3.2 Conformal Mapping (transformation)

When we make transformation between different non-linear projection systems, it is usually not sufficient to apply linear transformations without including terms of higher degree.

In this case, conformal mapping (transformation) can be expressed with the help of a polynomial consisting of a real port and an imaginary port of complex function.

1 The first degree terms

$$X + iY = (a + ib)(x + iy)$$
$$= ax + iay + ibx - by$$
$$= (ax - by) + i(ay + by)$$

(3-2.1)

These give

$$X = ax - by$$
$$Y = ay + by$$

(3-2.2)

If this transformation use the different coordinate origin, it must be add the shifted values (xo, yo) for each directions, and final are formulated as follows:

$$X = x_o + ax - by$$
$$Y = y_o + ay + by$$

(3-2.3)

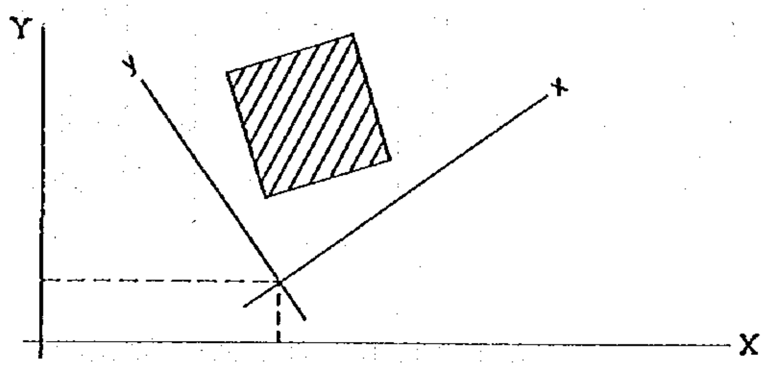


Fig. 3-2.1 TRANSFORMATION

This transformation have a characteristic properties as shown in the follows:

(1) Points remain points

(2) Angles remain unchanged angles

This transformation are often called "Helmat transformation" on the field of survey and photogrammetry.

2 The second degree terms

$$X + iY = (a + ib)(x + iy) + (e + id)(x + iy)^2 + \ldots\ldots$$

$$= ax - by + ex^2 - ey^2 - 2dxz + i(bx + ay + 2exy + dx^2 - dy^2)$$

(3-2.4)

Therefore,

$$X = ax - by + e(x^2 - y^2) - 2dx$$

$$Y = bx + ay + 2exy + d(x^2 - y^2)$$

(3-2.5)

And, popular formulae are shown in the follows:

$$X = xo + ax - by + e(x^2 - y^2) - 2dx$$

$$Y = yo + bx + ay + 2exy + d(x^2 - y^2)$$

(3-2.6)

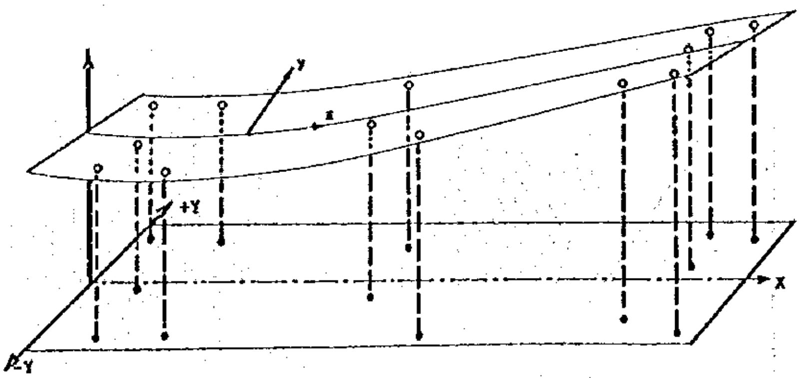


Fig. 3-2.2 TRANSFORMATION ON CURVED SURFACE

We explain with example as shown in the follows:

(I) Data for conformal mapping in the linear case (the first degree terms)

Point	Given coordinates		Coordinates in the new net	
	x	y	X	Y
1	82031.21	4842.32	82364.765	4964.448
2	70284.48	489.22	70617.707	611.689
3	83600.80	-6061.07	83934.188	-5939.095
4	87884.34	-15402.52	88217.483	15280.775
5	88736.20	4832.20	Unknown	
6	88644.12	4762.10		

(II) Observation equations for the example of conformal mapping

X_o	Y_o	a	b	L
1		82031.21	-4842.32	82364.765
	1	4842.32	82031.21	4964.448
1		70284.48	-489.22	70617.707
	1	489.22	70284.48	611.689
1		83600.80	6061.07	83934.188
	1	-6061.07	83600.80	-5939.095
1		87884.34	15402.52	88217.483
	1	-15402.52	87884.34	-15280.775

(III) Normal equations for the example of conformal mapping

X_o	Y_o	a	b	L
2	0	161900.415	8066.025	162567.0715
	2	-8066.025	161900.415	-7821.8665

(IV) Result:

$$x_o = 332.143 \qquad a = +1.000015910$$
$$y_o = 124.202 \qquad b = -0.000025427$$

(V) Adjusted transformation equation:

$$X = 332.143 + 1.000015910x + 0.000025427y$$
$$Y = 124.202 + 1.000015910y - 0.000025427x$$

(VI) Solution:

$$X_5 = 89069.878 \qquad Y_5 = 4954.223$$
$$X_6 = 88977.794 \qquad Y_6 = 4884.124$$

3.3 Methods of Determining Area

3.3.1 General

One of the primary objects of map information is determine the area of existing land use. If the lines are made to coincide with property lines and map are made with large scale, Computation are rather easy and can directly. But where the boundaries are irregular or curved figure and map are made with small scale, computation need for some technique. Several common methods were tested on case study (I).

3.3.2 Methods of determining area

The area of a land use may be determined by any of the following methods:

(1) It may be calculated by dividing the tract into triangles and rectangles.

(2) The area of the tract may be traced by planimeter.

(3) By calculating the area from the coordinates of the corner of the polygons tract.

(4) By calculating the area from the double meridian distance and the latitude of the sides of the tract.

(5) Graphic solution.

(6) Electro-optical

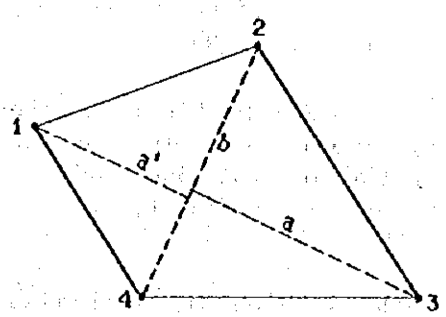
(Area by triangle)

This method are only used on the large-scale maps, and divided into many types.

(1) When a base length and an altitude are known as shown in Fig. 3-3.1, its area is determined by the following equation

$$\text{Area} = \frac{1}{2}\ (\text{base x altitude}) \qquad (3\text{-}3.1)$$

Base and altitude are normally obtained from scale-ruler on the maps.



a, a' : altitude length
b : base length

Fig. 3-3.1 AREA BY TRIANGLE (1)

(2) When the length of the three sides of any triangle are given, its area is determined by the nest equation

$$\text{Area} = \sqrt{s\ (s-a)\ (s-b)\ (s-c)} \qquad (3\text{-}3.2)$$

where

$$s = \frac{1}{2}\ (a + b + c)$$

a, b, c : length of the sides

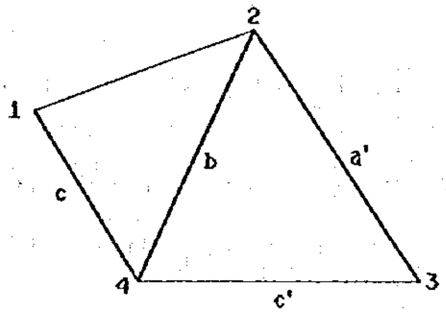


Fig. 3-2.2 AREA BY TRIANGLE (2)

(3) When the lengths of two sides and the included angle of any triangle are known, its area is given by the following equation

$$\text{Area} = \frac{1}{2}\ a\ .\ b \sin C \qquad (3\text{-}3.3)$$

Type-1 is popular method for quest of cadastral area in Japan.

(Planimeter Method)

This method is useful in roughly determining areas or in checking those that have been calculated by more exact methods. Its advantages lies in the rapidity with which calculations can be made.

Recently new type planimeter are developed with having micro-CPU. But this are not planimeter type but rather the following type.

(Area by Coordinates)

When the points defining the corners of polygon figure are coordinated with respect to some arbitrarily chosen coordinate axes, there coordinates are useful in calculating the area of the land. Tract to be determined are shown in figure-1 where each point 1, 2, 3, and 4 has coordinates x_1, y_1, ...x_5, y_5.

The area of the tract can be computed by summing algebraically the areas of the trapezoids formed by projecting the line upon the reference meridian. Thus,

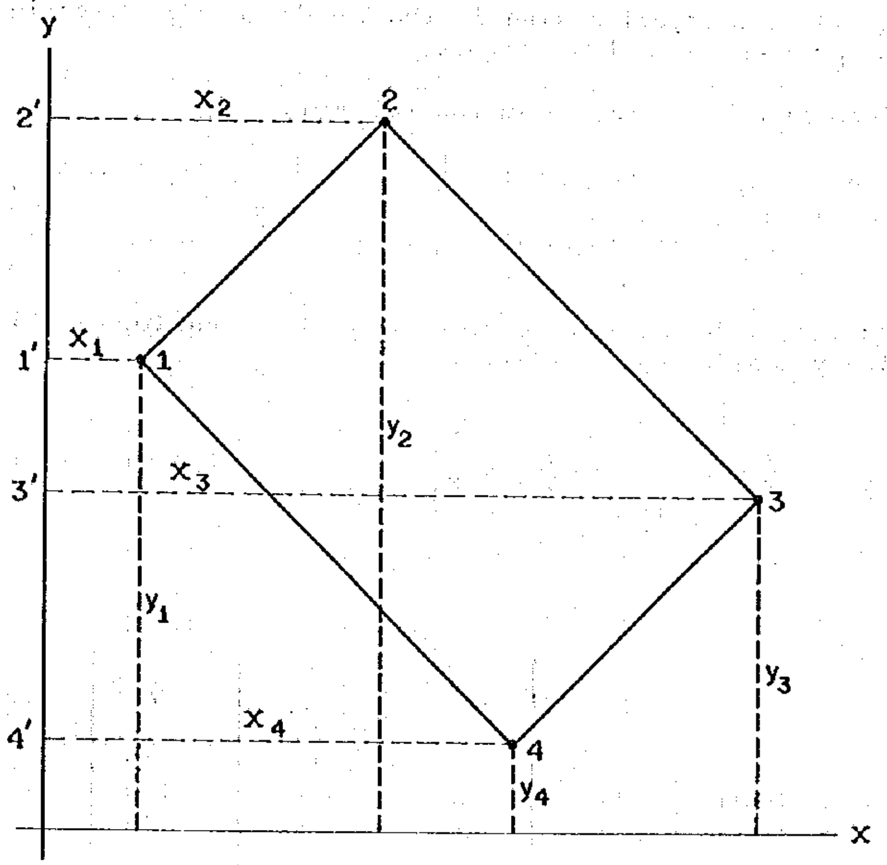


Fig. 3-3.3 AREA BY COORDINATES

$$\text{Area } 1\ 2\ 3\ 4 = \text{Area } 2'\ 2\ 3\ 3' + \text{Area } 3'\ 3\ 4\ 4' - \text{Area } 1'\ 1\ 4\ 4' - \text{Area } 2'\ 2\ 1\ 1' \qquad (3\text{-}3.4)$$

therefore

$$\text{Area} = \tfrac{1}{2}(x_2 + x_3)(y_2 - y_3) + \tfrac{1}{2}(x_3 + x_4)(y_3 - y_4) - \tfrac{1}{2}(x_4 + x_1)(y_1 - y_4) - \tfrac{1}{2}(x_1 + x_2)(y_2 - y_1) \qquad (3\text{-}3.5)$$

By multiplication and rearrangement of terms in Eq (3-3.5), the following equation are obtained.

$$2 \times \text{Area} = y_1 (x_2 - x_4) + y_2 (x_3 - x_1) + y_3 (x_4 - x_2) + y_4 (x_1 - x_3) \qquad (3\text{-}3.6)$$

and in general for any polygon having n stations,

$$2 \times \text{Area} = y_1 (x_2 - x_n) + y_2 (x_3 - x_1) + \ldots + y_{n-1}(x_n - x_{n-2}) + y_n (x_1 - x_{n-1}) \qquad (3\text{-}3.7)$$

In above equation, a negative sign is the result of the direction that calculations progress around the figure.

