APPLICATION OF COMPUTER IN CARTOGRAPHY

A CASE STUDY OF DIGITAL MAPPING

BY

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CERTIFICATION

THIS PROJECT TITLED APPLICATION OF COMPUTER IN CARTOGRAPHY A CASE STUDY OF DIGITAL MAPPING IS THE WORK OF T.S. AJIDE TO FULFILL THE REQUEST FOR THE AWARD OF POST GRADUATE DIPLOMA IN COMPUTER SCIENCE.

THE WORK HAS BEEN FOUND ACCEPTABLE.

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EXTERNAL EXAMINER **DATE**

DEDICATION

THIS PROJECT IS DEDICATED NOT ONLY TO ALL PATRIOTIC AND HARDWORKING PROFESSIONAL CARTOGRAPHERS BUT TO MY DEAR FATHER CHIEF EZEKIEL BABA AJIDE. IF DEAD CAN DERIVE PLEASURE FROM THIS, THEN PART OF THE DEDICATION GOES TO MY LATE MOTHER MAMA ASABI AJIDE.

NOTHING WORTHWHILE IS ACHIEVED WITHOUT SOME STRUGGLE.

ACKNOWLEDGMENT

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I wish to acknowledge the parts played by all officials of Kaduna polytechnic who have contributed in-no-measure to my coming for this programme.

"MAY GOD REWARD YOU ALL ACCORDINGLY AMEN.

TITILOYE S. AJIDE.

ABSTRACT

This project is about computers and mapping: how computers can make maps and how computers eventually will change both the nature of mapping and the appearance of maps.

The effects of electronic data processing and communications equipment upon maps and atlases will be as profound as its effects upon finance, manufacturing, warfare and entertainment.

Using the digital computer as a process control unit for cartographic drafting and as an accounting machine for geographic information is a special kind of computer application and one that only recently has emerged from a stage of exploratory arena of fine turning.

In examining this technological innovation, this project looks only briefly at hardware for capturing and displaying map data. Emphasis is also upon an understanding of the principles whereby present and future automated systems store, retrieve, analyze and display geographic data.

Definitions of common cartographic and computer terms are provided with a limited background in either of these two areas. Despite a basic non technical approach, the project should also prove interesting and informative to computer Scientists, Engineers, Cartographers and Surveyors.

Automated Cartography is of course, much more than the mere linking of sophisticated process-control equipment to the traditional mapping methods of the 1950s. The digital computer has had a profound effects on maps.

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CHAPTER ONE

APPLICATION OF COMPUTERS TO CARTOGRAPHY

1.0 INTRODUCTION

1.1 DEFINITION OF CARTOGRAPHY

Cartography has been defined as the act, science and technology of making maps. This is concerned with all stages of evaluation, compilation, design and drafting required to produce a new or reverse map document from all forms of basic data. Basically, we have three types of maps.

(a) Typographical maps – maps covering a large area of land and usually at small and medium scale.

(b) Cadastrial maps – maps covering a small area of land usually at large scale.

(c) Thematic maps – maps showing the representation of an area, landed properties, company's production rates or simply representation of data in colours for differentiation purposes.

1.2 COMPUTER:

Computer can be defined as a machine which accepts data from an input device, perform arithmetic and logical operations in accordance with a pre-defined program and finally transfers the processed data to an output device either for further processing or in final printed form.

It has a further capability of storing data as may be required. Before computer processing can commence, it is necessary to have an input device for the purpose of transferring data into the computer's internal memory.

A computer is automatic in operation in the sense that when the program and data for processing have been inputted into its memory the required output is produced without manual intervention as all the program instructions are executed automatically.

The above implies that computer processes or acts upon the data entered with the aim of generating an output which is regarded as information. Therefore, data are facts collected from measurements or observation about people, events, objects or concepts while information is a processed form of data which aids individual or organisations in decision making.

However, computers are used as aids in many human transactions and activities and such activity as related to Cartography.

1.3 **RELATIONSHIP BETWEEN CARTOGRAPHY & COMPUTER:**

The end product of the Cartographic procedure is the map. Many people think of maps as hand drawn paper-and-ink products, but now the production of maps by computer, either plotted on paper or drawn in the form of images on a graphic screen is becoming common place.

Digital maps are more easily adapted to a user's needs, especially when automated Cartography is combined with spatial database management within the context of a Geographical information system.

1.4 **DEFINITION OF AUTOMATED CARTOGRAPHY:**

Automated Cartography or digital mapping, is the process of storing, editing and generating maps using a computer.

The production of block diagrams and other representations of spatial data in graphical form is also part of automated Cartography. The effect of computer mapping techniques or traditional cartography has already been considerable. Digital mapping has been one of the strongest driving forces behind the development of geographical information system (GIS). Significant developments in the use of maps inthe coming decades can be predicted with confidence.

1.5 EFFECTIVENESS OF AUTOMATED CARTOGRAPHY:

Although the traditional concept of the map is changing. Paper maps will continue to be widely used, being other use requires low technology (a pair of eyes or even one eye), they are relatively cheap to produce in large quantities, easy to store and are well understood by the map-using community.

Although there is, some evidence that many people are unable to relate the pattern on a map to the corresponding real world features. It is clear that the major advantage of automated over manual Cartography lies in the computer's ability to store Cartographic and associated data and its speed in handling data and calculating results.

The map shown in fig 1.1 (to be attached) took only a few minutes to produce and is easily amended and redrawn. A manually drawn version of the same map would take many hours to produce.

It should be noted that a manually produced map cannot be easily changed whereas a computer drawn map takes its data from a database. This database can be readily edited and up dated when new information becomes available or amended when information becomes out of date and a new map can then be automatically redrawn.

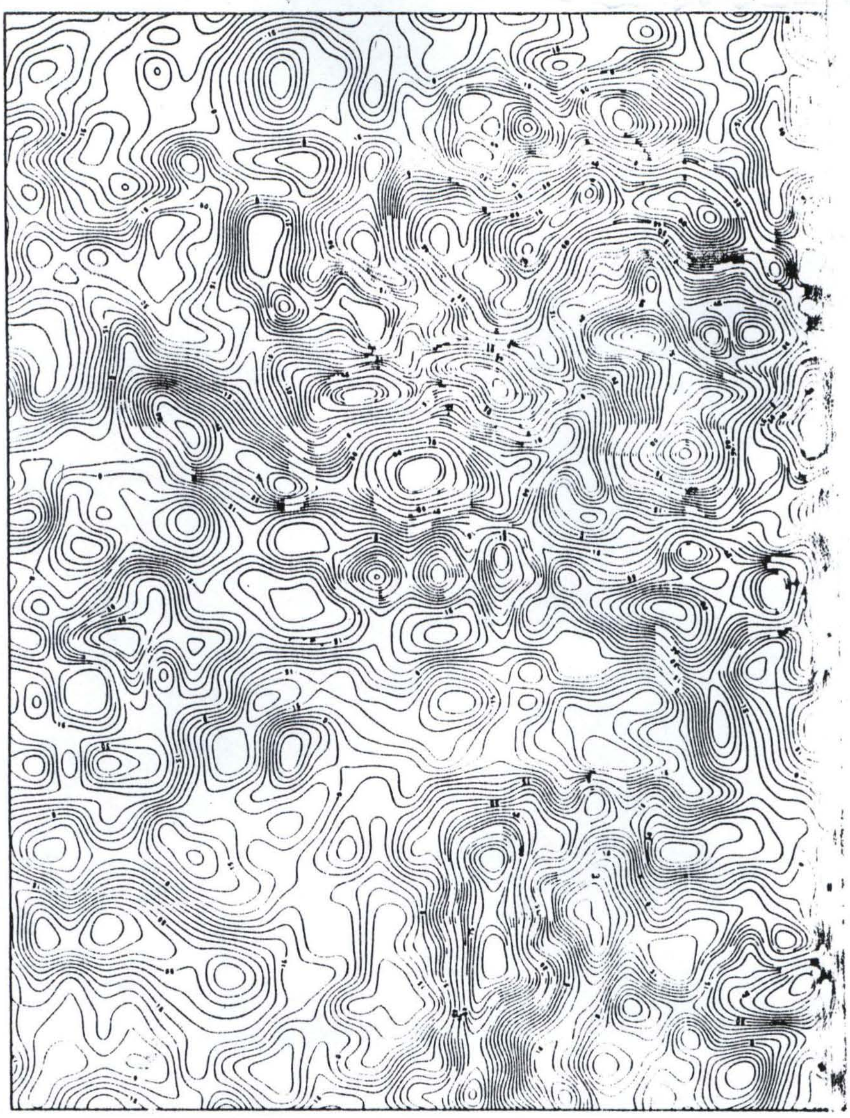


Figure 1.1 Machine-drawn contour map. (By courtesy of M. J. McCullagh.)

In addition, because a computer produced map can be redrawn quickly or is even on a graphics terminal, the cartographer can experiment with different contour intervals or levels of shading and can try different perspectives and projection with ease.

Maps can be generated digitally to suit different needs. For example, electricity, gas, water utilities require maps showing locations and attributes of pipelines or transmission lines and local authorities need maps showing bus routes and frequencies, location of street lights or positions of police stations (taking a few examples).

In the past, such maps have been time consuming and expensive to make. Other users of digital maps in developed and developing countries will include automobile associations, who will keep base maps of their areas in digital form and quickly display a map showing the relative positions of the broken down cars and the nearest mobile service unit.

In future, with increase in data collection of all kinds, much information will be collected in data banks. If part or all the map data is stored digitally, then continuous corrections of maps could be maintained. More frequent aerial photographic coverage will play increasing role in map revision.

As a result of many users of map and special demands, the major cities and conurbations should obtain now aerial photography on regular basis i.e yearly.

An advantage is the completeness of information and instantaneous record which is useful if all are in digital form for revision purposes.

CHAPTER TWO

2.0 WHY COMPUTER-ASSISTED TECHNIQUES?

Computers and digital technology have entered into almost every aspect of our everyday lives. Cartographers are therefore unable to ignore this trend. The digital technology is usually applied in order to achieve the following results.

- *Eliminate tedious, repetitive work*
- *Speed up production*
- *Increase productivity and improve product quality*
- *Allow for new products*
- *Facilitate the production process control*
- *Enable the computer analysis of data.*

On the other hand, the application of digital technology may have several serious draw backs. It may require the followings as well.

- *High initial investment and subsequent maintenance costs.*
- *Long and tedious implementation period*
- *Reorganization of production.*
- *Reduction and re-education of staff*

The rapid development of computer technology causes the equipment to become obsolete within a short period, this is a special problem. Obviously, there are as many reasons for the application of computer – assisted technology as there are against.

Map producing organizations around the world are faced with a variety of problems which differ from organization to organization. Special economic, social, technical and political circumstances in each country do not allow for universal solutions. Therefore in practice a careful study and pilot projects should precede the application of digital technology for every individual case.

However, in addition to traditional Cartographic products – "the graphical map"- a new product has appeared on the market – "the digital map". The latter is an organized set of cartographic data stored in computer readable media and representing a map image.

A collection of such data for a given region together with the computer programs for manipulation and retrieval of this data is termed data bank (or data base).

Some users requires maps in digital form. Computer technology may be applied for production of graphical maps as well as digital ones. For production of graphical maps, we have a choice between manual and computer-assisted production methods. But in the case of digital maps, cartographic organizations are forced to switch over to computer assisted techniques.

Generally, it can be concluded that computer-assisted production methods may replace the traditional methods in order to achieve the previously mentioned objectives, they also provide for completely new products.

2.1 <u>HOW THE COMPUTER- ASSISTED TECHNIQUES FIT INTO THE TOTAL MAP MAKING PROCESS.</u>

In general terms, the process of map making requires the following operations.

1. *Capture of relevant cartographic data*
2. *Processing the data into he required form and content.*
3. *Presentation of the processed data*
4. *Archiving*

The data capture is usually completed by experts in surveying, photo grammetry, geology, statistics, sociology etc. The cartographer then participates in processing of the data and is mainly responsible for the display and archiving of the data.

This general overview is equally valid for traditional as well as for computer assisted map production. Before any further processing or displaying is intended, it is essential that for computer assisted methods, the data is to be converted into a computer readable form and transferred directly into the computer or written in to computer readable media ie. (Punched tape, magnetic cassette, tape or disc or similar). This process is know as digitizing

In order to efficiently enable digitizing, special digitizing equipment is available; this will be discussed later on. The economic success of computer-assisted techniques in many applications highly depends on adequate solutions of digitizing processes. Digitizing may be simultaneously completed with data capture or at a later compilation stage.

Special drafting equipment is available for the graphical display of digitized (and processed) data. This may be used to complete final drafting as well as to facilitate intermediate checks.

