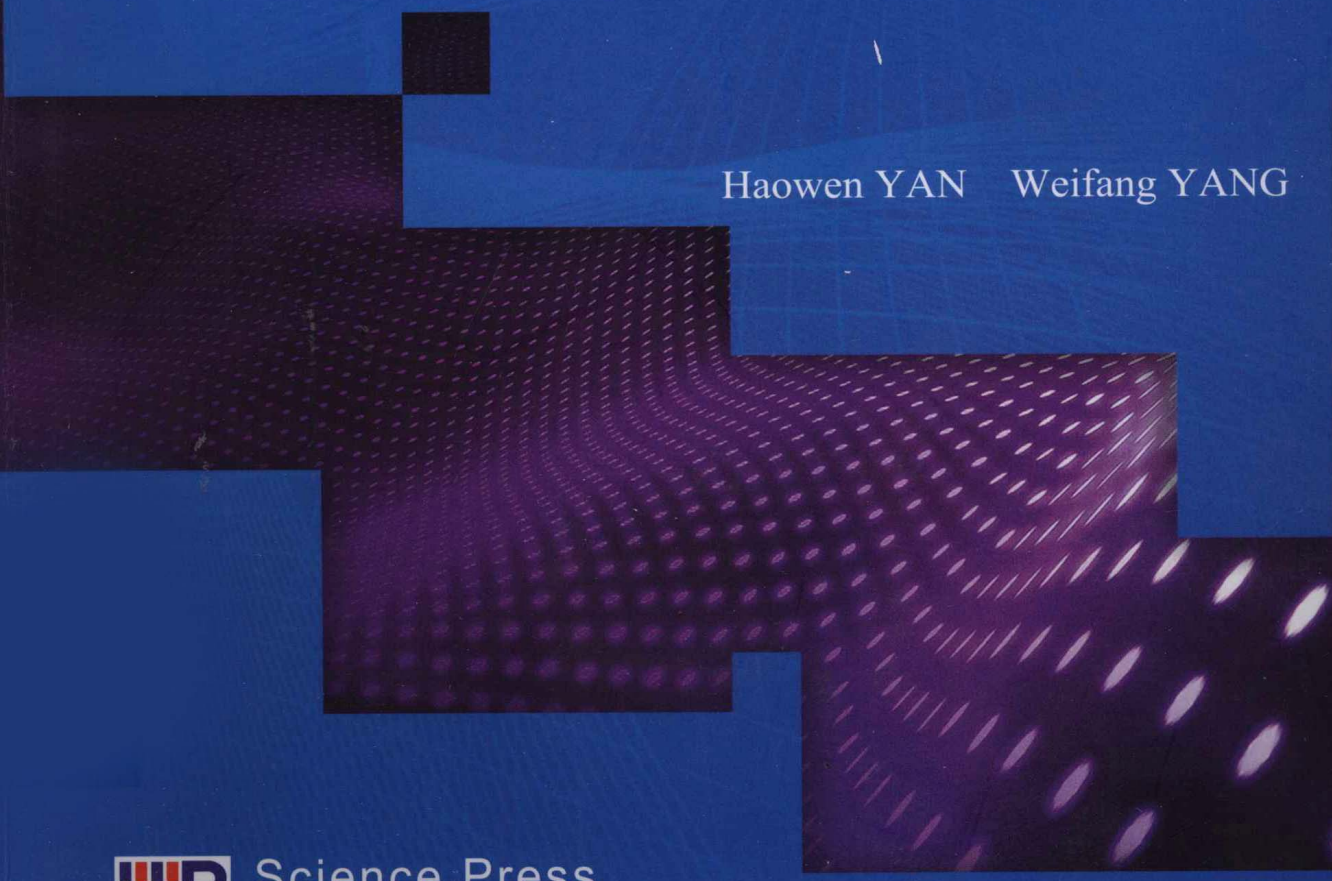
SURVEYING PRINCIPLES AND METHODS

测量学原理与方法

Haowen YAN Weifang YANG



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测量学原理与方法

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内 容 简 介

本书主要研究如何测定和记录地面点的位置、高程，以及如何确定地球的形状大小。全书分为两部分：传统测量学原理和当代测量学原理。第一部分论述运用传统仪器进行测量工作的技术和手段；第二部分论述地理信息系统、全球定位系统、摄影测量等的基本原理。

