Proceedings of CONF-APMM 2026 Symposium: Applied Mathematics and Quantitative Modeling
DOI: 10.54254/2753-8818/2026.PU37033

Probability and Statistics and Its Practical Applications in Real Life

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Abstract. With the widespread existence of random and uncertain events in natural society and daily production life, probability statistics has become a core mathematical tool for quantifying random laws and supporting scientific decision-making. This paper first sorts out the core theoretical system of probability statistics, including basic random event theories, common probability distribution, parameter estimation and hypothesis testing. Based on literature sorting and case analysis methods, this paper systematically classifies and analyzes the application scenarios of probability statistics in daily education, industrial quality inspection, meteorological prediction, insurance finance and inventory management. The study finds that probability statistics can effectively reduce decision risks and improve resource allocation efficiency in various industries, but there are practical limitations such as sample deviation, improper model selection and over-reliance on statistical results. Finally, this paper puts forward targeted optimization strategies for the existing application defects, and discusses the expansion direction of probability statistics combined with big data and artificial intelligence technology in the digital age.

Keywords: Probability and Statistics, Probability Distribution, Sampling Analysis, Risk Quantification, Practical Application

1. Introduction

Random phenomena run through all aspects of social production and residents' daily life, and human judgment of uncertain events has long relied on subjective experience, which easily leads to biased decision-making [1]. As a branch of applied mathematics, probability statistics establishes quantitative analysis standards for random events through rigorous mathematical deduction, and has formed mature sampling, estimation and testing methodologies after decades of theoretical development. At present, domestic and foreign scholars have carried out segmented research on the application of probability statistics in single fields such as finance and industrial manufacturing, but there is a lack of comprehensive combination of cross-industry practical cases and systematic summary of common application defects [2].

This paper takes the full-scenario practical application of probability statistics as the research theme, sorts out its complete theoretical framework first, then divides multiple application fields to carry out case demonstration, summarizes the prominent problems in the actual use process, and proposes standardized optimization suggestions. The research aims to solve the problem of

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disorganized application cognition of probability statistics in daily work, provide clear theoretical and practical reference for practitioners in various industries, and predict the innovative integration path of probability statistics with digital technology in the future. The research adopts literature review and practical case analysis as core research methods, and does not involve complex original experimental data.

2. Core theories of probability and statistics

2.1. Random event and basic probability theory

Random events refer to events with uncertain occurrence results under fixed experimental conditions, and probability is the quantitative index to measure the possibility of event occurrence [3]. The basic axiom system of probability includes non-negativity, normalization and additivity, which lays the logical foundation for subsequent statistical derivation. Common basic calculation models include classical probability, geometric probability and conditional probability. Conditional probability and Bayes' formula are widely used in reverse reasoning of event causes, such as fault diagnosis and risk screening in industry.

2.2. Mathematical expectation, variance and classical probability distributions

Mathematical expectation reflects the average level of random variables, while variance and standard deviation measure the fluctuation degree of data, and the two indicators together constitute the core characteristic values of random variables. Common continuous and discrete probability distributions include binomial distribution, Poisson distribution, normal distribution and exponential distribution. Normal distribution is the most widely used model in practical statistics, which can fit most natural and social data distribution laws under the central limit theorem.

2.3. Sampling survey, parameter estimation and hypothesis testing

Complete population survey often brings huge time and cost consumption, so sampling analysis becomes the mainstream data collection method [4]. Stratified sampling, simple random sampling and cluster sampling are three mainstream sampling modes with different applicable scenarios. Parameter estimation uses sample data to infer overall characteristic values, including point estimation and interval estimation, hypothesis testing verifies whether the overall assumption conforms to objective data through significance level setting, which is the core tool for data difference judgment in scientific research.

3. Applications in daily life and education fields

3.1. Probability analysis of daily random activities

Lottery, lucky draw and random selection are typical daily random events controlled by probability theory. Taking commercial lottery activities as an example, classical probability formula can calculate the winning probability of each prize level, and mathematical expectation can evaluate the long-term income of participants. Most lottery products have negative mathematical expectation, which explains why long-term participation will bring economic losses to individuals. In daily queuing, traffic light timing and other scenarios, Poisson distribution can fit the arrival law of crowds, so as to optimize resource allocation.

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3.2. Sampling statistics of academic performance and student learning situation

Educational management departments cannot test all students in a large-scale teaching evaluation, so stratified sampling is adopted to select representative samples to infer the overall learning level of students [5]. Teachers use normal distribution to analyze the score distribution of class examinations, judge the rationality of test paper difficulty through variance, and use hypothesis testing to compare the learning gap between different classes and grades. Statistical indicators such as pass rate and excellent rate are derived from probability statistical algorithms, which provide objective basis for teaching adjustment.

4. Applications in industry and public management

4.1. Sampling inspection and defect probability statistics of industrial products

Full inspection of industrial products will cause huge production cost waste, so sampling inspection based on the binomial distribution is widely used in production lines. Enterprises set qualified sampling standards according to the acceptable quality level (AQL), calculate the probability of misjudging qualified products as defective products through statistical formulas, and balance inspection cost and product quality risk. The number of defective products in batch production conforms to Poisson distribution, which can predict the fluctuation range of product defects in advance.

