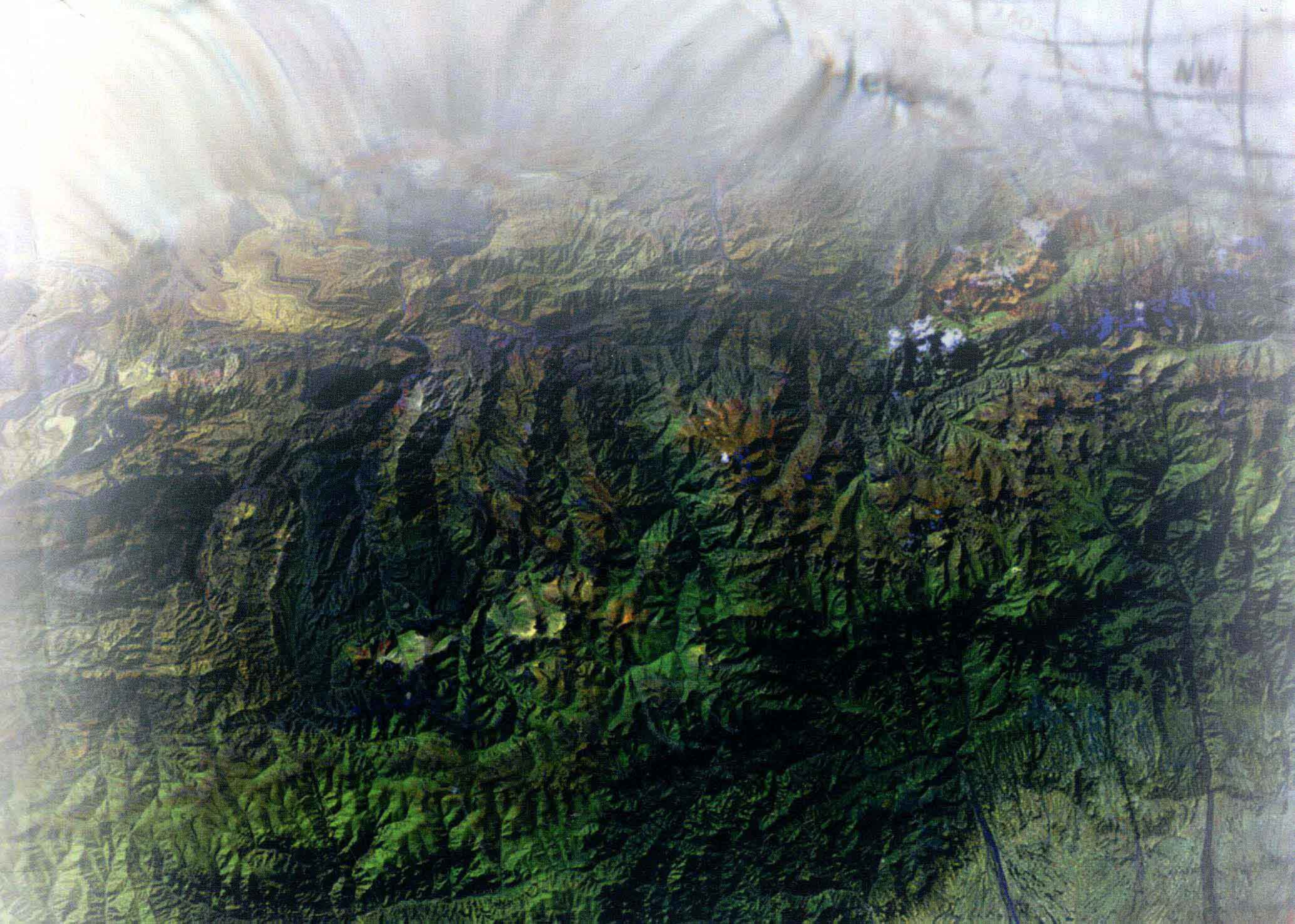
高等教育"十二五"规划教材

PRINCIPLE AND APPLICATION OF GIS

(GIS原理与应用)