Eq (   ) can also be expressed in the following form.

$$2 \times Area = x_2 y_1 + x_3 y_2 + x_4 y_3 + \ldots + x_n y_{n-1} + x_1 y_n - x_1 y_2 - x_2 y_3 \ldots x_{n-1} y_n - x_n y_1 \qquad (3\text{-}3.8)$$

If computations can be made by tabulating each x coordinate below the corresponding y coordinate as follows:

$$\frac{Y_1}{X_1} \times \frac{Y_2}{X_2} \times \frac{Y_3}{X_3} \text{----------} \times \frac{Y_n}{X_n} \times \frac{Y_1}{X_1}$$

Example

Station	1	2	3	4
x - coordinate y - coordinate	100 200	200 300	400 150	250 50

(Solution from Eq) (3-3.7)

$$2 \times Area = 200\ (200 - 250) + 300\ (400 - 100) + 150\ (250 - 2000 + 50\ (100 - 400)$$

$$= 72500$$

$$Area = \frac{7250}{2} = 36250\ m^2$$

(Solution from Eq) (3-3.8)

$$2 \times Area = 200\times200 - 100\times300 + 300\times400 - 200\times150 + 150\times250 - 400\times50 + 50\times100 - 200\times250$$

$$= 72500$$

$$Area = \frac{72500}{2} = 36250\ m^2$$

This method yields sufficiently accurate results in the case when digitizer (or coordinate-reader) and computer can be utilized.

(Area by double distance and latitudes)

Area can also calculated with the ,adjusted departures and latitudes using the double-meridian-distance.

A reference meridian is assumed to pass through some corner of the tract, usually for convenience the most westerly point of the survey; the double meridian distance of the lines are computed as described herein; and double the areas of the trapezoids or triangles formed by orthographically projecting the several traverse lines upon the meridian are computed. The algebraic sum of these double areas is double the area within the traverse.

The meridian distance of a point is the total departure distance from the reference meridian.

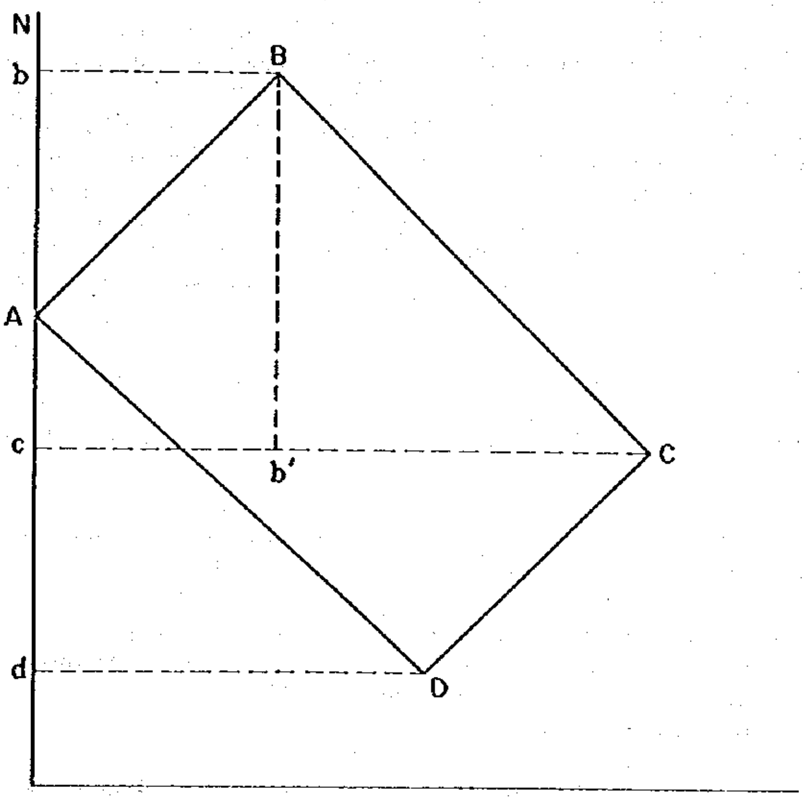


Fig. 3-3.4 AREA BY DOUBLE MERIDIAN DISTANCE

The meridian distance of B is Bb and is positive. The meridian distance of a straight line is the meridian distance of its midpoint. The double meridian distance lines is the sum of the meridian distances of the two extremities; thus, the double meridian distance of BC is Bb + Cc. It is clear that if the meridian passes through the most westerly corner of the traverse, the double meridian distance of all lines will be positive, which is a convenience (although not a necessity) in computing.

The length of the orthographic projection of a line upon the meridian is the latitude of the line; thus, the latitude of BC is bc and is negative, and that of DF is df and is positive.

From the figure it is seen that each projection trapezoid or triangle, for which a course in the traverse forms one side, is bounded on the north and south by meridian distances and on the west by the latitude of that course. Thus, the projection trapezoid for BC is Bccb. Therefore, the double area of any triangle of trapezoid formed by projecting a given course upon the meridian is the product of the double meridian distance (D.M.D.) of the course and the latitude of the course, or

$$\text{double area} = \text{D.M.D.} \times \text{latitude} \qquad (3\text{-}3.9)$$

In computing double areas, account is taken of signs. If the meridian extends through the most westerly point, all double meridian distances are positive; hence, the sign of a double area is the same as that of the corresponding latitude. Thus, in the figure the double areas of AbB, DdfF, and FfA are positive, the latitudes Ab, df, and fA being positive; while the double areas of CcbbB and DdcC are negative, the latitudes bc and cd being negative, Since the projected areas outside the traverse are considered once as positive and once as negative, the algebraic sum of their double areas is zero. Therefore, the algebraic sum of all double areas is equal to twice the area of the tract within the traverse.

(Graphic Method)

There are often many small segments on the small scale map, such as small houses or farms.

This is a work that takes plenty of time and labour. Small segments has many plotting and drafting errors.

Therefore, gathering the segments of the same category, as shown in the Fig. 3-3.5, and then calculation are carried out around the large boundary is often obtained better result than the summation of each areas by means of above methods.

(Segments) (Gathering) (Calculation of Area)

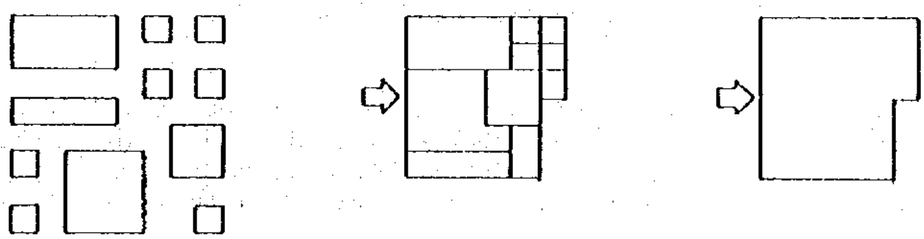


Fig. 3-3.5

This method is useful in determining areas or in checking with simplified instruments.

(Elector-optical Method)

This is divided into two or more types.

(1) To cut off a required area by a line running in a given direction.

In Fig. 3-3.6 ABCD represents a tract of land of Area.

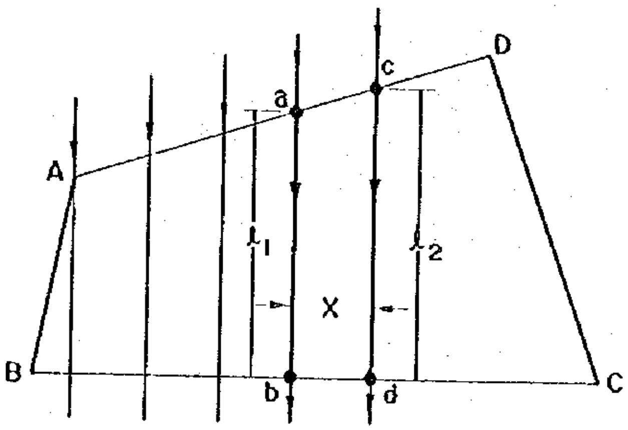


Fig. 3-3.6 MEASURING AREA

The line running are scanned with the constant width (x), in a given direction, and length l1, l2, ..., and ln are measured by the electro-optical detectors.

An area can be decided by the popular formula,

$$\begin{aligned} \text{Area} &= x \cdot (l_1 + l_2 + \dots + l_n) \\ &= x \cdot \Sigma\, l_i \end{aligned} \qquad (3\text{-}3.10)$$

or Simpson's rule.

The procedure is as shown in the following charts.

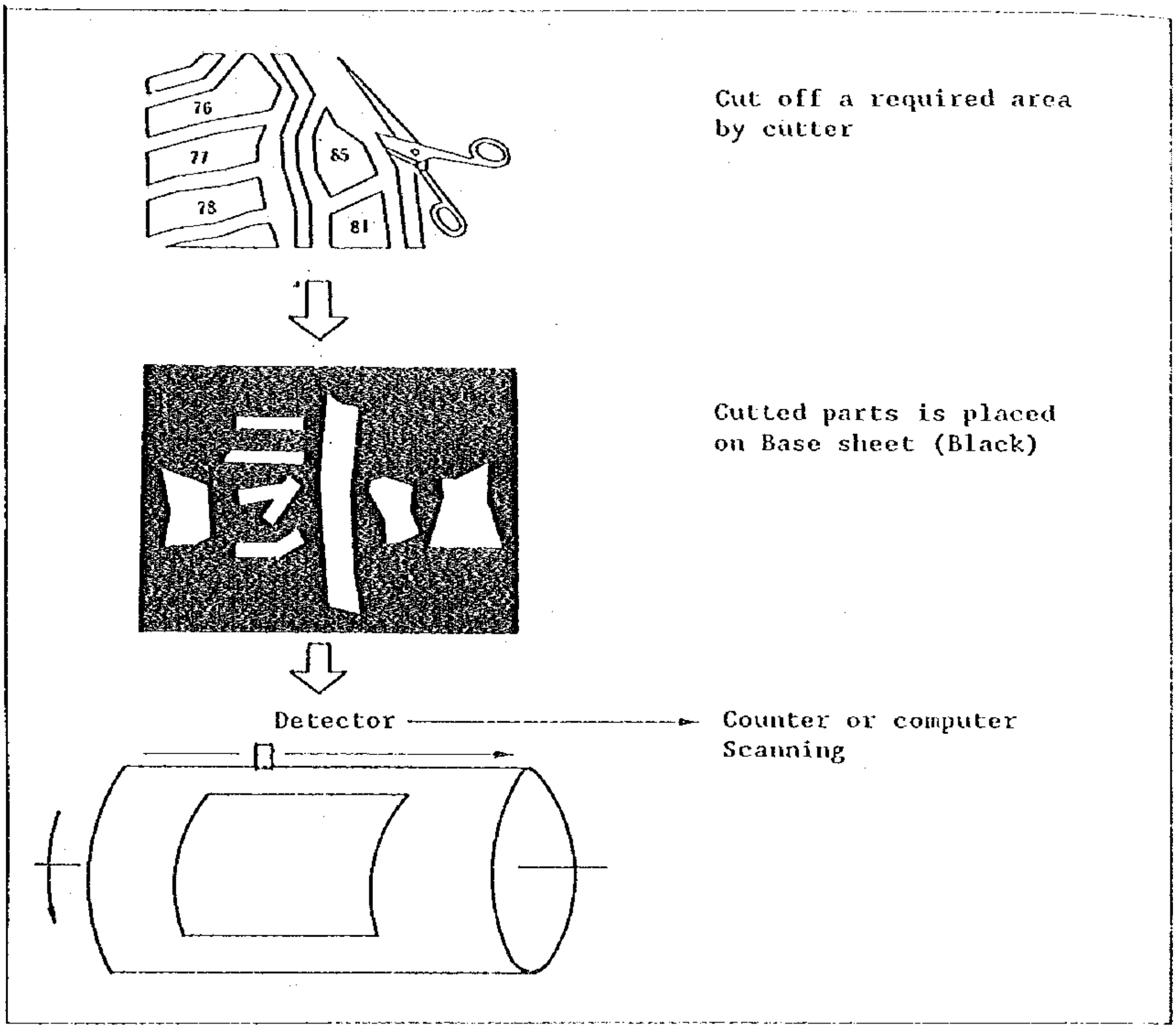


Fig. 3-3.7 LINE SCANNING METHOD

(2) Pixed Method

A pixel is defined as a contraction of picture element. This is same principle as line scanning method. The computation of area is not from the line length but from the summation of pixels. Usually the image scanner is used for the classification of pixel contraction, and the gathering data are stored on the disk file or magnetic tape of computer system.