形式上，本书全文以英文撰写；内容上，尽量吸收国外同行先进的理念和方法，力求思想的“国际性”，但在具体方法的应用上又以我国的标准、规范为依据，以便国内读者的使用。

本书可供测绘、地理、遥感、土木工程、地质等专业的高年级本科学生使用，亦可作为相关专业研究生的教学参考用书，或供相关领域的科技工作者参阅。

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Preface

Our aim of publishing such a book is mainly for Chinese undergraduates majoring in surveying and mapping, civil engineering, geography, geology, urban planning, and some other relevant studies. In addition, this book can be used as a reference by postgraduates, instructors and researchers of relevant communities.

To give an up-to-date and concise treatment of the subject, some published papers and books that have been used in foreign universities are referenced; additionally, a great deal of new material from internet has also been adopted. These references have been listed in the book, which may provide useful clues for readers who are interested in further research.

The book is divided into two parts. The first part discusses conventional surveying principles and the second part discusses new surveying techniques and principles.

Chapter 1, 6—12 are written by Haowen YAN; Chapter 2—5, 10 and Appendix are written by Weifang YANG. To ensure the quality, this book has been reviewed by Dr. Bisheng YANG(Chapter 1—8) from the Department of Geography of University of Zurich, Switzerland, Dr. Linyuan XIA(Chapter 9, 10) from Wuhan University, and Dr. Fenzheng SU(Chapter 11, 12) from the Institute of Geographic Sciences and Natural Resources Research, CAS.

Author in chief of the book is Dr. Haowen YAN.

Haowen YAN
Jan. 10, 2009
Lanzhou Jiaotong University

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Part 1 Conventional Surveying

Chapter 1 Introductory

1.1 Basic concepts of surveying

1.1.1 Definition and applications of surveying

Surveying is not only a science but also an art that deals with the determination of the relative positions of points on or near the Earth's surface (Bannister et al., 1998). These points may be needed for locating or laying out roads, airfields, and structures of all kinds; they may be needed for cultural, hydrographic, or terrain features for mapping; and in the military, these points may be targets for artillery and mortar fires. In this sense, surveying is an art because only a surveyor who possesses a thorough understanding of surveying techniques will be able to determine the most efficient methods required to obtain optimal results over a wide variety of survey problems; surveying is also a science because rigorous mathematic foundations are used to analyze and to adjust the field surveying data. The accuracy and the reliability of the survey depend not only on the field expertise of the surveyor, but also on the understanding of the scientific principles underlying and affecting all forms of survey measurement.

1.1.2 Classifications of surveying

Different criteria generate different classification results to surveying branches. Here, two classification criteria are employed to discuss the classification systems of surveying.

1.1.2.1 Classification by the shape of Earth's surface in surveys

Firstly, surveying is divided into two major categories, plane and geodetic surveying, according to the shape of the Earth's surface in measurement work.

(1) Plan surveying is a process of surveying in which the portion of the Earth being surveyed is considered a plane (Bannister et al., 1978). The term is used to designate survey work in which the distances or areas involved are small enough that the curvature of the Earth can be disregarded without significant error. For small areas, precise results may be obtained with plane survey-

ing methods, but the accuracy and precision of such results will decrease as the area surveyed increases in size. To make computations in plane surveying, the formulae of plane trigonometry, algebra, and analytical geometry will be used.

A great number of surveys are of the plane surveying type. Surveys for the location and construction of highways and roads, canals, landing fields, and railroads fall into plane surveying. When it is realized that an arc of 10km is only 1.027mm greater than its subtended chord; that a plane surface tangent to the spherical arc has departed only about 0.008m at 1km from the point of tangency; and that the sum of the angles of a spherical triangle is only 0.508s greater than the sum of the angles of a plane triangle for a triangle having an area of approximately 100km^2 on the Earth's surface, it is just reasonable that the errors caused by the Earth's curvature be considered only in precise surveys of large areas.