Between digitizing and display, the data are processed in a computer, microprocessor or similar, which may involve transformation, conversion, selection, editing, generalization, symbolization, etc.

Computer-assisted technology may be considered as a new, very powerful though expensive cartographic tool which does not hamper, but promotes and enriches cartographic production. As every other sophisticated tool, it requires expert usage. It may be harmful if inappropriately applied, but on the other hand, it becomes unavoidable in the right place and time.

The traditional and computer assisted methods of map production do not exclude each other. They may be compatible if correctly applied each in its optimum form.

Indeed, very often we find in practice the application of both traditional and computer-assisted techniques in various production phases next to each other in the same organization and even in the same project.

2.2 DIGITAL REPRESENTATION OF CARTOGRAPHIC DATA

2.2.1 Characteristics of Cartographic Features

Maps provide a two dimensional representation of objects and phenomena situated on the earth (although other planets have recently also been mapped). Individual map elements are cartographic features which represent individual generalized objects or phenomena. Each feature is represented traditionally on the map in the form of line, point or area symbols. In order to provide a direct link to the traditional representation we classify the cartographic features into three types.

- *Point features*
- *Line features*
- *Area features*

Computer representation is, however, not limited to two dimensions. A third dimension elevation may easily be added; but, because most maps are usually orthogonal projections, elevations are redundant. For specific applications, the three dimensional computer representation of features can be a great advantage. The given feature classification is directly applicable in three dimensional representation. Three dimensional representation also allows for a more adequate accommodation of the forth feature type. Surface features, which may include relief.

Each feature type should be provided with information on location and characteristics of the object or phenomenon to be represented. Traditionally, location is represented by placing the symbol correctly on the map sheet, characteristics are represented by selecting appropriate symbolization. Naturally, in computer cartography, instead of those graphical means, we have to apply digital means of representation.

Two types of data are associated with each individual feature:

- *Positional data*
- *Attribute data*

2.2.2 **<u>POSITIONAL DATA</u>**

Indicate location of the feature on the ground or the map and sometimes implicitly its shape. The attribute data contain information on all other relevant characteristics of the features. (e.g attributes of a point feature may include the following: town, capital, 1 million inhabitants, 10 sqkm, area etc). We distinguish two types of attributes:

<u>Numeric attributes:</u> e.g size, area, inclination, temperature, etc and **<u>semantic attributes</u>** (e.g class, type, name, quality etc). Each of them may be stored in the computer in a coded manner.

The positional data are usually represented in one of the two systems:

- Point system (which is also known as vector or line system)
- Cell system (which is also known as raster or area system).

In any case, the positional data have to be referenced to a coordinate system, either geographic, map projection, orthogonal or any other suitable system.

2.2.3 **<u>TWO DIMENSIONAL POINT SYSTEM</u>**

In a point system a basic (atomic) element indicating the position of a feature is a point. The position of a point in two dimensional space is completely defined by its X and Y coordinate in a predefined rectangular coordinate system (see fig. 1.1).

DIGITAL REPRESENTATION OF A POINT 6 & 7

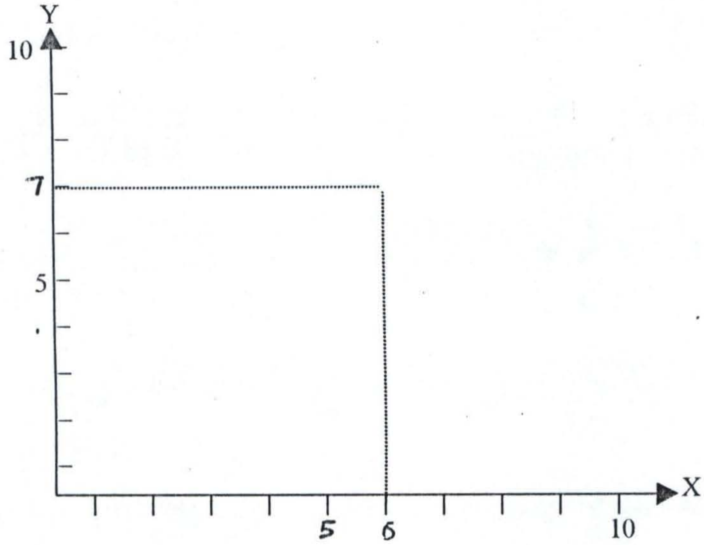


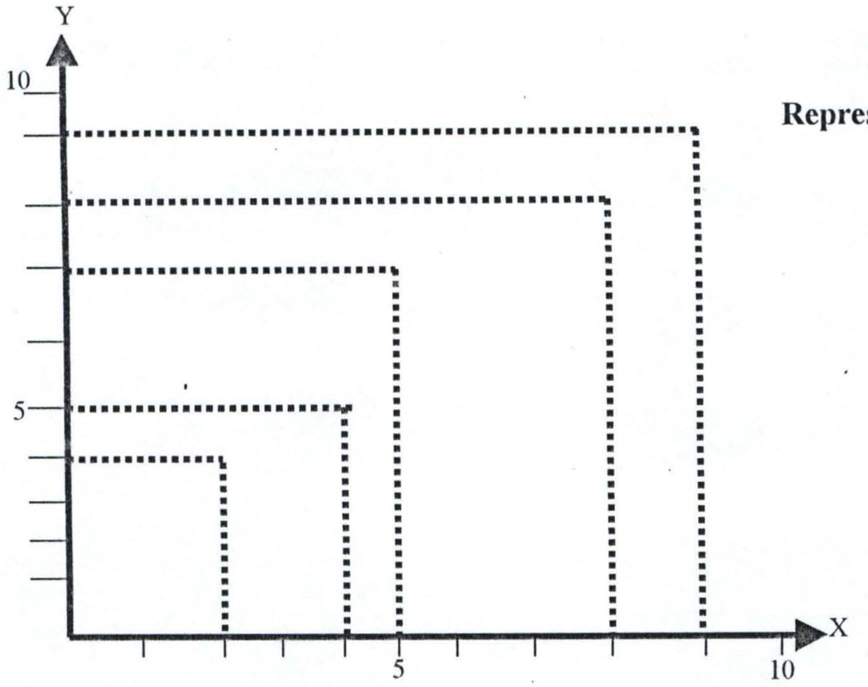
Fig 1.1

Consequently, the position of a point may be stored in a computer as a pair of numbers coordinates (e.g, 6,7 see fig 1.1). Knowing the coordinates, the location of the point may be re-established in the original coordinate system. Not only orthogonal, but also other types of coordinate systems may be used e.g polar coordinate system, geographic coordinate system etc. In any case the position is defined by a pair of numbers. For the correct application, it is always necessary to know the type of coordinate system which is used as a basis, the axis which is represented by a certain number and the measuring units used.

Otherwise, positional information is useless. Obviously, the position of a point feature may be represented in a computer by a pair of coordinates.

Theoretically, a line consists of an infinite number of points. So of line feature may be represented as a series of points given in proper sequence.

In order to make it practically, only selected points should be considered (see fig 1.2) various selection criteria may be applied. In most cases, one tries to select points in such a way that the line segments between the points are straight.



Digital Representation of a line.

4,2

5,4

7,5

8,7

8,8

9,9

Fig 1.2

The positional data of a line feature may be given in a computer as a series of pairs of coordinates, each representing a point on the line. The correct sequence of points should always be maintained.

2.3 PHASES OF COMPUTER-ASSISTED CARTOGRAPHY

Maps express environmental situations in the graphical language. In general terms the process of map making requires the following operations:

(a) Data Capture

(b) Processing the data to the desired form and content

(c) Displaying the data graphically

These fundamental processes within cartography can be compared to the three basic phases of any computer-assisted cartographic system, namely:

(a) Data capture and digitizing

(b) Data processing

(c) Data presentation

The a computer-assisted system data capture has to be followed by digitizing – conversion of data into a computer readable form. Each of the mentioned phases requires a special hardware configuration i.e the machines and instruments to perform the actual work. As with all digital methods, a digital computer is the central processing unit. Archiving of data is, as a rule, performed in a digital form.

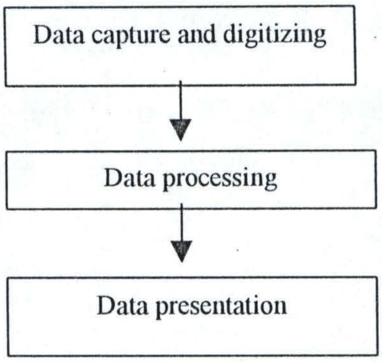


Fig 2.1

2.3.1 **DATA CAPTURE**

Data capture is the first step in the map production process. The positional data relevant for a specific map type may be collected directly in the field (field survey) or with the help of imagery (aerial survey). Field survey, photogrammetry and remote sensing may deliver positional data directly in digital, computer compatible form. For this purpose the geodetic and photogrammetric instruments must be provided with services which enable direct digitizing and recording. Data collected by remote sensing is mostly available in digital form (cell system). Another example of predominately automated collection of positional data is hydrographic survey. There is a general tendency to automate the survey methods as much as possible.

It is important to realize that in computer-assisted survey systems the sharp demarcation between surveying and cartographic activities disappears. Good cooperation and overall optimization of the system become an imperative.

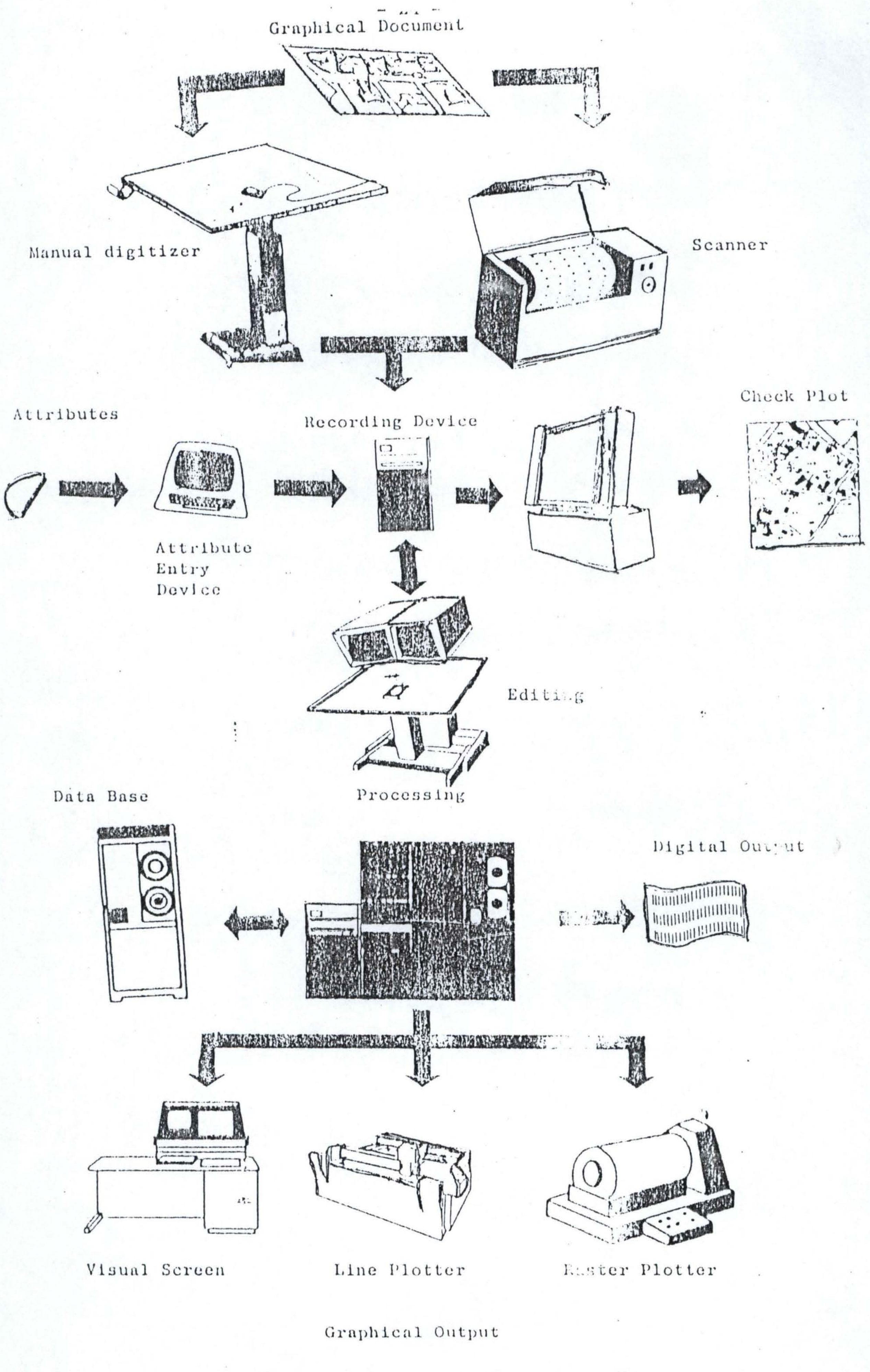
Very often, however, cartographic data are available in graphical form. In order to enable application of computer-assisted techniques cartographic digitizing becomes necessary.