After scanning the areas, each area can be obtained from the stored data by calculation. Its example shows below. This is popular drum scanning type.

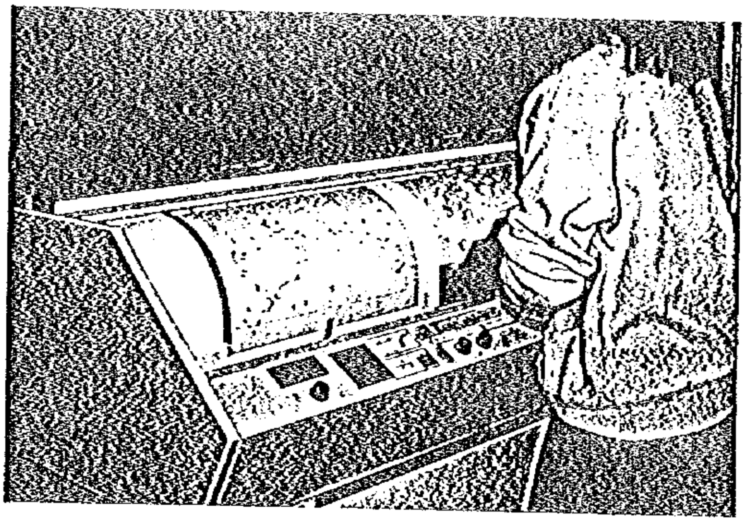
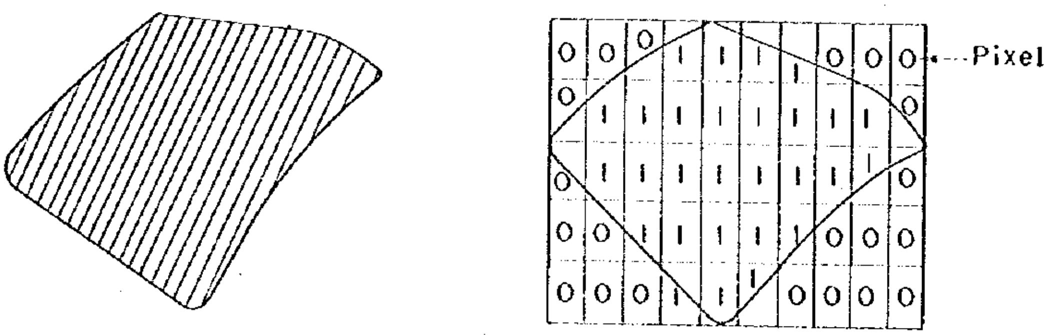


Fig. 3-3.8 IMAGE SCANNER (DRUM TYPE)

The measured data are stored in the computer memory with digital type.



on the scanner in the computer memory

Fig. 3-3.9 THE GATHERING OF PIXEL DATA

These types of device can classified the areas according to the color difference.

(3) Auto Digitizer Method

The principle of area calculation is same as the coordinate method.

The data gathering is carry out the following procedure.

1 Place on the required Area sheet on the drum, or flat (bed) table.

2 Scanning with photo-detector (the line or area senser).

3 Store data on the disk file or magnetic tape.

4 Classification of the line or junction points.

5 Sorting the line data.
(In this stage data are same as the data measured with digitizer, this is reason so-called "auto digitizer".)

This procedure is as shown in the follows:

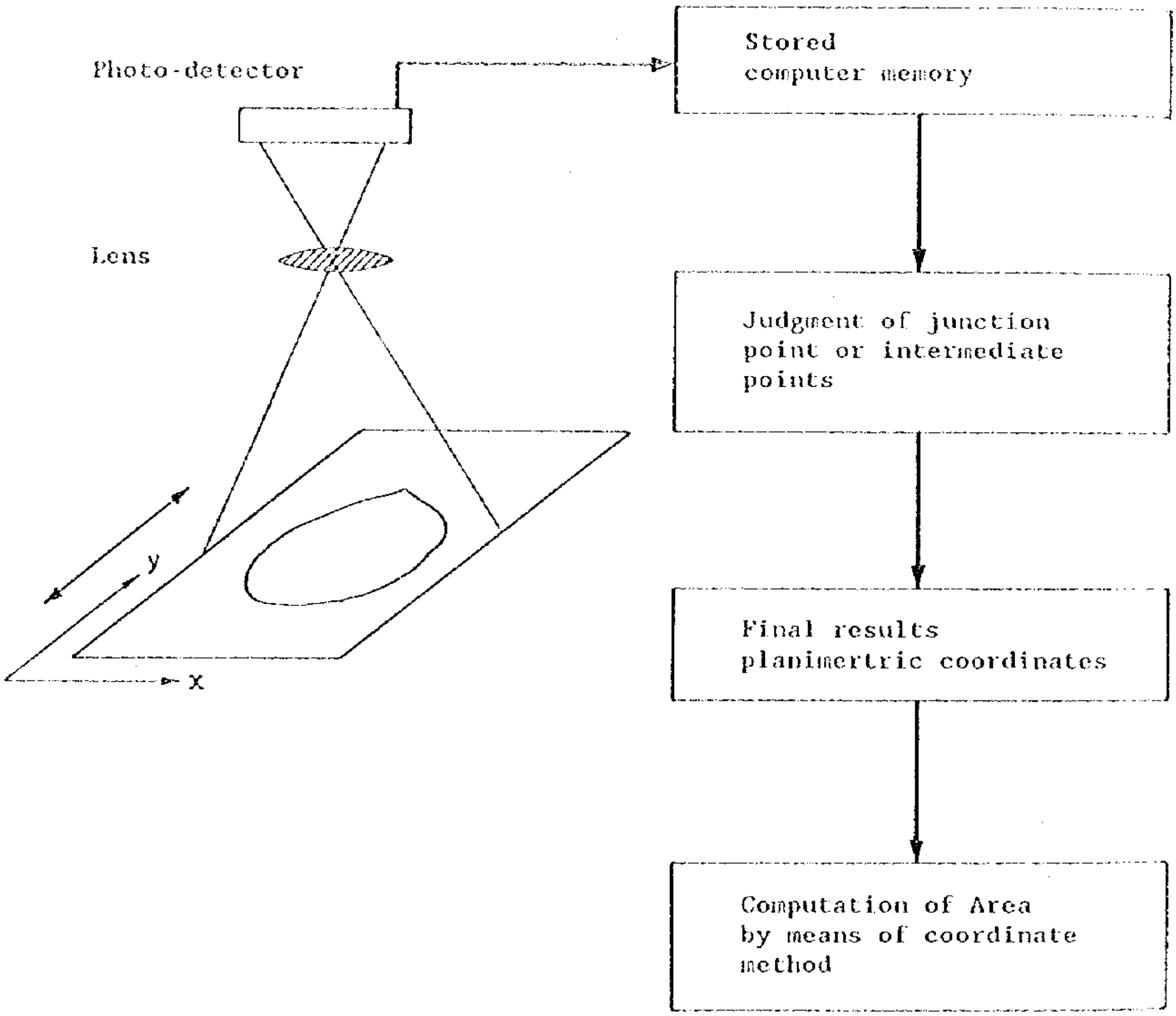


Fig. 3-3.10 AUTO-DIGITIZER METHOD

3.3.3 Instruments

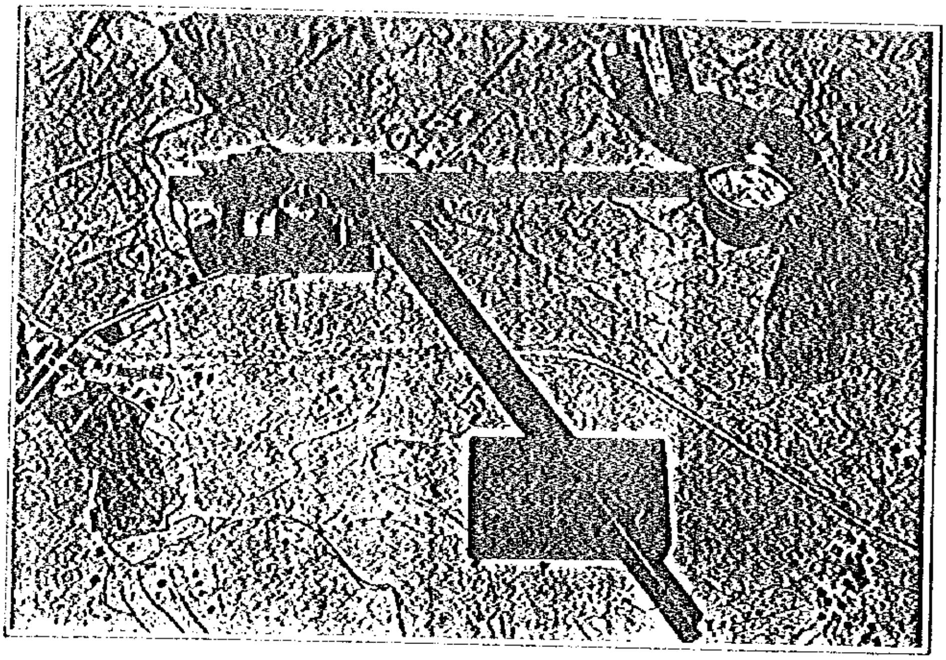
A. Use of Planimeter

Recently new types of instrument with electronic control are developing.

The planimeter may be divided into two types.

(1) The planimer based on the mechanical system

This is current use in DTCP as shown in photograph - 1.