(2) Geodetic surveying is a process of surveying in which the shape and size of the Earth are considered. This type of survey is suited for large areas and long lines and is used to find the precise location of basic points needed for establishing control for other surveys. In geodetic surveys, the stations are normally long distances apart, and more precise instruments and surveying methods are required for this type of surveying compared with plane surveying.

The shape of the Earth is thought of as a spheroid, although in a technical sense, it is not really a spheroid. In 1939, the convention of the International Union of Geodesy and Geophysics adopted 6 378 137m as the diameter of the Earth at the equator and 6 356 752m as the diameter at its polar axis. The equatorial diameter was computed on the assumption that the flattening of the Earth caused by gravitational attraction is exactly 1/298.257. Therefore, distances measured on or near the surface of the Earth are not along straight lines or planes, but on a curved surface.

Hence, in the computation of distances in geodetic surveys, allowances are made for the Earth's minor and major diameters from which a spheroid of reference is developed. The position of each geodetic station is related to this spheroid. The positions are expressed as latitudes (angles north or south of the equator) and longitudes (angles east or west of a prime meridian) or as northings and castings on a rectangular grid.

1.1.2.2 Classification by the functions of surveys

Secondly, surveys can be classified by names descriptive of their functions. Functionally, surveys are classified into construction, topographic, route, and special surveys. Special surveys, such as photogrammetry, hydrography, and property surveys, are conducted either with special equipment or for a special purpose.

(1) Construction surveys (sometimes called engineering surveys) are conducted to obtain data essential for planning, estimating, locating, and layout for the various phases of construction activities or projects. This type of survey includes reconnaissance, preliminary, location, and layout surveying.

The objectives of engineering or construction surveying include the following:

①The obtaining of reconnaissance information and preliminary data required by engineers for selecting suitable routes and sites and for preparing structural designs.

②The defining of selected locations by establishing a system of reference points.

③The guidance of construction forces by setting stakes or otherwise marking lines, grades, and principal points and by giving technical assistance.

④The measuring of construction items in place for the purpose of preparing progress reports.

⑤The dimensioning of structures for preparation of as-built plans.

Engineering or construction surveys, then, form part of a series of activities leading to the construction of a man-made structure. The term structure is usually confined to something that is built of structural members, such as a building or a bridge. It is used here in a broader sense, however, to include all man-made features, such as graded areas, sewer/power/water lines, roads and highways, and waterfront structures. Construction surveying normally covers areas considered small enough to use the plane surveying methods and techniques.

(2) Topographic surveying aim to gather surveying data about the natural and man-made features of the land, as well as its elevations. From this information, a three-dimensional map may be prepared. The topographic maps may be produced in the office after collecting the field data or preparing it right away in

the field by plane table.

(3) Route surveying refers to surveys necessary for the location and construction of lines of transportation or communication that extend across country for a certain distance, such as highways, railroads, open-conduit systems, pipelines, and power lines (Blachut et al., 1979). Generally, the preliminary survey for this work takes the form of a topographic survey. In the final stage, the work may consist of:

①locating the center line.

②determining elevations along and across the center line for plotting profiles and cross sections.

③plotting the profiles and cross sections and fixing the grades.

④computing the volumes of earthwork and preparing a mass diagram.

⑤staking out the extremities for cuts and fills.

⑥determining drainage areas to be used in the design of ditches and culverts.

⑦laying out structures, such as bridges and culverts.

⑧locating right-of-way boundaries, as well as staking out fence lines, if necessary.

(4) Special surveying are conducted for a specific purpose and with a special type of surveying equipment and methods (Burnside, 1985). Land surveys (sometimes called cadastral or property surveys) are conducted to establish the exact location, boundaries, or subdivision of a tract of land in any specified area. This type of survey requires professional registration in relevant departments in China. Control surveying provides a "basic control" or horizontal and vertical positions of points to which supplementary surveys are adjusted. These control points are further used as references for hydrographic surveys of the coastal waters; for topographic control; and for the control of many states, cities, and private surveys. Horizontal and vertical controls generated by land (geodetic) surveys provide coordinated position data for all surveyors. It is therefore necessary that these types of surveying use first-order and second-order accuracies. Hydrographic surveys are made to acquire data required to chart and/or map shorelines and bottom depths of streams, rivers, lakes, reservoirs, and other larger bodies of water. This type of surveying is also of great importance to navigation and to development of water resources for flood control, irrigation, electrical power, and water supply. Photogrammetry acquires spatial data by means of photographs, and generates various maps using computers nowadays.