Xia Chunlin　Li Ruren　Wang Chongchang
Ren Dongfeng　Chai Huabin

中国矿业大学出版社



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内 容 提 要

全书以英文为表述语言，系统介绍了 GIS 的基础知识、相关原理与工程应用。总体结构上可大致分为基础知识篇（主要包括 GIS 的基本概念、数据结构、数据源等），数据操作篇（包括数据管理、查询与分析和地图制图等）以及工程应用篇（包括 GIS 软硬件、工程案例与发展预测等）。每章均配有本章要点回顾，以方便教师教学和学生总结提高。

本书既可作为地理信息系统、测绘工程、资源环境与城乡规划管理、摄影测量与遥感、地质工程、资源工程、土地管理等专业及相关专业的《地理信息系统原理（概论）》双语教材，也适合作为上述专业的《专业英语》教材使用。

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PREFACE

Our world has moved into the information era. In the 21st century information and information science are essential for economical and social development of every nation in the world, and they are also an important symbol used to judge the comprehensive strength and development level of science and technology of a nation. GIS is a highly dynamic field, growing at a very rapid pace of technological change and increasing number of applications. In addition, as a multibillion-dollar industry, its place as a major information technology is without debate. GIS has spread into a worldwide infrastructure, reaching to the emerging nations and remote corners of our planet. GIS will affect common people's daily life, including how they live, work, study, travel, communicate, manage their finances, and the list can be further prolonged.

This textbook is designed not only to provide a solid foundation in both the concepts and application of GIS to the students who are majoring in the disciplines of Geographic Information System, Survey and Mapping, Urban and Rural Planning, Environmental and Resources Engineering and so on, but also to serve as a textboot of Professionl English for above students. At the same time it is also hoped to help the readers cultivating spatial thinking in the broader sense.

This book is organized into three parts. Part one (Chapter 1 to 4) includes the basic concepts of GIS, including map projections, coordinate systems, data models and structures, and data sources. Part two (Chapter 5 to 7) covers database management systems, inventory operations, spatial analysis, and making maps with GIS. Part three (Chapter 8 to 10) introduces GIS software, some actual GIS application examples, and ends with the future of GIS.

The authors have tried their best to guide the students and readers gradually get familiar with GIS without passing through the long, slow, and sometimes headache route of learning GIS, and to ensure that their first GIS experience is smooth and enjoyable. Therefore, this book will lay a foundation for an easier, more interesting and instructive tour through the GIS realm than what other more advanced and complicated books can offer.

ACKNOWLEDGMENTS

As with any book, there are many people to thank.

We would like to sincerely thank the authors of the following GIS-related books which provide us with valuable reference materials:

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Finally, thank you, all the students and readers, for using and reading this book. We hope it could open the GIS doors for you and expand your horizons.

Any comments and suggestions about this book are warmly welcomed. Please get in touch with us at:

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Contents

CHAPTER 1 GENERAL INTRODUCTION

Our world has moved into the information age. In the 21^{st} century information and information science are essential for economical and social development of every nation in the world, and they are also an important symbol used to judge the comprehensive strength and the development level of science and technology of every nation. After more than 40 years development, now GIS becomes an absolutely necessary part of information industry and few other information management systems have the integrative and analytical power of a GIS. At present GIS has attracted more and more attentions from all countries and circles, and is widely used by various departments and fields of national economy, such as resources and environment management, ecological environment monitoring, geological prospecting, urban and rural planning and design, survey engineering, etc. Along with the gradually deepening of people's understanding about spatial information, the popularization of digital products and the development of computer network technology, the range and quality of GIS application will be further popularized and broadened. GIS will affect how we live, work, eat, travel, communicate, manage our finances, and even how and when we have fun. Finally its application will present a social trend and become an important technical tool for people to live and to conduct scientific research and production.

Now qualified GIS specialists and technicians are urgently needed. At the same time it should be pointed out that GIS is not only for the specialists, but for everyone. Whatever your field of interest, it is quite possible that you may encounter and use a GIS in some way in the future. Students from many different disciplines and professions want to learn and use GIS, especially those majoring in surveying and mapping, urban and rural planning, etc. They must learn and master basic knowledge of GIS in order to facilitate their study and future work.

1.1 MAIN PURPOSE AND FEATURE OF THIS BOOK

If you are a beginner to learn geographic information systems (GIS), or eager to know what a GIS is and what it can do for you—then this book fits you very well. Actually there are already a lot of GIS textbooks available in bookstores, then what are the distinguishing features of this book?

