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Understanding the Notion of Probability for the Non-Statisticians

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Abstract

In our day-to-day life, we face a bunch of uncertainty in most of the real activities. The approach of probability is to quantify such uncertainties associated with the outcomes of any random experiment. A chance of occurrence of any statistical phenomenon can be calculated on the basis of some well-defined rules, called axioms. As a function of event, probability can be calculated on the subjective ground that again decides logically for the given setup of a random experiment. This article explains some key aspects of theoretical notion of probability and its mathematical calculations through some real examples.

Keywords: Probability, Random Experiment, Sample Space, Events, Sigma-Field.

1. WHAT IS PROBABILITY?

In real sense, probability is a measure of uncertainty of a random experiment. A random experiment is one where the outcomes are pre-defined as a set and, the outcomes of a single performance must produce an outcome from that set only with all possibilities of repetitions of the same random experiment. It is to be noted that in our day-to-day life, we face with the occurrences of several phenomena known as 'experiment'. Statistically, we are interested only in those which are random by nature. In another sense, we see that the probability is a quantification of our learning about a particular event as a part of the random experiment. For instance, one could be interested to know about the name of the future president of India. Definitely, this statement has 'no clue' to answer in specific way. In another example, one may be interested to know whether, "it did rain in Jaipur city last night". Now, every person may have different opinion depending upon his/her knowledge about the climate condition of the Jaipur city. In another example, one may state that "liquor drinking causes liver disease". The people may have more certain answer for the last statement as "yes". In all of the above situations, the uncertainty involves differently in the light of actual answers of these statements. That is why, I believe that the probability should be defined on the subjective ground and it may vary from person to person unless a structured frame of the random experiment is available. An alternative but a more refined definition of probability is suggested by (Hagan,2013) as;

"*A probability is numerical measure of degree of belief in the truth of a proposition based on the information held by a person at a time*."

1.1. Some important key words in probability theory

Event: An event is any collection of the outcomes. For example, the outcomes {H, T} of a coin tossing experiment defines an event. Also, the singleton outcome H or T or $\{\phi\}$ (the null set) is an event. There can be different types of events in the probability theory. The events are called *mutually exclusive* (or disjoint) if it is not possible for them to happen simultaneously. The events which are occurring with the same probability, called the *equally-likely* events.
Sample Space: It is a collection (or set) of all possible outcomes of a random experiment.
Sigma-field ($\sigma - field$): It is defined as a set of all possible events which is "closed" under the operations of countable union ($\cup_1^\infty E_i$) and complement (E^c) for any sequence of events $\{E_i\}$. Here the word "closed" refers that the resultant outcome after performing the operations must belong to the same set of the events.

The modern theory of mathematical probability is based on the concept of set theory and is supported by a set of axioms, commonly known as the *axiomatic approach* of probability. In light of that one may, further, define the probability as a measure of chance of occurrence of an event (Bhat, 2007).

1.2 Approaches of Probability

Based on the types of measurements, probability can be calculated in different ways. First approach is a "classical approach", where probability of an event can be calculated as a simple rate. For example, let A be an event of interest, then probability of A is defined by

$$\mathrm{P(A)} = \frac{\text{favourable cases to A}}{\text{Total number of cases (N)}}$$

This approach is quite mathematical and assumes that events are equally-likely, that is, each event has the same chance of occurrence. If the sample space is completely specified and the random experiment is exhausted, then only this approach is preferred to get an estimate of the desired probability of the event. For example, if 16 people survived, out of 100, in any unfortunate disaster, then the ratio of the number of survivors to the total number of persons estimates the probability of survival; which in this case is 0.16.

Second approach advocates the limiting behaviour of the probability for the defined rate of an event, say, A, that is, $\underset{N\to\infty}{\mathrm{P}}(\mathrm{A})$. In this approach, probability cannot exactly be determined rather, a limiting concept. In this approach, the events are considered to be repeatable by nature. We also called the second approach as "statistical approach". For example, probability of finding a defective piece in a huge lot of items at a manufacturing company. Another example is, probability of getting a "head" in a coin tossing experiment (which is close to 0.5). In both the examples, probability cannot be determined in an exact sense.

Noted that, if the outcomes of the events are neither equally-likely nor repeatable, we define the probability based on our own judgment and/or our subjective belief. Such an elicitation of probability is called the "subjective" approach of probability. For example, probability of falling down a ceiling fan.