Photograph - 1
Current
Planimeter
(KEUFFEL & ESSER
CO. GERMANY)

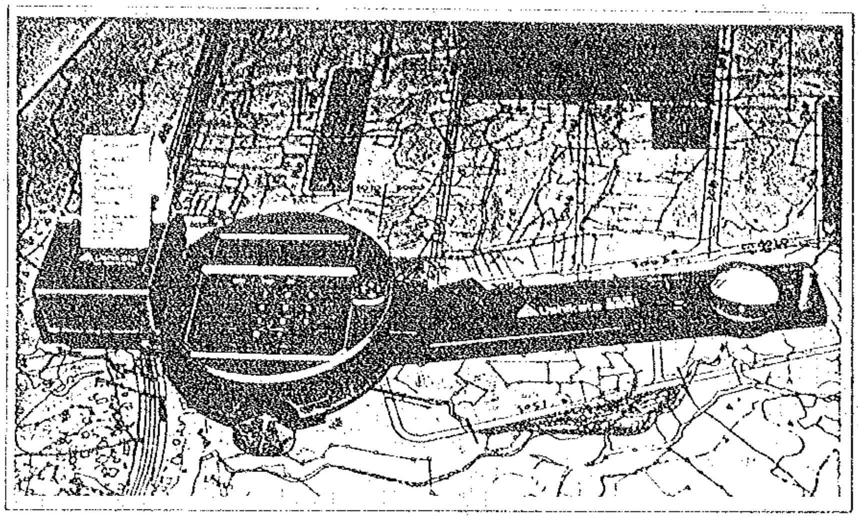
(2) The planimer based on the electronic control

These types are based on the same principle as the digitizer system.

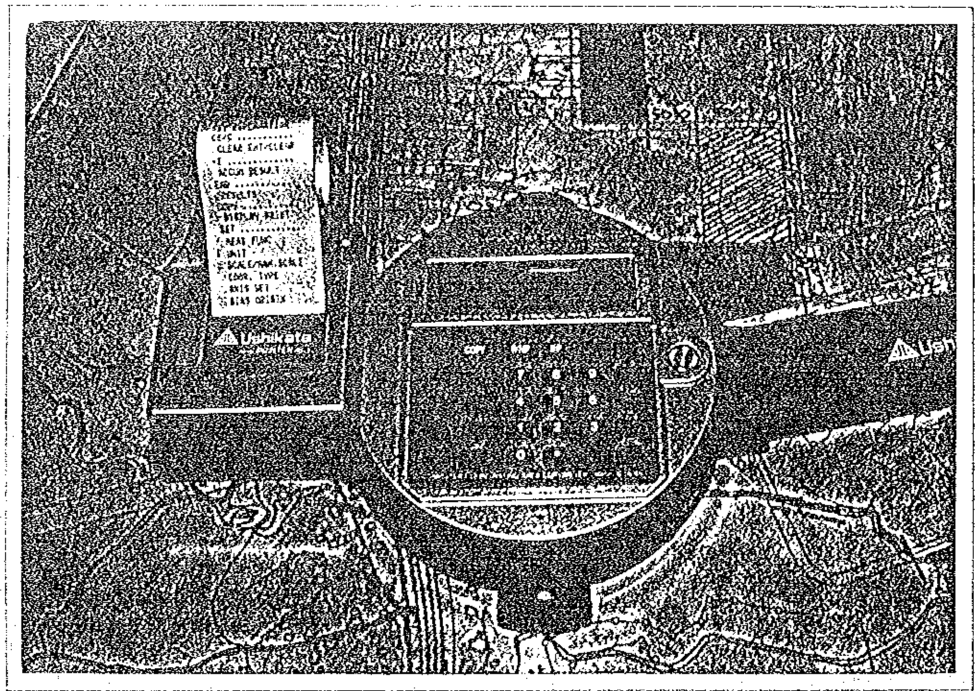
The needle point of the instrument around the perimeter indicate the coordinate of x and y.

These instrument include the encoder unit, and it measure the coordinate differences.

Photograph - 2 show the outline of these instrument.



Photograph - 2
Digital Planimeter
(Ushikata
x-plan 360_i)



Display, Output, and Key-Board Parts of X-Plan 360_i

The procedure of determining the area

(1) Procedure by mechanical planimeter

(a) Draw a square of any size (test chart)

(b) Determine the area (A) of the square

(c) With the use of the planimeter

(i) set the instrument and get the reading (R_1)

(ii) get the reading (R_2) by passing the needle point of the instrument around the perimeter of the area starting from one point and ending at the same point.

(iii) solve for the area using the principle of proportion

$$A_1 = P_o (R_2 - R_1)$$

$$\text{and} \quad P_o = \frac{A_1}{R_2 - R_1} \qquad (3\text{-}3.11)$$

(iv) solving the wanted area

$$A = P_o \times (\text{Difference of Reading})$$

note : usually R_1 set to zero value

(2) Procedure by electronic planimeter

1) General

These types of instrument can measure the line lengths, coordinates, and areas.

Operations are controlled by the stored computer programs, and are different from the measuring purposes.

Now, we introduce to an instrument with example. This instrument is composed with the many operational parts as shown in Fig. 3-3.11.

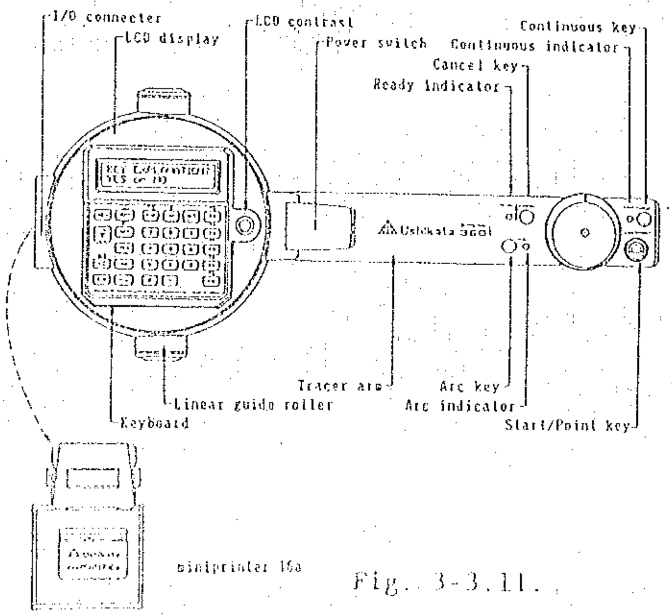


Fig. 3-3.11.

The fundamental functions and display messages are as follows:

[I] <u>Keys and the Functions</u>

[XXX] indicates the key's primary function actuated by simple pushing.

{XXX} is for the second function utilized when it is pushed succeeding [SFT].

<u>Measuring keys</u>

[S/P] 'Start-point' plots points to be measured.

{CONT] 'Continuous' alternates Continuous Mode for automatic plotting of curved lines and Point Mode for straight lines.

[ARC] 'Arc' defines an arc by plotting any point close to the middle of it and calculates length and area of the sector and radius.

[CAN] 'Cancel' cancels the last plotting.

<u>Processing keys</u>

[CE/c] 'Clear' clears the input numbers or measurements while showing "0" on the display.

{CL } 'Clear-Sigma' clears accumulated values.

[+] 'Plus-Sigma' calculates accumulation, numbers and average of measurements on the display. The attribute of the data is restricted to that of the datum firstly added.

[END] 'End' finishes measurement and displays existing measured data in the order preserved until next measuring starts.

{FEED} 'Feed' feeds paper one line at a time or continuously if it is held down.

[COPY] 'Copy' prints what is displayed.

{SET} 'Shift Set' selects the mode to set the interfacing parameters.

[SET] 'Set' initiates measuring condition setting or reconfirms the inputted conditions.

[YES] 'Yes' Affirms operator's desire to continue with displayed question or statement.

[NO] 'No' Denies the displayed statement or changes the kinds of measurement on the display. Also displays the contents of accumulation registers in the order.

[+/-] 'Plus-minus' reverses the sign of the displayed figure.

[P/C] 'P or C' alternates computer and printer as an output device.

[PNP] 'P-N-P' alternates auto-print (data-out) and non-print (non-data-out).

[#] 'Number' memorizes the input number as the initial value of the serial number for auto numbering.

[#P] 'Number-print' prints the optionally input numbers.

[SFT] 'Shift' pressed down when selecting the second function of each key.

Numeral Keys

[.] 'Decimal Point' sets the decimal point.

[0] - [9] 'Numerals' inputs numbers.

[F0] - [F4], [F5] - [F9]
'Function-key' transfers inputted figures joined with the key-codes "F0" - "F9".

[II] Measuring Conditions

Display Sequence (1) ~ (15) is shown on the display by pressing keys [SET] [YES] or [NO]. [YES] accepts displayed condition. [NO] gives alternative selection and [SET] with no other entry is used for verifying measuring parameters.

(1) <<Initial Display>>
Appears when power-on lever is lifted. Key-explanation is printed when [YES] is pressed. Press [NO] for (2).

(2) <<Function Select>>
Initiated by [SET] designates results of the 5 following items.
Coordinates ◇Segment length ◇Area ◇Total length ◇Radius

(3) <<Unit system select>>
Select unit system from the following.
◇Metric ◇English ◇User's Specified unit

(4) <<Metric unit select>>
Select ◇m ◇mm ◇cm ◇m/a ◇km/ha ◇km
Length units with no corresponding area units are automatically squared.

(5) <<English unit select>>
Select ◇in ◇ft ◇yd ◇yd/ac ◇mi

(6) <<User's special unit input>>
Any desired value of unit rate can be keyed in.

⑦ <<Scale adjusting method select>>
Select ◇Input Scale ◇Manual Scale

⑧ <<Input scale adjusting>>
Input denominator of the reduction scale that has 1 for numerator.

When the reduction scale for X and Y are different input each value for X and Y.

⑨ <<Manual scale adjusting>>
Input the recorded value of a standard line on the map and plot by [S/P] at both ends. When the reduction scale for directions X and Y are different, operate the same or each X and Y.

⑩ <<Coordinate system select>>
Select ◇Surveying coordinate
◇Standard (Mathematical) coordinate
◇Machine coordinate

⑪ <<Coordinate axis set>>
When coordinates are desired, press [S/P] at the origin and at a point on X-axis(+).

⑫ <<Origin bias set>>
Input origin bias for coincidence of the coordinate value to that on the map.

⑬ <<Decimal place set>>
Set decimal at desired place, 0 thru 10.

⑭ <<Numbering select>>
Select ◇Numbering of results by [S/P] (numbering within plot).
◇Numbering of results by [END] (numbering at end of plot).
◇No numbering.

[III] Measuring Purposes

The following requirements can be selected:

No.	Requirement	Special Explanation
1	Area	Automatic closing of area
2	Area;Line (circumference)	Automatic closing of area and circumference
3	Area;Line;Segment	Plotting arcs;Numbering the figures or points
4	Area;Segment;Coordinate	Manual number printing;Automatic adjusting of Coordinte axis
5	Area;Segment;Coordinate	Types of Coordinate;Numbering; Perpendicular of Triangle; Memory Back-up
6	Area;Segment;Coordinate	Adjust to the map-coordinate; Dualscaled Measuring
7	Area;Segment	Accumulation or Reduction of measurements
8	Area;Segment;Line	Scale adjusting by the dimensions on the drawing
9	Segment;Line;Radius	Two ways of curved line measuring
10	Area;Line;Radius	Circle measuring

Note : For further details the reader should refer to maker's manuals.

2) Operational procedure

The measuring is same manner as the mechanical planimeter, but the procedure is different and should be carry out according to the following steps.

[I] Preparation

(a) Connect the printer 16a firmly to 360i.
(b) Link the charger and charge 360i.
(c) Turn the machine on while pressing [CE/c] (Clear) key.
(d) Push [SFT] [P/NP] i.e. (P/C) (Printer or Computer) consecutively to bring **PRINTER** into the display.
When (4) is omitted, printer is assigned as its output device.