The graphical documents to be digitized may be: compilation manuscripts, photogrammetric manuscripts, field survey manuscripts, photo maps, published maps etc.

In case that graphical documents are digitized, he cartographic production becomes less dependent on survey processes. The disadvantage of such a procedure is that every feature must be retraced once more during digitizing, which could reduce he efficiency and the accuracy.

For entry of positional data from graphical documents we have special equipment at our disposal: cartographic digitizers. There types of cartographic digitizers are available: manual digitizers, line followers and scanners.

The attribute data may be collected applying the field interpretation (topography, geology, soils, forestry, etc) or various collection techniques (census, geographical names, statistics, property etc.) or measuring techniques


Graphical Document
Manual digitizer
Scanner
Attributes
Recording Device
Check Plot
Attribute
Entry
Device
Editing
Data Base
Processing
Digital Output
Visual Screen
Line Plotter
Raster Plotter
Graphical Output

(rainfall, air temperature, magnetism, etc) the interpretation may also be complete with the help of imagery (photo interpretation).

All attribute data have to be written onto computer readable media either simultaneously with corresponding positional data or separately. If they are entered separately, some link with the appropriate positional data must be realized. This can be done by maintaining the same feature sequence in both positional and attribute entry, by providing corresponding positional and attribute data with the identical unique code (address match) or by providing the attribute data with positional match to positional data (coordinates of a point which coincide with the positional data).

For <u>entry of attributes</u> we have: Keyboards, switches, menus, voice entry devices, etc at out disposal.

Data capture and digitizing is an error prone activity. Errors reduce the value of data. In order, to minimize this, error detection and correction procedures must be established along with digitizing. Such procedures are known as <u>data editing.</u> They should be considered an integral part of the digitizing procedure. Positional data are very difficult to check in digital form. Therefore, in order to detect errors, they are usually graphically displayed in he form of a check plot.

Attributes may be checked by displaying various feature types by different graphical symbols, each feature type separately or by textural attribute display next to the corresponding positional data. Naturally, in the case of many attributes per feature, they may be separately checked (possible in tabular form) and only the links with positional data are then displayed graphically.

In order to correct the digital data after he errors have been detected, a set of computer programs have to be available to enable necessary corrections.

2.3.2 PROCESSING

Data processing comprises of all data manipulations between edited digitizer output and input into he display unit.

The data manipulations to be executed depend on he purpose of the final output. In order to enable the manipulations computer programs must be available. Such a program represents a stream of computer instructions each of which completes a specific operation (e.g multiplication, reading of data, testing the outcome of an operation, etc.). the programs may be made to execute a large variety of tasks. In principle there are no limits as to what can be programmed. However, practical realisation is strictly limited by the cost of program development, size of computer, peripherals to be used and the cost of time of processing.

The computer programs may belong to one of the following categories: hardwire, firmware or software.

The hardwire programs are realized by physical equipment components to complete a certain task. The firmware programs use modifiable hardware (microprocessors). The programs are then cast into them by the user. The software programs comprise a stream of computer instructions stored in he memory. In contrast to the first two types, they may be reloaded. He former two types of programs are usually developed by manufactures of digital equipment.

The software programs may be purchased but also developed in houses by the user. He development of such a programs are usually developed by manufacturers of digital equipment.

The software programs may be purchased but also developed in house by the user. The development of such a program consists of writing, compilation (linkage) and debugging.

The programs are usually written in one of the available "Languages" (FORTRAN, PASCAL, COBOL, etc.). Such languages consist of a set of exactly defined statements which specify he actions of the program and which may be written in English. Programs written in such a way are called source programs and can be checked and directly understood by the programmer. Special programs (Compilers) provided by computer manufacturers are used to translate the program into a form that can be interpreted by the computer (Compilation). At the same time the program is checked for syntax errors. The checking of possible errors in a program may only be done by executing it with actual input data and controlled output (debugging). With large programs it may be a tedious and time consuming procedure. Cartographic digital data can also be used in combination with other data and appropriate programs in applying for data analysis for planners, geographers, etc.

2.3.3 **REPRESENTATION**

Traditionally, cartography deals with graphical presentation. Computer-assisted cartography offers a large variety of possibilities in this respect. Before the data are displayed, they must be properly prepared: put into the required graphical form and provided with drafting commands which then give access to drafting machines. This may be achieved by symbolization programs.

Such programs accept attributes, convert the corresponding positional data into appropriate graphical form (e.g generate double parallel line for road presentation), transform it into the coordinate system of the drafting machine and provide it with the required drafting commands to drive the drafting machine.

In order to enable graphic display of digital data special equipment is available: graphic output devices. Three types of graphic output devices are available: line plotters, raster plotters and graphical screens.

The line plotters enable ball point or wet ink drafting, scribing and cutting open-windows. Compared to manual drafting they all offer high speed and accuracy. With respect to line quality only the most sophisticated 9and expensive) machines reach the standards attainable by a good draftsman. Such plotters are sometime provided with a light spot projector, a tool which draws on photo sensitive material with the help of a light beam and produces an excellent line quality.

The second group of output devices are raster plotters. In contrast to line plotters they do not draw lines but produce dots, where required, covering the drafting material systematically in series of parallel scan lines. Consequently, they are especially suitable for area representation.

They range from very inexpensive, high speed models, which produce relatively low quality output, up to high resolution models with output on photo sensitive materials of printable quality. The top quality models may produce directly screened area in fills, compatible to offset plates.

The lines produced by raster plotters always have a see-saw appearance, which is hardly visible in high resolution models. He third group of output devices are graphic screens. The first two groups of output devices are 'hard copy' units, producing output on drafting material, while he screens are "soft copy" units ie. The graphic output disappears when the screen is switched off or erased. The drafting speed on screens is very high (the whole screen may be filled up in a matter of seconds). There are various screens available ranging from black and white to colour displays. Compared with other devices they are mostly limited in drafting area size (up to 2000 cm^2) and resolution.

The extremely high drafting and erasing speed make graphic screens very suitable as efficient editing devices.

In addition to this primary graphic cartographic output, digital data may be also presented in he form of printed lists or tables if required.

As already mentioned, a new cartographic product – a digital map has gained considerably in importance. It comprises of a map image stored on magnetic tape or other storage medium. Efficient application requires the standardization of data structure and format.

CHAPTER THREE

3.0 THE TOOLS FOR COMPUTER -ASSISTED CARTOGRAPHY

The equipment which is used in computer-assisted cartography (hardware) consists of three main groups of devices:

- electronic,computer
- digitizing equipment
- graphic output devices.

The electronic computer is the heart of the whole system. Its function is to process the data and to control digitizing and data display.

3.1 COMPUTER

The computer (mainframe) comprises of two basic components:

- Central processor
- Main memory

The computer peripherals which are of main interest for cartography are:

- magnetic disc unit
- magnetic tape station
- magnetic cassette station
- video terminal
- hard copy terminal
- hard copy terminal
- line printer
- keyboard

the peripherals such as paper tape and punched card units are of less importance.

We distinguish two types of computer systems with respect of the data transfer between mainframe on one side and peripherals, digitizing and graphic display units on the other:

- on-line
- off-line

in on-line systems the data transfer between mainframe and other above mentioned devices is realized through cables or telephone lines. If the data transfer is realized through removable storage media 9such as magnetic tapes) the systems are termed off-line.

3.2 MAINFRAME COMPUTER

The central processor executes instructions specified by programs and controls all other units. The main memory stores data and currently running program instructions. The size of the main memory is usually given as he number of addressable memory locations (number of "words"). Depending on computer type, words are 6 to 60 bits long 9most commonly 16 or 32 bits). A bit is a binary digit (in a 16 bit word we can store a number with about seven decimal digits). Byte is a part of the word and usually represents eight bits.

Memory size is given either in units of kiloword (KW), which represents 1024 words or in kilobytes (KB). A a large unit is mega (M), which comprises 1000 K-eg. 1MB = 1000 KB.

3.3 PERIPHERALS

3.3.1 MAGNETIC DISC

The magnetic disc performs the function of auxiliary mass storage device. It resembles a record and the disc drive a pick-up. The reading arm on the disc drive has direct access to any location on the disc. Moreover, several discs may be mounted on he single spindle as in juke boxes. Such an assembly is called a disc pack and enables access to any location on any of the discs in essentially the same amount of time. Disc packs with large storage capacity are available 980-300 MB is quite common size).

The disc may be considered an extension of the main memory with slower and less direct data access. They are applied to store the programs and large amounts of data until they are needed in the computer.

Because cartography deals with large data volumes, disc packs have become an essential part of cartographic systems. Discs written in one computer cannot be read by another computer type. They are re-usable new information may be written over the old one.

A special type of disc recently developed is the floppy disc. It is not rigid as a standard disc but flexible. Therefore, an envelope protects it form damage. It is less expensive, but has less storage capacity than the standard disc. In contrast to a standard disc, a floppy disc may wear out after long usage.

3.5 OPTICAL DISC

A new development in storage media is the laser written optical disc. Recording is done by laser beam causing tiny dots 9about one micron in diameter) on the metal disc surface. Such discs have a very large storage capacity (about a million MB), but there are still unsolved technical problems.

3.6 MAGNETIC TAPE

Magnetic tapes are plastic tapes coated on one side with magnetic material an wound on a reel. The read and write operations on reels are executed with the help of magnetic tape stations.

Magnetic tapes may be written in delectable densities 800 or 1600 BPI (bits per inch). Recently also "high density" magnetic tapes have appeared on the market – 6250 BPI. He tapes are normally available in lengths of up to 2400 feet. Between data blocks on magnetic tape, so-called inter-record gaps are left, which enable start/stop operations and read/write checks.

The capacity of a magnetic taps reel depends on its length, writing density and number of interrecord gaps. The 2400 feet reel at 1600 BPI has a capacity of about 40MB.

In contrast to direct access disc, the magnetic tapes are sequential storage devices – storage locations may be read or written only in the order as they physically appear on the tape.

Magnetic tapes allow for slower access to data than discs, but they are less expensive and require less shelf storage space. Therefore, in cartographic applications, magnetic tapes are especially popular as data transfer media among different equipment units and as permanent storage media (archiving).

However, experience has shown that there might be a loss of information on magnetic tapes if they are left unused for longer period of time. Therefore, it is recommended to read the tapes at least once pr year. The magnetic tapes are also re-usable- the new information destroys hte old. He reels may be protected against unwanted writing.

In contrast to discs, the magnetic tape are interchangeable among computers of different types and as such represent the most suitable medium for a bulk data transfer.

3.3.4 MAGNETIC CASSETTES

Contain tapes of lower density (100 BPI) and storage capacity (up to about 200 KB). They are compact, do not require threading and find application in smaller size computers and as digitizer recording devices.

3.4 OTHER PERIPHERALS

In order to enable user-oriented communication with the computer, so-called terminals are available. They usually contain a Keyboard for input of alphanumerically and other characters. The video terminals utilizes, in addition to the keyboard, a screen as output device, which echoes input and displays computer messages. Instead of the screen, he hard copy terminal utilizes a printing device for output on paper. The terminals enable creation, running of programs and direct data manipulation. The video terminals are faster and quieter, but the hard copy terminals provide a permanent copy of a computer session. For fast printing of output the line printers may be utilized, which can print up to 1500 lines of 132 characters per minute.

3.5 SYSTEM SOFTWARE

Computer are worthless without programs. In order to enable the computer usage the manufactures deliver a set of programs together with a computer which provide for some basic operations. Access to such software is usually through so-called command language, which consist of a set of English commands. The software enables program development and execution, control of input and output devices and data management.

3.6 DATA MANAGEMENT

The basic data organization units on disc or magnetic tape are files. A file is a storage segment, which can be directly accessed. The files may be created, copied, expended, deleted or edited using system software. The user programs also have access to the files and store, retrieve or modify the data.

The file begins with file header, which contains file identification. At the moment of creation the file is provided with unique user defined identification, which includes a name. The name may be used to retrieve the file. In addition a file may be provide with a protection code to prevent unauthorized usage.

