

## Preface

Early in my career I was given the task of designing a sub-critical nuclear reactor facility that was to be used to perform basic research in the area of reactor physics. We planned to run a series of experiments to determine fundamental parameters related to the distribution of neutrons in such systems. I felt that it was extremely important to understand how the design would impact upon the accuracy of our results and as a result of this requirement I developed a design methodology that I subsequently called **prediction analysis**. After working with this method for several years and applying it to a variety of different experiments, I wrote a book on the subject. Not surprisingly, it was entitled *Prediction Analysis* and was published by Van Nostrand in 1967.

Since the book was published over 40 years ago science and technology have undergone massive changes due to the computer revolution. Not only has available computing power increased by many orders of magnitude, easily available and easy to use software has become almost ubiquitous. In the 1960's my emphasis was on the development of equations, tables and graphs to help researchers design experiments based upon some well-known mathematical models. When I reconsider this work in the light of today's world, the emphasis should shift towards applying current technology to facilitate the design process. The purpose of this book is to revisit prediction analysis with the emphasis upon application of available software to the design of quantitative experiments.

I should emphasize that quantitative experiments are performed in most branches of science and technology. Astronomers analyze data from asteroid sightings to predict orbits. Computer scientists develop models for improving network performance. Physicists measure properties of materials at low temperatures to understand superconductivity. Materials engineers study the reaction of materials to varying load levels to develop methods for prediction of failure. Chemical engineers consider reactions as functions of temperature and pressure. The list is endless. From the very small-scale work on DNA to the huge-scale study of black holes, quantitative experiments are performed and the data must be analyzed.

The common denominator in all this work is the similarity in the analysis phase of the experimental process. If one can assume that the measurement errors in the obtained data are normally distributed, the **method of least squares** is usually used to "fit" the data. The assumption of normality is usually reasonable so for this very broad class of experiments the method of least squares is the "best" method of analysis. The word "best" implies that the estimated parameters are determined with the smallest estimated uncertainty. Actually, the theoretically best solution to the minimization of estimated uncertainty is achieved by applying the **method of maximum likelihood**. This method was proposed as a general method of estimation by the renowned statistician R. A. Fisher in the early part of the 20<sup>th</sup> century. The method can be applied when the uncertainties associated with the observed or calculated data exhibit any type of distribution. However, when the uncertainties are normally distributed or when the normal distribution is approximately correct, the method of maximum likelihood reduces to the method of least squares. The assumption of normally distributed random errors is reasonable for most situations and thus the method of least squares is applicable for analysis of most quantitative experiments. For problems in which the method of least squares will be applicable for analysis of the data, the method of prediction analysis is applicable for designing the proposed experiments.

Many of the examples of prediction analyses of experiments included in this book were done using the REGRESS program which is discussed in Section 3.10. The program is available free of charge and can be obtained through my website.

John Wolberg  
[www.technion.ac.il/wolberg](http://www.technion.ac.il/wolberg)  
Haifa, Israel  
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