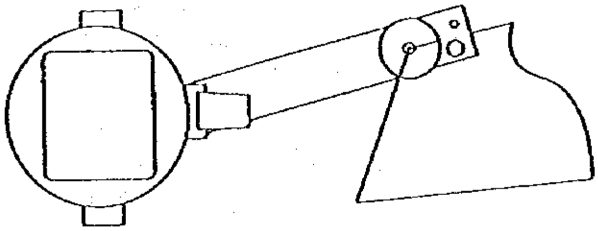
(e) Push [P/NP] (Print-non-print) to make **PRINT** come up on the display.
(f) Turn 360i off and on again to get the display KEY-EXPLANATION ?
(g) Push [YES] and then Key-Explanation is printed. When it is unnecessary, push [NO]

[II] Measuring Condition

(h) By pushing [SET] the requests for operator's selection of the output functions and conditions appear on the display.
(i) By using [YES] or [NO] please respond to the requests on the display to make selections with those factors below.
Functions: ◇Area ◇Total-length ◇Segment-length ◇Co-ordinates ◇Radius
Other Factors: ◇Unit ◇Scale ◇Co-ordinate Axis ◇Decimal Place ◇Numbering

[III] Set on the Starting Position

The Needle set the instrument on the starting point as shown below.



[IV] Measuring

(j) By the four keys on the tracing arm, points and lines are inputted.

[S/P] (Start Point) is used for the start of measurement and point straight line input.

[ARC] (Arc) is for defining an arc when pushed between [S/P]'s pushed at both ends of the arc.

[CONT] (Continuous) is used at the beginning of a curved line for continuous point input and pushed again at the end of it for recovering normal point-input mode.

[CAN] (Cancel) is for canceling the last input by [S/P] or [ARC].

[NO] (Cancel) is for canceling the last input by [S/P] or [ARC].

[NO] (No) has secondary function of recalling results provided in the memory to the display during measuring.

[V] <u>Completion of Measuring</u>

(l) Push [END] for closing computation of area and completion of measuring.

(m) [END] is also used for recalling all of the provided results to the display alternatively. The results are kept until the next start of measuring and are ready for reconversions with newly selected scales and units.

[VI] <u>Accumulation</u>

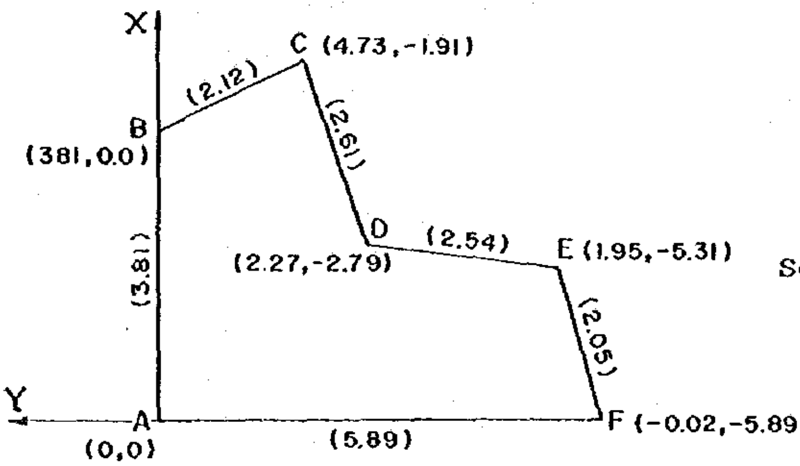
(n) [+] (Plus Sigma) is used for producing accumulation or reduction (used together with [+/-]), average and times of measurement by adding the measurement values that are presented on the display. It is available for all kinds of measurements including coordinate and radius. But in order to avoid confusion, the measurements in one kind are accumulated at one time and others are rejected until it is finished.

(o) [CL] (Clear Sigma) clears above values to zero.

(p) By [NO] values of accumulation, average and times of measurement are recalled to the display in sequence.

3) <u>Example</u>

To determine the following area with a scale of 1:100.



Scale 1:100

Note : (x,y) : measured coordinate
(l) : line length computed from measured coordinates (unit in meter)

. Operational procedures for condition set are shown in the follows:

[1]	reference number input
[# P]	reference number print
[SET]	condition set start
[N O]	coordinate not needed
[N O]	line segment not needed
[YES]	area needed
[N O]	total length not needed
[N O]	radius not needed
[N O] or [YES]	unit m (Metric) select
[N O] or [YES]	scale ratio adjustment select
[1] [0] [0]	scale ratio denominator (RX)
[YES]	confirm (RX)
[YES]	confirm (RY)
[N O] or [YES]	machine coordinate select
[N O] or [YES]	decimal to 2nd place select
[N O] or [YES]	no auto numbering select

. Results are printed out in the following form.

Conditions

# 1.		
COOR	(X.Y)	Y
LINE SEG	(d)	Y
AREA	(A)	Y
LINE	(L)	Y
RADIUS	(r)	N
m		Y
SCALE RATIO		Y
RX	100.	
RY	100.	
MACH.AXIS		Y
	D.P 2	
WITHOUT #ins		Y

Results

END	
A	17.17 m
L	19.02 m

Output List

X	3.2[illegible] m
Y	2.33 m
X	3.81 m
Y	0.00 m
d	3.81 m
X	4.73 m
Y	-1.91 m
d	2.12 m
X	2.27 m
Y	-2.79 m
d	2.61 m
X	1.95 m
Y	-5.31 m
d	2.54 m
X	-0.02 m
Y	-5.89 m
d	2.05 m
X	0.00 m
Y	0.00 m
d	5.89 m
END	
A	17.17 m^2
L	19.02 m

3.3.4 <u>Measurement by Using the Digitizer</u>

Outline of cartographic data processing system.

Maps have the many informations. Roads, railway and canals are often called the linear information. Land use and settlements have a area information. Though urban facility are express the symbol on the map, that position and its function are very important for the city activities.

A Map express these information on the paper. To grasp above information accurately is very important for urban planning.

This is a map measurement system using the digitizer and micro-computer, the fundamental components are shown in the next page.

For further fetails concerning the hard-ware of micro-computer (Canon A 200 II) and Digitizer (Haupton TG-8036 Digitizer) to reader may refer to the specific manuals by maker and the technical manual for case study.

This system are carried out according to the "menu" from the setting the map-coordinate to make the measurements and sum areas.