Magnetic tape files are terminated by he end of a file characters. They are physically contiguous and can be accessed only in the sequence as they have been written. After a file is written on tape, another file can be appended to it, but the files cannot be individually deleted.

The disc files need not be stored on contiguous storage locations, but are scattered anywhere on the disc. The files written on a disc are automatically include into an index (directory) which enables direct access to any file.

The file is quite a large storage unit. Therefore, it is subdivided into smaller units – records. The record is the smallest storage unit which may be, inside a file, directly accessed by a program. The record may be delimited by a predefined end of record character (usually "line-feed" character) or its length may be explicitly given at the beginning of each record (in number of bytes or words). We distinguish record size, record format and record access mode.

The size of a record is defined at the moment of writing. A file may contain variable or fixed length records. A file with fixed length records contains all records of equal size.

The records inside a file may be accessed sequentially or directly if the individual records are accessible only in a predefined order, then we speak of sequential record access. This order is usually the sequence in which the records are written.

In direct access mode, each record is provided with a unique number or key. Each record may then be directly accessed by specifying the number. Direct access records are usually fixed length records. In magnetic tape files the records may be accessed only sequentially, while disc files allow for both access modes.

Organization of data inside a record is completely in he hands of the user. At the moment of writing he user must define what and how to write. Also, when reading the user must know what has been recorded. If this information is not available, it is very difficult to retrieve the data. Inside a record various data elements (items) may be stored, e.g a coordinate, an attribute and a name.

The way the data elements are formally written is specified by a record format. Two basically different types of formats are possible: non-text (unformatted) or text string (formatted). The text string records contain data recorded as character strings. The characters are represented in one of the binary alphanumeric codes (ASCII, EBCDIC, etc). Each character usually occupies a byte. The data items are then either separated by a predefined item delimiting character (usually "space" or coma) or the number of characters for each item is prespecified. Such a data representation is user oriented because it may be readily printed. Every character corresponds to a stroke on a typewriter.

Non-text records have computer words as subdivision units. The item is then equivalent to a word or a number of words. Each word represents a number in internal computer coding. Such representation is more efficient for numerical data.

3.7 PROGRAM DEVELOPMENT AND EXECUTION

In order to enable the necessary data processing, computer programs must be available. The programs any be either purchased from software houses, universities, etc., or developed by the user.

When purchasing a program the buyer should, in addition to the price, consider the following: compatibility of the program with the buyer's computer configuration, installation problems, ease of operation, follow up (updating), error messages and recovery, freedom of bugs and whether the programs actually fulfill the user's requirements. The and conceptual developments cause that he programs become relatively quickly outdated.

Program development is a time-and labor consuming job. Therefore, in terms of money, the development of programs in-house become an expensive activity, which should be started only if all other possibilities are exhausted.

Program development is facilitated by system software. It consists of the following steps: 1. Task description and analysis, 2. Creation of a source program, 3. Translation into the computer-coded instructions and 4. debugging.

1. At first it must be clarified what should be done, what input is and how the output should look. After that one has to establish a set of well-defined procedures for the task completion in a limited number of steps (algorithms). At this point constraints have to be taken into account (available size and characteristics of computer and peripherals) and the speed of processing has to be estimated.
2. Finally, the program has to be written using one of the available languages (FORTRAN, BASIC, PASCAL, etc), which consists of a set of English statements. Each statement causes exact predefined operation. Such a program has to be typed and stored in a file (source program). It may be read and understood by anyone acquainted with the language in question.
3. The source program has to be translated into the stream of computer instructions. For this purpose special programs are available (compilers), which may be invoked by a command. After successful compilation, the executable program version becomes available.
4. There is no guarantee that the created programs perform correctly. Only some of the possible errors may be reported automatically during compilation. The only way to detect all possible errors (debugging) is controlled execution of he program using realistic input. The actual output may then be compared with the expected one. even so, it is not always easy to conclude where the error has been made.

The programs may be executed without the operator's intervention (batch mode) or in dialogue with computer using the terminal (interactive mode).

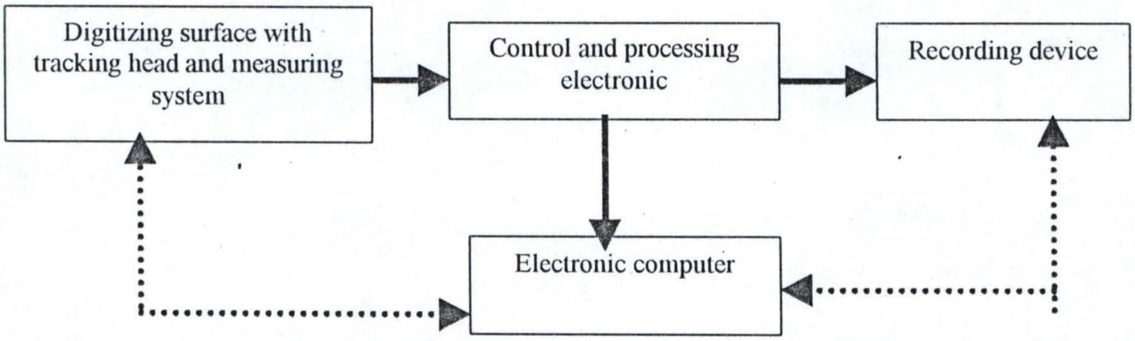
Larger computers, when provided with the appropriate operating system, may execute several programs simultaneously-in a <u>time-sharing</u> or <u>multiprogramming</u> system. In multiprogramming each user gets a portion of the mainframe computer, while in case of time-sharing each user disposes over the whole system for a fraction of time. The former system actually reduces the sizes of the memory per user, while the latter increases processing time per user.

3.8 DIGITIZING EQUIPMENT

A cartographic digitizer is an instrument for measurement of planar positional data, conversion of the measured data into digital form and their recording onto a computer compatible medium.

We can subdivide a cartographic digitizer into three main parts (see fig below):

- Digitizing surface with tracking and measuring device
- Processing and control electronics
- Recording device.



The digitizing surface is usually flat but in some instruments is in the form of a drum. The working area must be large enough to accommodate the sheet size to be digitized. Working areas between 0.3m and 1.5 x1.5m are usually available.

The tracking device has the function of locating the point to be measured. The measuring device then enable the measurement of coordinate distance between the tracking head and a predefined origin. Most often an x and y orthogonal coordinate system is applied. The measuring system also incorporates analogue to digital converters (encoders) which convert the assistance (or angles) into electrical pulses. These pulses are then accepted by control and processing electronics and are counted or decoded as required according to the type of encoders.

Processing and control electronics automatically control formatting, recording and eventually digital display of data.

Finally, the data are recorded onto a computer compatible storage medium. In an off-line operation we have a magnetic tape station, magnetic cassette recorder of floppy disc 9paper tape punchers are becoming obsolete).

An electronic computer may also be directly connected to the digitizer (on-line operation). In this case many of the functions, which are hardwired in control electronics can be replaced by programmed control. The function of the control electronics may be reduced in an extreme case to a simple interface between measuring device and computer, although the general trend is to relieve the host computer from control operations as much as possible. It is obvious that during digitizing all computer peripherals may be used. We may distinguish two modes of controlling the tracking operations:

- Manual
- Automatic

In the case of manual operation the operator identifies lines and points to be digitized an manually controls the movement of tracking head. In automatic operation control of tracking is taken over by computer programs or microprocessors and optical-electronically sensors.

Finally, we may distinguish two modes of tracking operation:

- Scanning
- Line following

In first mode requires that the tracking head scans the whole sheet area in a predetermined pattern (usually parallel lines). In every position of the tracking head, presence or absence of graphical element, grey level of the document or color has to be registered. The coordinate position of each recorded element (cell) need not be directly registered. Later it can be easily deduced from its recording sequence. It is obvious that such a tracking mode is hardly suitable for manual operations. The alternative is to direct the tracking head in such a way that it locks on to a line, which has to be digitized. This tracking mode is suitable for manual digitizing, but may also be automated.

3.8.1 ACCURACY

The accuracy standards for the measuring system of present cartographic digitizers are imposed by the necessity to reproduce the digitized line (by mean of graphic output device) in such a way that the human eye cannot detect any significant deviation between the original and the reproduced line. The resolving capability of the human eye and the graphical reproduction facilities combine to limit deviations to about 0.1mm. although the cartographer is actually interested in he overall accuracy, we find in practice that there are several measures for accuracy. They are related to different error sources within the measuring system. The manufactures of instruments tend to ignore inaccuracies, which are due to the operator in manual operations.

We distinguish the following accuracy indicators:

- resolution,
- repeatability
- accuracy.

The resolution is the smallest distance which can be measured with the system along an axis. The working surface of a digitizer can be though of as covered by grid squares, the side of each square being the measure of resolution. One can specify the position on the surface only on intersections of grid lines and not between them. In scanning systems resolution is defined as the cell size. The resolution in cartographic digitizers is usually between 0.01 and 0.1mm.

The repeatability is the tolerance within which cluster the coordinates of the repeated measurements of the same point. The point may be approached from any direction and the settings may be repeated as many times as desired. The repeatability of digitizers used in cartography is usually 0.025mm or worse.

The first two indicators of accuracy are not sufficient to describe the performance of the measuring system. Two further terms are connected with the instrumental accuracy of he digitizers: static accuracy (usually known as simply accuracy) and dynamic accuracy. Information on static accuracy should deal with the overall errors which may be expected in a stationary measuring system. It is usually given in the form of tolerances between measured coordinates of a practically error-free standard grid. For cartographic digitizers a static accuracy should not exceed 0.1mm. dynamic accuracy also includes the error sources which occur when the measuring system is in motion. With manually operated instruments, the operator has a great influence on dynamic accuracy.

3.8.2 CLASSIFICATION

there are many possibilities of classifying cartographic digitizers. As criteria for classification we may take accuracy, working area, etc. He most suitable criterion, however, which has been more or less already accepted in practice, seems to be the way in which tracking operations are executed and controlled. We distinguish three main groups of digitizers:

- manual digitizing tables
- line followers (semi-automatic)
- raster scanners (automatic)

the former two types provide the output in point system in contrast to the third type which outputs in cell system.

3.8.2.1 **MANUAL DIGITIZING TABLES**

The digitizing table is constructed as a flat surface mounted on a pedestal base. It is usually counter-balanced so that, in most models, the surface can be adjusted to any desired angle and height. On the top of the table a light-weight tracking head is situated, which may be held in the hand and moved all over the surface. Such a head is termed cursor. The position of the cross hair mounted on a cursor may be measured in the digitizer coordinate system.
The control electronics is either accommodated in a separate cabinet or inside the pedestal. We distinguish two types of manual digitizers:

- digitizers with cursor mounted on an arm
- digitizers with a free cursor.

Both types are also available as light-weight, small size desk top models. They are usually less accurate and therefore, applicable only for special purposes.

3.8.2.2. **MANUAL DIGITIZERS WITH CURSOR MOUNTED ON AN ARM**

In most digitizers of this type a very lightweight cross-slide system is mounted on he top of the table. One of the arms of he cross slide system carries a cursor see fig.

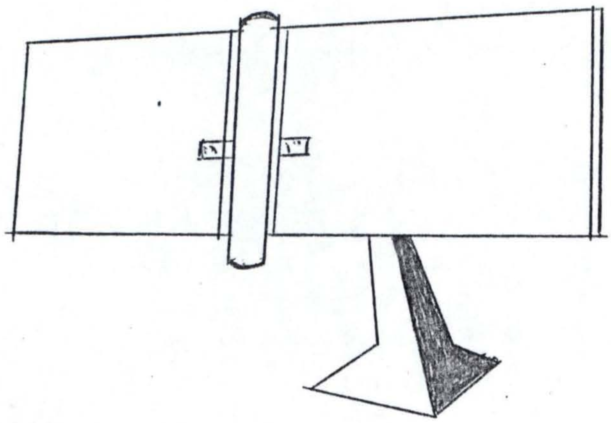


Fig 3.2.2

The two arms of the cross-slide system define the axes of the plane coordinate system. The coordinate values are defined by displacement along the arms. The displacements are quantisized by encoders which produce electronic pulses in proportion to the movement. Two types of encoders may be applied- linear or rotary. The rotary encoders re operated though rack and pinion or wire and pulley set-up (rarely through screws). The pulses generated by rotation are counted or decoded to produce the numeric coordinate values.

The polar digitizers may be included here. Instead of rectangular coordinates the polar distance and angle are measured. Digitizers of this type are seldom used because of unfavorable error propagation. The arm on which the cursor is fixed disturbs the free view on the digitizing document and he free movement of he cursor. Therefore, the digitizers with cursor mounted on an arm are seldom used for cartographic purpose.