The main purpose of this book is to help the readers gradually get familiar with GIS without passing through the long, slow, and sometimes headache route of learning GIS. This book will lay a foundation for a easier, more interesting and instructive tour through the discipline than what other more advanced and complicated books can offer. The authors and editors have tried their best to keep the text up to date and ensure that your first GIS experience is smooth and enjoyable.

GIS involves not only one but a great many technological revolutions, such as computer science, cartography, global positioning system (GPS), remote sensing (RS), survey engineering, etc. This book also provides readers with a carefully chosen distilled version of the theory and content from these relevant disciplines to help them started. Therefore if you want to go further, you know where are the proper paths forward.

To master and apply GIS intelligently requires you to think like a geographic information scientist, that is, geographic information science requires some mental readjustment. One of the purposes of this book is to gently guide you through this readjustment, and help you to cultivate the ability of thinking graphically and spatially, mapping out information, and finding analytical solutions based on maps and graphics.

1.2 SOME DEFINITIONS OF GIS

During the past forty-odd years many definitions of GIS have been evolved. It is nature that "What is GIS?" can be answered in different ways and from various points of view. Common to all the definitions is that one type of data, ***spatial data***, is unique because it can be linked to a geographic map. Table 1.1 and Table 1.2 are two databases. A database contains columns (attributes) and rows (records). The computer parts list in Table 1.1 is not spatial, because the parts can be located anywhere. While the list of schools in Table 1.2 is spatial, because one of the attributes, the street address, locates the schools on a map.

Table 1.1 **Computer parts**

Part Number	Part Name	Quantity	Note
743351	keyboard	12	Lenovo brand

Continuous Table 1.1

Part Number	Part Name	Quantity	Note
745672	mouse	35	Logitec brand
746835	monitor	24	17 in.
748230	hard disk	18	40 G

Table 1.2 **Schools**

School Name	Number of Students	Location
No. 1 Elementary School	502	335 James Street
No. 2 Elementary School	465	35 Sixth Avenue
David Middle School	1280	103 John Street
St. Mary Technical School	656	48 Center Square

The definition of GIS can start with a simple description of the three principal parts of a GIS (Fig. 1.1):

(1) Geography: The real world, the spatial realities.

(2) Data and information: Their meaning and usage.

(3) Systems: Computer technology and its support infrastructure..

As will be discussed, GIS is much more than a computer system—it is also a methodology in science and applications, a new profession, and a new industry and business. GIS has become a representative example of the new Information Age.

In the next sections some definitions of GIS will be introduced one by one.

1.2.1 Data and Information

In the research and development of GIS, two terms, ***data*** and ***information***, are often encountered. Data and information are closely related but different from each other.

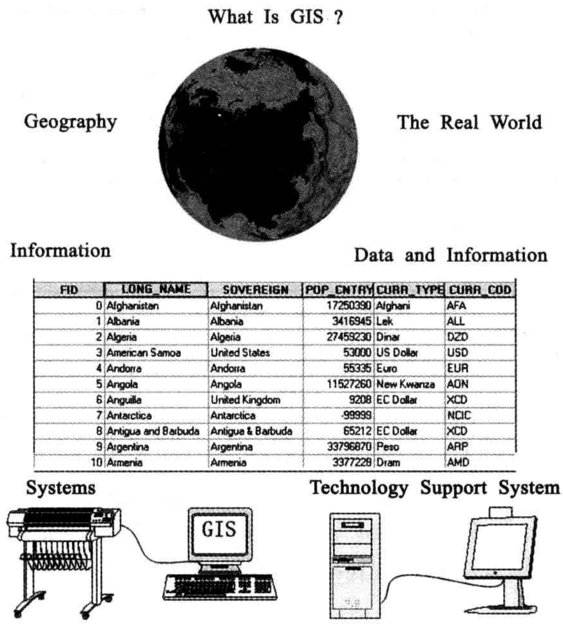
① Data are the expression of information, and information are the content of data. Essentially, data are the expression of objective objects, while information are the meaning contained in the data.

② Data are the unprocessed raw material. Data collecting and processing are essential for the design and establishment of GIS.

③ Data are the recognizable symbols which have been recorded or digitized. Not only the numbers (numeric characters) are data, but all the characters, sign, mark, and image can also be data.