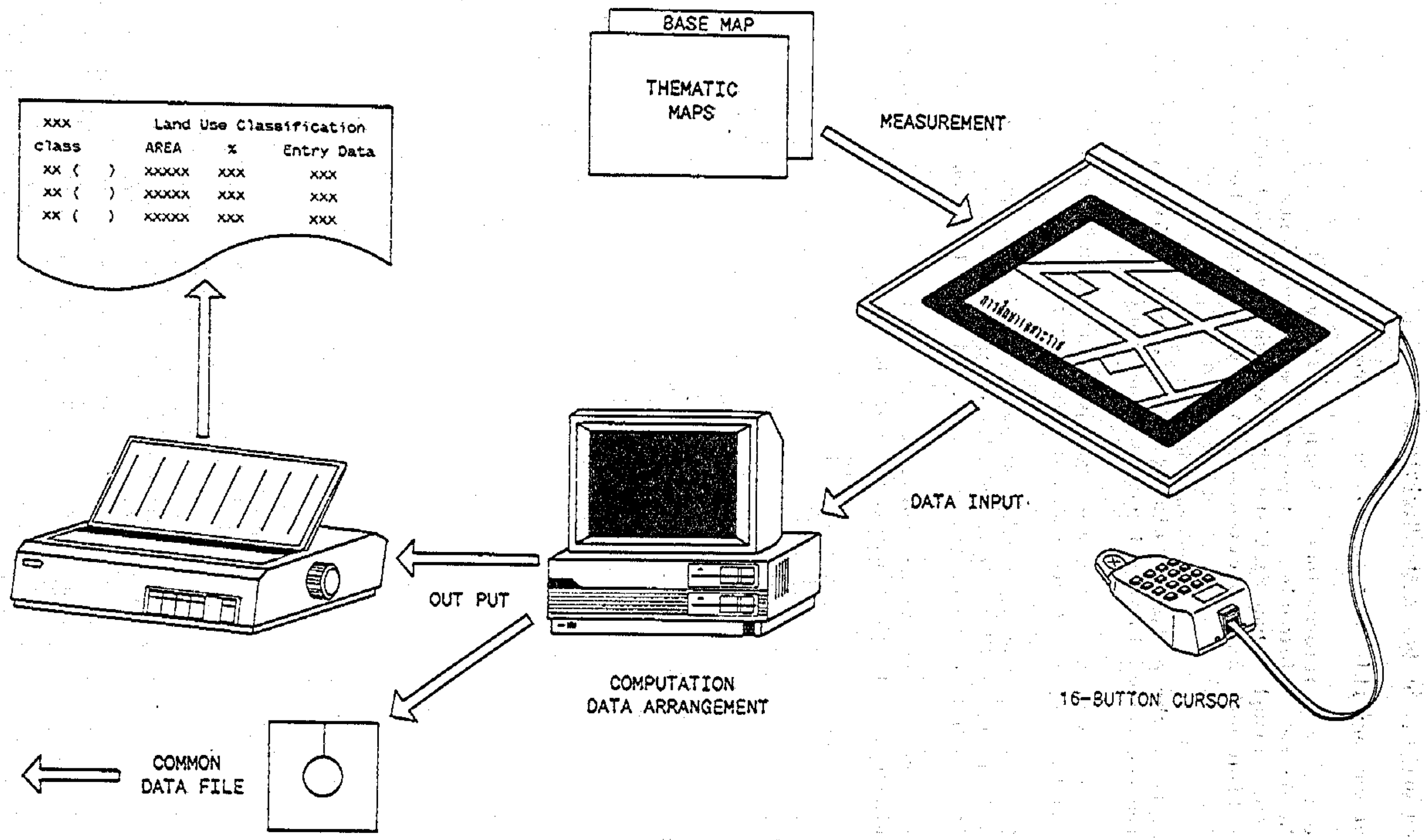


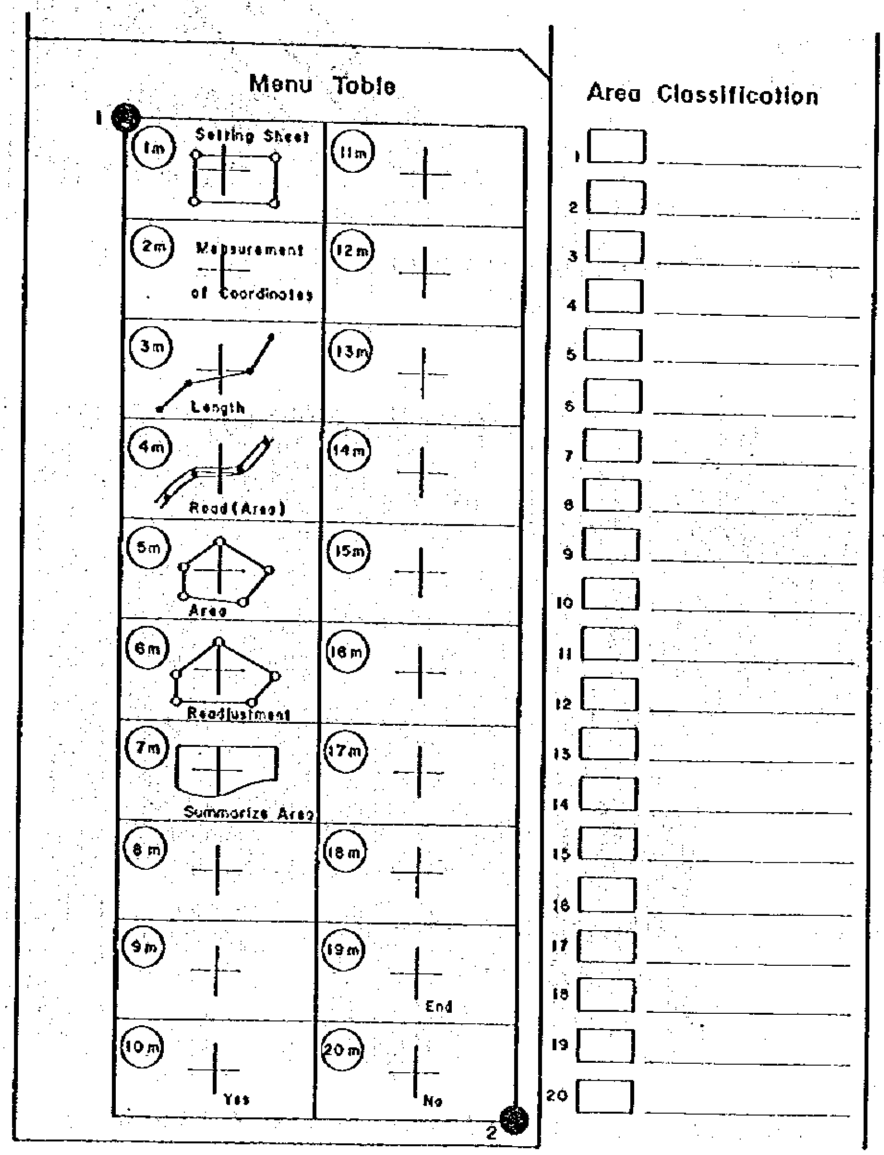
Fig. 3-3.12 OUTLINE OF CARTOGRAPHIC DATA PROCESSING SYSTEM

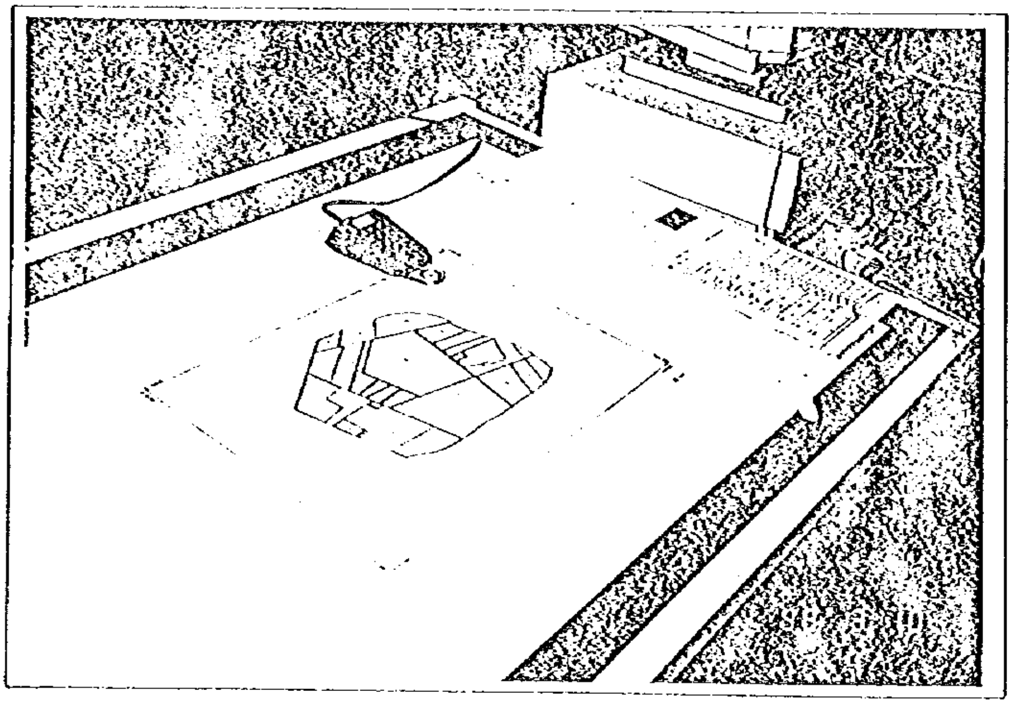
Selection of procedure routine

In case of selection of working, CRT display express the following message.

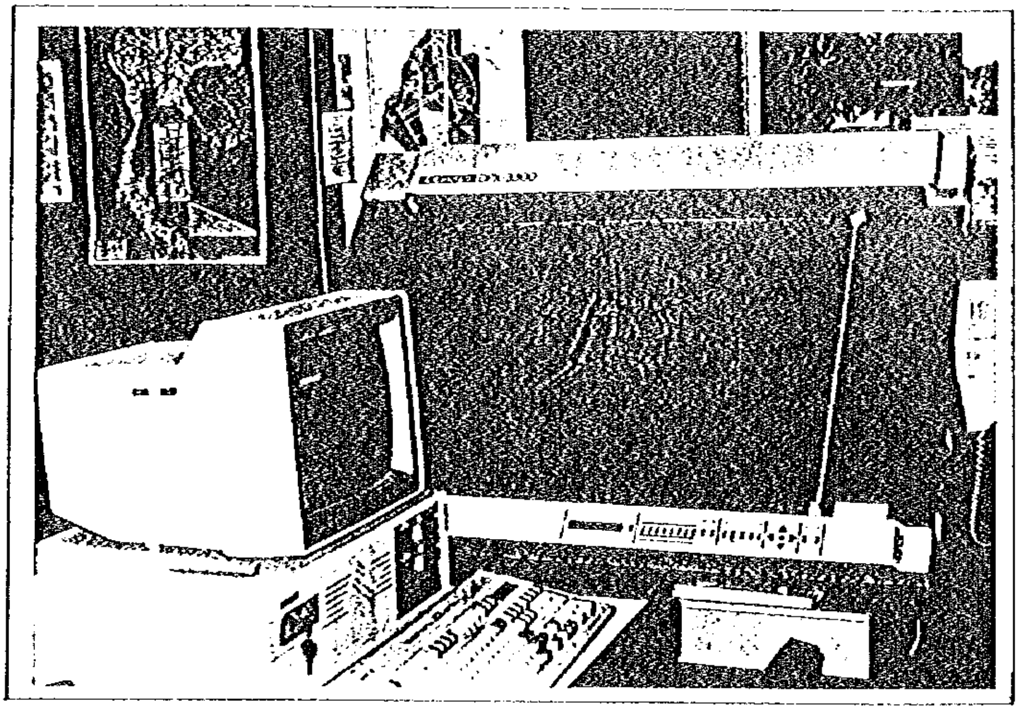
```
Working Menu!
Please select the menu
------------------------
Setting Sheet
```

Operation starts from "Menu". After setting procedure finished, we can select the each menu and measure the areas.





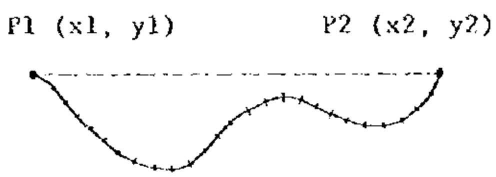
INPUT DEVICE (Digitizer)

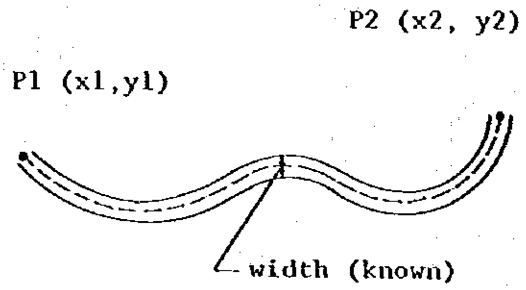
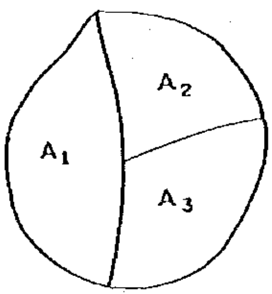


OUTPUT DEVICE (Printer and X-Y Plotter)

Fig. 3-3.13 INPUT-OUTPUT DEVICES

Table 3-3.1 SELECTION OF MENU AND ITS FUNCTION

Menu Selection	Function
① Setting sheet	decide the mathematical relation between map coordinates (x, y) and ground coordinates (X,Y) as following equations. Common points of each coordinate need 3 points minimum. 4 or more point use usually. $X = ax + by + c$ $Y = dx + ey + f$ x, y : map coordinates X, Y : Ground coordinates a, b, c, d, e, f : unknown coefficient
② Measurement of coordinates	Compute the ground points (X, Y) from map coordinate (x,y). $X = ax + by + c$ $Y = dx + ey + f$ x, y : digitizer coordinate a, b, ..., e, f : transfer coefficients x, y : unknown
③ Measurement of Length	Compute the length between point P1 (x1, y1) and P2 (x2, y2). In case of curved figure, it must measure short interval. Length express the ground scale. 

Menu Selection	Function
④ Measurement of Road	Same as 3 category. But this area routine enable the area of linear figure in case of known width.  Width input from menu table (≤ 20 m) or key-board (> 20 m).
⑤ Measurement of area	Calculate the acreage according the identified code. In case of land use, building classification each classified total can be obtained by menu operation (< 20 classification).
⑥ Measurement of area (re-adjustment) 	Consider an boundary (Acreage is A) have several divided area (Acreage is Ai). In usual case, two Acreage are not equal at measured stage. $A \neq \Sigma A_i \ (i = 1, m)$ Therefore, two acreage must be coincide with correction-factor (c). This operation divide into two stage: (1) Computation of a boundary (A) (2) Computation of sub-boundary (Ai)
⑦ Print out summarize acreage	Collect the measured acreage data each classified group, and print out each value and summation.

Coordinate transformation

There are a number of survey problems where a coordinate transformation may give a convenient solution.

It may occur that points with known coordinates should be transformed into another system, a number of points being given in both coördinate system.

Example of these problems are : the so called two points problem where the coordinates of a station are determined by the establishment of an anxiliary point and observation to two station previously fixed.

The transformation of the coordinates of a local system to s system of a higher order.

There are several type of transformation which can be applied.

However most popular transformation are two types as shown in next page.

(1) Conformal transformation

. First order equation

$$X = a + cx + dy$$
$$Y = b + cy - dx \quad (3\text{-}3.12)$$

. Second order equation

$$X = a + cx + dy + e\,(x^2 - Y^2) + f\,(2xy)$$
$$Y = b + cy - dx + e\,(2xy) + f\,(x^2 - y^2) \quad (3\text{-}3.13)$$

(2) Affine transformation

. First order equation

$$X = a + bx + cy$$
$$Y = d + ex + fy \quad (3\text{-}3.14)$$

This system use the latter transformation because measured maps are not exactly.

The coefficient a, b, c, d, e and f can solve from three simultaneous equations or method of least square. We adapted the letter method.

Now we consider the next equation.

$$Xi = a + bxi + cyi$$
$$Yi = d + exi + fyi \quad (3\text{-}3.15)$$

where

X_i, Y_i : each ground point
x_i, y_i : map point corresponding the ground point

Normal equation for request the unknown a, b and c from above equations by means of method of least square are as follows:

$$
\begin{aligned}
[X] &= a \cdot n + b[x] + c[y] \\
[xX] &= a \cdot [x] + b[xx] + c[xy] \\
[yX] &= a \cdot [y] + b[xy] + c[yy]
\end{aligned}
\qquad (3\text{-}3.16)
$$

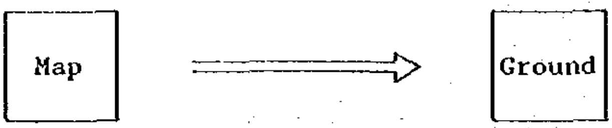
[ ] : indicate the summation of each term

We can solve a, b and c from above three simultaneous equations.