1.2 Basic principles in surveying

One of the surveying purposes is to determine the positions of points on Earth's surface, and draw them on maps according to given scale and symbols. Such a procedure begins with the establishment and surveying of a series of points in the surveyed area. The points are called "control points". After this so-called "control surveys", other points used to represent the characteristics of Earth's surface are surveyed and drawn on the map one by one, in light of those pre-determined control points. The post-determined points are called "details". This process demonstrates the basic principles generally obeyed in survey work, i. e. to all surveys:

(1) To consider the whole before the sections.

(2) To establish in the first instance a control framework, and then to fix detail by measurements respect to this control framework (Kavanagh, 2002).

Surveyors benefit a lot from obeying the following principles:

(1) To avoid the error accumulation in the surveyed area.

(2) To ensure the accuracy consistency in the surveyed area.

(3) To make the field work efficiently, due to simultaneous surveying of several parties in the surveyed area.

1.3 Survey references

There are several references conventionally and commonly used in surveying. They are survey geographic reference, survey grid reference and survey vertical reference.

1.3.1 Survey geographic reference

Surveying involves measuring the location of physical land features relative to one another and relative to a define reference on the surface of the Earth. In the broadest sense, the Earth's reference system is composed of the surface divisions denoted by geographic lines of latitudes and longitudes (Figure 1.1). The latitude lines run east and west and are parallel to the equator. The latitude lines are formed by projecting the latitude angle out from the center of the Earth to its

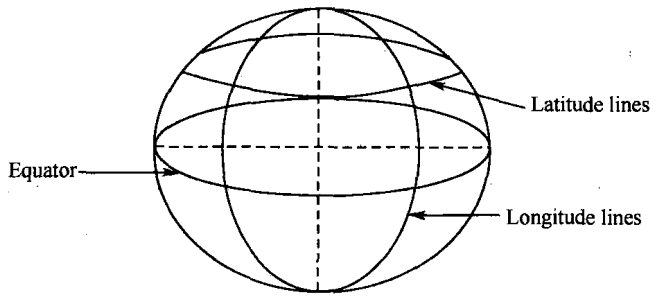

Figure 1.1 Geographic coordinate system

surface. The latitude (maximum is 90°) itself is measured at the Earth's center, north or south from the equator plan. The longitude lines run south and north and converge at the poles. The lines of longitude (meridians) are formed by projecting the longitude angle out to the surface of the Earth at the equator. The longitude angle itself is measured at the Earth's center, east or west (maximum is 180°) from the plane 0° of longitude, which was arbitrarily placed through Greenwich, England.

The geographic coordinate system is used in navigation and geodesy, but those engaged in plane surveying normally use either coordinate grid systems or this one as a basis for referencing.

1.3.2 Survey grid reference

Almost all states and nations have adopted a grid system best suited to their requirements. The grid system itself is limited in size so that no serious errors will accumulate when the curvature of the Earth is ignored. Advantages of grid systems are the ease of calculation (plan geometry and trigonometry) and the availability of one common datum for x and y dimensions in a large are, usually thousands of square miles. The coordinates in most grid systems can be referenced to the central meridian and to the equator so that translation to geographic coordinates is always easily accomplished.

1.3.3 Survey vertical reference

Geographic reference and grid reference describe how x and y dimensions (horizontal) of any feature can be referenced for plane surveying purposes. Although vertical dimensions can be referenced to any datum, the reference datum

most used is that a mean sea level (MSL). Mean sea level is defined as the average height of the sea for all stages of the tide after long periods of observations. It is obtained by averaging the hourly heights of many years observation results, and it is assigned an elevation of 0.000m. The vertical distance of a given point above or below mean sea level then becomes the elevation of that point (Figure 1.2). Permanent points whose elevations have been determined (benchmark) are available in most area for survey use.