3.8.3.3. MANUAL DIGITIZERS WITH FREE CURSOR

The digitizers with free cursors do not share the above mentioned disadvantage. The cursor is, in this case, connected to the control electronics only by a flexible wire (see fig). The light weight free cursor gives the operator complete freedom of movement.

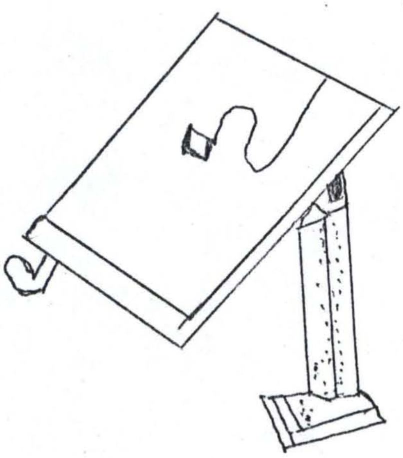
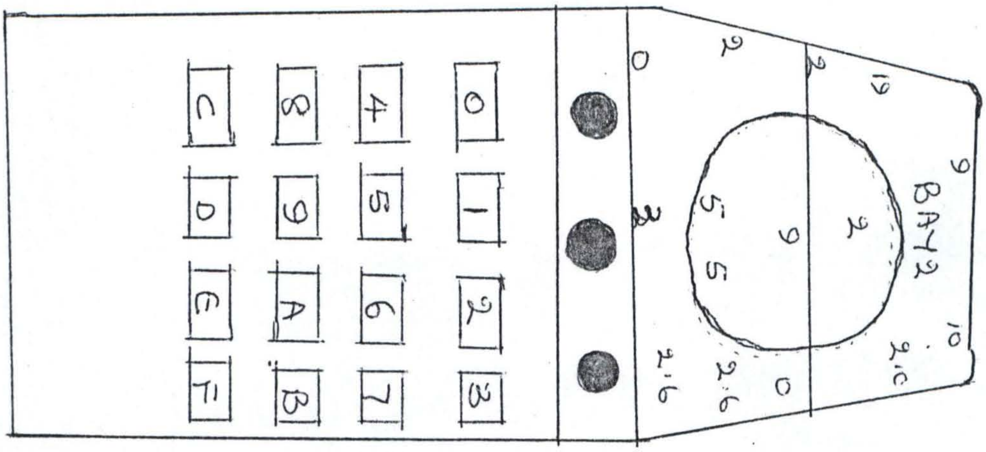


Fig 3.2.3

In digitizers of this type the table top consists of a flat plastic mat in which a rectangular grid of wires is embedded. Electric generators pulse the wires producing the discrete signals in response to the coil situated in the cursor. The location of the cursor relative to the grid (which represents a coordinate system), is determined by decoding the signal. The digitizers of this type are characterized by almost complete absence of mechanical moving parts. Until recently the free cursor digitizers with cross-slide system under the table top and the magnetic follower to track the cursor were produced. But they are no longer manufactured and it is unlikely that they will appear again.

Cursor are available in various shapes. They are usually supplied with a plastic disc with a cross engraved in the centre (see fig.



The cross is used for positioning and tracing. The magnifier may be added for higher tracing accuracy. Instead of a disc with a cross, a marking ball point or a scribing point are optionally available.

In order to enable command entry, the cursor is normally provided with four to sixteen buttons. One of he buttons enables coordinate registration, while the others are sued for entry of special functions. The registration button may be replaced by a foot switch. The table surface is usually available either opaque or back lighted. The free cursor digitizer is by far the most popular type in cartographic applications. They are produced by numerous manufacturers. Some of he well-known manufacturers in Europe are: Aristowerke (W. Germany), Ferranty (Gt. Britain) contraves (Switzerland), Benson (France), and in the U.S.A. Altek, Summargraphics, Keuffel and Esser and many others.

Typically, those tables have a resolution of 0.025mm and an accuracy of 0.125mm.

Free cursor digitizers with a relatively small, transportable surface (about 0.2x0.2m) and lower accuracy are commercially known as <u>tablets.</u> They are produced in the form of thin pads. Their application is restricted to special purpose (menu, input for graphical screens).

3.8.2.4**LINE FOLLOWERS**

Manual digitizing is a time consuming and tedious operation especially when dealing with complicated lines. In order to relieve the operator and speed up digitizing, line followers have been designed, which operate in a semi-automatic digitizing mode-when brought to a line the tracking head (which includes a sensor) follows the line automatically as long as it is clearly defined (until the end point, junction or unclear segment is encountered).

The operator is needed to bring the tracking head to the starting point of each line and to interfere when problems arise. Such line followers resembling flatbed drafting machines were produced in the past. Moreover, very often the existing drafting machines were provided with the sensor and the control electronics to fulfill the line following task. Because of their prohibitive price and relatively slow speed they have almost disappeared from the market.

The new generation of line followers use laser beams instead of high inertia mechanical tracking sensors. Actually, only one manufacturer (laser-Scan, Gt. Britain) presently delivers digitizers of this type (Fastrak).

The map to be digitized has to be reduced photographically to a negative of maximum area 96x68mm. It is then displayed on an optical screen (1x1m together with a cross, movable by a joy stick. In order to digitizer a line the operator has to position the cross on the line and to initiate follower. The laser beam systematically scans the line on the negative in a local raster system. The raster scan data are simultaneously processed with scanning by the computer, which returns line coordinates in point system into the storage.

2.8.2.5**RASTER SCANNER**

The raster scanner allows for a completely automatic digitizing operation. The operator is needed only to insert the graphic document and to start the operation.

The tracking head consists of a light source, which produces a light spot on the graphic document and a sensor (photo cell), which measures the amount of reflected or transmitted light. The head is automatically moving to scan the whole document in a series of parallel lines. The registration of amount of light is triggered at every successive spot location. The spot size is normally selectable between 0.05 and 0.20mm.

The output of such a digitizer is, naturally, in a cell system. The spot size represents the resolution. The coordinate location of each registration is not directly needed, because it may be derived from the sequence of registrations. The amount of registration indicates presence or absence of graphical elements.

3.8.2.6**ACCURACY AND SPEED**

Although the principle of a scanner is know for a relatively long time, the practical application of scanners at productional level started at the end of the 1970's. In contrast to manual digitizers the scanners are a relatively new product, manufactured at only a few places. Some are: Optronic, Broomall (USA), Scitex (Israel), Messerschmidt and Bolkow (W. Germany).

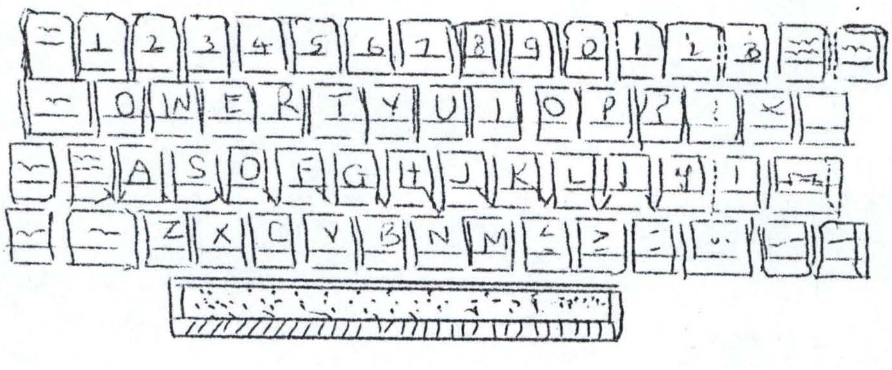
CHAPTER FOUR

4.0 ATTRIBUTE ENTRY DEVICES

Attributes may be simultaneously entered with digitization of corresponding positional data or at a later stage and correlated to the positional data in some way or another. So all devices mentioned in the following may be used in combination with manual digitizers or line followers. The raster scanners, naturally, do not allow for manual entry of attributes at the moment of digitizing. Scanned data may be displayed using an interactive graphic system, which allows for comfortable attribute entry.

4.1 KEYBOARD AND TYPEWRITER

Straightforward entry of attributes may be achieved by keying them on a keyboard. Standard alphanumeric keyboards with full range of characters are available (see fig).



If only numeric attributes are to be entered smaller and handier numeric keyboards may be used with the choice of only 10 digits. Such a numeric keyboard or a keyboard with a small number of selected characters may be directly attached to a manually operated cursor.

It is useful to have the entered characters echoed on the visual display (cathode ray tube, mixie tubes) in order to check for typing errors and enable corrections.

The typewriter actually provides for the hard copy of all introduced attributes, but because it is heavy, clumsy and noisy it is hardly used in combination with a digitizer. It may be, however, suitably applied if the digitizing and attribute entry are separated.

4.2 THUMBSWITCHES OR SETTING SWITCHES

The switches are inexpensive entry devices. The thumbswitches comprise of banks of setting drums. On each drum a digit may be manually set and then the whole number recorded by depressing the registration button. The change of one digit does not necessitate the resetting of the whole number, as it is needed if a keyboard is used. The number is constantly displayed on the setting drums. A similar effect may be achieved by digit setting buttons.

4.3 MENU

A menu may be realized with the help of a sheet of paper on which a number of small boxes has been drawn, each labeled with a particular attribute. It may be placed on the surface of a manual digitizer and its position registered. Before digitizing a feature the operator has to place the cursor inside the box, which is correspondingly labeled, record a point inside the box and procede digitizing the features. The coordinates recorded inside the box are identified as an attribute specified inside the box. In order to enable this, a program has to be available for every menu. Various interchangeable menus may be prepared. Each of them has to be provided with unique identification.

The menu do not require high accuracy digitizing surface. Therefore, they may be mounted on low accuracy tablets, which are especially handy and movable. The digitizer an tablet may share the same cursor. Even low accuracy touch sensitive tablets are available, which make a cursor redundant and enable digitizing by finger touch.

4.4 VOICE INPUT DEVICE

Recently, devices have been developed, which enable the writing of spoken words directly onto a computer compatible medium. Such a device consist of a microphone (usually with a head set), speech recognition processor and recording device (or interface to a computer). The available devices have the capacity to recognize up to a few hundred utterances each of up to a few seconds in duration. The operator is required to train the device to recognize his commands and to create vocabulary tables. Different operators can work with the same tables if their voices do not differ too much.

It is very helpful if a voice input device is provided with a response system, which repeats the recognized command through a loudspeaker or displays it visually.

4.5 COMPARISON OF ATTRIBUTE ENTRY DEVICES

In case the digitizer is directly connected with the computer (on-line), all mentioned devices may be also used as command input devices for dialogue with the computer. The computer may then also check the correctness of entered attributes.

The keyboard is the most flexible and general input device, which puts no restriction on the length, number and type of attributes to be entered. Unfortunately, if the keyboard is used the operator's attention is diverted from he working sheet at the moment of attribute entry. Moreover, the operators need training as typists. They also must either remember all attributes or constantly consult the attribute lists or code books.

The thumbswitches are low cost input devices, which may replace keyboards in case entry of numerical attributes is required.

The operator does not need to remember the attributes when a menu is used, because all needed information may be directly provided on the menu sheet. the attribute entry is then an operation similar to digitization. The disadvantage of such an attribute entry is the limited number of attributes which may be accommodated on one menu sheet. For different data types, different menu sheets must be designed.

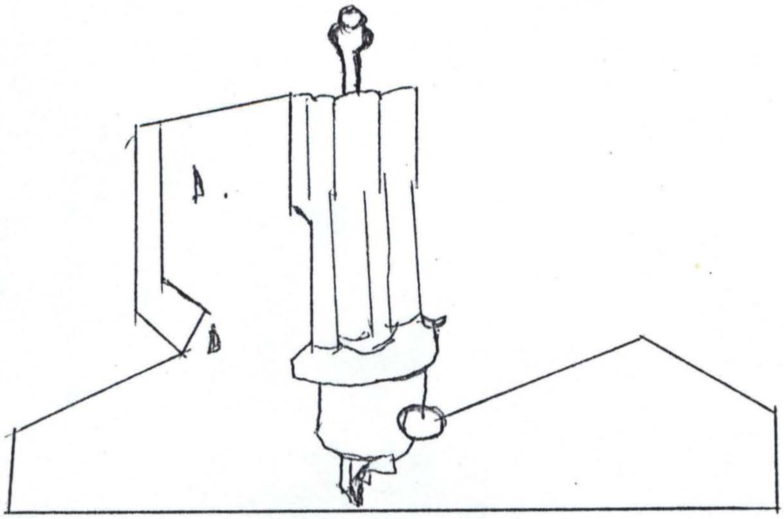
The voice input devices put limitations on a number of available attributes. The operator needs to remember the correct "word", but it leaves both hands free and causes the least diversion from digitizing operation at the moment of attribute entry.