4.2. Probabilistic forecasting of meteorological events

Meteorological stations collect historical temperature, precipitation and wind speed data, use regression statistics and distribution fitting to establish meteorological prediction models [6]. The probability of rainfall, typhoon and extreme high temperature output by weather forecast is calculated based on the frequency of historical similar meteorological events. Probability statistics can quantify the uncertainty of meteorological prediction, remind the public of risk level, and support urban flood control, agricultural planting planning and disaster prevention and mitigation work.

5. Applications in finance and insurance industry

5.1. Calculation of insurance premium and accident probability

Insurance operation logic is built entirely on probability statistics. Insurance companies sort out historical claim data of different age groups, occupations and regions, fit the accident probability distribution of insured persons, and calculate the basic premium through mathematical expectation of compensation amount [7]. Life insurance, property insurance and medical insurance all adjust premium standards according to variance of risk loss, and use a large number law to ensure the long-term stable profit of insurance institutions.

5.2. Quantitative analysis of investment income and market risk

Quantitative finance deals with normal and t-distributions as tools for fitting the variation of asset return rates—variance and covariance give a numerical account of correlation risk among investments. Value at Risk (VaR) is a model that estimates, by means of a statistical quantile, the

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worst-case loss of a portfolio at given levels of confidence, thus helping to bound the downside risks. Probability statistics is able to remove emotional bias from investment choices and to standardize the treatment of risk.

5.3. Statistical prediction of market demand and enterprise inventory

Retail and manufacturing enterprises collect historical sales data, use time series statistical models to predict future market demand distribution, and calculate the optimal inventory quantity through loss probability of out-of-stock and overstock [8]. Excessive inventory will increase capital occupation cost, while insufficient inventory will lead to sales loss, probability statistics can balance the two costs and realize lean inventory management, which is widely used in e-commerce warehousing, supermarket retail and factory raw material procurement.

6. Existing problems and optimization suggestions in practical application of probability statistics

6.1. Common defects in practical application

First, sampling deviation is widespread: many practitioners adopt convenient sampling instead of random stratified sampling, resulting in samples cannot represent the overall characteristics, and statistical conclusions appear serious deviation [9]. Second, the probability distribution model is selected improperly. Most people directly use normal distribution to fit all data without testing the distribution type of actual data, leading to wrong prediction results. Third, over-reliance on statistical significance ignores practical significance. Even if the hypothesis testing result is significant, the actual economic and production value of the difference may be negligible. Fourth, the lag of data update makes the statistical model lose timeliness, especially in finance and e-commerce with rapidly changing market rules.

6.2. Optimization suggestions for standardized application

Enterprises and researchers should formulate standardized sampling schemes according to the characteristics of research objects, calculate reasonable sample size to reduce sampling error. Before modeling, carry out normality test and distribution fitting test on original data to select the most matching probability distribution model. While paying attention to statistical significance, combine production and business reality to judge the practical value of statistical conclusions. Regularly update basic data and retrain statistical models according to the change cycle of industry rules, and set error correction mechanisms for model prediction results.

7. Discussion: development expansion combined with big data and artificial intelligence

Traditional probability statistics is limited by small sample data, while big data technology provides massive multi-dimensional sample data for statistical modeling, which greatly improves the accuracy of parameter estimation and probability prediction [10]. Machine learning algorithms such as Bayesian learning are essentially derivatives of probability statistics theory, artificial intelligence models take probability distribution as the core loss function to realize intelligent identification, automatic risk early warning and dynamic demand prediction.

From now on, the joining together of probability statistics with digital technology is likely to be a leading development. Probability statistical methods offer a way to make sense mathematically of

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black-box AI models, and big data improves the basis of sampling for statistics. This combination will help to widen the scope--within schooling--of probability-based analysis, and will encourage decisions concerning uncertainty to be more exact, more rational, and more efficiently implemented.

8. Conclusion

The present paper gives a systematic account of the basic theoretical structure of probability and statistics, and sets forth—by means of case studies—their actual utility for education, for industrial processes, for meteorology, for insurance and for planning of enterprise inventories. Probability and statistics provide exact numerical methods of analysis applicable to a wide range of uncertain social phenomena. They substitute vague personal judgments with quantitatively grounded indicators, and help reduce risk when making decisions about scarce resources. Nevertheless, the application of such methods still runs into difficulties—such as sampling bias, wrong model choices, old or faulty data or unwarranted reliance on statistical significance—which may lead to misleading or incomplete conclusions.

The optimization ideas presented here are directed toward standardizing the full statistical workflow—sample gathering, model construction and interpretation—as a means of reducing recurrent misuse in applied situations. Due to the limitations of present-day research, the paper relies mainly on qualitative case studies rather than on quantitative models built from independent primary data. Future work may profitably employ real industry data to establish practical models and to evaluate the value of the improvements proposed here. Within the current digital transformation context, probability statistics no longer suffer strictly from small-sample handicaps thanks to big data and AI techniques. It is destined to develop as a basic analytical tool—one that makes social decisions, of many kinds, more scientifically grounded and reliable.

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