④ Data themselves may not have any meaning. For example, the number "1" can exist independently of GIS, and independently of the composition and stages of GIS.

⑤ Information are the explanation, application and calculation results of data. Only after explanation can the meaning contained in data be understood and data become infor-



FID	LONG_NAME	SOVEREIGN	POP_CNTRY	CURR_TYPE	CURR_COD
0	Afghanistan	Afghanistan	17250390	Afghani	AFA
1	Albania	Albania	3416945	Lek	ALL
2	Algeria	Algeria	27459230	Dinar	DZD
3	American Samoa	United States	53000	US Dollar	USD
4	Andorra	Andorra	55335	Euro	EUR
5	Angola	Angola	11527260	New Kwanza	AON
6	Anguilla	United Kingdom	9208	EC Dollar	XCD
7	Antarctica	Antarctica	-99999		NCIC
8	Antigua and Barbuda	Antigua & Barbuda	65212	EC Dollar	XCD
9	Argentina	Argentina	33796870	Peso	ARP
10	Armenia	Armenia	3377228	Dram	AMD

Fig. 1. 1　Three principal parts of a GIS

mation.

⑥ Information express the content, quantity or nature of event, object, phenomenon and etc. by means of numbers, characters, symbols, images, languages and so on, in order to provide people (or system) with knowledge about the new facts of real world, and the knowledge can be used as the foundation of production, management and decision making.

⑦ Geographical information are the general name of the numbers, characters, images, symbols and so on which are used to formulate the characteristics, link and regular pattern of the quantity, quality, distribution of the inherent elements or matter in the geographical circle or geographical environment.

1.2.2　A GIS Is a Toolbox

Peter Burrough defined GIS as "**a powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes**" (Burrough, 1986).

The definition is known as "**toolbox definition**". A GIS can be seen as a set of tools for dealing with spatial data. Of course, these tools are computer tools, and a GIS can then be thought of as a software package required for dealing with spatial data.

1.2.3　Functional Definition of GIS

Several experts and authors have tried to define a GIS based on its **functions.** The functions fall into classifications which are subtasks that are arranged orderly as data move from the information source to a computer management system and then to the GIS users and decision makers. One of the functional GIS definitions states that GISs are "**automated systems for the capture, storage, retrieval, analysis, and display of spatial data**" (Clarke, 1995). This has also been called a "process definition" because we start with the tasks of data collecting and end with tasks of analyzing and interpreting the information. The following chapters of this book are arranged in such order of tasks and each task will be discussed in detail as the book progresses.

1.2.4 A GIS Is an Information System

Jack Estes and Jeffrey Star defined GIS as "**an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data**" (Star and Estes, 1990).

This definition emphasizes that a GIS is an information system, and it means that a GIS collects, examines and classifies data, selects and rebuilds them to find the appropriate information to answer various questions or fulfill different tasks. In this definition the reference to ***geographic coordinates*** is an important point, because the coordinates are the key link between spatial data and map. In Chapter 2 this theme will be discussed in detail.

Another information system definition of a GIS is one that has stood the test of time remarkably well. In 1979, at the newly established stage of GIS, Ken Dueker defined a GIS as "**a special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines or areas. A geographic information system manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses**" (Dueker, 1979).

The phrase "***special case of information systems***" implies that GIS has a heritage in information systems technology. GIS did not create the technology of database management, and actually there has existed in computer science a 40-year-odd tradition in this field all the way from the earliest spreadsheet programs, through relational database management, to the present object-oriented database management. Information systems have been widely used in library, in business, and around the Internet, and GIS just opened another new application field of information systems.

In Dueker's definition of GIS, the database itself consists of a set of observations, which implies a scientific approach to measurements. Scientists take measurements and record those measurements in some kind of system to help them manage and analyze these measurements. The measurements are spatial data, that is, they occur over space at different times and at different locations at the same time.

The observations can be ***features***, ***activities***, and **events.**

(1) A ***feature*** is a term from cartography meaning an item to be placed on a map

(Fig. 1. 2).

① ***Point features***, such as an elevation bench mark or a house, have only a location.

② ***Line features*** have several locations strung out along a line in sequence like a pearl necklace. For example a river or a border is a line feature.

③ ***Area features***, such as a school or a piece of field that is enclosed in a loop consisted of one or more lines.