Because attribute entry devices show such operational differences, we very often find several types of attribute entry devices attached to a digitizer.

When the digitizing and attribute entry are separated the disadvantages of keyboards and typewriters are no longer so apparent.

4.6 DRAFTING MACHINES

The quality of the plot depends to a great extent on the choice of drafting tools. A drafting tool may be fitted into a tool holder, which is provided with mechanism to move the tool up and down, (see fig)



In order to minimize the number of necessary tool changes Multi-positional tool holders may be provided, allowing simultaneous mounting of several tools (usually between two and eight). The tool selection is then automatically controlled by a program as well as the necessary offset for successively used tools.

More sophisticated drafting machines offer options on many tool types:

The (pressurized) ball point is an economic tool which allows very high drafting speeds. The line quality is relatively low. It is available in only one line thickness. Fiber tip pens have similar characteristics. In both cases various colours may be obtained.

In ink pens adaptors, the commercially available capillary pens may be fitted. Line thickness 0.1 to 2.5mm in different colours may be drawn. Slow ink flow limits the drafting speed. The necessity to refill the ink container is disturbing. Present ink pens use forced ink feed to improve the ink flow.

The standard round or conical tipped scribing tools provided with hard scribing points (tungsten carbide, saphire, diamond) may be fitted into scribing adaptors. Interchangeable points up to 02mm are available. In order to enable scribing of thicker lines scribing chisels are sued. The chisel must be tangentially oriented to direction of scribing in order to function properly. This means, that this tool has to be provided with tangential control-a small step motor and control circuitry- which analyses the tool path and rotates the chisel appropriately. The same assembly may be usually, used to accommodate cutting knife in order to cut peel coat masks. The quality scribing poses also limitations in speed otherwise the scribing tool may not be in sufficient contact with material or the material may become too hot.

In order to guarantee the correct tool pressure, the tool holders are spring loaded or provided with air pressure adaptors. In older types of machines the tool pressure was adjustable by weights.

The most sophisticated drafting tool is the light spot projector (Photo head). It draws by means of a vertical light beam projected onto photo sensitive material. It may be attached to the drafting machines in place of a tool holder.

CHAPTER FIVE

5.0 ACCURACY AND CONCLUSION

5.1 CLASSIFICATION

The line plotters may be subdivided into plotters of:

- low accuracy
- medium accuracy
- high accuracy

although the accuracy has been used as a basis for classification, the mentioned classes share, as a rule, other characteristics-price, choice of tools, etc.

The well-known manufacturers of line plotters are: Aristowerke, benson, Contraves, Kern, Kongsberg, Wild (in Europe) and Calcomp, EIA, gerber, Xynetics (in the USA).

5.1.1 LOW ACCURACY PLOTTERS

Low accuracy plotters are characterized by a relatively low drafting accuracy (0.3mm or worse). The choice of drafting tools is restricted to ball points or fiber tip pens. Other tools are seldom available. The software is simple.

All this results in poor graphical quality of lines. The drafting speed is not high; the low price is compensation for bad performance.

Most of the plotters are provided with continuous paper feed. They are often used as on line graphic terminals in computer centres and employed for quick direct graphic output of graphs, check plots, simple thematic maps and engineering plots (cross sections, etc). Very often they are available as desk top models with working areas of up to 0.30m.

5.1.2 **MEDIUM ACCURACY PLOTTERS**

The machines belonging to this class are characterized by a drafting accuracy between 0.1 and 0.2mm. the drafting surface is mostly flatbed and vacuum held.

The choice of drafting tools is more extensive than for low accuracy plotters. Ball points, fiber tip pens, (pressurized) ink pens and scribing points are, as a rule, available. Sometimes even scribing chisels with tangential control may be provided.

The medium accuracy plotters features high maximum velocity 9up to 1m/sec). Their applications are many fold: engineering designs (highway, railway), large scale mapping, thematic mapping, check plots, etc.

5.1.3 **HIGH ACCURACY PLOTTERS**

This group includes the most accurate and sophisticated drafting machines. Drafting accuracy is better than 0.1mm and resolution smaller than 0.01mm. the drafting speed of the more recent models is relatively high (up to 1m/sec.) but the acceleration is some what lower.

They offer a complete choice of drafting tools including tangentially controlled scribing chisels, cutting knives and light spot projectors. Some of the light spot projectors are provided with tangential control. The graphical quality of lines, especially those drawn by light spot projector, is very good.

The high accuracy plotters are usually used off line and provided with sophisticated software. The application of such plotters is many-fold, including the production of high quality printing originals.

5.1.4 <u>RASTER PLOTTERS</u>

Raster plotters require input in a cell system. The whole drafting area is consistently subdivided in a number of small Arial units (usually squares) forming a raster. The drafting tool is driven in a series of straight lines, each parallel to the next, hence covering the whole area. The input data must contain either required grey level code or simply black/white code in a correct scan sequence. After the whole drafting area is scanned, the picture is formed on drafting material. Raster plotters are becoming more and more popular, because they are superior to line plotters in drafting speed and ease of area representation. However, the lines drawn by raster plotters are built up of small individual dots, which cause difference appearance than in the case of line plotters. Of course, in case of fine resolution (small dot size) the difference can be seen only under magnification.

The resolution of raster plotters varies from a few microns (in more expensive models) to a few tenths of millimeter. It is often selectable. The drafting speed of raster plotters does not depend on line lengths to be drafted, but only on the total drafting area.

The usual classification of raster plotters is according to the type of drafting tool:

- electrostatic plotters
- photo optical plotters
- ink jet plotters
- dot matrix plotters

The raster plotters are often provided with line to raster conversion routines, which allow data input mode (firmware and soft-ware solutions are available).

Ink jet and photo optical plotters allow for colour plotting. Ink jet, electrostatic and dot matrix plotters have relatively low resolution. Electrostatic plotters show great speeds (up to 50mm/sec. Paper speed). Photo optical plotters provide for high quality graphical products.

5.1.5 **ELECTROSTATIC PLOTTERS (fig.)**

The drafting tool in electrostatic plotters is stationary. It consists of an array of stili, which spans the whole width of paper. The paper is moved over the array at a constant speed (see fig).

So if instructed, the stili charge the paper passing over them creating electrostatic dots. The paper is then exposed to liquid toner, which makes the dots visible. No further handling is necessary.

The material to be used is a special electrostatic paper, which does not show great stability. The translucent paper of better stability may be used also.

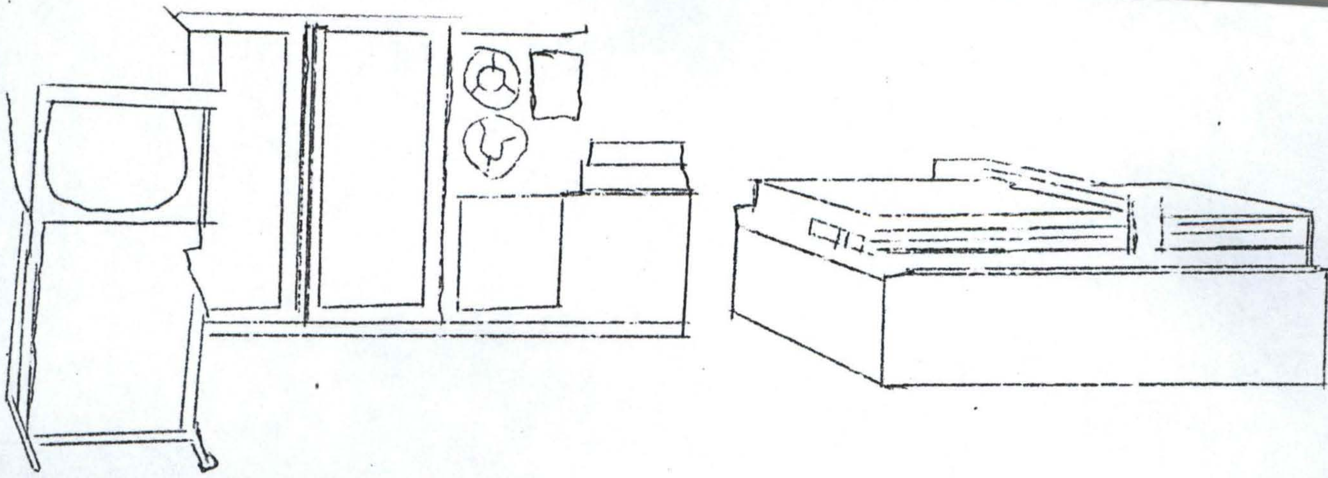


Fig High accuracy plotter (Aristo)

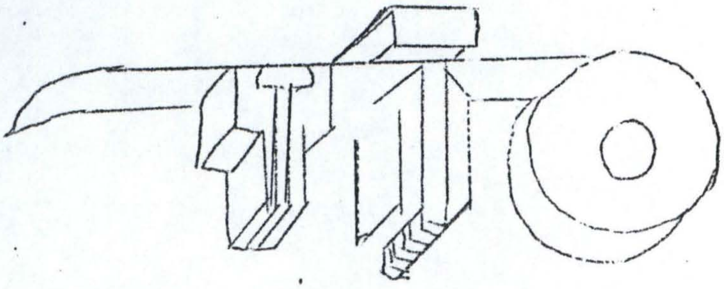


Fig.

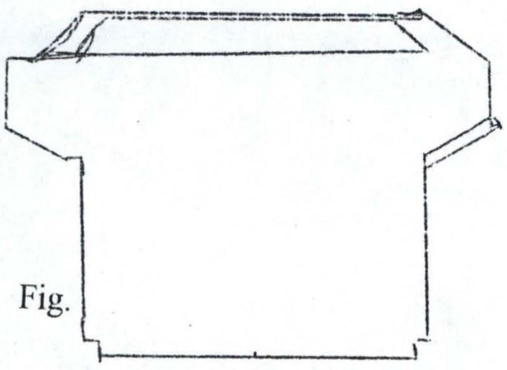


Fig.

The resolution is normally 0.1mm or worse. The accuracy is mainly influenced by paper instability and paper transport control. The width of the drafting area is available in the range from 0.30 to almost 2.0m. the length of the plot is limited only by the length of paper roll (50m).

The drafting speed is actually equal to the paper travel speed, which ranges from about 0.01m/sec. To over 0.05 m/sec. The electrostatic plotters deliver output very fast and at a low cost.

They are every suitable for check plots or maps to be produced in a few copies only (as a research tool), but without colours. When reduced in size, the output may give quite agreeable originals for printing, the registering inaccuracies being the main problem.

The software usually includes line to raster conversion as well as several fonts. The plotters are often employed as line printers. The manufacturers of electrostatic plotters are among others: Benson, Calcomp, Versatec.

5.1.6 INK JET PLOTTERS

Ink jet plotters use ink spray as a drafting tool. It has as a consequence relatively large resolution (over 0.2mm). the ink may be sprayed in a number of shades, so that images of varying grey levels may be created. By using the three standard process colours (yellow, magenta, cyan) in succession and over each other the colour images may be created too.

The drafting speed is comparable to the speed of electrostatic plotters. The ink jet plotters are usually drum type plotters.

They are suitable for production of thematic colour maps, which are needed in a few copies only. The number of manufacturers which produce ink jet plotters is restricted (Applicon).

5.1.7 PHOTO OPTICAL PLOTTERS

The photo optical plotters utilize light or laser beams as a drafting tool. The photosensitive material is used for drafting. The modulation of light sources enables creation of images of varying grey levels. The colour writing may be accomplished by the three sequential exposures onto a colour film through green, blue and red filters. In order to enable easier handling of photo material the drafting surface is usually of a drum type flattened onto the drum surface. It is exposed in parallel lines along the circumference of the drum.

The drafting areas are available from 0.20 x 0.20m to almost 1x2m. The resolution is usually selectable (0.02 to 0.20mm). drafting speed depends on selected resolution. The laser drafting tool enable essentially higher speeds (over 1000 drum revolutions a minute).

The accuracy is relatively high (better than 0.1mm) if the film base is a stable material.

Considering all those characteristics, it becomes obvious that the photo-optical plotters are capable of producing high quality graphics, which may be directly copies onto printing plates. Recent models even enable soft-or hardware halftone screen generation capability as an option. There are even attempts to design photo optical plotters to draw directly onto offset plates.

The most well-known manufacturers of photo optical plotters are: Optronics and Scitex.

5.1.8 DOT MATRIX PLOTTERS

The dot matrix plotter operates similarly to a typewriter. On every raster position a dot pattern is printed, which enables generation of varying grey levels by selective choice of number of dots. Because the printing is mechanical the resolution is, as a rule, large (0.25mm or worse). The ribbons of different colours may be used to give output in required colour. By over printing the three standard process colours, the extensive colour hue may be realized. The bad ribbon quality often influences the output in a negative sense. The manufacturer of dot matrix is Trilog.