1.3. Mathematical conditions of probability

In the modern set theory, the probability can be considered as a function of event and is regulated by few conditions, called the 'axioms'. The three axioms of probability function (Bhat , 2007) and (Mood et al., 2017) are given by,

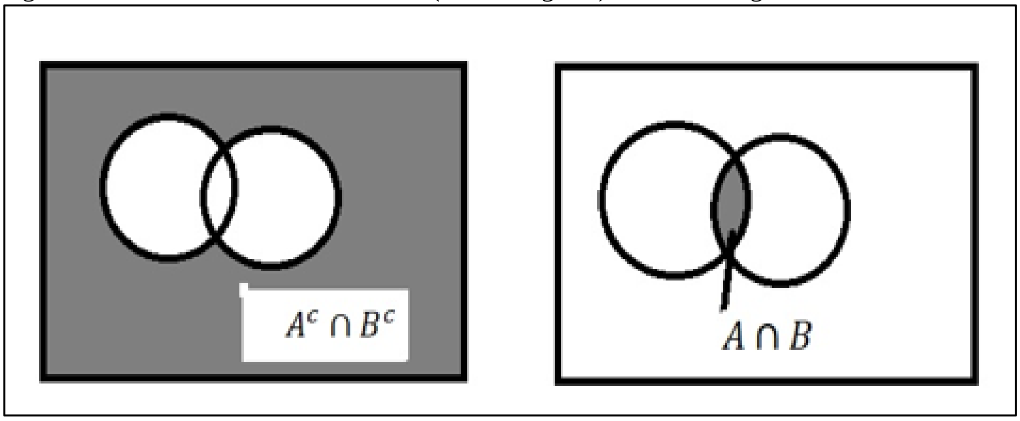
- $P(A) \geq 0$, for any event A
- $P(\Omega) = 1$, where Ω is the sample space
- For the mutually exclusive events, $A_1, A_2, \ldots, A_n$ we have, $P(\cup_{i=1}^\infty A_i) = \sum_{i=1}^\infty P(A_i)$.

2. SOME EXAMPLES

2.1. Probability in psychology

In psychology, the probability can equally be helpful to determine the chance of curing a psychological disease. Let A and B are the two events showing that disease-I and disease-II can be cured respectively with probabilities P(A) and P(B). Consider a situation where a new variety of disease has emerged that is completely different from the existing ones and can be considered as neither a part of A nor B, that is, $A^c \cap B^c$. Or, in another case let the new disease is a combination of both A and B, that is, $A \cap B$. In either of the two cases, it is quite possible to calculate an estimate of probability of curing the newly arrival disease; provided the sufficient amount of data is available from some previous records. It is to be noted that if the disease is treated independently then the $P(A \cap B) = P(A).P(B)$. This relation is also valid for the events A^c and B^c. Consider a sample of 100 patients visited to a psychological clinic. Let 50 patients are showing the symptoms of disease-I so that $P(A) = 0.5$ and, let 55 are showing the symptoms of disease-II with $P(B) = 0.55$. Then, $P(A \cap B) = 0.275$. Also, if 60 of them are showing the symptoms of either of the two diseases such that $P(A \cup B) = 0.4$. Then $P(A^c \cap B^c) = \left(1 - P(A)\right) * \left(1 - P(B)\right) = 0.225$. The two diagrams in Figure 1 are showing the desired events for a better understanding.

Figure 1: Demonstrations of the disease (shaded regions) via Venn diagram.



2.2. Probability in economics

The role of probability in the field of economics cannot be avoided due to following reasons:

- The uncertainty of economic indicators like, inflation rate, exchange rate of money, wealth indices, etc.
- The out-reach of the government policies, especially, in the remote areas of a country.
- The heterogeneity of economic models.
- The uncertainty of economic policies within the nation.

In all of the above situations, one has to face the different challenges on the part of data. In quantitative analysis, an economist has to make a decision for a better future planning on the basis of past experiences of the data. For example, the unemployment rate is a genuine concern for the governments and the economists provide the best possible future estimate through a carefully chosen probability model, say, autoregressive integrated moving average (ARIMA) model. (Tripathi & Upadhyay, 2019) have used an extended form of AR model to analyse the exchange rate data of India. For a good learning on the use of probability in economics, one may refer to (Hong, 2018).

2.3. Probability in sociology

In sociology, most of the time, you are uncertain about the truth of a null hypothesis regarding the subject of interest. For example, the proportion of doctorates in a particular city, the percentage of smokers in a large town, etc. For these, one of the best ways to conduct a survey based on a random sample from the chosen locality. The sample units are selected with certain probabilities. In some situations, you may decide a desired sample size probabilistically, based upon the nature of the population. For instance, an optimum allocation technique is used to decide the sample size in a heterogenous population (see, for example, (Chatterjee, 1971)).

Besides above, there are plenty of applications of probability theory in different parts of social science, like political science, demography, geography, social work, etc.

3. CONCLUSION

This article explains the meaning of probability and its applications in various disciplines of social sciences. Starting from the basic notion, the mathematical conditions were explained. A real picture has been put for psychologists to cure a particular disease by using the simple probability laws through Venn diagram. Although the concept of probability is very vast, I tried to manage it to understand the notion of probability theory in simple words, specifically, for the non-statisticians working in different areas of social sciences.

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