(2) "***Activities***" imply a relation with the social sciences. Human activities create geographic patterns and distributions, leading to the administrative map, census map, location of building lot, etc. —all relate to people's daily lives.

(3) "***Event***" implies that geographic data refer to both the spatial location and time. ***Time*** gives us a fourth dimension and becomes a part of the data because events happen in certain time and features exist over a period of time. The houses in Map 1 of Fig. 1. 2, for example, were built in 2009, therefore were not shown on a map made in 2003.

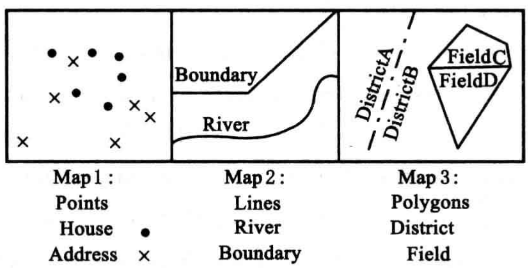


Fig. 1. 2 The Feature Model: examples of point features (houses and address), line features (river and boundary), and area features (districts and fields)

Dueker's GIS definition assumes that events can also be shown as points, lines, or areas in space and on the map.

① An example of a ***point event*** is the site of a fire disaster.

② A ***line event*** could be the route of a journey.

③ An ***area event*** may be the spreading of arid and sandy zone.

The information element can be useful to the GIS user because it exists, it has data associated with it, and it has cartographic reality as a feature on a map.

We use the information mapped in GIS for doing exactly what an information system should do: solve problems, do queries, obtain an answer, or try out a possible solution. So we manipulate the data, not by hand but by computer. We manipulate data about events or activities by using the digital map features that represent them as "handles". In other words, the points, lines, and areas in this map database are used to manage the data.

Another important part of Dueker's GIS definition is that GIS is a ***generic problem-solving tool***; it is not established only for a specific project or an unique task. The value of GIS depends on its ability to apply general geographic methods to specific geographic regions and tasks.

Finally, in Dueker's definition a GIS can also be used to conduct ***analysis***. After data is input into GIS the analysts can extract what is necessary to make predictions and explanations about geographic phenomena so as to make decisions. Geographic information science goes beyond description, to include analysis, modeling, and prediction. The information systems definition, then, leads back to the role of a GIS as a ***problem solver***.

1.2.5 GIS Is an Approach to Science

As a tool or an information system, GIS technology has changed the entire approach to spatial data analysis. The prominent characteristic of GIS and several relevant revolutionary changes lies in the capability of spatial data analysis and management. The convergence of GIS with other closely related technologies, those of surveying, remote sensing (RS), air photography, the global positioning system (GPS), and mobile computing and communications, has led to a spectacular development of these technologies.

As a result, the way of the standard operating procedure of geographic and spatial information handling has greatly changed:

① First, the technology of GIS has become much simpler, easier, more popular, cheaper, and has infiltrated into other disciplines such as geology, forestry, anthropology, epidemiology, business, etc.

② Second, this evolution has led to the birth of "***geographical information science***" (Goodchild, 1992). Goodchild defined geographic information science as "***the generic issues that surround the use of GIS technology, impel its successful implementation, or emerge from an understanding of its potential capabilities***" (Goodchild, 1992). He also noted that this involved both research on GIS and research with GIS. On the other hand, Goodchild noted that the level of interest depends on innovation, and without innovation it is hard to sustain a multidisciplinary (rather than interdisciplinary) science.

1.2.6 GIS Is a Multibillion-Dollar Business

Groups monitoring the GIS industry estimate the total value of the hardware, software, and services conducted by the private, governmental, educational, and other sectors which deal with spatial data to be more than billions of dollars a year. Especially, for the past one and a half decades, the increment rate of GIS industry has been double—digit annually. Anyone who participates in national or international GIS conferences can feel an atmosphere of healthy growth, eloquence, lofty aspiration, and the daily renewal resulted from GIS.

Main reason for this gratifying situation was the radical cost reductions in technology dating back from early 1980's, when computers became more powerful and cheaper. This decline in cost and the successful performance of the workstation as a tool in engineering projects have led to a rapid increase of "installed base" of GIS. At present almost every major academic institution in all countries offers courses of GIS. Most local and central government agencies use GIS, not to mention the engineers, businessmen, planners, architects, geologists, and so on. This growth in pure numbers, added to the functional advancement of GIS, makes it a huge business.