5.1.9 MICROFILM PLOTTERS

Although the microfilm plotters are either line plotters or raster plotters, they have common specific characteristics: the output is drawn on microfilm or microfiche in standard sized (16,35 or 105mm). The microfilm plotters are characterized by relatively high accuracy (about 10 microns), fine resolution (better than 10 microns) and high graphical output quality. The drafting speed is quite high-an average frame may be completed in a few minutes. Because of their speed, the microfilm plotters may be used to produce open window colour masks by filling in the areas.

The maps recorded on microfilm may be displayed on microfilm reader for viewing or enlarged and printed.

The microfilm plotters utilize high precision cathode ray tubes to draw images. The picture is then optically reduced and photographed on microfilm. The latest models employ laser beams to write directly on film. Manufacturers of microfilm plotters are: Calcomp, Ferranti, Imtec, Laser-Scan.

5.2 **CONCLUSION**

Automated Cartography, computer-aided cartography and digital mapping are different names for essentially the same process, the generation of maps and diagrams by computer.

In this project, hardware for automated cartography has been described. The graphics terminal, various types of printer (line printer, dot-matrix printer and inkjet) plotter (drum, flatbed) and film writers have been described in terms of their suitability for output of maps and diagrams.

Software is required in order to make the hardware work. Since a wide range of different software packages is available, two of the more widely-used packages can be chosen to demonstrate the way in which such packages are used.

SYMAP is the best-known line printer mapping package, it has a large number of users in universities, colleges and research institutions. SYMAP has the advantage that no specialized hardware is required and is thus useful for introductory teaching at degree level.

There are several reasons why computer mapping is increasing in popularity. First of all, more spatial data are becoming available in digital or computer-readable form.

The map user can select features of interest from the digital map and display them in a way that is suited to his or her requirements. Secondly, computer mapping allows the user to experiment; if the final project is not satisfactory then the labour involved in redrafting the map is negligible in comparison with manual methods. Thirdly, digital maps can be combined with other kinds of spatial data in a Geographical information system.

A computer-drawn amp is generally the end product from such a system, which allows the user to combine map data with other kinds of data about places (economic, demographic, geological and statistical data, for instance) in order to produce cartographic and tabular output to suit a specific purpose.

5.3 INVESTMENT COST

The realization of computer-assisted Cartographic production requires substantial investment. The type of hardware components to be acquired as well as their number depends on the type and amount of map production.

The list below gives only approximate prices for individual units for an averagely automated cartographic set up as at June 2000.

Unit		price in Naira
PC Arc/info for Windows 1 computer	-	326,000
One AO size Digitizers	-	570,000
1 unit High Powered GIS Workstation Computer	-	320,000
Calcomp Postscript compatible plotter	-	1,250,000
AO Colour GIS scanner	-	2,200,000
Arc view Software	-	255,000
Freehand 8 cartographic software	-	210,000
HP 800 series computer with cable	-	45,000
UPS to provide power for 3 working days	-	150,000

Some of the mentioned equipment components require an air-conditioned environment.

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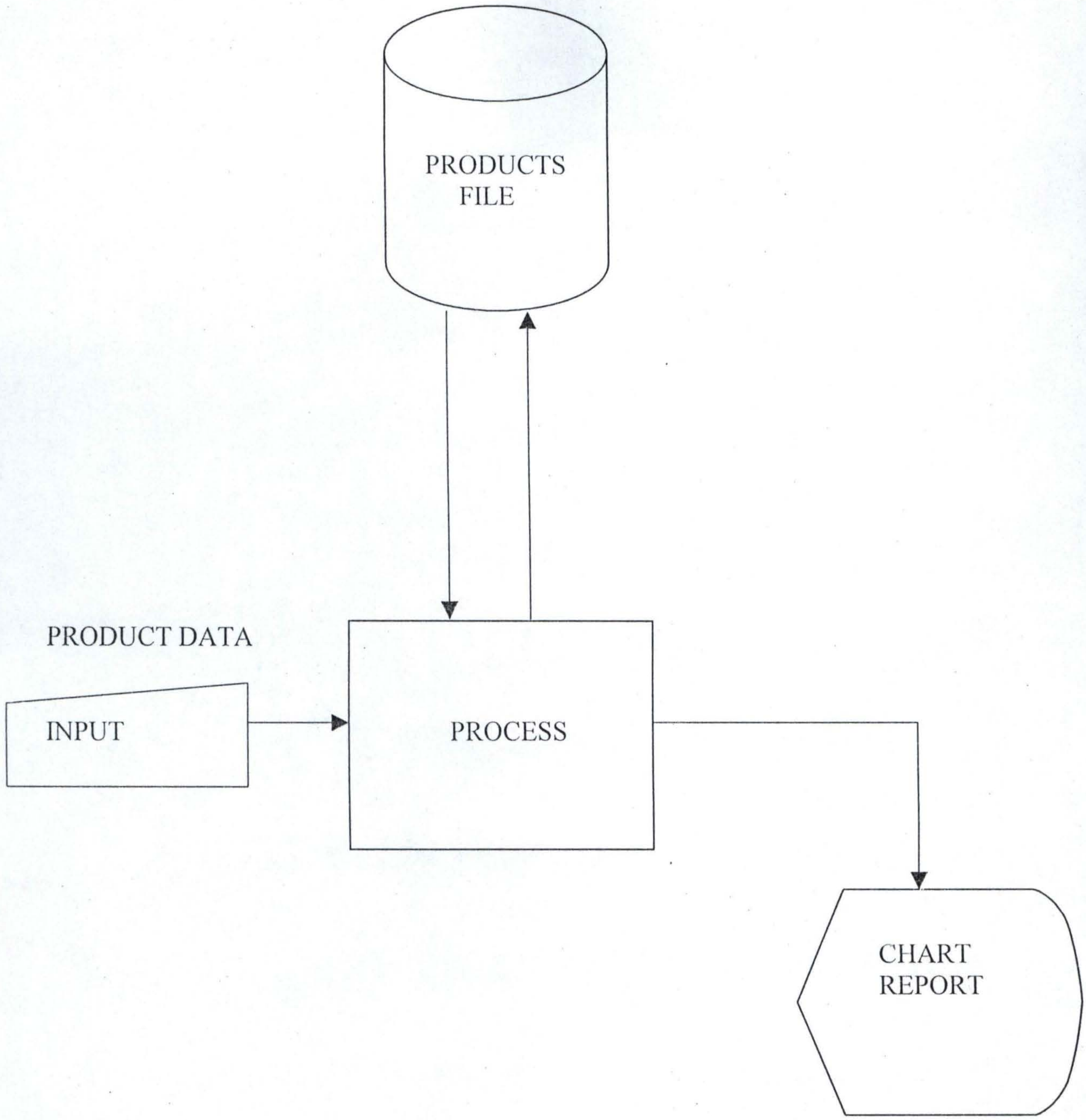
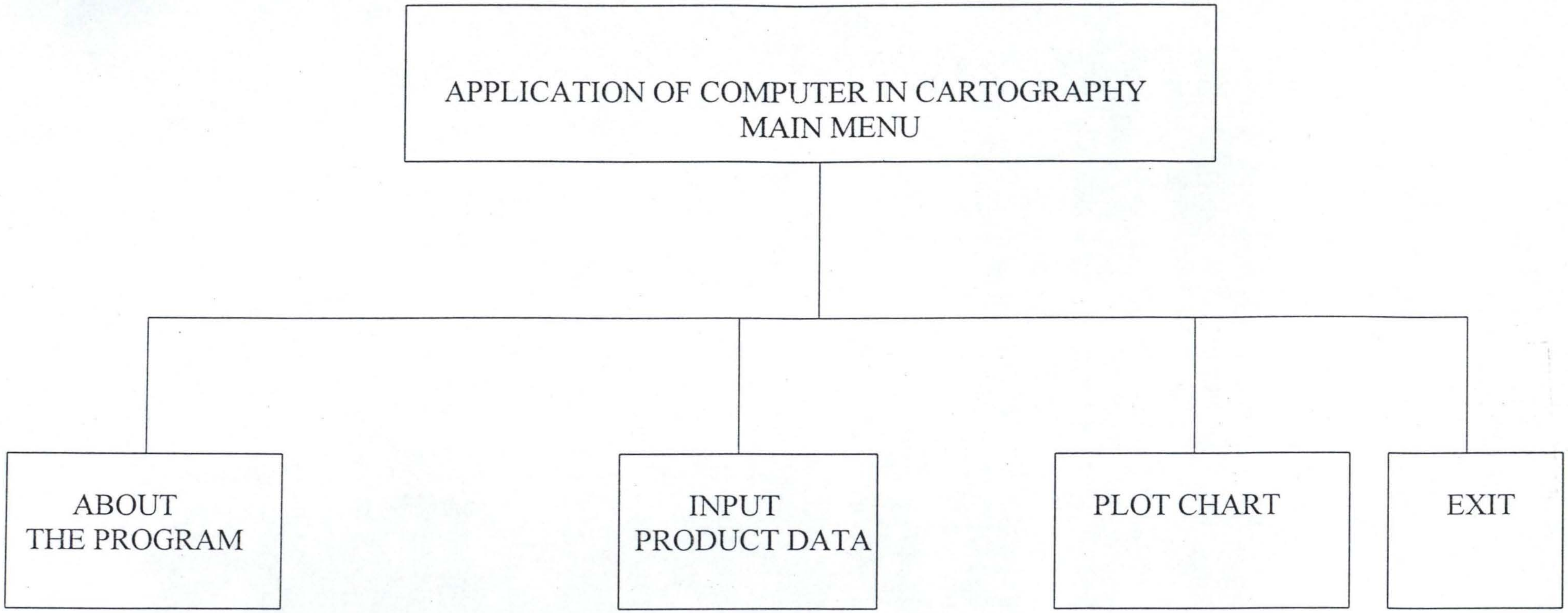
4. INTERNATIONAL INSTITUTE FOR AERIAL SURVEY AND EARTH SCIENCES (ITC). From Selected Papers Presented at the XIVth 1SP Congress, Hamburg, 1980. ITC Journal,. Special Issue 1980 Volume 3
5. ITC Notebook on automated Cartography 1992.
6. Extract from the Audio-Visual Course " Introduction to Mini Computers" Produced by Digital Equipment Corporation

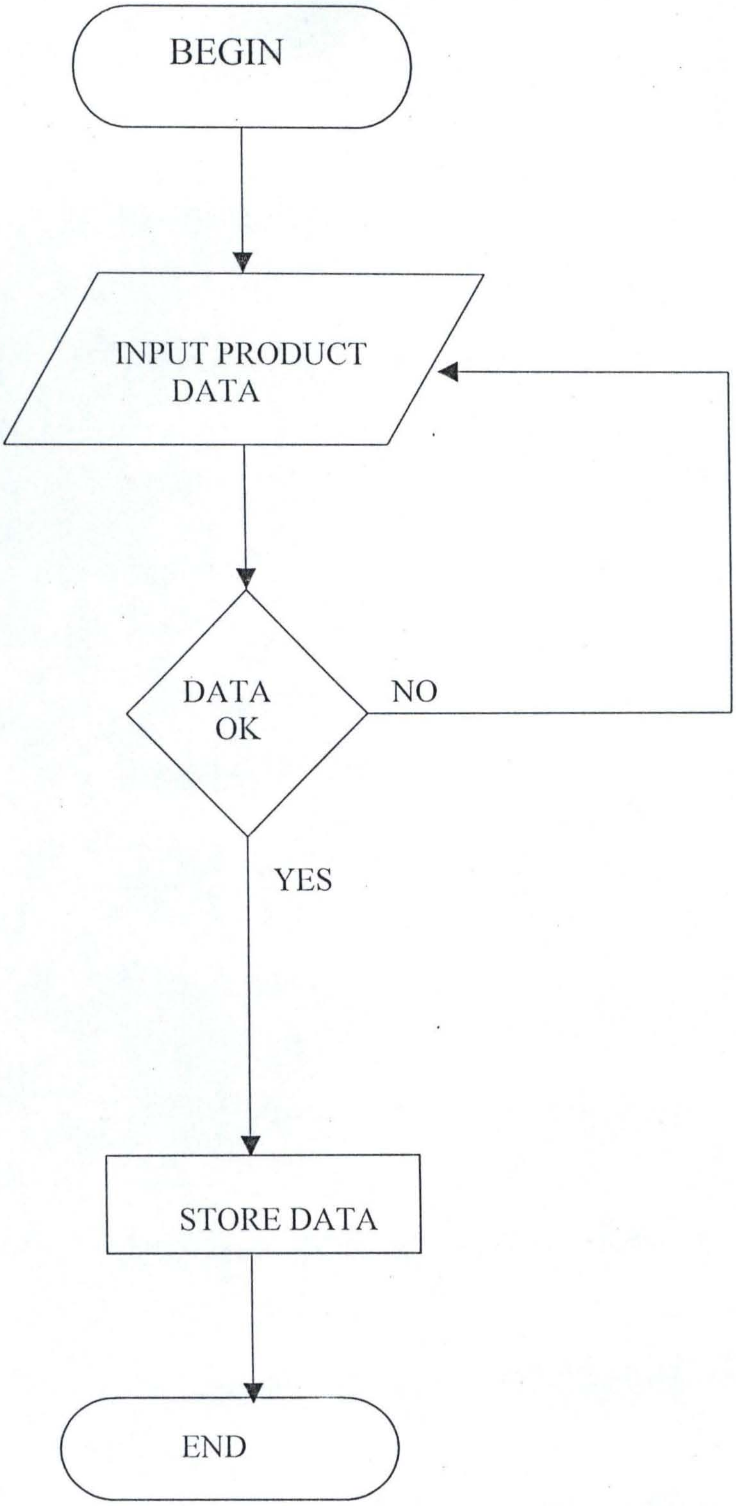
   ITC Enchede 1995.