Similarly we can arrange the normal equation for Yi terms.

$$
\begin{aligned}
[Y] &= d \cdot n + e[x] + f[y] \\
[xY] &= d \cdot [x] + e[xx] + f[xy] \\
[yY] &= d \cdot [y] + e[xy] + f[yy]
\end{aligned}
\qquad (3\text{-}3.17)
$$

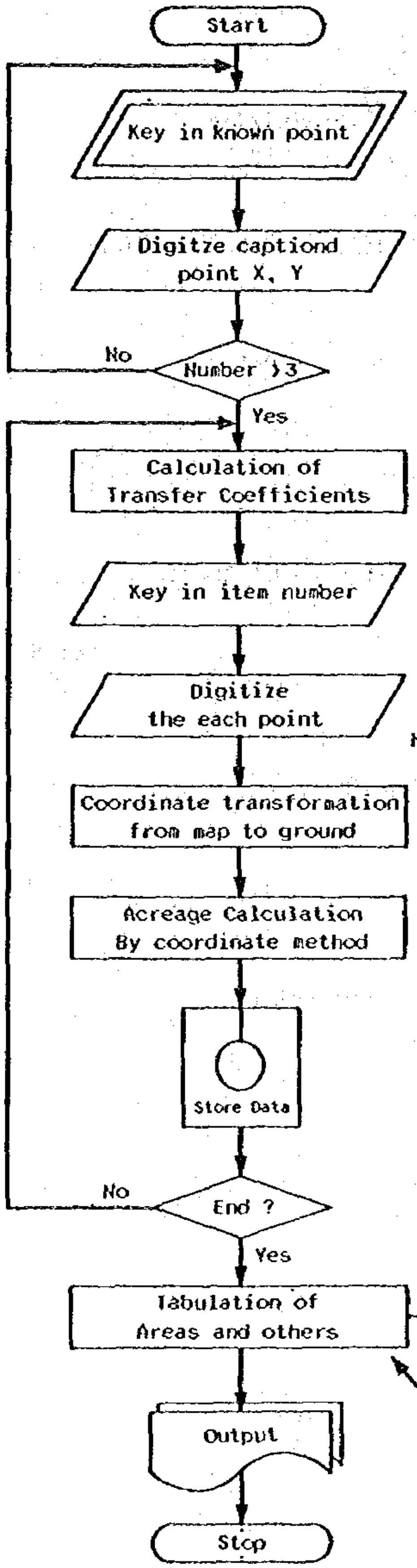
And we can also solve d, e and f from above simultaneous equation.

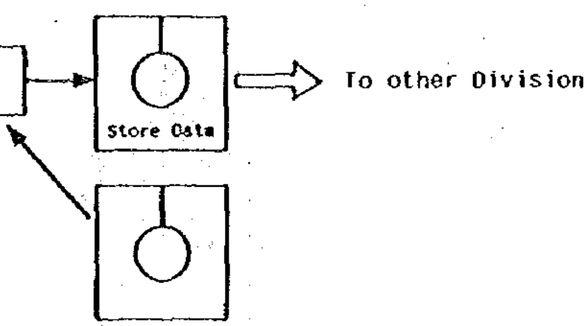


Transformation
coefficients

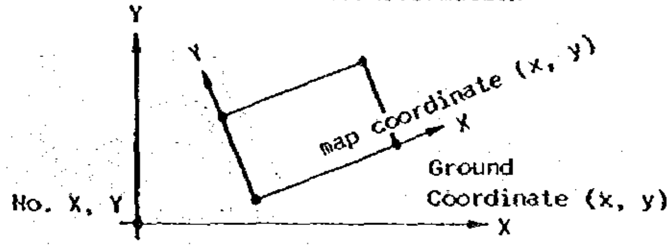
All measured data tre stored in the floppy disks, and we can obtain the total values after sorting the measured data as shown in Fig. - .

General Flowchart





Coordinate Transformation



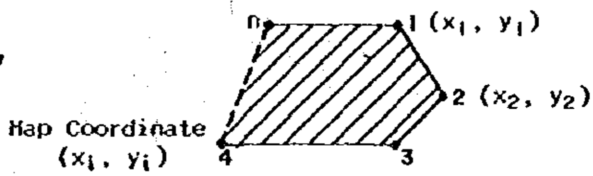
Known : X, Y, x, y

Unknown : a, b, c, d, e, f

$X = ax + by + c$

$Y = fx + ey + f$

Measurement



$X_i = ax_i + by_i + c$

$Y_i = dx_i + ey_i + f$

$S = \frac{1}{2}(x_1(y_1 - y_n) + x_2(y_3 - y_1) + \ldots + x_n(y_1 - y_{n-1}))$

Fig. 3-3.14 FLOW-CHART OF COMPUTATIONS

PROCESSING FLOW CHART OF DATA COLLECTION

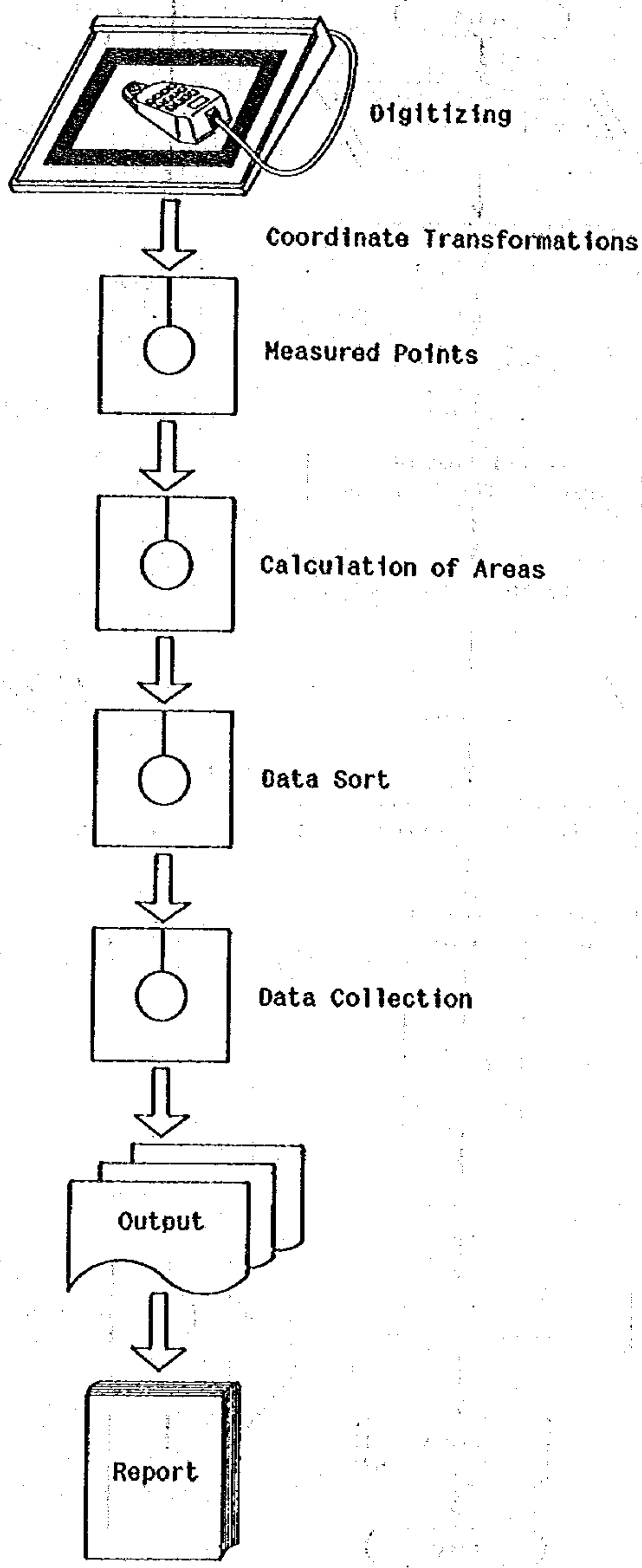


Fig. 3-3.16 FLOW-CHART OF DATA

Setting Sheet

Input no. of known points by menu

Please select the menu
4

Input ground coordinate of point 1 by keyboard in meters (name,X,Y)
? 1,20000,10000

Input map coordinate of point 1 (by digitizer)? 811 , 1756.25

Input ground coordinate of point 2 by keyboard in meters (name,X,Y)
? 2,24000,10000

Input map coordinate of point 2 (by digitizer)? 4744.25 , 1772.25

Input ground coordinate of point 3 by keyboard in meters(name,X,Y)
? 3,24000,13000

Input map coordinate of point 3 (by digitizer)? 4730.25 , 4719.25

Input ground coordinate of point 4 by keyboard in meters (name,X, Y)
? 4,20000,13000

Point	Residuals of x (Vx)	Residuals of y (Vy)
1	-0.1908	-0.0631
2	0.1909	0.0630
3	-0.1912	-0.0626
4	0.1910	0.0627

Mean Square Error = .2843198 m.

Do you accept(y/n)?
Please select the menu

Example - Calculation of residual values

Point	Residuals of x (Vx)	Residuals of y (Vy)
1	-0.8006	4.7006
2	0.8060	-4.7306
3	-0.8055	4.7265
4	0.8000	-4.6965

Mean Square Error = 6.762023 m. M.S.E. is large, then must re-measure

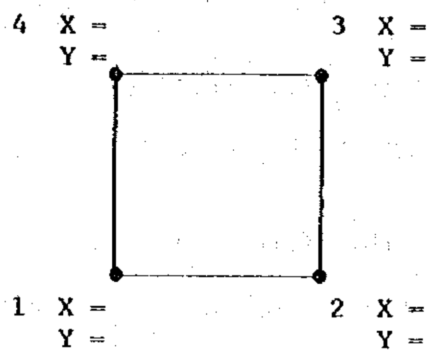
Point	Residuals of x (Vx)	Residual of y (Vy)
1	-0.8890	0.1321
2	0.8888	-0.1314
3	-0.8885	0.1310
4	0.8886	-0.1317

Mean Square Error = 1.270542 m. Same above M.S.E.

Point	Residuals of x (Vx)	Residuals of y (Vy)
1	-0.3151	0.4461
2	0.3155	-0.4471
3	-0.3154	0.4468
4	0.3150	-0.4458

Mean Square Error = .7729003 m.

Adapted coefficients



Example - Coordinate transformation

Please select the menu

Convert map coordinate to ground coordinate!

Input identification no. by keyboard? 001

Input map coor. (by digitizer)? 3130 , 2921.5

Do you want to do any more points(y/n)?
Please select the menu
yes

Input identification no. by points(y/n)?

Input map coor. (by digitizer)? 1929.5 , 3279.75

Do you want to do any more points(y/n)?
Please select the menu
yes

Input identification no. by keyboard? 003

Input map coor. (by digitizer)?

Point	Map Coordinate	Ground Coordinate
001	3130, 2922	22364.81,11178.82
002	1930, 3280	21146.58,11549.82
003	3727, 2805	22971.21,11056.93

yes

Input identification no. by keyboard? 003

Input map coor. (by digitizer)? 3727.25 , 2804.75

Input the name of land use by menu
Please select the menu

When you input the coor., you must use key '1' except the last point!

Input no. or name of block area by keyboard? 001

Input map coor. of point 1 3269.5 , 3837.25

Input map coor. of point 2 2839.25 , 3981

Input map coor. of point 3 2396.5 , 3665.75

Input map coor. of point 4 2521.25 , 3056

Input map coor. of point 5 3126 , 2927.5

Area of this block = 685188 sq.m.

Do you want to calculate more(y/n)?
Please select the menu

yes

Input no. or name of block area by keyboard? 002

Input map coor. of point 1 2009.5 , 3973

Input map coor. of point 2 1571 , 3644.25

Input map coor. of point 3 1631.5 , 3344.25

Input map coor. of point 4 1902.75 , 3396.25

Input map coor. of point 5 1871.75 , 3567.75

Input map coor. of point 6 2089.5 , 3613.5

Area of this block = 180466.6 sq.m.

Do you want to calculate more(y/n)?
Please select the menu

When you input the coor., you must use key '1' except the last point!