However, some contributions to the rapid development of GIS from other factors should not be neglected:

① First, at its beginning the GIS industry was supported by the ***existing mass data*** which were inexpensive or even free because they could be obtained from government agencies, some academic institutions and other organizations.

② Second, the public have given strong backing to the GIS industry. For example, a great many user groups, network conference groups, and GIS societies have been established like bamboo shoots after a spring rain.

③ Third, the ***GIS-related computer technologies*** have played an important role, such as the graphical user interfaces, help windows and automatic installation routines.

④ Fourth, GIS has merged and cooperated very well with ***relevant technologies***, and has benefited a lot from these practices.

The rapid development of GIS has been a marketing phenomenon of amazing breadth and depth, and the momentum will remain unchanged for many years to come. Clearly, GIS will continue to force its way into our daily life to such an extent that it will soon be impossible to imagine how we live and work without GIS.

1.2.7 A GIS Plays An Important Role in Society

In the GIS circle there has been an argument that in the definition of GIS not only the technology, software, or science should be mentioned, but also the social aspect should be included, because GIS has greatly changed the way people live and work.

Nick Chrisman (1999) defined GIS as "**organized activity by which people measure and represent geographic phenomena then transform these representations into other forms while interacting with social structures.**"

This definition has emerged from an area of GIS research which has investigated how GIS fits into society as a whole, including its institutions and organizations, and how GIS can be used in decision making, especially in a public setting such as a town meeting, or on a community group web site. This latter field is termed ***Public Participation GIS*** (***PP-GIS***).

GIS has become part of the way of carrying out works by many organizations, such as the National Planning Committee or rescue headquarters. The result has been a shifting in the work procedure, campaign commanding, job assignments, responsibilities, and even the power relationships of the organization. Many in the study of GIS have focused on describing and analyzing these impacts rather than looking technically at GIS or GIS application. Several books have been published, including Ground Truth (Pickles, 1995), which introduced GIS's humanistic and social features.

Nick Chrisman's definition of GIS includes all of the social aspects of GIS functions. For example, a GIS may be used to collect data about land holdings as ownership parcels. However, the application and dissemination of the data will vary according to the nature and experience of the social group which uses the GIS. In a profit-oriented social group, for example, a GIS might be seen as a tool for speeding building permits and promoting real estate sales. While in a more conservation-oriented social group, a GIS might be considered as a means for arousing public enthusiasm about environmental protection and afforestation. Although the GIS in the two social groups are roughly the same, the members, the purpose of application, and the degree of administrative control might be quite different from each other. It is the human factors involved that determine much about the GIS, rather than the technical aspects.

Another element included in Chrisman's definition is the ***measurements*** which are the data resource and basis of GIS. It is unavoidable that the measurements possess various accuracy and reliability. A GIS is based on the "best available data", but in reality some of the data are incomplete, outdated, or incorrect. How GIS users deal with this problem will influence the result of GIS application. A GIS, like a map, is always affected by a set of ***errors*** which have been agreed on.

1.3 A BRIEF HISTORY OF GIS

Originally GIS rooted in cartography. Drawing of ***general-purpose maps*** began many centuries ago and they closely related to topography. In the 20th century, ***thematic maps*** appeared which concentrate on a specific subject or a theme, such as traffic, administrative divisions, population distribution, etc. Although the above mentioned two types of maps, general-purpose maps and thematic maps, can be used in GIS, it is the latter that led cartography toward GIS. Some thematic maps are closely related with each other, such as the farmland map and hydrology map, the geology map and mineral deposit distribution map, and so on.

It was the field of planning that first began to exploit thematic maps by extracting data from one map to place them on another.

During the 1960s, many new types of thematic maps were becoming available in standardized scales, such as topographic and land cover maps from the U. S. Geological Survey, and soil maps from the U. S. Department of Agriculture's Soil Conservation Service (now the Natural Resource Conservation Service). It became fairly straightforward to select the right maps, trace off a layer, or photographically build a "separation" for one type of feature on the map, and then to combine the layers mechanically.

An event in GIS history that is worth notice is the presentation of an important model