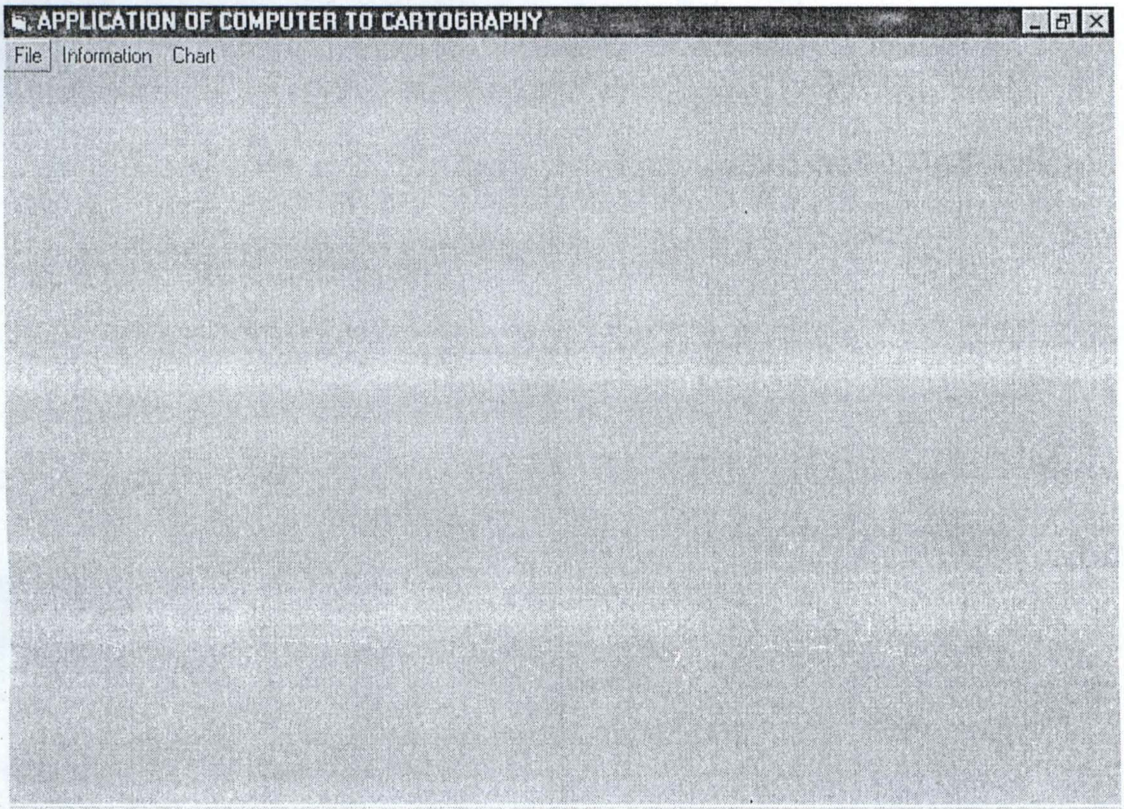
SYSTEM FLOWCHART



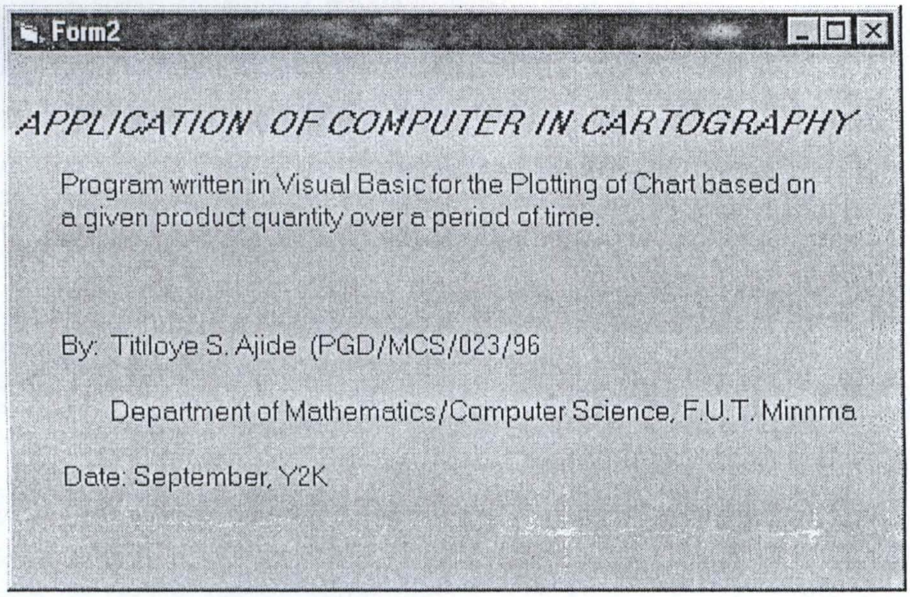
PROGRAM BLOCK DIAGRAM

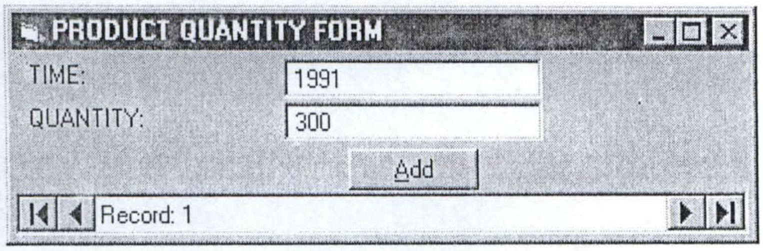


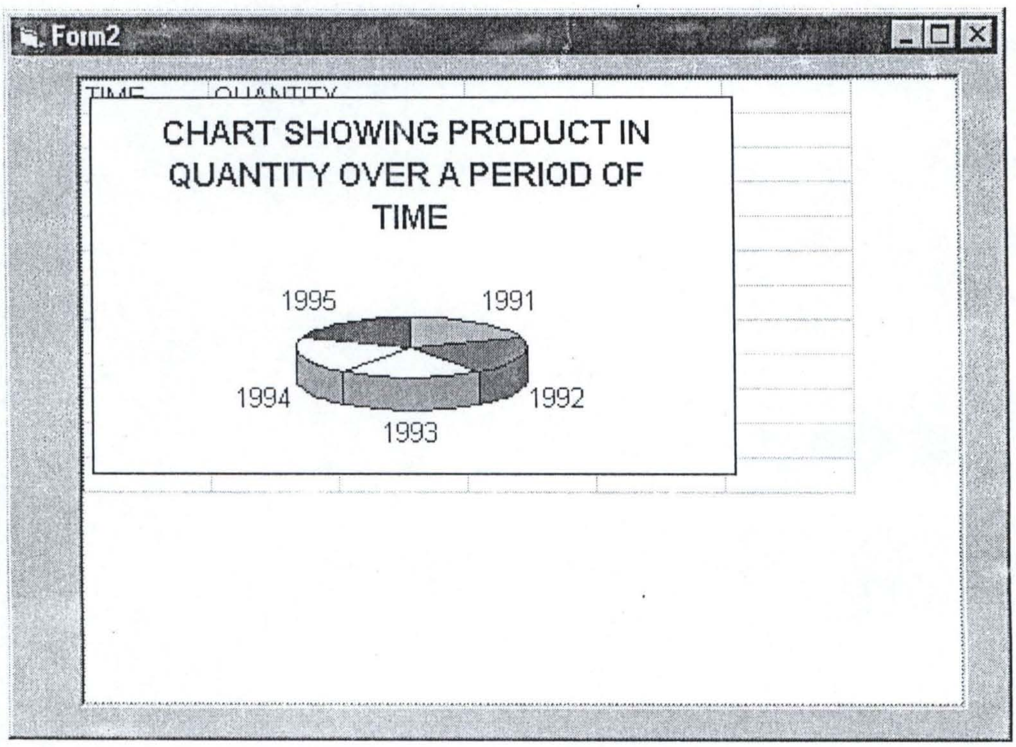
PROGRAM FLOWCHART


APPLICATION OF COMPUTER TO CARTOGRAPHY
File
Information
Chart

TIME	QUANTITY
1991	300
1992	350
1993	340
1994	400
1995	500


Form2
APPLICATION OF COMPUTER IN CARTOGRAPHY
Program written in Visual Basic for the Plotting of Chart based on
a given product quantity over a period of time.
By: Titiloye S. Ajide (PGD/MCS/023/96
Department of Mathematics/Computer Science, F.U.T. Minnma
Date: September, Y2K


PRODUCT QUANTITY FORM
TIME:
1991
QUANTITY:
300
Add
Record: 1


Form2
CHART SHOWING PRODUCT IN QUANTITY OVER A PERIOD OF TIME
1995
1991
1994
1992
1993

```
'' Program : Application of Computer in Cartography
' Written by: Titiloye S. Ajide
'Reg. No.  :  PGD/MCS/023/96

Private Sub Cp_Click()
'e = Shell("c:\progra~1\micros~1\office\excel.exe", 1)
'AppActivate e
Form2.Show
End Sub



Private Sub fe_Click()
End
End Sub



Private Sub fi_Click()
frmFORM3.Show 1
End Sub



Private Sub Ia_Click()
ABOUT.Show
End Sub


Private Sub cmdAdd_Click()
  Data1.Recordset.AddNew
End Sub



Private Sub cmdDelete_Click()
  'this may produce an error if you delete the last
  'record or the only record in the recordset
  Data1.Recordset.Delete
  Data1.Recordset.MoveNext
End Sub
```

```vb
Private Sub cmdRefresh_Click()
  'this is really only needed for multi user apps
  Data1.Refresh
End Sub
```

```vb
Private Sub cmdUpdate_Click()
  Data1.UpdateRecord
  Data1.Recordset.Bookmark = Data1.Recordset.LastModified
End Sub
```

```vb
Private Sub cmdClose_Click()
  Unload Me
End Sub
```

```vb
Private Sub Data1_Error(DataErr As Integer, Response As Integer)
  'This is where you would put error handling code
  'If you want to ignore errors, comment out the next line
  'If you want to trap them, add code here to handle them
  MsgBox "Data error event hit err:" & Error$(DataErr)
  Response = 0  'throw away the error
End Sub
```

```
Private Sub Data1_Reposition()
  Screen.MousePointer = vbDefault
  On Error Resume Next
  'This will display the current record position
  'for dynasets and snapshots
  Data1.Caption = "Record: " & (Data1.Recordset.AbsolutePosition + 1)
  'for the table object you must set the index property when
  'the recordset gets created and use the following line
  'Data1.Caption = "Record: " & (Data1.Recordset.RecordCount *
(Data1.Recordset.PercentPosition * 0.01)) + 1
End Sub
```

```
Private Sub Data1_Validate(Action As Integer, Save As Integer)
  'This is where you put validation code
  'This event gets called when the following actions occur
  Select Case Action
    Case vbDataActionMoveFirst
    Case vbDataActionMovePrevious
    Case vbDataActionMoveNext
    Case vbDataActionMoveLast
    Case vbDataActionAddNew
    Case vbDataActionUpdate
    Case vbDataActionDelete
    Case vbDataActionFind
    Case vbDataActionBookmark
    Case vbDataActionClose
  End Select
  Screen.MousePointer = vbHourglass
End Sub
```