Bayesian Logic

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We have all heard the expression, “As sure as the Sun will rise tomorrow.” And it’s a great bet that the Sun will indeed rise tomorrow. On the other hand, a rogue anti-matter asteroid may be on a collision course with Earth, and “boom,” the Earth disintegrates tonight; ergo, no sunrise tomorrow. In the first case, the probability that the Sun will rise tomorrow is so high that it might as well be a fact. In the latter case, the Earth being annihilated, never to revolve again, is so vanishingly small, that it might as well be impossible. The range between what we consider to be fact and what we consider to be impossible constitutes, in human terms, “the realm of probability.” It also marks the full range of our uncertainty or the unknown. Any new knowledge we acquire is necessarily a direct function of how well we can characterize this realm. Bayes’ Theorem is uniquely designed to do this.

Bayesian probability theory can be seen as formalizing the mechanics of human reasoning on uncertain issues. Bayesian probability theory is based on a simple mathematical formula for updating our confidence in the probability of some uncertain hypothesis or phenomenon considering some new or recurrent evidence at hand. Essentially, Bayes’ Theorem formalizes the logic that each time we observe the Sun rise we can be a little more confident that it will continue to rise in the same fashion, or in more prosaic terms, “what goes around comes around.”

Bayes’ Theorem combines some new evidence associated with a given hypothesis or phenomenon to assess the increase or decrease in the probability of the hypothesis or phenomenon being true. In the case of the Sun rising, Bayes’ Theorem might be employed every time the Sun is observed to rise across a given span of time to formalize the likelihood of the Sun rising again the following day. The more times it is seen to rise, the more likely it will continue to rise.

Bayes’ Theorem can be applied in either direction along a continuum by the same line of reasoning that every day the Sun rises increases the likelihood that it rose the day before we started checking on it. It can also be applied at various scales to establish a more comprehensive view. We can determine, after only a few hours of Sun behavior, that it will most probably move in an arc across the sky, or we can look across the galaxy and determine a limit on the life of the Sun based on the statistical distribution of ancient stars exhausting their fuel and dying out. Each of these assessments is based on the projection of the known onto the unknown via the suggestions of the real-world evidence and expressed in terms of probability. We can never be certain that the Sun will rise again, but we can invest a provisional faith in the probability of the sunrise that, in the near term, can approximate certainty.
The process that Bayes’ Theorem most often utilizes in assessing probability is one of incremental accumulation. That is, the assessment of a single sunrise would be of little use for predicting the long-term behavior of the Sun, so the basic equation of Bayes’ Theorem is calculated over and over again for each new sunrise across however many sunrises seem appropriate to establish a reliable pattern.

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Under the tenets of the scientific method the subjective proposal of a given hypothesis is examined for compatibility with existing data and its predictions experimentally tested in the real world. The description of the scientific method can be seen as an informal version of the Bayesian process, where the probability of some proposed, nominally subjective, theory being true is formally tested under the impact of experimental evidence and the results applied in favor or repudiation of the proposed theory or prediction. However, Bayesian logic takes the scientific process one crucial step further.

Not only is Bayes’ Theorem a good litmus test for a proposed theory, it is also uniquely suited to derive a new theory in the first place. By using the historical record of the search for knowledge in a given field as its evidence, Bayes’ Theorem can be applied to project a certain categorical probability into the character of the current unknown based on past relationships between the previously unknown and the subsequently known. It formalizes the process of making an educated guess based on past evidence. For example, by examining how the historical succession of our cosmological theories compare to the subsequent discoveries of fact, a Bayesian pattern of how we misconstrue the universe has evolved over time. This evolutionary pattern can then be compared to our current cosmological theory to help predict how it, too, most probably diverges from the nature of reality.

This application of Bayes’ Theorem across the history of human discovery compares our prior presumptions to our subsequent discoveries in a way that rationally suggests the near term character of the unknown based on how our current presumptions might diverge from our future discoveries. By characterizing the most common human conceptual deviations of the past to our present world view, we can predict our most likely deviations from our future world views. This book employs this type of Bayesian reasoning across both the process of the human search for knowledge and the products of that search in order to establish a broad brush overview of a Bayesian predicted universe. This added element of formally characterizing the near-term unknown identifies Bayes’ Theorem as a candidate for augmenting the scientific method in that it formalizes the next theoretical guess.