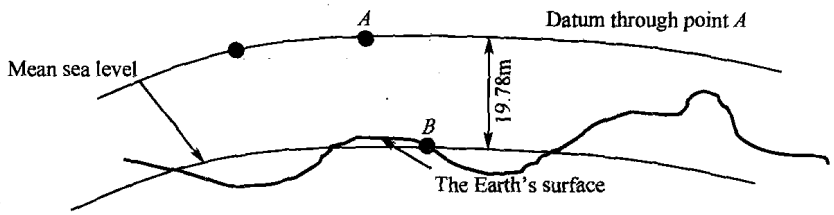

Figure 1.2 Principles of surveying vertical reference

In China, mean sea level was firstly determined and published in 1956 according to the so-called original elevation point in Qingdao city, and this vertical reference is called "Huanghai datum 1956". 29 years later a new datum named "National datum 1985" was ordained.

1.4 Methods used in point locations

The methods used to locate points are very simple in concepts. Four methods are usually employed to determine a point by measuring:

(1) Two distances.

(2) Two distances and one right angle.

(3) One distance and one angle.

(4) Two angles.

In Figure 1.3, A and B are points whose coordinates are known and C is a point to be located; four methods for locating unknown point C are illustrated. These methods can be used in detail surveying, traverse surveying, or laying out of points in civil engineering.

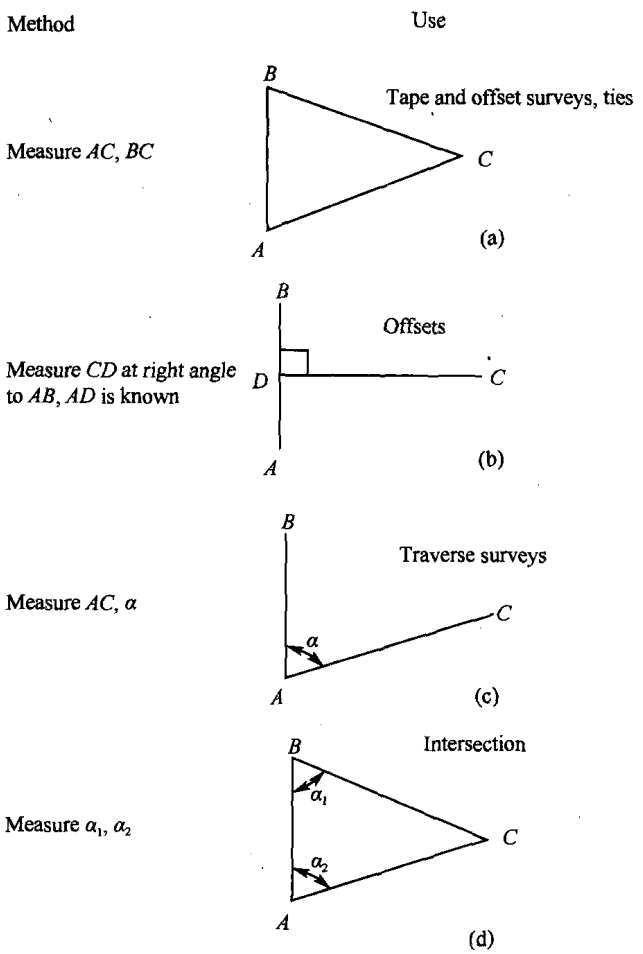

Figure 1.3 Four location methods

1.5 History of surveying

Surveying is a profession with very long history. Since the time people first owned property, boundary markers have been required to distinguish one property from another. Historical records dating back almost 5000 years show evidence of surveyors in China, India, Babylon, and Egypt. The Egyptian surveyor, called "harpedonapata" (means rope stretcher), was in constant demand because the Nile River flooded more or less continuously, destroying boundary markers in those fertile farmlands. The surveyors used ropes with knots tied at set graduations to measure distance.

Ropes were also used to lay out right angles. The early surveyors discovered