Input no. or name of block area by keyboard? 006

Input map coor. of point 1 1974.25 , 3046.25

Input map coor. of point 2 1816 , 3035.75

Do you want to calculate more(y/n)?
Please select the menu

18

Name	Area sq.m.	rai
001	19026.18	11.89
002	33118.28	20.70
003	65346.90	40.84

Total area = 117491.4 sq.m. = 734321 rai

3

Name	Area sq.m.	rai
001	685188.00	428.24
002	180466.60	112.79

Total area = 865654.6 sq.m. = 541.0341 rai

6

Name	Area sq.m.	rai
006	169466.40	105.92
002	99373.60	62.11

Total area = 268840 sq.m. = 168.025 rai

Grand total of area = 1251986 sq.m. = 782.4911 rai

9

Name	Area sq.m.	rai
001	12019500.00	7512.19

Total area = 1.213699E+07 sq.m. = 7585.618 rai

Grand total of area = 10213699E+07 sq.m. = 8368.108 rai

Table 3-3.2 shows the difference in existing measurement, Digital planimeter and Digitizer system. Only case (3) can correct the errors occurred from map-distortion.

Table 3-3.2 COMPARISON OF EXISTING METHOD WITH CASE STUDY METHOD (LANG SUAN)

Methods / Land Use	Existing Method + Planimeter (1)	Existing Method + Digital Planimeter (2)	Digitizer Method (3)
1 (Residential)	670.52	686.30	680.65
2 (Commercial)	215.47	221.56	219.51
3 (Industrial)	345.87	342.27	337.87
4 (Warehouse)	71.84	69.92	69.45
5 (Religious)	34.90	36.81	36.00
6 (Education)	49.22	46.17	45.31
7 (Governmental)	22.85	27.40	20.57
8 (Livestock)	120.38	117.68	117.03
9 (Open Space)	48.61	50.98	50.18
10 (Road, Soi)	682.15	675.18	675.18
11 (River, Canal)	715.97	709.52	740.61
12 (Agriculture)	15,906.96	15,888.52	15,620.12
Total	18,894.74	18,866.52	18,613.12
Ratio	+1.015(+1.5%)	+1.013(+1.3%)	

3.4 Digital Mapping

The problems of growth and economic expansion faced by city planners and managers today and the corresponding need for rapid access to map data have led to the development of digitally integrated cartographic systems. In these systems, spatially oriented data relating to municipal services such as water and gas systems, storm and sanitary sewer lines, street and freeway centerlines, and boundary lines are keyed to digitized planimetric map data that may be combined into a single composite data base.

Usually we can divided into two groups:

(1) Mapping system

This system use the photogrammetric instrument with the computer, graphic display unit, data correction unit, and output devices. The object of this system is to make a mapping data or drawing a map.

(2) Digital data collection system

A typical digital data collection system consists of a work station at which an operator digitizes map detail with a cursor or analytical plotter. These data are stored and can be recalled for graphic display. The planimetric data can be divided into categories, allowing the recall of separate information types such as roadways, railroads, drainage, side-walks, driveways, fences, parking lots and buildings. The work stations can be interfaced with a minicomputer which in turn controls a high-speed plotter where plots can be generated for editing.

The former system is very difficult to correct the data, and it spend very long times.

In case of data collection are a few items such as housing, or road, this method is very useful. "Digital Mapping" is called for Digital data collection systems.

Because the data are available on an instant-access basis through graphic display, the systems provide users with an effective tool for information management. They can access the elements of the data base, display them on a screen in various combinations, or make hard copy. The system enable users to arrive at decisions quickly and to provide vital information to the public.

We explained additional details with example in section 1.3.4.

Digital Mapping

Planimetric Map

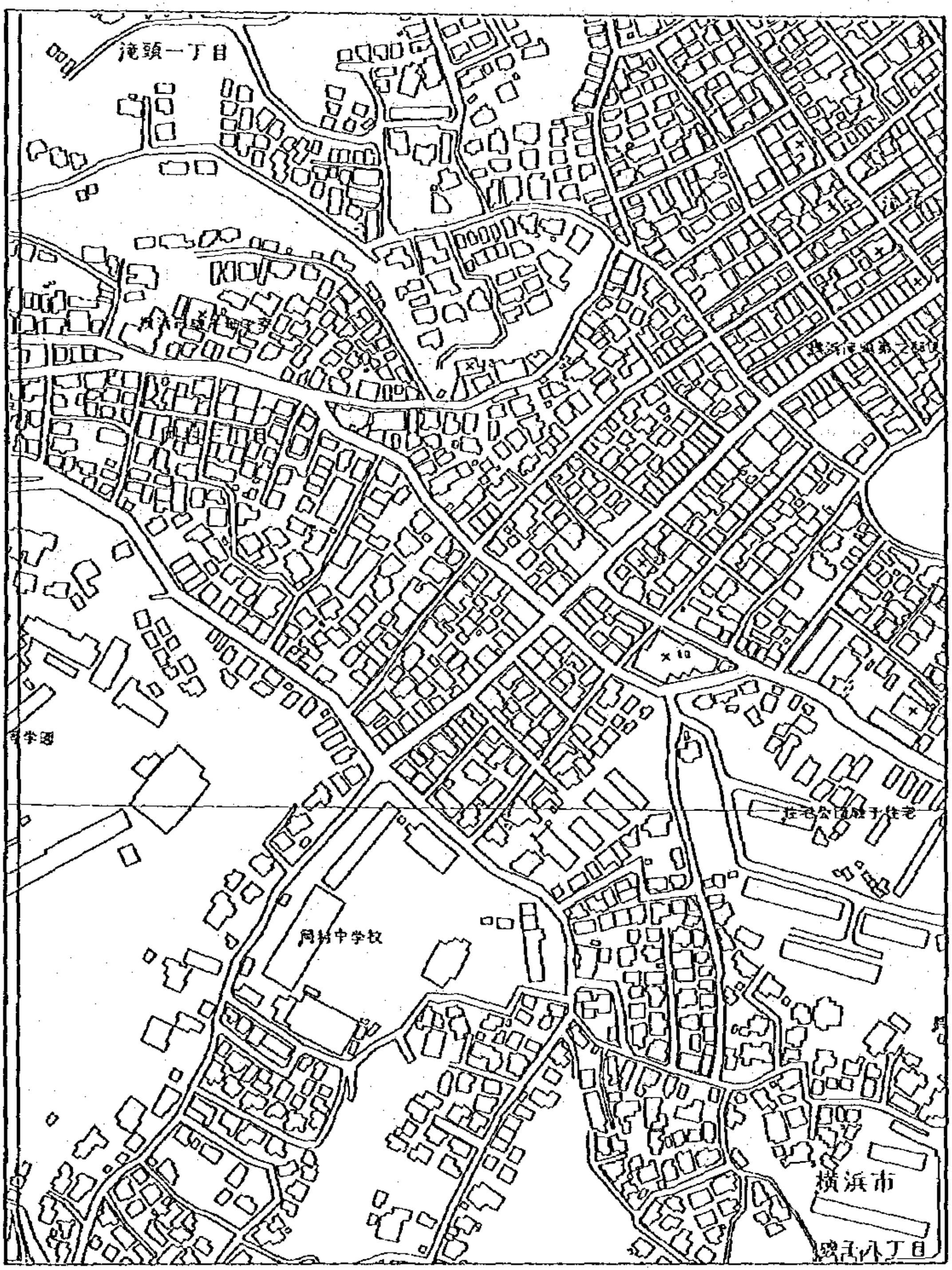


Fig. 3-4.1 PLANIMETRIC MAP

This map was drawn with a automatic plotter original data was gathered from a map by means of digitizing.

Digital Mapping

Automatic Contour Drawing

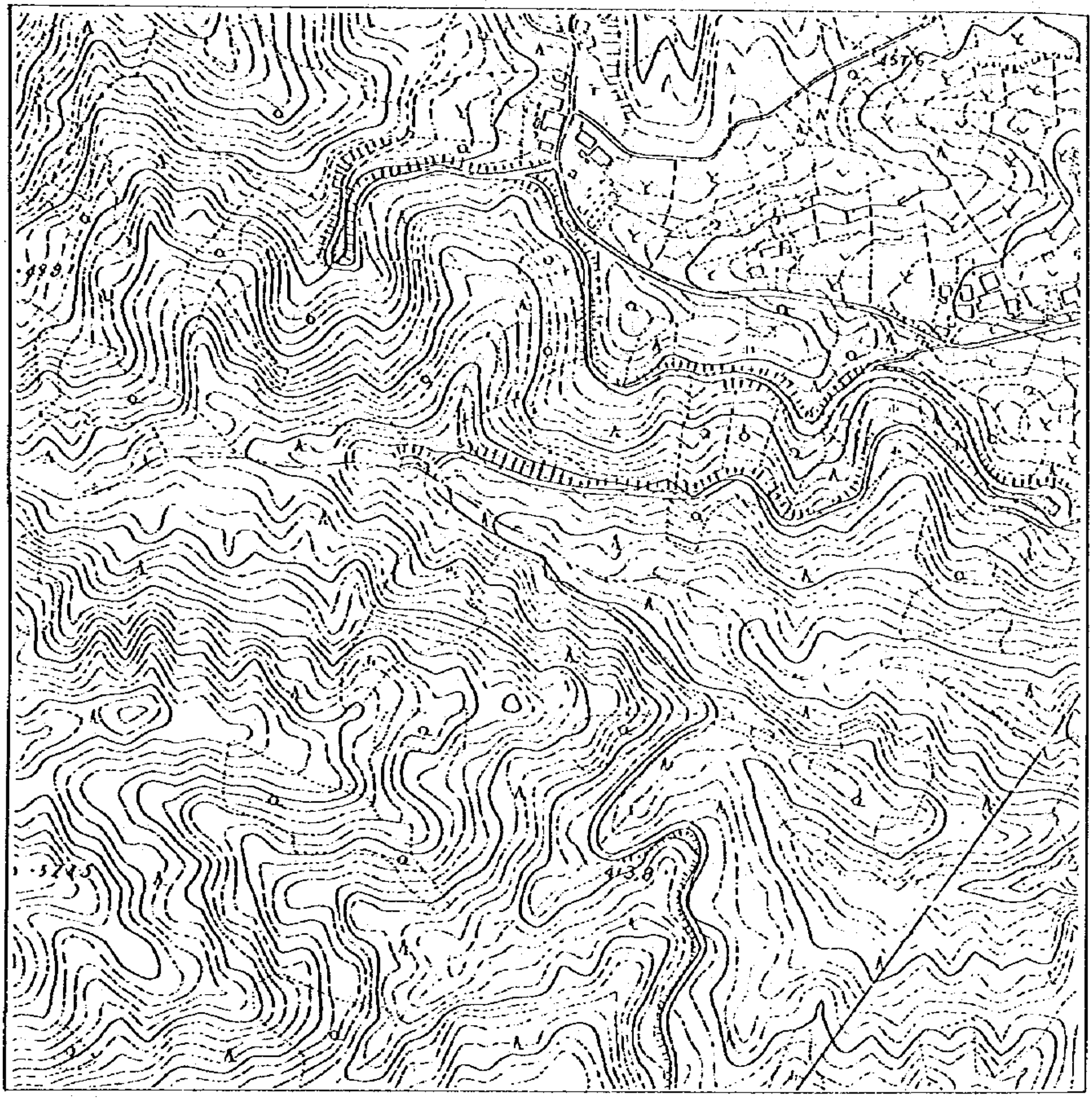


Fig. 3-4.2 TOPOGRAPHIC MAP

This contours was drawn with a automatic plotter original data were measured with the analytical plotter (planicomp C-100 system) by method of Digital terrain models (DTM), grid interval 20 m.

JICA