingly trivial observation, everything flows.

W. Briggs, *Uncertainty*, DOI 10.1007/978-3-319-39756-6_1

1.1 Truth

Truth exists, and so does uncertainty. Uncertainty acknowledges the existence of an underlying truth: you cannot be uncertain of nothing: nothing is the complete absence of *any*thing. You are uncertain of something, and if there is some thing, there must be truth. At the very least, it is that this thing exists. Probability, which is the language of uncertainty, therefore aims at truth. Probability presupposes truth; it is a measure or characterization of truth. Probability is not necessarily the quantification of the uncertainty of truth, because not all uncertainty is quantifiable. Probability explains the limitations of our knowledge of truth, it never denies it. Probability is purely epistemological, a matter solely of individual understanding. Probability does not exist *in* things; it is not a substance. Without truth, there could be no probability.

Why a discussion of truth in a book devoted to probability? Since probability is the language of uncertainty, before we can learn what it means we need to understand what it is that probability aims at. Hempel understood this, but couldn't help himself from writing the word without scare quotes, as if "truth" might not exist, [110]. What is the nature of probability's target? What does it mean to be uncertain? How do we move from uncertainty to certainty? How certain is certain? It will turn out that statements of probability (assuming they are made without error, an assumption we make of all arguments unless otherwise specified) are true. When we say things like "Given such-and-such evidence, the probability of X is p", we mean to say either that (the proposition) X is true, or that not-X is. So truth must be our foundation. What follows is not a disquisition on the subject of truth, merely an introduction sufficient to launch us into probability. This chapter is also a necessity because the majority of Western readers have grown up in a culture saturated in relativism. There is ample reason Pilate's question is so well remembered.

Our eventual goal is to grasp models, and models of all kinds, probabilistic or otherwise, are ways of arguing, of getting at the truth. All arguments, probabilistic or not, have the same form: a list of premises, supposeds, accepteds, evidence, observations, data, facts, presumptions, and the like, and some conclusion or proposition which is thought related to the list. Related how and in what way is a discussion that comes later, but for now it loosely is associated with what *causes* the proposition to be true. Arguments can be well or badly structured, formally valid or invalid, and sound or unsound. Unlike most logical, mathematical, and moral arguments, which often end in truth, probabilistic arguments do not lead to certainty. Whenever a probabilistic argument is used, it is an attempt to convince someone how certain a proposition is in relation to a given body of evidence, and *only that* body of evidence.

Anybody who engages in any argument thus accepts that certainty and truth exist. We should have no patience for philosophical skepticism, which is always self-defeating. If you are certain there is no certainty, you are certain. If it is true that there is no truth, it is false there is no truth. If you are certain that "Every proposition is subject to uncertainty" then you speak with forked tongue. Certainty